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CCJ
COMBINED CYCLE Journal

POWER USERS Mega Event

2022 Conference and Vendor fair
San Antonio Marriott Rivercenter
August 29 – September 1

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INDEPENDENT VOICE OF THE GAS-TURBINE-BASED GENERATION SECTOR

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

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

C T Genelba
Pampa Energía SA

Empire Generating Co
Owned by Empire Acquisitions LLC
Operated by NAES Corp

Fairview Energy Center
Owned by Competitive Power Ventures
Operated by NAES Corp

McIntosh Power Plant
Lakeland Electric

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

Amman Levant Power Plant
AES Jordan PSC

Anson and Hamlet Generation Plants
North Carolina Electric Membership Corp

Athens Generating Plant
Owned by Kelson Energy
Operated by NAES Corp

BASF Geismar
BASF Corp

Central Eléctrica Pesquería
Techgen

CPV Valley Energy Center
Owned by Competitive Power Ventures and Diamond Generating Corp

Energía del Valle de México I
Owned by EVM Energía del Valle de México Generador SAPI de CV
Operated by NAES Corp

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

Griffith Energy
Owned by Griffith Energy LLC
Operated by CAMS

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

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

Lawrence County Generating Station
Owned by Hoosier and Wabash Valley Power Assn
Operated by NAES Corp

Liberty Energy
Vistra Corp

Magnolia Power Project
Owned by Southern California Public Power Auth
Operated by Burbank Water and Power

Mid-Georgia Cogen
Owned by Rockland Capital
Operated by IHI Power Services

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

MPC Generating
Owned by Mackinaw Power
Operated by Cogentrix Energy Power Mgt

Pleasant Valley Station
Great River Energy

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

Rolling Hills Generating
Owned by Eastern Generation LLC
Operated by CAMS

Rumford Power
Cogentrix Energy Power Mgt

Salem Harbor Station
Owned by Footprint Power Salem Harbor Development LP
Operated by NAES Corp

Saudi Aramco Power Generation Sites
Saudi Aramco

Sentinel Energy Center
Diamond Generating Corp

State Line Power Station
Owned by Liberty Utilities and Evergy

Walton County Power
Owned by Mackinaw Power
Operated by Cogentrix Energy Power Mgt

Washington County Power
Owned by Gulf Pacific Power LLC
Operated by Cogentrix Energy Power Mgt

Whitewater Cogen
Owned by LSP Whitewater LP
Operated by NAES Corp

Worthington Generation Station
Owned by Hoosier Energy Rural Electric Co-op
Operated by NAES Corp

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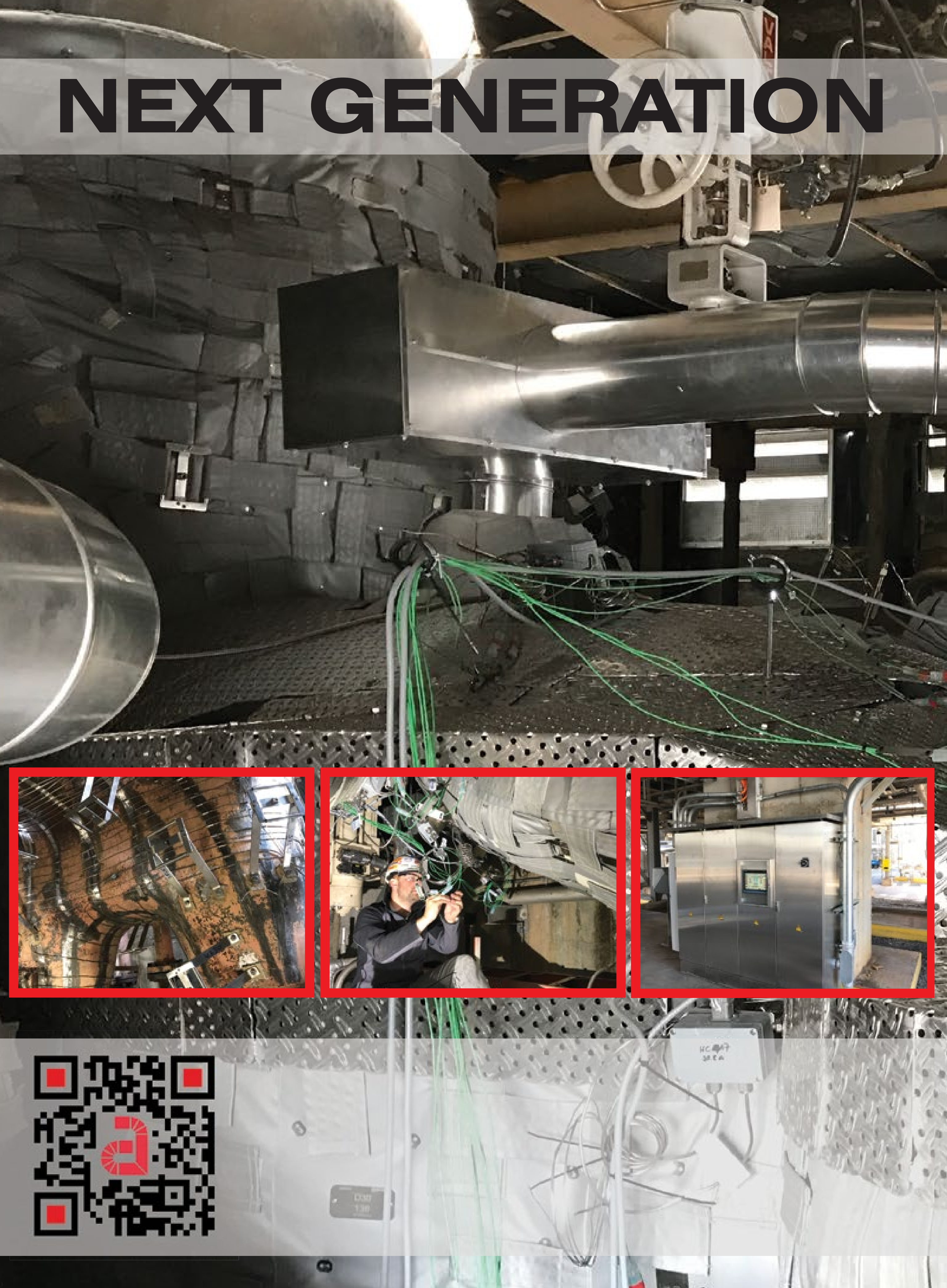
NEXT GENERATION



POWER USERS

2022 Annual Conferences

San Antonio Marriott Rivercenter
August 29 – September 1

CCUG COMBINED CYCLE USERS GROUP

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STUG STEAM TURBINE USERS GROUP

POWER PLANT CONTROLS USERS GROUP

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LTUG
Legacy Turbine Users Group

7EA Users Group

Frame 6B Users Group™

FRAME 5 Users Group

SILVER

ATS

AZZ BUS SYSTEMS

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Filter-Doc Corporation–Memphis, TN — Combustion Turbine Inlet Services

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CleanAir Performance Group

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EMW filtertechnik

FLANGE BAND-IT™ FLANGE LEAK DETECTOR

GTPS Gas Turbine Parts & Services

GROOME Industrial Service Group

KING Filtration Technologies, Inc.

NATIONAL ELECTRIC COIL

Pioneer MOTOR BEARING

Reuter-Stokes a Baker Hughes business

ROCHEM FYREWASH

SvoBaTech Svoboda Bauer Technical Services

ZOK

Technical Program at a glance

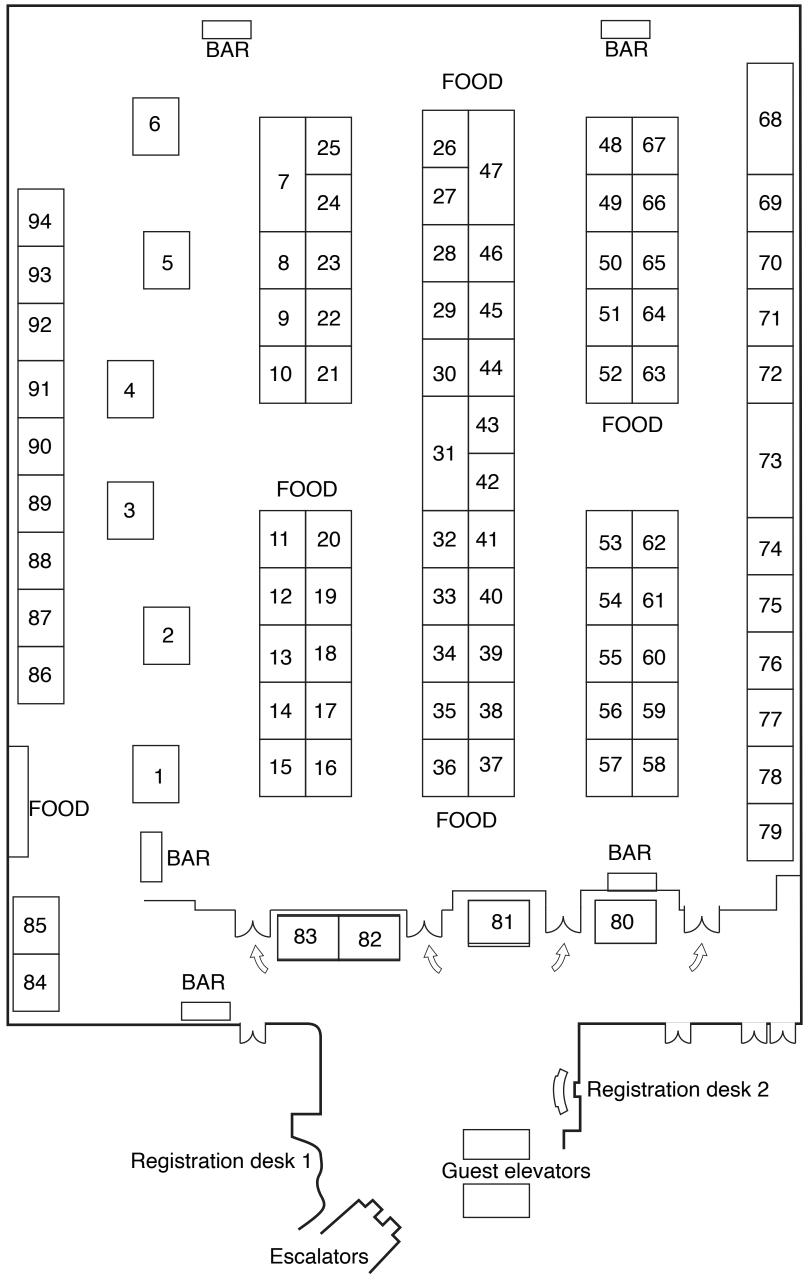
DAYS	CCUG	GUG	STUG
Monday, August 29	AM: Training (vibration analysis) PM: User + vendor presentations	AM: Training (insulation systems) PM: User presentations + roundtable	AM: Training (evaluating equipment upgrades) PM: User presentations + roundtable
	Vendor Fair, 5:30 – 8:30 p.m.		
Tuesday, August 30	AM: Vendor presentations PM: User presentations + roundtable	AM: Vendor presentations PM: Vendor + user presentations + roundtable	AM: Vendor presentations PM: Siemens + user presentations + roundtable
Wednesday, August 31	AM: MD&A + Siemens PM: GE	AM: Siemens PM: GE	AM: MD&A + GE PM: GE + FieldCore
Thursday, September 1	AM: User presentations PM: No sessions scheduled	AM: User presentations PM: No sessions scheduled	AM: User presentations + roundtables PM: No sessions scheduled

Breakfasts: 7 - 8 a.m. daily
Luncheons: 12 – 1 p.m. daily

PPCUG	7EA	Frame 6B	Frame 5
AM: No sessions PM: Training sessions	AM: MD&A shop tour or legacy-engine short course PM: Vendor presentations	AM: Legacy-engine short course PM: User presentations + roundtables (safety, renewables)	AM: Legacy-turbine short course PM: Vendor presentations
AM: Vendor presentations PM: Siemens	Vendor presentations	GE Day	AM: Baker Hughes PM: User presentations + roundtables (engine, safety, auxiliaries)
AM: Baker Hughes + GE PM: GE + user presentations	GE Day	Vendor presentations + roundtables (inlet air, compressor, combustion, turbine)	AM: Training (generator, controls) PM: Training (rotor) + user presentations + roundtables
No sessions scheduled	AM: Vendor + user presentations + roundtable PM: MD&A shop tour	AM: Vendor presentations + roundtables (I&C, generator/exciter) PM: No sessions scheduled	No sessions scheduled

Vendor Fair

Monday, August 29, 5:30 – 8:30 p.m.



Alphabetical order

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C C JENSEN, Oil Maintenance	49
CleanAir Engineering Inc	41
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TOPS Field Services LLC	92
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TRS Services LLC	93
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Veracity Technology Solutions	81
Viking Turbine Services Inc	53
Woodward Inc	66

Booth number order

Booth no.	Company
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2	American Thermal Solutions
3	Power Services Group
4	Cutsforth Inc
5	Emerson
6	PSM
7	Sulzer
8	TG Advisers Inc
9	Core Tech Industrial Corp
10	Doosan Turbomachinery Services Inc
11	AZZ Inc (The Calvert Company)
12	3angles Inc
13	EthosEnergy
14	Environex Inc
15	JASC
16	K-Machine
17	Integrity Power Solutions
18	Donaldson
19	Nederman Pneumafil
20	Shell Oil Products
21	TTS Energy Services
22	GTC Control Solutions
23	Bearings Plus
24	Advanced Turbine Support
25	National Electric Coil
26	Rochem Technical Services
27	AP4 Group
28	Emory Industrial
29	Hy-Pro Filtration
30	Falcon Crest Aviation Supply Inc
31	MD&A
32	SvoBaTech
33	Koenig Engineering Inc
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64	AAF International
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88	Buffalo Pumps
89	Toshiba America Energy Systems
90	Thompson Industrial Services LLC
91	Miba Industrial Bearings
92	TOPS Field Services LLC
93	TRS Services LLC
94	Southwest Impreglon Inc

2022 conference preview, 2021 highlights

The eighth annual meeting of the Generator Users Group returns to in-person conferencing at the Power Users mega event in the San Antonio Marriott Rivercenter, August 29 through September 1, following virtual meetings in 2021 and 2020. From 2015 to 2019 in-person meetings were conducted in Las Vegas, San Antonio, Phoenix, Louisville, and St. Louis.

2022 conference overview

The technical program for the upcoming meeting was developed by an all-volunteer steering committee of electrical engineers and managers (sidebar)—many with decades of relevant experience. An overview of the presentations scheduled for the week beginning August 29 follows. All sessions are *user only*. Presenting vendors are allowed in the room only when it is their time to present.

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

Monday, August 29. The first morning features a training session on generator insulation systems, with Siemens, GE, and NEC participating. User presentations dominate the afternoon. Topics are vendor quality, stator-winding manufacturing issues, the sharing of lessons learned by one utility, a stator-winding installation case study on the importance of correct alignment of endwinding support system components, and diagnostics for outage planning. A roundtable discussion on materials, manufacturing, and installation challenges closes out the day's classroom program. Doors to the vendor fair open at 5:30.

Tuesday, August 30. Vendor presentations dominate the program until the afternoon refreshment break. The lineup is as follows:

- HV stator-coil rewind, *National Electric Coil.*
- Accurate partial-discharge evaluation; new-bar pre-qualification, *AES Kinectrics.*
- Advances in fiberoptic core and coil monitoring, *B-Phase.*
- Isophase-bus anti-condensation measures, *Electrical Builders Inc (EBI).*
- CO_2 purge, *Airgas, an Air Liquide company.*
- Troubleshooting plan using EMSA—a case study, *Cutsforth Inc.*
- HV bushings: Inspection, testing, manufacturing, and failure examples, *MD&A.*
- 7F generator issues, *AGT Services Inc.*

Three user presentations follow the afternoon break: Fixators are not as fixed as you'd expect, flex connectors, and main- and neutral-lead mod for Siemens modular units. A roundtable discussion on common failures and maintenance issues closes out the day's activities.

Wednesday, August 31. Siemens presents in the morning, GE in the afternoon. Siemens topics include the following: Generator monitoring (case studies), FASTWedge, major findings in the fleet, enhancements for robotics inspections, optical flux probe, pole cross over (tutorial), generator purging, flexible connectors (tutorial).

GE's presentation topics: Hydrogen leakage investigations, TIL-2260—MELCO-built core iron looseness, TIL-2337—Rotor core migration, TIL-2323—H65/H84 nozzle-assembly design update, H65/H84 seal-ring RCA, supply chain issues, collector-ring flashover prevention, air-cooled collector megger issues, generator fan design, robot development updates.

Thursday, September 1. User presentations and a roundtable discussion are featured until the meeting concludes at noon. Presentation topics include these: Bus-duct circulating-current issues, case history of a sudden field excitation increase, fleet issues seen by one utility, and shaft grounding-brush issues.

Steering committee, 2022

Dave Fischli, *generator program manager,* Duke Energy

Andres Olivares, *generator specialist,* Calpine

Jeff Phelps, *principal engineer/generator SME,* Southern Company

Joe Riebau, *senior manager—electrical engineering/NERC,* Constellation Power

Craig Spencer, *director of outage services,* Calpine

Jagadeesh Srirama, *senior electrical engineer,* NV Energy

Advisor: Jane Hutt, *webmaster,* Intl Generator Technical Community

2021 virtual meeting

The 2021 conference of the Generator Users Group aired on consecutive Thursdays from July 15 through August 5, plus Wednesday, July 21. Siemens Day was July 21. GE Day was July 22. Sessions started at 11 a.m. Eastern each day and concluded at about 3:30.

As noted above, presentations

Participate in the Generator Expert Skill Register

Clyde Maughan has spearheaded several generator-themed industry initiatives in his 70-plus years (yes, 70+) of unselfish service to power producers, most recently the Generator Expert Skill Register.

Finding a well-qualified generator expert for a specific assignment sometimes can challenge plant management, particularly so during these unsettling times of pandemics, global supply-chain issues, and shortages of just about everything.

Given the ongoing tsunami of personnel changes at generating companies, OEMs, and specialty service companies, many in yesterday's pool of generator experts may well have moved on. How do you find the person you need?

Maughan came up with the Skill Register idea—perhaps best described as a "yellow pages" directory online—while snowed in at his Schenectady (NY) home a couple of years ago. He partnered with CCJ General Manager Scott Schwieger to launch the Register, now hosted at https://www.ccj-online.com/generator-expert-skill-register.

They invite every engineer with deep generator experience to register and provide the requested background information and skill description summary. This allows the generator owner's staff to review the posted material at https://www.ccj-online.com/generator-experts and communicate directly with those who seem to best fit the requirements for the task at hand.

This is a win-win: Qualified engineers often do not know who needs their services and the generator owner/operator rarely has a current list of problem-solvers.

by users and vendors—but not the OEMs—are available to registered owner/operators in the GUG section of the Power Users website at www.powerusers.org.

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

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

A goal of all user groups operating under the Power Users umbrella is to quickly disseminate technical material presented at its conferences to the managers, engineers, and technicians who would benefit most from it by improving plant performance. CCJ is working with Power Users to facilitate access to this information.

Fact: Everyone is not interested in everything presented at a meeting and very few, if any, with equipment responsibilities today have the time to "pan" for information that might help them grow in their chosen profession.

CCJ and Power Users believe they can help in this regard by enabling readers to quickly locate technical material conducive to making better O&M decisions. As you read through the summaries below, bear in mind they are not intended to provide the "answers" you might be looking for, but rather point you to presentations by experts who can.

Think of this article as a "TV Guide" of sorts for the web. To our knowledge, no one previously has provided such a service to the power industry. Now you can peruse a meeting's content in sound bites and locate relevant details in a minute or two. Efficiency!

We apologize in advance for possibly overstepping our editorial bounds by identifying presentations we believe to be excellent for a particular reason (exceptional photos, for example). Our opinions are based on years of attendance at user-group meetings and in hallway discussions with knowledgeable plant personnel like you.

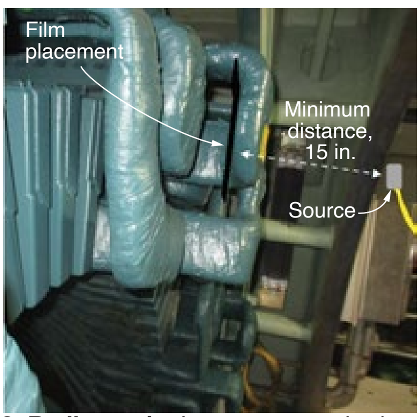
If you have any thoughts to share on our approach here, we would welcome them. Please drop an email to Scott Schwieger at scott@ccj-online.com.

User presentations

Rotor tooth-top cracking

- A valuable paper for all who have responsibilities involving rotor operation and maintenance.
- Two Westinghouse 68-MVA genera-

1. Tooth-top cracking solution was to machine off cracked areas on both sides of the 28 rotor teeth (left) on a 42-year-old generator. This required 112 cuts—one on each side of each tooth on both ends of the rotor (right)



2. Radiography is a proven method for detecting braze defects or cracking in the copper

3. Visual and dc resistance checks were made on each bushing. Overheating, identified here, damaged silver plating

4. A 3-in. hole in the stator end turns, a cable, slicing into the outer axials, and severe slicing of bar insulation from the broken-loose gas baffle contributed to this failure after only four years of service

tors that after 42 years of moderate-duty operation were found with many serious problems—including extensive tooth-top cracking of the rotor-body forging (Fig 1, left).

- Two highly skilled engineers developed ingenious repairs (Fig 1, right) that are described with many excellent photos.

Radiographic inspection of phase straps (TIL-1965)

- Valuable and interesting study of use of radiographic inspection to replace OEM recommendation of stripping insulation to look for cracking of copper leads (Fig 2).
- Findings seem to indicate successful results: No cracks found, time and cost saving significant.
- But some complications, for example: (1) Large isolation area roped off may interfere with other work. Stripping of insulation still required if cracks found.

Stator-winding resistance tests: Troubleshooting and investigation

- Excellent discussion of high DLRO (digital low-resistance ohmmeter) readings found on stator winding copper:
  - One was a true reading that led to corrective action on an incorrectly assembled bolted joint (Fig 3). This action likely prevented a catastrophic failure.
  - The other was attributed to improper DLRO "homemade" leads being used.
- The message: Use care and good judgment in dealing with instrumentation readings.

Generator failure and subsequent extent of condition inspections

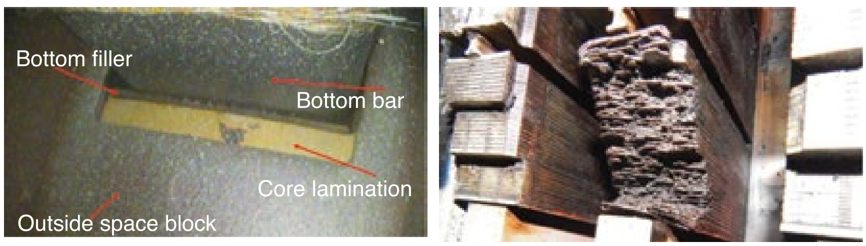
- Many slides describing extensive problems (Fig 4) found on seven combined-cycle generators with only a few years of operation.
- Problems ranged from small ones, such as minor greasing in stator windings, to large ones, such as partial core restacking, stator rewinds, and field rewinds.
- An instructive presentation.

Stator-winding collateral damage resulting from an isophase-bus fault event

- A valuable, well-illustrated presentation describing an accurate analysis of a catastrophic isophase/stator-winding failure (Fig 5).
- Well worth spending some time

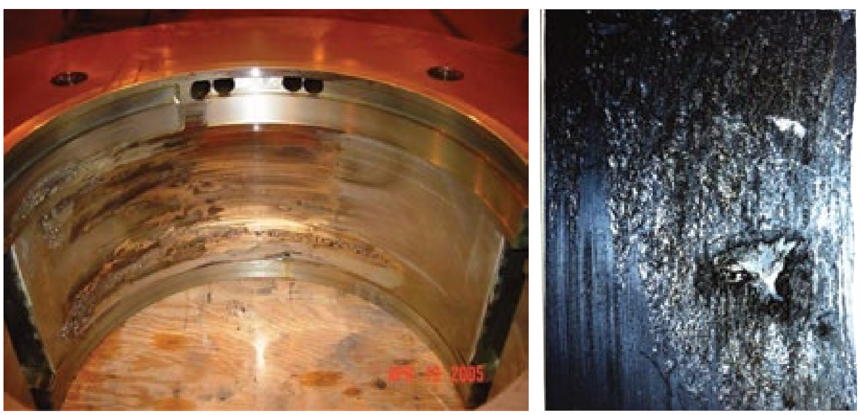
5. Damage resulting from an isophase-bus fault included the bushing-to-PT compartment failure at left and neutral and line enclosure damage at right

6. Main-lead mechanical and electrical failures included broken J-strap leaves at left and J-strap overheating/arcing at right



7. Core looseness can lead to outside space block (OSSB) migration on large generators (left). Tooth loss on 7FH2 generators (right) most often is associated with units made by Mitsubishi Power

8. High-voltage connection inspections by qualified personnel allow rapid identification of overheating issues



9. Unintended magnetism can cause problems such as eddy current damage to bearing journal at left and housing damage to turbine bearing at right

10. Nomex tab rivet failures were in evidence after retaining rings were removed to inspect endwindings. Photo shows jumper condition with melted blocking

with this presentation following the logic illustrated in the analysis and resolution of a huge event.

Vendor presentations

Generator main-lead failures, *MD&A*

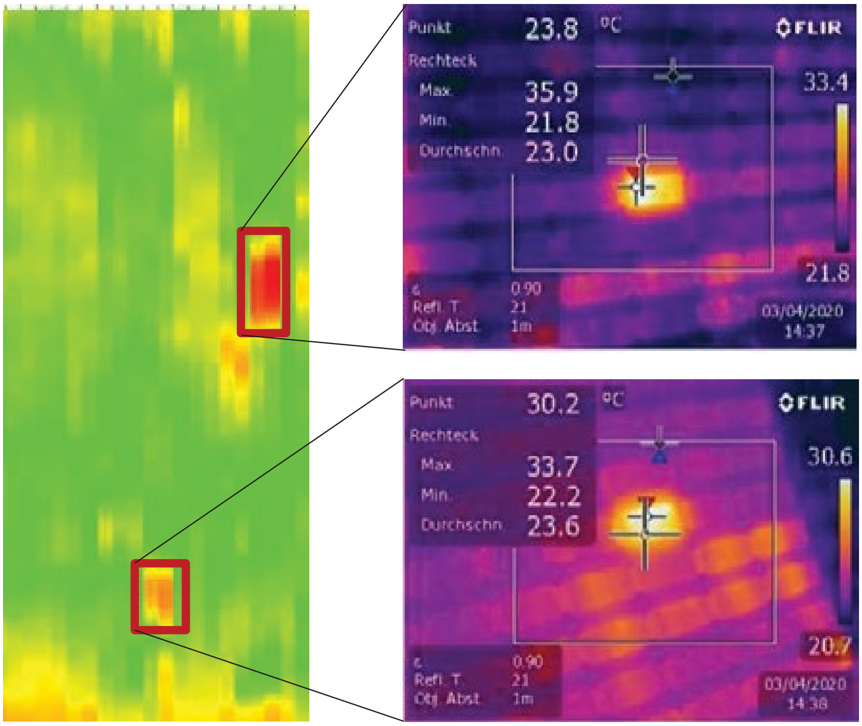
- An excellent tutorial on field-winding main-lead design, failures (Fig 6) and repairs.
- Highly valuable reading for anyone responsible for field operation and maintenance.
- Many excellent photographs and drawings.

Generator-stator core looseness and failures, *AGT Services Inc*

- A detailed review of serious core-looseness problems on modern GE generators for large gas and steam turbines—specifically, outside space block (OSSB) migration on 390H and 450H GTs and 324 STGs (Fig 7 left); trailing-edge end-iron looseness on 7FH2s (typically on peaking/high cycling units); tooth loss on 7FH2s built by Mitsubishi Power (Fig 7 right).
- Concludes that "Modern GE stators need to be evaluated for core tightness frequently."
- Very important reading for anyone responsible for reliability of the models of GE generators identified in the first bullet point.

Generator-stator bolted and brazed connection inspections, *AGT Services Inc*

- Tutorial on connection inspection, with emphasis on bolted designs.
- Many photographs illustrating good and poor connections (Fig 8).
- Valuable presentation for anyone with responsibilities relating to stator-winding reliability.



11. Two example hot spots in a stator core are compared using the rated-flux measurement technique

12. Repairs are made in photo at left to correct a stator failure (T6 neutral phase ring at flex leads). Rewind complete, the phase ring is prepared for bump testing at right

13. Rewinding of GVPI generator stators is a time-consuming, expensive task. Bar removal options are mechanical stripping, shown here, and water jet blasting. Latter requires specialized equipment and highly skilled technicians

Unintended magnetism and corrective measures for improved maintenance programs and risk reduction, *MPS Gaussbusters*

- Comprehensive review of unintended (residual) magnetism in turbine/generator components.
- Many photos and sketches illustrating components and problems (Fig 9).
- A good presentation for anyone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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

involved in overall equipment operation and repairs.

Generator retaining-ring failure case studies, *MD&A*

- Well-illustrated retaining-ring design and function tutorial. No retaining-ring failures.
- Discussion of Nomex tab rivet failures on certain GE generator designs (Fig 10).
- Some useful information for those responsible for operation and maintenance of generator fields.

Stator-core condition assessment with CPC 100, *Omicron*

- Good tutorial on stator design, duties, and fault measurement (Fig 11).
- Emphasis on measurement with CPC 100 and at higher frequency, 400 Hz.
- Valuable presentation for anyone with responsibilities for stator-core maintenance.

Rewind versus repair when commercial and technical aspects are diametrically opposed, *National Electric Coil*

- Detailed summary of decision process, commercial versus technical, on two stator winding failures.
- Details of the cleaning and repair work are well illustrated (Fig 12).
- Valuable reading for plant personnel responsible for generator maintenance.

Successfully rewinding GVPI generator stators, *National Electric Coil*

- Valuable semi-tutorial presentation on rewinding of GVPI stators (Fig 13).
- Discussion of relative merits of GVPI vs hard-coil windings.
- Useful presentation for anyone with responsibilities relating to generators.

OEM presentations

OEMs Siemens and GE each had four hours of presentation/discussion time with the virtual attendees at GUG 2021. Siemens Day was July 21; GE Day was July 22. As noted earlier, most of the material presented by Siemens speakers is posted on the company's Customer Extranet Portal a/k/a Siemens Energy Portal (https://siemens.force.com/cep), that by the GE presenters at https://mydashboard.gepower.com.

Siemens Energy

Colleen Crawford, generator service frame owner, opened Siemens Day by introducing the engineering team participating in the conference. The presenters were:

- Randy Whitener, manager, Generator Service Engineering.
- Michael Garmon, principal engineer, Generator Engineering.
- Eric McDonald, manager, Generator Services.
- Forrest Morlan, engineer, Generator Engineering.
- Ben Humphries, principal key expert, Generator Engineering.
- Jim Lau, expert engineer, Generator Engineering.
- Chris Mize, materials engineer, Generator Engineering

Generator-fleet significant findings during the period June 2020 to June 2021 increased sharply in the stator winding/stator core to 45% from the 24% recorded from 2017 to present. Meanwhile, rotor (18%) and exciter/collector (14%) findings dropped significantly compared to historical data of 25% and 21%, respectively.

Discussion points include the AeroPac™ drip pan—in particular the pans welded to the generator frame and subject to cracking from vibration. An upgrade to a flexible mounting is available to mitigate vibration damage. Issues with main leads, bushings, and parallel rings also are discussed, from the standpoints of inspection, performance, and replacement. Guidelines for success are offered in the service and other bulletins identified.

Generator stator case studies begins with an overview of SGen6-1000A fleet performance. The product line, introduced in 2002, now numbers north of 200 units. Significant events experienced in the fleet over the last 20 years are identified in a table presenting both cause and corrective action taken.

A stator-winding case study takes you from the finding of two ground faults observed during maintenance hi-pot testing to the root cause of the problem: "Local overheating due to displaced core seals caused insulation debonding; cracks initiated and propagated in the de-bonded insulation due to load cycling." Recommendation was to inspect and replace displaced core seals. A product bulletin is identified for users similarly affected.

The Global Vacuum Pressure Impregnated (GVPI) technology used in making Siemens stator coils over the last three decades is discussed. While this technology offers many advantages, it can present challenges if a rewind is necessary. An alternative to a GVPI rewind is Siemens' Rapid Stator ReCore™ offering. In brief: A wound core is shipped from the factory to the plant "ready to install." The generator base frame remains on foundation during the replacement process.

Maintenance case studies includes presentations on the following:

- The company's fault isolation process: How to find a fault, isolate a fault, test to confirm the existence of only one fault, and address the fault component.
- A robotics update, which should be of significant interest to plant personnel, focuses on reduced clearances for inspection and higher-resolution cameras.
- Emerging technologies that you might want to learn more about include FME Artificial Intelligence Attendant and Stator Online Flush Technology (SOFT™).

Stator slot wedge tightness evaluation methods described in the Siemens slide deck are those listed below. Plus, the presenters review issues encountered when operating with loose wedges.

- Conventional tap test.
- Ripple spring measurement.
- FastGen™ wedge impact test.

Electrical engineers ripe for a technical refresher will find value in these tutorials:

- "Generator endwinding mode shape," which reviews the natural frequencies of the stator endwinding that are excitable in service. Bear in mind that identification and control of excitable natural frequencies are required for controlling endwinding vibration.
- "Causes and effects of negative sequence current." Recall that negative sequence currents are based on unbalance in the armature current and these create a reverse rotation flux wave that heats the rotor surface and causes vibration. You may remember that large unbalances can cause significant heating of a machine.

GE Gas Power

Ryan LeClair, generator product line manager, and Tom Freeman, chief customer consultant, led the GE team at GUG 2021. The technical presenters:

- Ross Sacharow, leader, Global Generator and Electrical Systems

Product Service.

- Paul Defay, senior engineer, Fleet Management.
- Guillermo Ramos, Generator Product Services Engineering.
- Dhruv Bhatnagar, technical leader, Generator Application Engineering.
- Ben Mancuso, technical leader, Generator Design Engineering.
- Peter Finigan, engineering lead, Generator Design.
- R Daniel Cárdenas, engineer, Global Generator and Electrical Product Services
- Ian Hughes, principal engineer, Fleet Management.

TIL-2256, TopAir* 60-Hz 21Z/23Z rotor slot insulation cracking. Evidence of cracked slot cover channels and migrated slot liner strips has been identified during field inspections at different customer sites over the last decade. Plus, during rings-off inspections, deformed copper top turns (in the slot portion) have been detected. This experience has been detailed in two customer information bulletins (the second, in 2014, an updated version of the first, published in 2012), which offer guidance on the reported problems. Important to note: This is not a safety concern.

The well-illustrated presentation provides a list of the generator models so affected as well as photos and drawings to facilitate your understanding of the issue. At the time of the meeting, no forced outage had been caused by the damaged insulation components, deformed copper, or slot-liner strip breaking/migration in the rotor slot. However, the risk of a ground fault during operation does exist.

Recommendations from the OEM on when to inspect, what to look for, suggested remedial action, etc, are provided.

7FH2 stator-core step-iron damage. Discussion focuses on key fleet findings regarding core lamination damage and looseness—in particular in generators outsourced for manufacture by third parties—such as MELCO. TIL-2260 is the document of importance. A case history is included.

Stator core update for the 324/390H fleet. Outside space block (OSSB) migration is reviewed for both the 324 and 390H, and the results of thermal and mechanical root-cause analyses (RCAs) are presented.

When to include new coils in a rotor rewind. Practical presentation for decision-makers explaining how to decide whether to replace or not to replace copper coils based on inspection reports, age/service, style of winding/configuration, etc. Excellent photos. A second presentation discusses possible scenarios for the axial migration of generator field coils.

Other presentations:

- Generator stator bar repair.
- Recent H65/H84 fleet experience, which focuses on inner nozzle-shield findings (cracking).
- Generator core compression bands discusses the purpose of core compression bands, their design, and experience with them.
- Short presentations on recommended lifecycle maintenance to achieve high generator reliability; health monitoring; and inspection outage preparations.

POWER PLANT CONTROLS USERS GROUP™

The Power Plant Controls Users Group conducts its fifth annual symposium at the Power Users mega event in San Antonio at the end of August. This group, organized to provide an open forum through in-person conferences and online seminars, disseminates information of value to owner/operators regarding the operation, maintenance, inspection, troubleshooting, and repair of control systems tasked with maximizing equipment performance and reliability.

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

2022 conference overview

The technical program for the upcoming meeting was developed by an all-volunteer steering committee of industry engineers with deep controls experience (photo). An overview of the presentations scheduled for the week beginning August 29 follows. Note that all PPCUG sessions are user-only. Presenting vendors are allowed in the room only when it is their time to present.

Expectation is that most of the presentations will be made available to owner/operators through the Power Users website a few months from now. If you are not registered to access material on the Power Users website, this is a good time to sign up at www.powerusers.org: It's easy and there's no charge.

You can get a good idea of the fine work this organization performs by perusing the summaries of presentations made by both users and vendors last year. They follow the 2022 overview immediately below. You're likely to find some best practices and lessons learned ripe for implementation at your plant.

Monday, August 29. The program begins after lunch at 1 p.m. with a series of training sessions—including:

- How to set up a Mark VIe controller.
- Tools of the trade: Watch Windows, Toolbox Trender, dynamic data recorders.
- Updating control constants to prevent data loss.
- Trip logs.
- PI historian.

Tuesday, August 30. Introductory remarks begin at 8 a.m., with half-hour presentations by the suppliers listed below following immediately. Morning session ends with lunch at noon.

- *OEM versus non-OEM controls,* AP4.
- *Digital twin,* PSM.
- *Controls upgrade? Lessons learned,* GTC Control Solutions.
- *Controls and excitation overview,* MD&A.
- *Direct EGD interface with GE Mark VI/VIe,* Emerson.
- *Operator-initiated generator purge/DHCP upgrades,* Environment One.
- *Group discussion.*

The afternoon session comprises four presentations by Siemens—supply chain, energy market trends and distributed control technology, flexing for the future, and updates from the world of cyber—plus one by Southern Co on GE controls enhancements.

Wednesday, August 31. The day is dominated by Baker Hughes and GE; user presentations and group discussion are scheduled from 3 p.m. to 5.

Baker Hughes will present a controls overview, supply-chain update, and summary of current and future offerings before the morning break at about 9:45. Then GE takes over. Its topics:

- Supply chain/obsolescence.
- From theory to practice.
- Inside the black box.
- System advancements—safety, controllers, foundation field bus.
- Controls Technical Information Letters and accessories.

2021 user presentations

Slide decks for presentations by owner/operators at PPCUG 2021 in the Marriott St. Louis Grand, Aug 23-27, 2021, are available for viewing by registered owner/operators on the Power Users website (https://powerusers.org). The preces below can quickly point you to subject matter of interest.

Legacy DCS network conversion to Ethernet is from a one-off type of powerplant and it's knee-deep in control engineering lingo, but offers some valuable pointers if you are experiencing failures with a 1990s-era DCS based largely on proprietary technology. The plant in question experienced two serious control-system failures, one in 2016 and the other in 2019.

During the first incident, plant staff had to shut down an entire fuel processing (coal gasification) block manually because of failed relays in a fiber termination unit that affected both primary and redundant communications networks. Failed relays were the root cause of the second incident with similar consequences, but at a

PPCUG steering committee for 2022: Brian Hall, TECO Energy; Bryan Eddins, Duke Energy; Peter So, Calpine; David Martorana, Tenaska; Clift Pompee, Duke Energy; Jason Justice, Southern Co (l to r). Camera shy: Adam McCool, Tenaska

different termination unit.

The DCS OEM had released a new (still proprietary) network module mid-2019 which allowed the plant to migrate to an Ethernet hub and spoke network. This eliminated a single point of failure. However, the plant *decoupled* the network design from the supply of proprietary modules. This "moral of the story" ensured a robust network design based on standard hardware for industrial environments and allowed the owner/operator's engineers to become familiar with the design and installation, which should reduce response times in case of a future network failure.

Several lessons learned are offered but are very specific to this DCS and plant design.

Combined-cycle control system modifications

The generic presentation title belies some very practical information about specific aspects of a combined-cycle control and monitoring system—alarm rationalization, wheel space thermocouples (T/C) bypass, historian updates, and high temperatures in Mark VIe controller panels. Most combined cycles likely are dealing with one or more of these issues.

This owner/operator, with dozens of gas turbines and combined cycles, has its own standardized alarm-management rationalization process and screen display design. Alarms were reclassified, consolidated, and prioritized into six categories, with presentation to the operator greatly simplified. Comparing the alarm screens of "before rationalization" and after alone is worth the effort of linking to these slides.

Wheel space T/Cs are physically difficult to access. Months and even years can go by before they are replaced. Fail notices clutter up alarm screens and distract operators from more important alarms. If a temperature element fails, the control system reads a faulty signal and protection is compromised.

In a similar rationalization exercise, the plant added a feature to the wheel-space T/C screen allowing operators to turn off bad temperature elements, and disable faulty readings and alarms associated with them. Meanwhile, the control code substitutes an appropriate neighboring working element so control remains functional and a diagnostic alarm annunciates, alerting I&C specialists to plan replacement at the next opportunity.

Historian changes after upgrade. Fair warning! Upgraded GT control system tags may be taking up much more space than you are aware of in your plant historian. One plant in this owner/operator's system noticed that more than 300 new tags were automatically added to the plant's PI system after upgrading to the Mark VIe.

Options were to expand (and pay for) historian licensed tags or modify library databases to eliminate the new tags. Rationalizing the tags was selected, along with creating new standards to determine which tags to add to historians—including physical inputs/outputs, learned critical tags, totalizer tags, critical timers and counters, deadbands, and max/min ranges.

Hot panels. Several of the owner/operator's plants have experienced Mark VIe controller failures over the last five years. The new "rip and replace" panels were running up to 20 deg F hotter than the migration Mark V panels. Top-fitted vent filter/fan units are being added to the panels running hot. As a temporary mitigation, just opening the top of the panel to let heat escape was able to drop the temperature by 20 deg F.

GT/ST auxiliary controls improvements

Steam-turbine (D11) and gas-turbine (7F) lube oil systems' leak detection and instrument upgrades; motor starting coil monitors; and fuel-oil recirculation system controls are the focus of this presentation. Leak detection for both the ST and GT are based on level measurement in the lube-oil tanks, along with associated alarms. Good details on types of measurements, alarms, setpoints, measuring device (Magnetrol guided-wave level transmitter), etc, are provided.

Lube-oil instrument upgrades included:

- Transmitters added to monitor pump discharge pressure before the check valve and to calculate the differential pressures across filters and heat exchangers.
- Added filter in-service status message.
- Existing pressure switches replaced with transmitters, easing maintenance.

Gas control valve issue

In the category of "it's the little things that'll getcha," locating and removing a plug in the drain line of a gas control valve (GCV) solved a big problem, but not before enormous consequences were experienced in reduced unit output and hours of diagnostic time.

The GCV in question, on a 1999-vintage cogen plant with a 80-MW 7EA gas turbine and 39-MW steam turbine, had been replaced within the last eight months but caused a unit trip during baseload ops at valve position of 62% or less. Stroking the valve offline failed to get beyond the 62% position. Installing a new servo valve did not change the situation.

The valve OEM had no replacement available and you can read about the mitigation strategies the plant undertook to continue to operate at limited load and steam supply. Fortunately, the OEM had heard of similar symptoms with this valve at another site. It turned out the problem at the other site was a plastic "dust plug" inserted in a drain line. Staff at this plant found a metal plug in the drain line location, which was allowing oil to build up on one side of the actuator, inhibiting full stroke.

Once the plug was removed, the valve stroke was verified to operate correctly. Lessons learned include tighter communication with the OEM, better oversight of contractors, and

comparing photos and drawings of old and new equipment for discrepancies.

Anti-icing protection

This set of slides is for you if you're experiencing icing incidences and damage even after you've installed the OEM's anti-icing package at your 7F compressor inlet.

The OEM's current response to the issue is that sites increase the ambient temperature enabling anti-icing protection from 41F to 45F, and increase and maintain the temperature differential between dewpoint and the compressor inlet at from 10 to 15 deg F once anti-icing is enabled.

After analysis, this owner/operator determined that the OEM's model and methodology rely too heavily on relative humidity/dewpoint readings. Comparison of side-by-side GT units revealed that these sensor readings showed substantial differences—that is, sensors drift. What's more, operators have no alternative except to depend on these readings.

The operator's counter-solution starts with this premise: Icing concerns exist when temperature is below 41F and humidity is greater than 80%. The methodology is to enable anti-icing when turbine control instrumentation detects temperature below 41F and relative humidity greater than 78%. Then the control system uses the inlet bleed heat (IBH) control valve to maintain compressor inlet temperature between 39F and 41F. This continues until compressor inlet temperature is detected to be 45F or greater

The control system is given the ability to open the IBH control valve up to 15% to eliminate icing concerns. The demand position of the valve is determined by whichever is greater, the original OEM control demand or the alternative control scheme demand.

Two additional features: (1) Dewpoint temperatures from both GTs can be compared, and if a 10 deg F deviation is detected, an alarm will annunciate, and (2) operators can bypass relative- humidity requirements (and the original OEM scheme) if/when dewpoint measurements are not believable.

Overall recommendation to other users is as follows:

- Execute on the OEM's recommendations, including the challenging piece of increasing the amount of compressor bleed heat to raise and maintain the temperature 15 deg F above the original 10 deg rise in the spec.
- Await outcome of OEM's root-cause analysis around this issue.
- Install this operator's solution to monitor and control in parallel with the OEM's.

1. Automated gas manifold/ hydrogen monitoring system is recommended for plants wanting to reduce the time required to come back from an outage

2021 vendor presentations

Slide decks for presentations by products and services providers made at PPCUG 2021 in the Marriott St. Louis Grand, Aug 23-27, 2021, are available for viewing by registered owner/operators on the Power Users website (https://powerusers.org). The preces below can quickly point you to subject matter of interest. Nearly 200 users attended the Power Users event, which hosted annual conferences for the 7F, PPC, and ST Users Groups and a vendor fair showcasing products and services from more than a hundred suppliers.

Environment One

Automated gas-manifold and generator-purging best practices

Remote automated generator purging is on the minds of many users as they seek to cut the time required to come back from an outage. Mark Williams, regional manager (Americas), described for the PPCUG crowd what an automated purge system looks like, and more importantly, showed them, with a series of photos of the gas manifold/H_2 monitoring system (Fig 1) and remote automation panel.

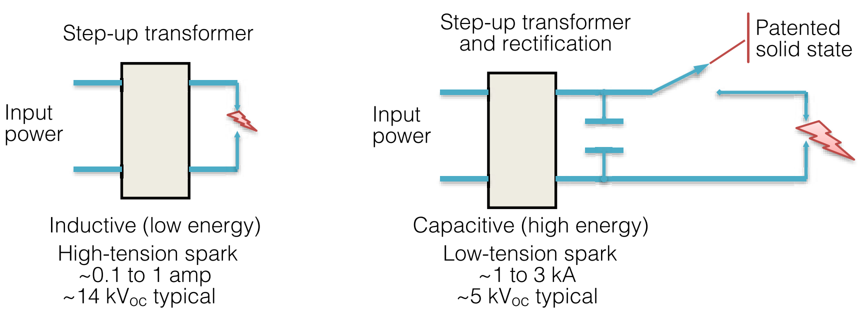
Asking yourself these questions Williams posed to the audience should help you decide if you should take a closer look at the full slide deck:

- How long is it taking to purge your generator?
- Are you having CO_2 delivery issues?
- Can you confirm the amount of CO_2 that has flowed to the generator?
- Do you have CO_2 rated regulators and are they in functional condition?
- What gives you the most concern when going into a purge?
- Do operators have a good understanding of the process and are they well-trained?

Chentronics

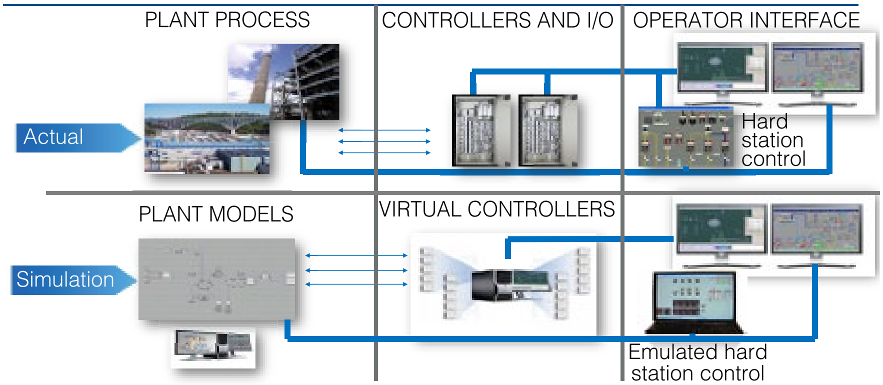
High-energy ignition and flame detection

More a company and product profile than a technical presentation, the Chentronics (part of Koch Engineered Solutions) presentation offered a review of two types of igniter systems (low tension and high tension, Fig 2), and their relative advantages and disadvantages. Highlights of the Chentronics design include high-efficiency universal input power, patented solid-state electronics, high reliability (22-year mean time between failures claimed for its SureSpark product), complete system from one vendor, and expertise in a wide range of applications, including burners/pilots, flares, and gas turbines. SureSpark is further distinguished by the use of a semiconductor in the spark gap.



2. High-spark-energy/low-tension ignitor system at right features patented solid-state circuitry; the high-tension/low-spark-energy design at left does not

3. Digital motor controllers are powered by 120-Vdc batteries, have IP65-rated enclosures, accept 24- or 125-Vdc trip signals, and come with hazardous environment certification



4. Digital-twin simulator offers key benefits in pre- and post-commissioning operating environments, though it does require maintenance annually or more often

Young & Franklin/AP4 Energy Services

Electric gas valve installation

Core message in the YF/AP4 team presentation is for users to relieve themselves of the incessant headaches (leaks, varnish, cleaning, filter replacement, etc) presented by valve hydraulic systems and replace OEM-supplied actuators with Y&F's electromechanical actuators (EMA).

EMAs offer a ten-fold return on investment over the life of the product, they claimed.

Applications discussed (with product and installation photos) were electric stop/ratio valves, gas control valves, and inlet-guide-vane actuators. Installation ("easier than you think") is handled by TC&E and requires five pre-outage days to run cables and mount digital motor controllers (Fig 3), three outage days for the mechanical install, and one day for calibration and commissioning.

Emerson Automation Solutions

Using digital-twin technologies to improve plant operations

James Thompson, lead engineer, updated the PPCUG audience on plant experience with Emerson's digital-twin technology, especially when used as a simulator. The digital twin "embeds" simulation within the Ovation DCS via "virtual controllers" using physical models of all powerplant main and sub-systems (Fig 4), workstation software, and replicated control logic.

The value stack justifying the digital twin are operator training on a system as close to the actual DCS as one can get, DCS controls checkout, operating procedure development, engineering test bed, and process model visibility.

Two case studies are presented, the first to demonstrate the benefits before plant commissioning, the second to demonstrate benefits after plant commissioning.

The first case revealed DCS logic issues early on and problem transitional states at controls interface points; provided testing of configuration heavy algorithms and validation of set points and alarms and multiple operating modes; and helped establish operating procedures.

The second case, involving one owner/operator's three combined cycles demonstrated pre-testing of logic changes in a safe environment, optimization of plant startup conditions, and deeper insight into the behavior of turbine controls.

Thompson stressed that the digital twin does require maintenance at least annually, because plant conditions are always changing. The maintenance should be tailored to the way the digital twin is used. For example, if used primarily for training, ensure the degree of realism has not been compromised; for process optimization, ensure process models are up to date; for controls optimization, ensure DCS and virtual controls are synchronized.

Cutsforth Inc/Kent Smith Consulting

A case study on electromagnetic interference (EMI) monitoring

Steve Tanner, Cutsforth, and Kent Smith begin with some basics on EMI monitoring before diving into several case studies. EMI is used to detect and identify electrical defects like arcing, gap discharge, corona, and micro-sparking. Each of these has its own characteristic "demodulated" waveforms which can be detected by non-intrusive radio frequency EMI monitors which typically require no outage time to install around motors, generators, isolated-phase busses, and transformers.

Signals are transmitted to the control room and data aggregated and trended by Cutsforth's InsightCM™ platform and software, then archived in the historian.

The first case study involved a shaft grounding event. First indicator was voltage spikes greater than 100 V, followed by a notice from the M&D center that electromagnetic signature analysis levels were trending higher than values predicted by the M&D models. Two different monitoring systems were displaying similar anomalies.

Inspection of the generator revealed the lead from the shaft ground monitoring (SGM) instrumentation to the plant ground system had become disconnected. When reconnected, the voltage levels returned to normal. Bearing degradation and electrolysis leading to a shutdown could have been the consequence without early detection of the issue.

The second case study involved a weather-related event. First sign was spikes measured during rain/snow in mid-February from the radio-frequency cable tester (RFCT) at the generator step-up transformer (GSU), which were different from the RFCTs at the generator and the generator circuit breaker (GCB).

During the spring outage, 13 insula-

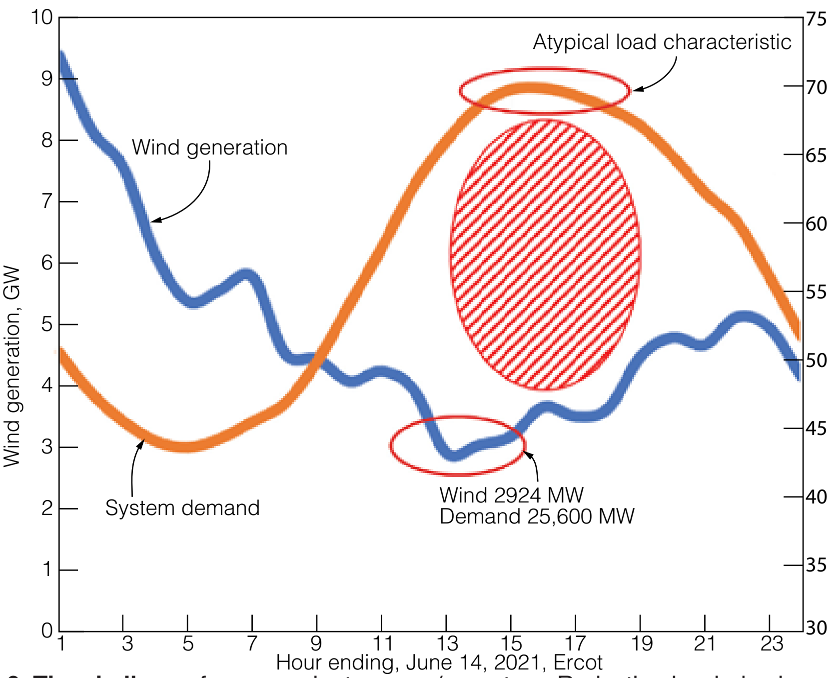
5. RFCT installed on the frame ground; usually coupled around the generator to the neutral ground connection tors in one of the isophase ducts were found damaged from water intrusion. This would have led to a multi-day forced shutdown at some point in the future. Periodic readings or ad hoc EMI inspections likely would not have revealed this issue.

The presenters stress that the permanent EMI continuous monitoring system (Fig 5) with InsightCM "collaborates" with existing monitoring techniques to identify defects.

EthosEnergy Group

Gas-turbine operability challenges in an unstable grid environment

Chris Chandler, chief technologist for turbine optimization, warned the PPCUG crowd that recent grid-wide reliability events in California (summer 2020) and Texas (calamitous winter freeze 2021) were likely to be experienced nationwide as the percentage of renewables on grids keeps growing. Because gas turbines and combined cycles will be expected to "pick up the megawatt slack" when renewables output drops by hundreds, and even thousands, of megawatts precipitously, combined cycles need to adapt for operation at the "lowest sustainable limit" (LSL, Fig 6).



6. The challenge for powerplant owners/operators: Reduction in wind coincides with an increase in demand, driving the need for maximum gas-turbine operating flexibility (shaded area). Texas experience shows that as temperatures increase, wind capacity generally decreases

Balance of Chandler's presentation explains how the company's Ecomax Extended Turndown optimization package can extend the life of the equipment while operating more hours at LSL. It addresses the consequences of operating at prolonged maximum turndown states, most importantly the inability of the HRSG to adequately attemperate and higher CO production from the combustor.

Operators are alerted in real time what the LSL is and the Ecomax Extended Turndown "knobs" are used to operate at that point until CO becomes an issue. The system can boost GT output by 5 to 15 MW per unit at the low end, says Chandler. As of this presentation last year, the concepts had been validated and the program was in commercial development with a lead user. CCJ

Air-Cooled Condenser Users Group

The Air-Cooled Condenser Users Group (ACCUG) began in 2009 as a grassroots body to stimulate technical exchange among ACC owner/operators, OEMs, third-party vendors, and consultants—focusing on these three areas: Chemistry and corrosion, design and performance, and operation and maintenance.

Annual in-person meetings began in fall 2009, the first in the Las Vegas offices of NV Energy, which together with CCJ founded the organization. Conferences since have been held throughout the US, plus one in Mexico and one in China. But because of Covid-19, ACCUG 2020 was postponed and ACCUG 2021 was conducted virtually in October.

In-person conferences benefit from one-on-one interaction, the ability to discuss specific details with sponsors, and a specific site visit with ACC tour. But going virtual did carry some advantages—including deep dives into valuable ACC experiences in Iran and South Africa.

ACCUG 2021 was fully recorded and is now available for viewing on-demand and at no cost via http://acc-usersgroup.org/presentations/2021-virtual-conference.

As a first step, the editors suggest you read this conference summary, prepared by Consulting Editor Steve Stultz, to find items of interest and then dig into the details on the web. The following passage illustrates this process and its benefits.

Stultz's summary introduces you to Huub Hubregtse, owner of ACC-Team Technology, The Netherlands, an expert on gearboxes (and other components as well). He said the following: "What's happening is when you have side winds, the fans will start rocking, moving a little bit one side up the other side down, giving the end bearing quite heavy loads. Oil has actually passed through the gearbox and end-bearing chamber (Fig 1) and is dispersed by centrifugal force. If you see this type of pattern, you know what's wrong. You know that your gearbox could fail fairly quickly." If this piques your interest in learning more about gearbox issues and solutions, access Hubregtse's presentation on the user group's website.

In a later example, Hubregtse discussed steam evacuation systems and a site visit to investigate excessive backpressure. He brings readers in with: "So I told the guy, let's have a look!" His case history walks you through the solution.

Such narrative recollections, captured both during the presentations and during the Q&A sessions, provide guidance with credibility.

Day One

Moderator for the first day of the conference, focusing on chemistry and corrosion (and two-phase FAC, was Barry Dooley, Structural Integrity Associates (UK), who opened the meeting with a presentation on the "Latest in ACC Chemistry and Corrosion."

"Corrosion basically is the same worldwide with all chemistries and plant types," he stated. More pointedly, Dooley added, "the air-cooled condenser controls the plant's chemistry."

His presentation began with a review of key aspects discussed since the first conference in 2009. Those interested in such primer material should listen to Dooley's recorded presentation. The visuals provided clearly show typical damage indicators at tube entries, support structures, and transport ducting.

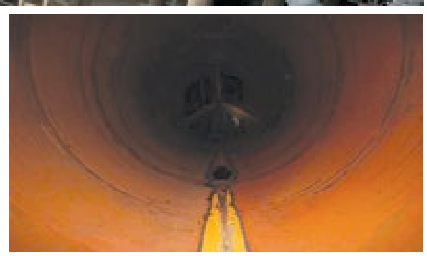
He also reviewed the Dooley Howell Air-Cooled Condenser Corrosion Index (DHACI), now used worldwide. This metric also is explained in ACCUG Guideline Document 01, "Internal Inspections," available at http://acc-usersgroup.org.

Dooley continually monitors global efforts to address ACC corrosion, including the following: increasing bulk condensate pH, applying an amine or film-forming substance, filters and condensate polishers, coatings, alternative materials, and ACC design.

Medupi's ACC. Sabelo Khanyile, Eskom, South Africa, provided a window on the large supercritical units in his home country to show the complexities of corrosion assessments related to both cycle-chemistry treatments and plant operations (Fig 2). He also noted that "temperature is a significant factor" when analyzing the effects of treatments.

Using the DHACI, Khanyile included many visual examples of "good universal hematite formation" (Fig 3). During the discussion period, Dooley came back to this to clarify: "There has to be magnetite first. Red oxide follows. But in two-phase this can't happen, so it takes place during shutdown."

Dooley as the day's moderator moved quickly to the expanding experience with film-forming substances (FFS, CCJ No. 63, 2020, p 71). Many



1. Fan housing shows evidence of gearbox wear (left)

2. ACC at Medupi Power Station in South Africa is one of the world's largest (above)

3. Hematite formation at Medupi (right)

4. Dominion's Warren County Power Station shared its significant experience in reducing iron transport and the positive impact of amines

of those who had attended previous conferences quickly recognized the increasing focus on this topic.

He then provided a detailed summary of international FFS experience while highlighting "still missing" information that will come only through experience. Dooley's highlights emphasized the complexities of FFS application and the lingering lack of a full understanding.

Some chemicals in use today remain proprietary by their suppliers. Application methods and amount are in the trial phase. Therefore, cautions remain for end users.

Dooley's final thought: "Much care also is required when using FFS for possible problems in the remainder of the plant (boiler/HRSG tube failures, drums, valves, etc)."

FFS trials on large scale

Jeff Demattos, Cogentrix, discussed FFS application at four identical H-class 1 × 1 combined cycles with triple-pressure HRSGs, covering varying results from ammonia only, anodamine, and filming amines.

A key section in his presentation included details on "Filming Amine Hypothetical Risks versus Cogentrix Experience." This is worthy of review by anyone considering amine application and incudes many photographs of results. It is of particular value to those interested in the chemical evolution of these particular units, leading to the Cogentrix "typical chemistry today."

Shana Ferrante then presented on widespread FFS applications across the Dominion Energy fleet (Fig 4). Ferrante, formerly with Suez WTS Systems USA, covered inspection and operational objectives of these applications.

Dominion wants to minimize downtime, reduce iron transport during startups, improve iron levels during operation, and analyze for chloride and sulfate. "Reducing high iron levels during startup is a key benefit of using amines," she said. Listen to the discussion for feed points, dosing, and results. Inspection photos clearly show improvements related to DHACI guidelines.

"Another set of eyes." Cogentrix and Dominion site data formed the basis for an interesting discussion by Ken Kuruc, Hach, on the importance of corrosion-products monitoring. The discussion of both online and grab samples included some helpful tips (for example, proper cleaning of sample bottles) based on experience, which he listed as things to "keep in mind." Kuruc included clear and easy-to-follow steps and details. His verbal summary brought it back to the basics: "Look at this (online particulate monitoring) as another set of eyes that is available 24/7/365"

Ronny Wagner, Reicon, Germany, ended the discussion with a look back to early FFS experiments in Moscow, and the more than 30 years of development and applications, both with and without air-cooled condensers.

Questions and general discussions for the day followed.

Day Two

ACC design and performance was the focus of Day Two, beginning with a review of the operational histories, challenges, and solutions associated with the massive ACCs serving South Africa's large supercritical coal-fired stations (Figs 5 and 6).

Stellenbosch University is actively involved with the nation's operating units for measurement research and analysis, as well as for fan design. Daniel Els compared two large stations—Medupi and Kusile—with varying startup modes (direct and thyristor-type soft start), and a measurement setup of strain gauges, accelerometers, magnetic sensors, and both wired and wireless connections to measure shaft speed and torsion, fan torsion load, and shaft bending.

Hannes Pretorius continued with an overview of the university's ACC research.

Discussion of extended gear life, oil conditioning, and remote monitoring by C C Jensen's Axel Wegner followed. He provided graphically supported coverage of abrasive and other wear mechanisms on bearings and gears, particle visibility, abrasion, and erosion. Els recommended that ACCs be equipped with dedicated gearbox kidney-loop filters with remote monitoring.

Bhaumik Modi, Hudson Products

5, 6. The ACC at Kusile Power Station in South Africa (above) and view of fans from below (right)

impacts of changes in operation conditions on equipment and performance.
- Move critical maintenance strategies from reactive to predictive.

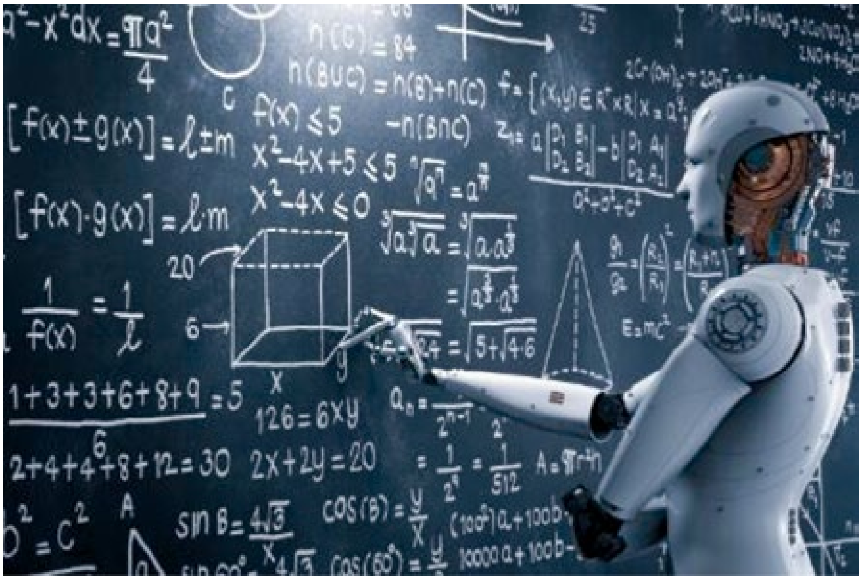
Melisie focused on common issues (vibrations and bearing failures) while simultaneously monitoring assets and wind conditions. He explained, "This helps, for example, determine if problems are with the side winds or with the fan itself."

Look for the little things to see typical problems

Hubregtse, introduced at the beginning of this report, then gave his informative talk on ACC maintenance, focusing on fans, gearboxes, motors, pumps, and evacuation systems. His presentation was based entirely on hands-on experience and case histories. Included were typical life expectations and recommendations for spare-parts inventories.

An interesting component noted during discussion of gearbox maintenance, is a breather filled with silica that absorbs water from air entering and leaving the gearbox during thermal expansion.

"Maintenance on the steam evacuation system," he said, is quite



7. A representation of the digital twin

8. Powerplant cooling systems in Iran by type and location

Corp, followed with a look at the latest thinking on axial fan design. He reviewed the history of fan development and ongoing efforts to reduce fan noise. All development milestones encompass aerodynamic (fan blade shape) and structural design issues as well as manufacturing. "Airfoil selection," he explained, "is the first and most critical part of the design process."

The latest designs feature so-called resin transfer molding manufacturing to fabricate structurally reliable FRP blades. This method allows for complex blade shapes and monolithic design.

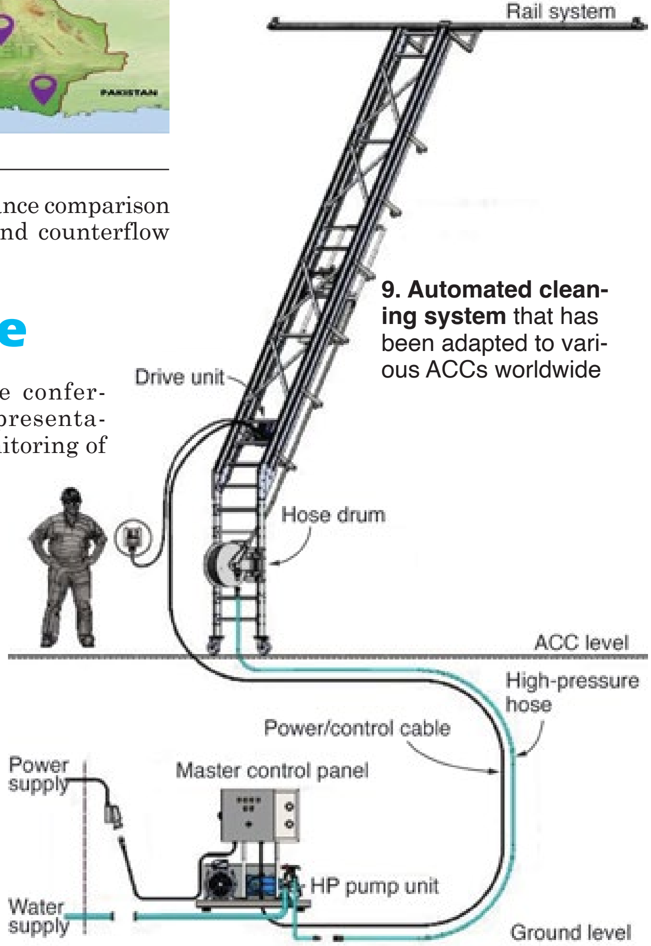
Wind, gravity, pressure

Another topic with increased attention was windscreens, covered here for both A- and V-type frame designs. Current research was presented by Cosimo Bianchini, Ergon Research, Italy, who focused on modeling details with sub-models for fans, bundles, and designs—both with an without screens.

Formal presentations for Day Two ended with a performance comparison between co-current and counterflow ACC tubes.

Day Three

The final day of the conference began with a presentation on real-time monitoring of ACC fans by Mirko Melisie of Howden (The Netherlands). He focused on what he termed the "digital twin" (Fig 7)—that is, in-depth asset analytics are available through a dynamic link between real-time performance data and physics-based models. The purpose is three-fold:
- Detect rotating-equipment failure before it occurs.
- Understand the



9. Automated cleaning system that has been adapted to various ACCs worldwide simple, but a key is the gaskets. Be mindful that gaskets are subject to temperatures of 480F to 570F, and when the system cools, thermal movement will damage them.

"Pumps," he says, "are rarely kept in stock, but you should have some spares around for seals, gaskets, bearings—things like that."

Questions focused on oil quality and testing, bearings, and unit vibrations. During the Q&A, Dooley offered the idea of a global database on common maintenance items and common failure modes, leading to guidance documents. The ACCUG leadership is considering this.

Cooling systems in Iran

ACCs in Iran were introduced by Mohammadreza Vaghar of the country's MAPNA Development Co. Iran's first wet cooling system was installed in 1959, the first ACC in 1985 (Fig 8).

High winds can be an issue in Iran, and several plants are planning for the possible retrofit of windscreens. Vaghar shared CFD analyses used to identify the preferred geometries.

Automated cleaning

Arndt Krebs, JNW Cleaning Systems, offered a detailed view of a patented mobile cleaning system adapted to various air-cooled heat exchangers in Germany and elsewhere in Europe, plus South Africa and the US (Fig 9).

ACCUG Guidelines

EPRI's Andy Howell, the ACCUG chairman, was last on the list of formal presentations with an in-depth look at three ACCUG Guidelines covering steam-side inspection, finned-tube cleaning, and air in-leakage. The thumbnails:

- ACC.01, "Guidelines for Internal Inspection of Air-Cooled Condensers."
  - Guidance to ensure a comprehensive inspection.
  - Focal point for the ACC community to optimize steam-side inspections.
  - Use of a quantifiable index to show improvements and allow comparisons among ACCs.
- ACC.02, "Guidelines for Finned-Tube Cleaning in Air-Cooled Condensers."
  - Guidance for important issues involved in the cleaning of finned tubes.
  - Expandable document for ACC community to input on experiences and needs.
  - An initial basis for cleaning options.
  - Effects of blocked fins on system performance.
- ACC.03, "Guidelines for Air In-leakage in Air-Cooled Condensers" (in preparation).
  - Guidance for in-leakage issues specific to ACCs.
  - Expandable document for input on experiences and locations.
  - Identify the effects of air in-leakage on performance and system chemistry.

ACC.01 and ACC.02 are available for download at no cost from the ACCUG website (www.acc-usersgroup.org).

2021 ACCUG update

- Steering committee: Andy Howell, EPRI; Barry Dooley, Structural Integrity Associates (UK); Riad Dandan, Dominion Energy; and Rishi Velkar, NV Energy.
- Conference sponsors: C C Jensen, CONCO, Evapco Dry Cooling, Galebreaker Industrial, IPC Lydon, MVM EGI. Reicon, SPG Dry Cooling, and Suez.
- Conference coordinators: SV Events and CCJ.

Finally, please visit the organization's website at www.acc-usersgroup.org to access the Q&A Forum, presentations from past meetings, registration information for upcoming events, and group-generated specific technical information. CCJ

COMBINED CYCLE USERS GROUP

The Combined Cycle Users Group returns to San Antonio in 2022 where it was launched in fall 2011 as an independent, user-directed group to serve owner/operators of combined-cycle, combined heat and power (CHP), and cogeneration plants. This year's in-person meeting follows virtual meetings in 2020 and 2021.

2022 conference overview

Technical program for the upcoming meeting was developed by the all-volunteer steering committee of engineers and managers identified in the sidebar—many with decades of relevant experience. An overview of the presentations scheduled for the week beginning August 29 follows.

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

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

Monday, August 29. Monday morning training is four hours on the basics of vibration analysis. The afternoon session includes the following presentations:

- Online HRSG inspection: Tying together offline inspection and maintenance.
- Repair versus replacement of P91 non-return valves—a case study.
- HRSG inspection tools.
- Insurance hot topics.

Tuesday, August 30. A potpourri of topics important to O&M personnel focused on improving plant performance are addressed in the following presentations by vendors and users:

- HRSG life extension and long-term maintenance planning: A data-driven approach.
- Group 1 turbine oils—a return to reliability.
- Is your SCR/CO system ready for turndown?
- Advantages of periodic field testing on critical pumps.
- DCS-replacement knowledge sharing: Lessons learned.
- Better filtration pays for itself: The impact of HEPA filters on gas turbines.
- P91 planning and inspection.

Following the afternoon break. several short presentations based on user experiences, plus a discussion period, are planned until closing at 5 p.m.

Wednesday, August 31, is reserved for MD&A and the turbine OEMs. MD&A launches the day right after breakfast with these two presentations:

- Steam-turbine valve outages: Common issues.
- Unintended reliability risks through parts replacement/obsolescence.

A safety discussion follows until the morning break at 9:45.

The Siemens team is next at the podium with presentations on cybersecurity, battery technology advancements, plant operating flexibility, and upgrade assessments.

GE dominates the afternoon with presentations on market analytics, decarbonization, transformers, impact of increased low-load operation and cycling on steam turbines and HRSGs, and HRSG lifecycle management.

Thursday, September 1, features user presentations on carbon capture, a condenser explosion, non-jurisdictional pressure vessels, and a case history on the failure of an excitation auxiliary transformer. The meeting closes at noon.

2021 virtual meeting

User and vendor technical presentations and discussions were conducted July 13 and 27, and August 3; GE Day was July 20, Siemens Energy Day was July 28.

Steering committee, 2022

Chair: Phyllis Gassert. director of asset management (PJM), *Talen Energy*

Vice chair: Brian Fretwell, director of mechanical services, *Calpine*

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

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

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

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

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

Marih Salvat de Jesus, operations manager, *Tenaska Virginia Generating Station*

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

70,000 MW per year increase via ECOMAX® with Tru-Curve®

Flexible and responsive auto-tuning solution to maximize performance and efficiency

THE CHALLENGE: A US chemical refinery with a fleet of four 172-MW 7FA gas turbines was looking to maximize the performance and efficiency of their units as part of their long-term sustainability goals. Without an auto-tuning solution, they were forced to contract a third-party to perform manual tuning which had a great effect on their bottom line. It also didn't maximize MW output potential, caused the units to burn more fuel than needed, decreased life of parts, and was not minimizing CO_2 emissions.

The plant was in search of an auto-tuning solution as well as guidance and education around de-rating their units and properly reading and identifying the significance of combustion dynamics monitoring system (CDMS) alerts.

The CDMS gave them the ability to receive alerts when they exceeded combustion limits and they had a remote monitoring agreement with the OEM, however it was costly and inefficient to bring in someone to manually tune the units every time the CDMS indicated an issue. The current tool was only for reporting and identification with little ability to solve any tuning issues internally.

To maximize efficiency, they needed a nimble and responsive solution that could be controlled from within the plant. Adding to the challenge, the units did not initially have raw NO_x probes, limiting their flexibility within the control system.

THE SOLUTION: After discussions with EthosEnergy's engineering team, the plant contracted EthosEnergy to install ECOMAX® with Tru-Curve® auto-tuning on one of the units. This allowed greater flexibility and control from within the control room via a computer-based turbine controller utility. As a result, there was no longer a need for a tuner to come to site after a combustion inspection, hot gas path inspection, or major inspection, saving on planning and costs.

It also allowed winter and summer max firing temperature adjustment while mitigating combustor dynamics, increased parts life, and automatic de-rating of the gas turbine if combustion dynamics could not be maintained below established limits.

Because the unit was always tuned, this allowed operation up to the firing limit year-round, truly maximizing the performance of the unit.

After a full cycle of reliable run-time and a review of combustion hardware, the same system was successfully installed on the remaining three gas turbines at the site and later across eight other units for the parent company across North America, including the following engine types: 7FA, 7EA, and 501D.

THE BENEFITS:

- Firing temperature increase from 2400F to 2424F.
- Observed one MWe per 10 degrees of firing temperature increase for a total output increase of 9.6 MWe.
- Observed 8000 lb/hr of HP steam flow per each 10 degrees of firing temperature increase for a total output increase of 10.4 MW_{eqv} of steam.
- 20 additional MWs for 98 MMBtu of additional fuel (4.9 INHR).
- 465k MMBtu per year of fuel savings.
- 27,200 tons per year of CO_2 reduction from increased steam efficiency and lower CO from tuning improvements.
- Over 70,000 new MWs per year produced at 4.9 MMBtu per MW.

About ECOMAX® with Tru-Curve®

Burning a lean premixed flame can keep NO_x emissions low; but, too lean of a flame can result in instability. This instability (combustion dynamics) can result in costly damage to the combustion chamber and downstream components. Manual tuning demands a conservative balance between emissions compliance and combustion dynamics.

ECOMAX® is a fully automated platform which manages emissions, provides flexible operation, and increases thermal efficiency of a gas turbine power plant. The base system automates tuning for continuous NO_x and CO compliance, flame stability, and acceptable combustion dynamics. Turbine fuel-to-air ratio is a key parameter affecting gas turbine (and power plant) performance. Although raising the turbine's baseload fuel-to-air ratio will improve power output and heat rate; emissions and combustor dynamics are adversely affected.

Tru-Curve® is a module for ECOMAX® that raises the turbine's baseload fuel-to-air ratio. Specifically, it is a bias of combustion operation toward one edge of the operational envelope, while ECOMAX® continues to manage emissions and combustor dynamics within the envelope.

SUMMARY: ECOMAX® with Tru-Curve® allowed the units to run up to the firing limit year-round, generating substantial gains in performance (a cumulative 70,000+ MWh per year), reduced fuel consumption, and greatly reduced emissions (27,000 tons per year CO_2 reduction).

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Discover how we can help you turn potential into performance, supporting you through the complexity of business today, while transitioning to tomorrow.

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EthosEnergy

As noted above, presentations by users and vendors—but not the OEMs—are available to registered owner/operators in the CCUG section of the Power Users website at www.powerusers.org.

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

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

User presentations

Catastrophic failures: Does your backup system work. . .really?

"A $400 relay takes out ST/G; multiple single-point vulnerabilities found," which appeared in CCJ No. 68 (2021), p 76, was compiled from information shared in this presentation.

The case study reminds why attendance at user-group meetings is so important. It focuses on the trip of a 2 × 1 F-class combined cycle at baseload with duct burners in service that was caused by an operator who opened the wrong breaker in the switchyard, and the failure of the plant's ac pumps to restart after that event. A review of critical systems identifies single-point vulnerabilities tied to the steam turbine and its auxiliaries.

Presentation tells how plant personnel conducted their troubleshooting, what they found, and the changes made to prevent a recurrence. Recommendations made to users based on this experience might be a valuable addition to your station's lessons-learned file.

Arc flash—remote racking best practices

Arc flashes are low-frequency, high-impact events but their occurrence is increasing industry-wide. About 2.5% of arc-flash incidents result in the death of a worker; 95% are caused by human error, so training and strictly adhering to, and updating, best practices are vital.

By adhering to the guidance offered in this presentation, you and your colleagues likely can make your plant a safer workplace. Key material from this slide deck was used to develop the CCJ article, "Learn from one utility's arc-flash safety program," published in issue No. 68 (2021), p 83.

Plant's valve maintenance program with Millennium Power Services

Discussions at CCUG and other user groups remind that poorly maintained valves can negatively impact plant performance—perhaps even contribute to a forced outage. The O&M manager at this combined cycle offers a solution: Partner with a qualified third-party services firm having the capability to inspect, monitor, and repair valves as part of an ongoing maintenance program.

The PowerPoint describes the successful program developed by vendor and staff to track and prioritize maintenance for the 200 major valves serving three 1 × 1 G-class combined cycles, thereby bringing the plant up to industry standards. Several best practices to take away from this experience. You can get the CliffNotes version, "Service provider tracks valve health, makes expert repairs, cuts maintenance cost," in CCJ No. 69 (2022), p 70.

Blockage of inlet filters due to snow, debris, dust

This presentation was developed to stimulate discussion on filter blockage, why it occurs, and how to mitigate it. You can use the slides to guide a lunch-and-learn in the plant break room (plant manager must provide the pizza) to get personnel thinking about how to prevent the operational upsets that filter blockages can cause. Such an interactive discussion on a practical topic is far better than a formal presentation that promotes snoring by "participants."

Some highlights: Benefits offered by pre-filters; challenges presented by wildfires (smoke and ash); backgrounder on particle sizes; mitigation strategies for snow, ice, freezing; and blockage scenarios—solutions and planning.

Roundtable: QA/QC process to check contractors

Registered users can listen to a recording of the roundtable, posted on www.powerusers.org. Alternatively, you can read the following summary of the session developed by CCJ editors.

During the QA/QC roundtable, led by two members of the CCUG steering committee, two polls were conducted. When attendees were asked if their facilities had a formal plan for welding contractor QA/QC, 13.4% said "yes," 14.2% said "no"; the others did not answer. When asked if they used a third-party QA/QC service to monitor contractors, 16.4% said "yes," 11.9% said "no," and 71.6% did not answer. However, since there were about 140 attendees at that point, more than one quarter did respond, so the sample size isn't trivial.

Experiences shared by attendees suggest those who answered in the negative to both questions may wish to get their leadership to reconsider the value of having a formal QA/QC plan:

- "We've found valves welded in backwards!"
- "Our sites have often had 100% dropouts of 'certified' welders who show up but can't pass a performance test."
- "We've had a contractor cut out equipment even before the appropriate measurements have been made."
- "The foreman of a contractor crew, on whom we depend for the QA/QC, got Covid, and workers were not following procedures without the foreman's supervision."
- We've had major problems with failed welds on 12-in. P91 HRSG steam headers."

Follow-on discussion indicated that these weren't isolated incidents; many plants are suffering from poor weld quality, repeat work at failed weld locations, and general rework. Roundtable leaders suggested having a formal QA/QC oversight process, or making your existing one more robust, with these elements: pre-planning, implementation, and completion/verification (Sidebar, pages 42-43).

The details involve mostly common sense—and include the following: verify proper materials are being used and include drawings and manufacturers' data report on pressure vessels (U1A form) during preplan; verify contractor welding procedure specifications (WPS), work breakdown structures (WBS), and procedure qualification records (PQR) during implementation phase; and review NDE and post-weld heat-treatment reports to verify completed work.

The important thing is to formalize, checklist, and document that the proper steps have been taken and confirmed with written or digital records.

Valuable contributions from audience members included these:

- Use a PMI (positive material identification) machine to verify alloys.
- Have stores verify that materials arriving onsite match the materials data sheets before accepting.
- Check transmitters from overseas for cybersecurity issues.
- Require that plans be developed in collaboration between contractors and site personnel to ensure that scope of work is aligned.
- Consider either hiring a third-party QA/QC contractor or certifying one of the site staff for this function, increasing their compensation if necessary.

A representative from one of the largest combined-cycle owner/operators noted that his company pre-tests all welders coming onsite even though

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Resource qualification an important step in contractor

Average length of service of the contractor's employees and the skill levels of the various tradespeople are important qualification metrics, advises Bill Kitterman, GM, Bremco, a recent addition to the SVI family of companies. He recommends that you ask for and carefully review resumes. Contractors worth considering for your work should have them ready for your review without asking, Kitterman says.

In your evaluation, be sure to differentiate between supervisory personnel and crafts. Length of service, formal training, and work experience of supervisors is particularly important. For example, service time is an indicator of the company's health, quality of management, job performance, etc. At SVI/Bremco, supervisors average more than 15 years of company service; crafts about half that.

Pay particular attention to craft skill levels. What codes are welders qualified to? Does the contractor have millwrights, fitters, iron workers, riggers, etc, on staff? Most HRSG work requires all of these skills. In Kitterman's experience, the more the owner/operator knows about the contractor's capabilities and personnel, the smoother the planning process and conduct of the actual job.

Quality assurance. Evaluation of supervisory and craft resources are only one part of the due diligence effort. Perhaps just as important to project success is the support staff responsible for quality assurance and safety.

Your QA audit, in the specific case of HRSG work, should focus on knowledge of ASME and NBIC (National Board of Boiler and Pressure Vessel Inspectors) code requirements, experience in code work, welder qualifications, registering of repairs and work, etc.

The QA department and its procedures are particularly important when work involves repair or changes to boiler pressure parts. A plant manager auditing a specialty contractor for such services wants to verify staff capabilities with respect to weld inspection, familiarity with the code, accessibility of staff code experts to field personnel, availability of QA specialists to monitor repair work, etc. Last thing any owner/operator wants is to slow down or halt a job while waiting for a weld-quality verification or a code interpretation.

Kitterman says SVI/Bremco has two QA experts on staff—both certified weld inspectors. Note that some welders also are CWIs. At SVI/Bremco, QA staff is responsible for maintaining code stamps (National Board "R," and ASME "S" and "U" certificates of authorization), promptly answering questions from field personnel regarding what the various codes allow and what they don't, visiting sites where specialty work—P91/T91 welding, for example—requires their expertise, etc.

Important to investigate is the contractor's experience in making repairs and modifications similar to the ones you require. Where possible, you want to avoid having contractor personnel "learn" on your project. Part of this effort is a review of weld procedures and qualifications specific to the work at hand.

Project reports. Sometimes overlooked, says Kitterman, is the value of complete, orderly paperwork at the project's conclusion detailing work procedures followed, welder qualifications, identification of welders with specific welds, materials receipt and test reports, quality-control documentation, applicable drawings, etc. All this, and more, should be archived by the owner/operator in support of required registration of work conduct-

evaluation

ed, as well as for insurance and other purposes.

The diligent contractor will file all applicable paperwork as required by regulatory authorities immediately following job completion. Be sure to check that procedures are in place to make this happen. Using HRSG work as an example, repairs to pressure parts require signoff by an uninvolved third party to verify job integrity. One example: An authorized inspector from an insurance company offering boiler and machinery coverage would supervise a hydro test. Upon successful completion of the test, repair forms and other certifications can be filed with NBIC, state/local jurisdictions, etc.

A safe working environment is one of the few things on which all people agree. Plants and contractors take particular pride in having "no lost-time accidents." This, of course, doesn't happen by accident: It takes thorough training, testing, retraining, recordkeeping, vigilance, management commitment, etc.

A safety audit is an important part of the plant manager's due diligence effort. You can get a quick read on a particular company's commitment to a safe working environment by reviewing its safety manual, suggests Kitterman. It should be a living document—one capable of addressing any and all customer and site-specific safety requirements based upon sound OSHA guidelines. Names and contact information for members of the company's safety committee should be in evidence. Further, committee members should be a mix of management and craft personnel.

A conscientious contractor will perform an initial job-hazard analysis, continues Kitterman, to address site-specific challenges as well as to incorporate any policies required by the plant owner/operator into the project safety plan. In addition, brief daily meetings for contractor personnel are important for communicating unsafe conditions and changes to the existing safety plan. If you don't see mention of these actions in a prospective contractor's safety manual that company may not be your best partner.

Next, carefully check safety-training records. At a minimum, all field personnel should be current on OSHA-required training. Ideally, the contractor should have someone on staff capable of teaching the standard 10- and 30-hr OSHA courses to employees and also be able to conduct or supervise other required training—such as forklift operation and confined-space working practices. Latter includes training to pass the so-called pulmonary function test, which qualifies workers to use a respirator and work with it.

Review of government and insurance records can offer an objective assessment of the candidate contractor's safety performance. For example, companies are required to log work-related injuries and illnesses on OSHA 300 forms and maintain that file. The Experience Modification Ratio (EMR) is another index to check.

EMR, an industry factor used in Workers' Compensation Insurance, is based on an employer's claim history and determined by the claims paid and reserved in the previous three years along with the audited premiums paid. It is considered a fairly accurate reflector of a company's safety record, and is often used as a factor for prequalification during a project's bidding process. An index of more than 1 is indicative of a poorer-than-average safety record; below 1, better than average.

Lesson learned: Heat tracing demands constant attention

What follows are details on heat-trace initiatives shared by one of the discussion leaders, some of which were not discussed during the roundtable because of time constraints.

Get off on the right foot. Plant personnel learned during commissioning, and afterwards, that poor installation practices coupled with the lack of documentation made it difficult to troubleshoot the heat-trace system. This required staff to spend roughly 60 man-hours per week identifying and fixing issues with heat-trace circuits not functioning as designed. The poor performance of the heat-trace system jeopardized reliability and operability by allowing critical instruments and equipment to freeze-up.

The facility was constructed by a single EPC contractor with multiple equipment suppliers. Design of the heat-trace system was subcontracted to a reputable supplier while installation was handled by the EPC contractor's craft electricians, who had little or no experience with heat-trace equipment.

The various scope-of-supply boundaries and types of heat tracing proved problematic. Many field changes were required to complete the installation—changes performed without the knowledge of the designer and poorly documented.

Heat tracing was designed to maintain an equipment temperature of 40F at an ambient of -8F. The heat-trace supplier implemented the use of microprocessor-based temperature control and monitoring panels which required other new equipment—including various temperature sensors, new alarm capability, DCS integration, self-testing circuit cards, and programmable RTD outputs.

The lack of qualified oversight from the heat-trace designer during equipment installation and in preparing documentation of as-built conditions proved challenging for the plant operator once it took possession of the facility.

The first step in fixing the problem was to bring back the original heat-trace designer to audit the entire system and identify and correct any deficiencies. This required all 612 individual circuits to be reviewed to ensure the correct materials were used along with the correct installation practices. Next, all the documentation was updated to reflect as-built conditions. This information and a thorough review ensured the system was designed and installed as originally intended.

With the proper installation and operational techniques identified for the new technology, the plant operator developed a heat-trace guide to provide a laymen's approach to better understanding of equipment and operational requirements. In the guide, details which had been segregated because of scope breaks are included in one location, eliminating the need for multiple sources of documentation. The guide is written in plain language and includes pictures of installed equipment to better acclimate the reader and facilitate troubleshooting.

Success. Using the original design team to identify and fix the installation issues the heat-trace system achieved its specified objectives. System performance now is aligned with the original design intent, ensuring safe and reliable operation of plant equipment during times of inclement weather.

Upon release of the guide, personnel were immediately able to reference site-specific information for heat-trace issues in a timely manner. Today, only about 10 man-hours per week are required to properly trouble-shoot system issues, down from the 60 mentioned earlier. The guide also helped personnel identify equipment improperly installed, before it adversely impacted heat-trace performance.

More ideas. One or more of the following best practices pertaining to the development/design, and construction/startup of a plant-wide heat-trace system may have value at your facility.

Development/design

- Add smart-panel amp indication on each circuit as well as a light to visually indicate that the circuit is energized. This makes it easier for operators to walk down the system, verifying that the heat tracing is on and working when it should be.
- Have your engineer do a detailed evaluation of all vendor equipment (gas and steam turbines, HRSGs, etc) requiring heat tracing and make sure that the information is clearly presented to the heat-trace system supplier.
- The mechanical engineer responsible for the heat-trace design scope should be the same person who reviews the vendor's design isometrics. The field engineer may not necessarily understand the mechanical properties of the piping system and may miss things that should be included in the isometric drawings. In addition, the mechanical engineer is better positioned to be aware of potential piping changes needed.
- Since the heat-trace design usually is not complete until late in the project, the necessary conduit cannot be installed until very late in the schedule. You can benefit by moving a large portion of this work forward. For example, run small (12 in.) cable trays in areas known to require heat tracing (finger racks, main racks, bottom of HRSG, etc); once the heat-trace design is finalized and power connection devices are located, only short pieces of conduit from the tray to the devices are needed.

Construction/startup

- Ensure that compressor bleed-valve actuators and inlet-filter differential-pressure instruments are heat-traced and insulated properly for adequate freeze protection.
- Coordinate with the instrumentation fitters to make sure that when cutting back the heated tube bundles they leave at least 3 ft of heat-trace cable on both ends. When they cut the heated tube bundles short, there is not always enough cable to reach the power connection kit inside the heated enclosure, or to trace the root valve. This results in having to relocate power-connection kits and add jumpers to accommodate.
- Ideally, start the heat-trace crew when the piping discipline is at least 65% complete. Prior to this, the pipe systems generally are not complete (missing valves, permanent supports not installed, etc) which creates rework for heat-trace crews. This will allow a large runway ahead of the heat-trace crew, increasing productivity. Impact upon the project completion schedule and weather conditions may override this.
- When installing the rubber boots in the termination kits, the leads tend to bunch up at the bottom and touch. If there's a ground fault during commissioning, 80% of the time it's likely to be in the rubber-boot connection.
- Perform a thorough heat-trace audit each summer to identify and address any issues before the cold weather sets in.

they have certifications. The weld performance tests include a plate test, a bend test, a monster or super coupon test, and a coupon-9Cr wire test. Regarding the last, the rep said that welders might be qualified on carbon steel but not higher-alloy materials. He said, "9Cr material flows much faster and easier."

Underground circulating-water pipe inspection

Tests revealed circ-water flow rates were marginal and pump vibration was a likely indication of a balance problem. The 8-yr-old pump was removed and visual inspection showed severe erosion of its cast-iron impeller—a dramatic change since its last inspection three years earlier.

It turned out that the wrong material had been selected. The cast-iron impeller was replaced with one made of stainless steel. Rebalancing was the next step, with stiffeners added to the upright pump support. No visible damage has been exhibited after five years of service.

The presentation offers a punch list of things to consider during inspection planning, tools and aids to have on-hand, and photos of what to look for.

The slides included in the presentation are a veritable tutorial with bulleted checklists on these topics:

- Planning for safety and timing.
- Tools and aids should include a rock hammer and extra radio.
- Notes of caution, such as not allowing heavy loads to cross where the pipe is buried.

Roundtable: Cold-weather preparation

Registered users can listen to a recording of the roundtable, posted on www.powerusers.org. Alternatively, you can read the following summary of the session developed by CCJ editors.

If this CCUG roundtable is any guide, winterization continues to vex plant personnel. Many of the issues can be traced to inadequate design bases and insufficient equipment (Sidebar, pages 44-45).

However, the root cause appears to be building "outdoor" facilities in locations which clearly require far better protection against protracted frigid conditions. Exhibit One: The Ercot experience in early 2021.

The roundtable was led by two highly experienced engineers, both with management responsibilities at plants in locations subject to freezing temperatures that were designed as outdoor facilities.

One of the discussion leaders noted that the lowest ambient temperature experienced at his plant was minus 23F while the heat-trace design basis was plus 2F. The other said his plant was designed to minus 8F, but that does not account for wind-chill. He noted, "Most equipment, even our HRSG drums, lack enclosures and are open to the wind."

However, the facility has added warming sheds on top of the HRSG to keep personnel warm, and purchased several 120-Vac instrument space heaters wired to plug into outlets. These are used in transmitter boxes and ductwork with failed heaters.

Some of these temporary measures have their risks. Portable gas or propane heaters, for example, used in enclosed space elevate CO exposure to workers and present fire hazards.

The impacts aren't solely on the equipment either. "Operators find reasons to be absent when it is cold outside," the discussion leader continued. Steel-toed buck boots were purchased for winter work and rooms are booked in nearby motels to keep employees off the highways. Plus, personnel are reminded to look up for icicles in areas which may have leaks and to review work orders to identify equipment which may be leaking.

Equipment of special interest includes drip-pot drains, attemperators, air filters (which can become plugged with ice), and outside air compressors. The heat-tracing contractor was tasked with conducting an audit to compare design conditions to actual.

An attendee suggested that plants check for clogged drain lines using

NDE. He said it takes his plant about three hours to check all HRSG drains in this way. And actions taken in other seasons, like a contractor removing heat tracing for a valve repair in summer, need to be checked.

Users struggling with winterization might spend quality time listening to the recording. Here are a few takeaways:

- Review the 32F action plan (or prepare one if your plant doesn't have one).
- Review alarm points and operational permissives which may be impacted by cold-weather operation.
- Order bulk chemicals and review chemical properties to determine freeze points.
- Stage electric and propane heaters in problem areas.
- Develop HRSG drain procedures with valve identification in case there is only enough fuel to operate one unit.
- Perform a heat-trace audit in August/September and evaluate heat-trace insulation for deficiencies, keeping in mind that heat tracing cannot protect areas with water-soaked insulation.
- Verify calibration of all transmitters suspected of freezing or of overheating.

How to effectively treat powerplant cooling water with fewer chemicals

Forced to eliminate use of chlorine for biological control in its cooling tower, the plant tried bromine. However, that promoted the growth of a resilient and chemically resistant form of filamentous blue-green algae. Its growth in spring and summer got out of control, requiring the removal of forebay trash screens for cleaning every third day at great expense.

Presentation summarizes the technologies investigated to solve the problem. Alternatively, you can read the article in issue No. 64 (2020), p 53. The best practice described was a major reason for the plant receiving Best of the Best honors in CCJ's annual awards competition.

Roundtable: Confined-space safety best practices

Registered users can listen to a recording of the roundtable, posted on www.powerusers.org. Alternatively, you can read the following summary of the session developed by CCJ editors.

This discussion was facilitated by three members of the CCUG steering committee. One of the surprising statements during the opening remarks was that there is no accepted way to classify "confined space." The OSHA definition, for compliance purposes, has three criteria: space is large enough and configured so that a worker can enter bodily, has limited or restricted means for entry or exit, and is not designed for continuous employee occupancy. The gray areas here were underscored by the fact that the representatives of these three facilities "saw things differently."

One of the panelist's noted that many process plants classify all enclosed spaces as confined. In other words, they do not distinguish between a permit-required or non-permit-required confined space.

Much of the discussion focused on three options for rescue teams: third party offsite, trained onsite, and local fire department. There are pros and cons with each. Examples: the local fire department is experienced with rescue events but may not be able to respond in a timely manner, typically within 15 minutes; an onsite team may be most familiar with the facility but the additional responsibilities may be a burden on shrinking staffs; and a third-party team may have its own equipment but not able to respond on short notice.

The panelists created a list of "possible best practices":

- Sign in and out for all (permit and non-permit) confined space work—described as a nuisance but necessary (Sidebar, p 49).

- At least one continuous air monitor per team in a confined space.
- Create and review the rescue plan before entry.
- Document the time-weighted average personal air sampling pump readings when welding, to understand potential for contaminants.
- Use "Rite in the Rain" or equivalent all-weather paper to print permit materials and avoid the problems associated with using off-the-shelf paper when it gets wet.
- Invite local fire department personnel to the site to get familiar with the spaces.
- Use tubes (familiar in real estate) with labels and rare earth magnets to house confined space permits.
- Step through "what ifs" before starting the project.
- Test communication devices.

A few which might be added based on the Q&A are make sure contractors understand the distinction between permit- and non-permit-required confined spaces and defer to the more rigorous one, perform audits on confined spaces early in the outage, and know where everyone is working to avoid issues with falling objects.

Cybersecurity: Application and misconceptions in power generation

The slide deck for this presentation is a summary of broad talking points on cost, need for management guidance, government requirements, etc. It does not offer actionable plant-level information, in the opinion of the editors. Suggest listening to the presentation, available in the CCUG section of www.powerusers.org.

New safety equipment installed at CCGT plants

Two members of the CCUG steering committee walk you through some of their safety best practices (such as separating high-risk zones of the plant—where chemicals are handled, for example—from those seeing regular traffic) and share their experiences with newly installed safety equipment. This well-illustrated PowerPoint might form the basis of a productive lunch-and-learn in your plant's break room.

Some of the topics covered: Importance of designating chemical safety areas, racking devices, safety curtains, transformer-yard access control, fall-protection improvements, hazard identification with illustrated examples, lighting additions, etc.

Lessons from the field: Generator circuit-breaker maintenance

"Interesting" doesn't do justice to the generator circuit-breaker failure events described by two utility users, although that's the word they used. "Threatening" might be more accurate.

While the events themselves tend to be unique and site-specific, many readers can relate to the pain, and the "lessons from the field" they presented. Above all, it never hurts to be reminded that virtually anything can take you out in a powerplant and everything needs to be checked, rechecked, etc.

A short article based on this presentation appeared in CCJ No. 68 (2021), p 76.

Vendor presentations

Kinetic shock: An alternative way to thoroughly clean your HRSG, *Groome Industrial Service Group*

Calling it "safer, faster, and deeper" than dry-ice blasting, Groome CEO Jeff Bause introduced attendees to KinetiClean HRSG tube cleaning, a patented kinetic shockwave technique widely used in other industries but new to combined cycles. You can get the details in the recorded presentation or slide deck at www.powerusers.org, or read an article on the subject in CCJ No. 68 (2021), p 56.

Improving reliability in segmental-ring boiler feed pumps, *Hydro Inc*

Segmental-ring designs are lower first cost than barrel pumps but are less robust, attendees were told. They exhibit significantly less mass and therefore lower stiffness and damping, and are more susceptible to external factors (pipe strain, soft foot, tie-rod torque value, and sequence) and hydraulic instability when operating off the best-efficiency point.

A case study focuses on a segmental-ring pump exhibiting repeated catastrophic failures (that is, shaft breakage) that was analyzed for root causes, then modified with engineered solutions. One impressive result, among others: Reducing the last-stage casing gap from 0.007 to 0.008 in. to 0.001 to 0.002 in. improved pressure-carrying capacity from 2500 to 4000 psig.

Leveraging pump testing and condition monitoring for an effective predictive-maintenance strategy, *Hydro Inc*

Presentation argues for certified performance testing and vibration/condition monitoring for pumps as part of a preventive-maintenance strategy, especially for plants at which "original design may not be how the plant operates today." Differences in performance at low- or maximum-flow conditions can be considerable, attendees were told, plus impellers may have been modified, or other factors are likely affecting performance and reliability.

Several slides show how pump testing relates to reliability and performance and can help assess impact of process demands on pump condition.

Improving combined-cycle plant performance, *EPRI*

Presentation began with some stats on the Top 20 combined-cycle plants to engage the audience in a review of techniques to improve heat rate and boost output:

- The Top 20 have an average 88% capacity factor, remainder of the fleet about 60%.
- Heat rate for the Top 20 averages 6860 Btu/kWh (best is 6649), remainder of the fleet averages 7400.

The slides amount to a summary of EPRI products, including report #3002005048, which identifies and analyzes 50 mods/actions to improve heat rate, 32 capital projects, and 18 maintenance actions, etc.

Operability challenges in an unstable grid environment, *EthosEnergy Group*

This message also was delivered in-person at the Power Plant Controls User Group meeting in St. Louis, Aug 23-27, 2021. The presentation is summarized in that section of this issue on p 29. Recall that both the PPCUG and the CCUG operate under the Power Users umbrella.

Covered piping systems: Regulatory requirements and practical findings for steam piping programs, *HRST Inc*

Presentation reviews ASME Standard B31.1, focusing on "oft overlooked Code requirements," common problem areas, and case studies. First includes written O&M procedures covering topics mandated by the Code, review of dynamic events since the last condition assessment, and record-keeping.

Reading of the four case studies described is recommended. They cover HRSG interstage attemperator issues; a spray-water line to a bypass valve for an HRSG at an LM6000-powered plant that illustrates cyclic operation can cause more problems than one-time events; HP interstage piping at an early 2000s G-class unit exhibiting vibration issues; and creep damage at a P91-P22 HRSG weld.

Obtaining simple-cycle GT speed in existing CCGT powerplants—opportunities and pitfalls, *HRST Inc*

This is a treatise on whether and how a plant with frame engines can adapt to meet the 30-min non-spinning reserve market—given the speakers' contention that the 10-min market is the domain of aero machines.

The five combined-cycle fast-start considerations addressed: Drum ramp

Site map helps track confined-space status

One of the discussion facilitators has shared his plant's safety best practices with colleagues for years via CCJ's editorial pages. One, not discussed in detail during the confined-space roundtable but worth revisiting here, is described below. It protects against entry into a confined space after LOTO clearance. The example given was an HRSG door left open following an outage.

This facility has over 150 confined spaces to keep track of, challenging the responsible individuals. A control room operator (CRO) and a member of the plant's safety committee, advocated for a visual way to account for confined-space status in the control room. After reviewing different ways to keep an eye on the confined spaces, he noticed that most of the solutions relied on technology that increased costs as well as the workload of the CRO. He focused his task on finding a low-risk, low-cost, low-technology, high-results outcome.

The idea was to create a site map showing the major equipment and some of the underground systems on a white magnetic board that included all the plant confined spaces. This map would be in the control room above the LOTO cabinet (photo).

The CRO worked with NAES Corp drafting to develop a simplified site plan for his plant. In addition to the major equipment and underground information, the 45 × 45-in. map also includes the following:

- Safety showers in green.
- Tornado shelters.
- Water storage tanks and capacities.
- Manholes with system identification and numbers.
- Electrical manways.
- Hazardous chemical locations.

For work requiring entry into a confined space, the CRO moves the magnetic label for the associated confined space from the label storage board (right of the window in the photo) to the left-hand side of the site map and then places a red magnetic dot at the location of the confined space on the map.

This provides plant personnel a visual of the approximate location of open confined spaces at any given time. After a confined space has been closed and returned to its normal state, the label and dot are removed and returned to the storage board. Keeping the process simple enables its success.

The map also provides a visual representation of the plant to facilitate discussions among plant personnel and contractors and to show evacuation routes and muster points, and all door swings.

The confined-space map, in use for well over a year, is a safety and awareness win for both employees and contractors.

Confined-space mapis mounted above LOTO cabinet and alongside the label storage board

rates, purge-time calculation/credit, startup-procedure checks, venting capacity, and demin-water capacity. Presenters contend that many "older" combined cycles can adapt to participate in the NSR30 markets. Risks and rewards are identified.

Effect of variable-load-path gas-turbine operation on HRSGs, *HRST Inc*

Variable load path (VLP) operation is one way for combined cycles to become more flexible to compete with renewables. Essence of VLP is to modify the typical linear gas-turbine operating curve to stay within an "envelope" in which GT load and turbine exhaust-gas flow are controlled independently by modulating IGVs to achieve the desired TEG mass flow.

Attendees were told that the potential negative impacts of this transition can be addressed with equipment modifications or changes to lifecycle expectations. The important point made by the speakers: Use thermal analysis to understand the impacts and then optimize the upgrade options with a practical operating envelope.

HRSG liner plates: Improvements and necessary upgrades, *IAFD Inc*

Recall that a liner plate is any internal duct/piping steel that "touches: the gas path directly, usually the insulation and protection systems. Hot spots identified by external thermography are "the first-line indication of heat getting in behind the liner system." Because most slides in this presentation are photos of failures and of subsequent repaired and upgraded areas (little explanation, if any), you might want to listen to the recorded presentation.

Condenser performance monitoring with advanced instrumentation, *Intek Inc*

Focus is on new instrumentation said to make it easier to both monitor condenser performance and identify the root causes of degradation. Most plants have a standard instrumentation package to monitor cooling water inlet and outlet temperatures, steam pressure and temperature, and condensate temperature—but that's about it.

Adding instrumentation for air in-leakage; cooling-water flow, temperature, and fouling, and high-density temperature arrays; and differential-pressure meters, allows for deeper analysis to troubleshoot losses and what to do about them. Slides include graphs/graphics to show how the data are converted into performance insights—supported by several case studies.

Generator fast purge system for emergencies and normal operation at Cleco's Arcadia Station, *Lectrodryer*

New, automated fast-purge system for hydrogen-cooled generators enabled plant to reduce its gas purge time from 12 to four hours, and added the ability to "emergency purge," something most combined-cycle plants are not equipped to do. The vendor's package includes a generator fast-degas system and gas monitoring and control piping skid. First system took three weeks to install.

Main-steam/hot-reheat isolation and non-return valves: Key problems and resolutions, *MD&A*

Check/non-return/flapper-type valves, which allow flow in only one direction, generally are difficult to service because they operate with two centerlines which must be maintained during servicing, and require special tooling that many repair shops do not have on-hand.

Some plant personnel have been led to believe that such valves do not have to "blue" 100%. Not true, attendees were told. More likely, the presenters said, the valves have not been properly repaired so users accept a new normal. An inspection and repair case study illustrates how this work should be done.

OEM presentations

GE Gas Power and Siemens Energy each had a day for their programs.

GE's was July 20, 2021 and included the impact of gas-turbine upgrades on BOP systems and equipment, case study of a 7F upgrade, generator lifecycle considerations and forced-outage avoidance, HRSG pressure parts/replacement, steam-turbine low load and cycling operation, turbine-valve outage considerations, and case study on steamer operation.

You can get the details on the OEM's MyDashboard website as indicated in the introductory remarks on the first page of this report, or you can access the CliffNotes summary in CCJ No. 68, p 22.

Siemens Energy Day was July 28, 2021 and included presentations/discussions on battery solutions, cybersecurity, plant assessments, startup optimization, continuous performance optimization, and decarbonization. Most of the material presented by the Siemens speakers is posted on the company's Customer Extranet Portal (https://siemens.force.com/cep). Find a summary in CCJ No. 68, beginning on p 18. CCJ

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HRSG FORUM

Experts assess drain-line, bypass-valve cracks using lab analysis, reams of data

The two user-driven presentations during the eighth virtual HRSG Forum, Apr 5, 2022, organized by Chairman Bob Anderson, took deep dives into issues plaguing combined cycles with high transient operating hours: Drain-line and bypass-piping cracking. The first confirmed yet again that lab metallurgical analysis of failed components is a must, even if it adds a day or two to an outage, while the second revealed the growing importance of data mining in failure assessment.

Albert Olszewski, Constellation Energy Generation, titled his presentation "Why Failure Analysis Is Performed," and the implicit "answer" is, to avoid repeat cracking failures of the same component in the same location. Olszewski's initial slides showed three crack failures (Fig 1) over a year's operation of a 2-in., P22, wye-block fitting with a full-penetration weld on an HP evaporator drain line to the blowdown tank. After each discovery, the crack was excavated and weld-repaired by the plant without engineering being involved.

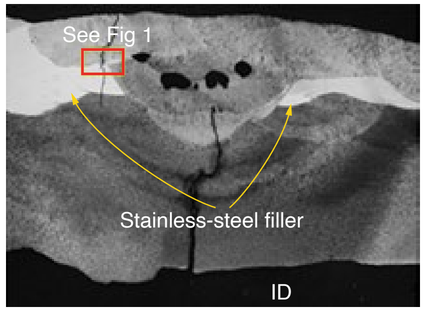
Then the plant replaced the wye-block, only to experience a "terrible crack" right through the weld within a year and a half of operation. Engineering finally was called in. Metallurgical analysis (Fig 2) revealed improper stainless-steel filler material in the field weld, probably from a welder grabbing the wrong filler rod during construction. Remnants of improper weld filler material used since construction seemed to explain the repeated leaks and how often they occurred.

During the post-preso discussion, Chairman Anderson re-iterated that best practice is to *always* take a sample to the lab for analysis when failures like this one occur. However, he added, such decisions that extend forced-outage durations rarely are taken unless senior management has agreed pre-failure that this is a best practice.

1. Repeated cracks and leaks were discovered at this location of the hot-reheat drain piping. They were excavated and weld-repaired with plant guidance before engineering was called in

The Q&A was a veritable brainstorming session about other factors which could affect this type of cracking (for example, pipe movement and inadequate supports), ways to obtain additional data (for example, add thermocouples to measure transients), etc—so best to link to Olszewski's recording at https://HRSGforum.com. Some experts cautioned that the stainless-steel filler may not be the root cause of the crack.

Most everyone knows that data mining permeates our work and personal lives, but it's refreshing to see it laser-focused on a specific plant problem common to many combined cycles. Diederic Godin, senior manager, Mechanical and Optimization, at Capital Power, and Valve Doctor Ory Selzer, application engineering manager at IMI-CCI, tag-teamed, with Godin setting the context of the plant design and the failed component, while Selzer focused on analyzing the operating data and details of an improved component design.



2. Lab metallurgical analysis revealed areas where improper stainless-steel filler weld material was used, as well as areas where improper weld material was covered up to make it appear Code-compliant

3. Cracks in the HRH bypass dump arrangement were discovered at the nozzle housing (upper area) and at the water manifold (lower area)

Capital Power acquired its Goreway plant in Ontario, in 2019, about a decade after it went commercial. The failure involved a two-stage, low-noise, hot-reheat (HRH) dump valve system to the air-cooled condenser (ACC)—including a 16 × 24 in. steam pressure-control valve with desuperheater, a 24 × 34 in. second-stage desuperheater, and a 34-in. low-noise resistor ahead of the ACC.

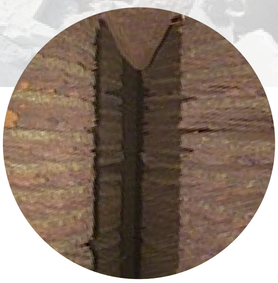
The end plate cap from the first-stage desuperheater also was found liberated, with no evidence in the process data that it was missing. The desuperheater thermal liner posed problems early in life, apparently,

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)

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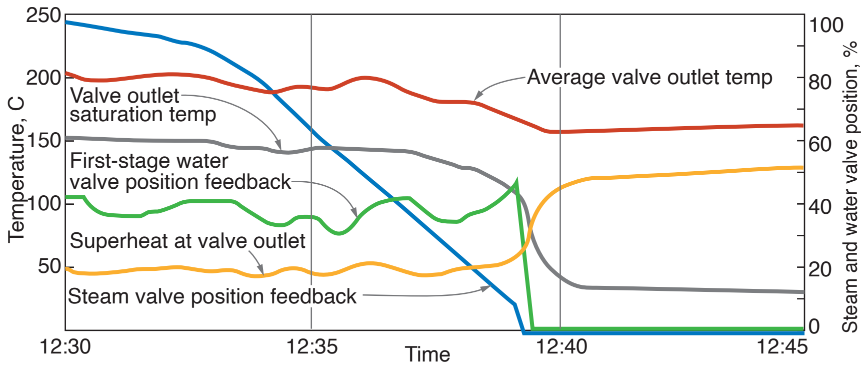


4. The 50-deg-C superheat override drives the behavior of variables near the 12:40 point on the x-axis, affecting the failure area

and was removed after only a few years of operation under the previous owners.

The external water manifold and nozzle housing are in one "spool." Cracks were discovered at the nozzle housing to steam-pipe connections and in the manifold (Fig 3). Capital decided to replace the valve and desuperheater with an improved design. But once the upgraded outer pipe spool, nozzles, and manifold for a new desuperheater were purchased, internal erosion damage was discovered on the diffuser, so the upgraded design included a new diffuser. The final unit was being installed literally as Godin was making his presentation.

Selzer then turned to the root-cause analysis. IMI Insyt, with specialized data mining techniques, acquired four weeks of operating data in small intervals representing 28 startups across three units, or 25-million data points total. In other words, not an analysis you'd want to attempt using Excel spreadsheets. The startup data important to this component were then overlaid to detect patterns and anomalies.

The "big catch" was a massive quench down to saturation taking place at the desuperheater first stage during each hot start after the bypass (dump) valve opens, a quench that should be taking place at the second stage. This was occurring because of a 500-deg-C minimum superheat override setpoint in the DCS logic (Fig 4). Several other "critical findings" also fell out of the analysis. But you'll have to get them from the video tape at https://HRSGforum.com. They provide the hardware design modifications and control logic revisions.

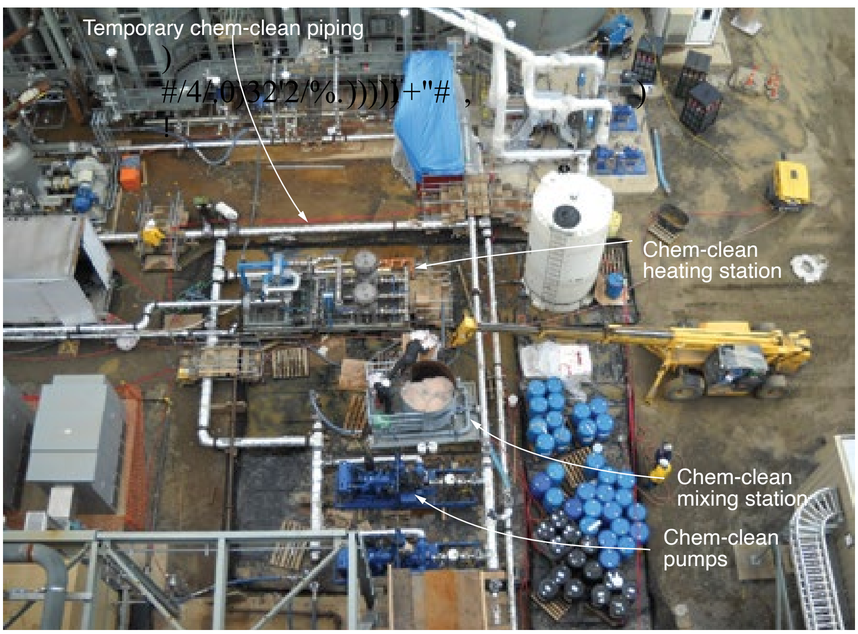
Attendees wondered where the end cap was found (just upstream of the ACC) and whether there were any operating "symptoms" suggesting that it was missing (none). Another in the audience suggested that the plant should have seen a change in pressure drop when the end plate was lost. In response to another inquiry, Godin noted that a sample of the liberated end cap was not taken for analysis.

Barry Dooley, Anderson's co-moderator for these forums, asked if the failed component was analyzed metallurgically and the answer was "no." He then added that reheaters 1 and 2 are typically constructed of T23, one of the worst materials for exfoliation. Godin responded that he would "dig into this."

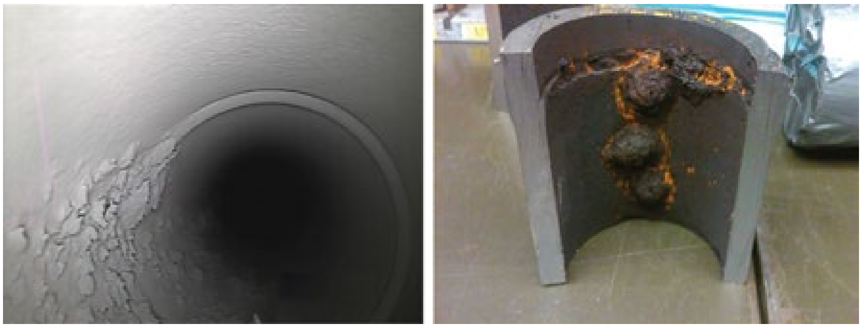
Experts address why, when, and how to deal with HP evaporator deposits

The most recent HRSG Forum, Virtual Session No. 9, held July 21, 2022, broadly addressed high-pressure (HP) evaporator deposits, and specifically under-deposit corrosion (UDC), a leading cause of HRSG tube failures (HTF).

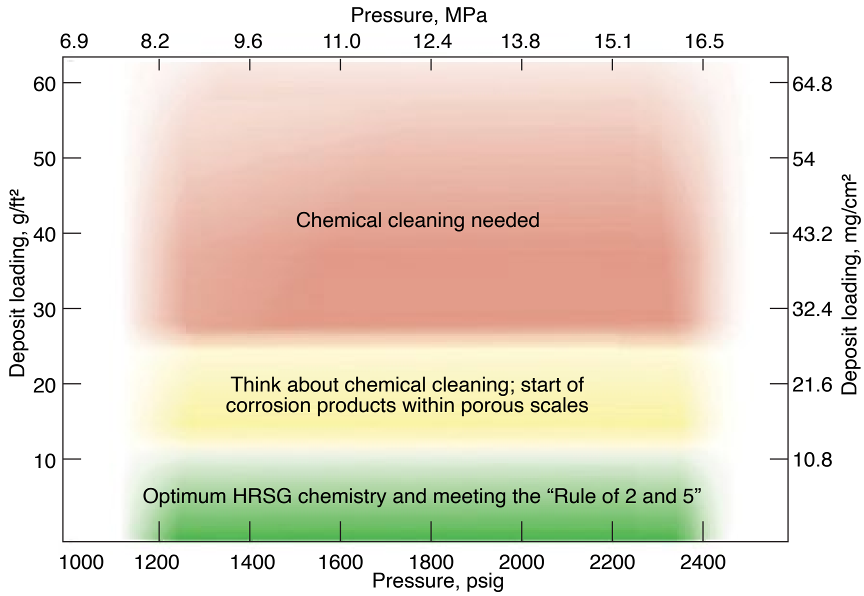
The first presentation, by Barry Dooley, Structural Integrity Associates Inc, focused on why UDC occurs, how to detect and analyze it, and its role, along with other mechanisms, in contributing to HTF explained why/when removing these deposits is important. Then the second presentation, "So I Need to Chemical Clean My HRSG. . .Now What?" delivered by Doug Hubbard, an independent consultant, was chock full of practical guidance for the onsite user community. Both presentations are available for view-



1. Substantial real estate is necessary on-site for a chemical cleaning, including for frac tanks (right), cleaning fluid containers, temporary piping, heat exchanger with aux boiler/steam source, pumps, mixing station, and discharge collection areas



2. Cleaning to remove corrosion cells (right) is more involved than a cleaning to remove high levels of iron-only UDC (left)



3. Deposit loading and operating pressure can guide decisions about when to start planning for, then conducting, a chemical cleaning for deposition (iron, copper, silica, calcium, others), UDC, and hydrogen damage in HP evaporators

ing at https://hrsgforum.com/2022-recordings.

Hubbard's years of experience, with one of the nation's largest electric-utility powerplant owner/operators, were etched into every slide, wisdom suitable for a laminated pocket guide of bullet points one pulls out during all stages of chemical cleaning (Fig 1). For example, he inserted the slide on waste disposal of cleaning discharges twice, to drive home how this aspect of the process can haunt you.

"Waste disposal can be up to half the cost of the cleaning," he said. Those 20,000-gal frac tanks that the cleaning contractor had delivered to your site? "Inspect every one of them," Hubbard urged, "and make sure they were thoroughly cleaned, and if not, send them back." If you don't, then you just took ownership of any nasty residue from the last place those tanks were used, such as the oil/gas fields.

Good questions to ask: What do you do if you fill up your frac tanks? How do I handle the material if it is deemed hazardous waste? How do I manage a spill after the tank leaves the site? To think through these scenarios, Hubbard doesn't just say "involve" your environmental subject matter expert, he/she must be "intimately involved" in the entire project, from initial planning to project closure.

Resist the temptation to cut a few hours from the cleaning process, even if the higher-ups are pressuring you in the interest of getting back on line quickly. In fact, Hubbard recommends *doubling* the time for chemicals to circulate from what is indicated by the static test (usually done by your contractor)—for example, from six to 12 hours—especially if it's a cleaning for UDC and hydrogen damage.

You've just spent extensive man-hours and dollars planning the cleaning, installing temporary piping, pumps, heat exchangers, etc—and now you want to save three hours of outage time and risk subverting the result? Where's the logic?

One good reason to allow ample margin in circulation time: You won't really know if your tube sample is representative of all the corrosion deposits in the HP-evaporator tube surfaces.

You must ensure that the unit is "fully flushed" to avoid an aggravating startup. Passivation of the unit, done chemically after the cleaning, only gives weak protection of the surfaces until the system is restored during a normal startup. For this reason, the unit must be returned to service immediately after cleaning and run at full drum pressure for at least 76 hours (an empirical value from Hubbard's experience) to maintain the passivation layer.

It is critically important to "hydro" the unit prior to circulating the chemicals, he warns. "Leaks are manageable when you are passing only water through; they don't get better as cleaning proceeds," Hubbard noted wryly. Don't assume your valves will hold either, he added. If you do have a leaking valve during cleaning, remember to flush the other side.

Three types of cleanings delineated by Hubbard are (1) pre-operational (to remove mill scale, cutting oils, etc), (2) high-deposit iron removal, and (3) UDC/H2 damage cleaning. Each cleaning has its own characteristics with respect to solvent selection, circulation times, discharge material, etc. Cleaning time will be appreciably higher if you have any corrosion cells (Fig 2).

Determining which level of cleaning you need is based on analysis of the deposits and static and dynamic tests with the deposit material. A static test involves taking a 1-in.-tube cross section, placing it in a beaker with solvent and stir bar on a hot plate, and timing how long it takes for the deposit to break up and fall to the bottom. In a dynamic test, the tube sample is placed in a test loop and solvent is pumped around to determine how long it takes for the corrosion products to break up.

Cleaning generates hydrogen gas, so make sure the system is properly vented of gases and air at the high points at least every hour. An "enormous quantity of fumes can get into the steam turbine," he cautioned, if you don't backfill the superheater with ammoniated condensate.

Other bullet points for that pocket guide:

- Don't assume all the deposits are iron, even if that might be the case the majority of the time.
- Flows should be between 2 ft/sec (minimum flow for the cleaning solvent) and 5 ft/sec (maximum flow for the corrosion inhibitor).
- Color-code a system flow diagram, mark dead legs, valves, and the cleaning path (fluid entry point and exit point).
- Walk down the system as the clean-

ing proceeds.

- Cover storm drains.
- Add 5-10 deg F to the cleaning process temperature as extra margin; remember that the fluid temperature is *not* the tube surface temperature.
- Pull samples while cleaning is taking place to "see what's going on."

Evaporator failure mechanisms. Dooley's slides first placed UDC in the context of other leading chemically induced HRSG reliability issues and contributors to failures, then went on to show resplendent examples of UDC, UDC with acid phosphate corrosion (APC), and pictures of deposits under various treatment regimes.

Using the term "Repeat Cycle Chemistry Situations (RCCS)," Dooley explained that damage and resulting failures arise when a plant has experienced two or more of these RCCSs: Corrosion products, HRSG evaporator deposition, contaminant ingress (no reaction), drum carryover, lack of shutdown protection, inadequate alarmed on-line instrumentation, not challenging the status quo, non-optimum chemical cleaning, and high level of air in-leakage. RCCS analysis methodology is based on over 260 plant assessments globally.

If you want to benchmark your plant's situation, Dooley's slides also include categories within several of the nine RCCS listed above. For example, under "contaminants," Dooley notes "high number of condenser tube leaks" and "continuing to operate when contaminant levels exceed action and shutdown limits."

The balance of the slide deck discusses why taking tube samples is critical, how to analyze tubes for deposits and damage, and what the morphologies look like under close examination by high-powered lab instruments. A detailed chemical and physical analysis of the deposits and deposit gradations, distribution, and loading, along with tube conditions, are required before determining how to mitigate or prevent them in the future (Fig 3). Several slides of tube samples show the consequences of poor chemical cleanings and/or application of film forming substances.

During the Q&A, Dooley notes that 65% of the plants assessed experience online instrumentation issues, but also that operators often are not trained on how to recognize and respond to an exceedance event.

Technical guidance documents are available from IAWPS at no cost for many of the topics Dooley addressed (www.iapws.org). CCJ

International Association for the Properties of Water and Steam

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

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

Supply-chain woes restricting the availability of valve parts, access to valve repairs

A conversation with Aaron Florek, executive director, Millennium Power Services

"Material shortages is the number-one issue the industry is facing today," says Millennium Power Services' Aaron Florek. "Generally speaking, the raw materials needed for valve parts are either out of stock, have incredibly long lead times, or are simply unavailable. But this is not the case at Millennium: We have the resources to keep your valve projects moving forward without the challenges others may face."

The industry always has lived with the necessary evil of long lead times for OEM parts; it has become "par for the course" in plant operations. However, when the already-long lead times are now twice as long, or longer, because OEMs are waiting on materials and parts, then you're in real trouble if you don't have an alternative.

"Almost all OEM parts you order for your equipment are manufactured overseas. That means they're facing universal supply-chain issues," Florek says. "If you need an OEM part fast, you might be out of luck these days. In some cases, you can't even get the part at all."

What can powerplant managers do when it seems OEM parts will be unavailable for the foreseeable future? Florek's answer: Align with a domestic supplier having the capability to make the parts required. "That's our business model," he continues.

"Millennium Power Services has never been more relevant than it is today. The supply-chain issues we're seeing only further illustrate the need for your plant to have a domestic, responsive valve manufacturer on call at all times." Recall that Millennium is an industrial-valve service provider serving the entire US from its shops in Massachusetts, Maine, and Virginia. All of the company's valve parts are manufactured at these facilities.

Millennium also has the flexibility to refer to an unlimited number of vendors to get what customers require. Overseas OEM providers typically are stuck with one source—which is precisely why they're facing huge delays in their manufacturing.

"We continue to meet, or exceed, our customers' requests—including emergencies, which seem to occur almost every week now. We are just as responsive today as we were pre-Covid, and we continue to grow every year."

One of the greatest advantages of a valve repair shop equipped with machining facilities is that it allows Millennium to think "outside the box." If one material is unavailable, we can discuss alternatives with our clients to come up with quick solution—despite shortages. "Our materials are sourced domestically," Florek reminds. "We get them from the same people we've always gotten them from. They are not affected by the severe supply-chain issues plaguing overseas manufacturers.

"Beyond that, we have one of the industry's largest inventories of valve parts. Plus, we can manufacture most parts in just a few days. Remember, too, we usually can repair your valves in a fraction of the time it takes to get new ones—or parts—from the OEM. Repairs typically are less expensive and faster, so it's often a win-win situation."

"We can repair, refurbish, and manufacture parts for pretty much any valve," Florek continues. "We use a state-of-the-art 3D scanner and conduct other analyses to understand the materials used in a part, the amount of wear on that part, and provide root-cause analysis with recommendations for improvements. We aren't there to just do a repair or replacement; we can rethink the component and application from the ground up."

Florek went on to say another offering that sets Millennium apart from other service providers is its TrimKit program, which helps determine whether the company should manufacture or refurbish your valve parts. All components required for a particular job—refurbished or new—are shipped to the job site in a protective case. Project complete, the used parts are put back in the shipping case and sent to Millennium.

"Our customers can come to us for everything they need," says Florek. "They don't have to outsource their parts from 10 different suppliers. We are their single-source vendor."

What our customers have told us:

- **Maintenance supervisor.** "We've been using Millennium's services onsite for close to 10 years. They do valve work, safety-valve testing, and safety-valve overhauls, and their valve-parts turnaround is extraordinary. If you need something in a pinch, they won't leave you hanging and you'll never be the one waiting on them."

  This client, which also uses Millennium's TrimKit program, added: "TrimKit has everything you need and it's all labeled. It's easy to store, move around, and hand over to contractors. With the TrimKit, you have everything needed to repair the valve."
- **Maintenance manager.** We throw almost everything we can at Millennium and the company has yet to fail us. "They reverse engineer our parts, provide TrimKits, safety valves, control valves; the list could go on and on. The Millennium team understands valves and it gives us peace of mind knowing we have the best people on valve repairs. On our last outage, we found problems with our CCI valves. Millennium took the valves to their shop and repaired them in a tenth of the time it would have taken the manufacturer to help us."
- **O&M manager** credits Millennium with the creation of his plant's maintenance program. "We overhaul three or four valves per unit annually. TrimKit assures our valves always are in working order. The biggest benefit of the company's parts program is that it takes the pressure off of us. Anything you need, they either have a replacement in inventory or will quickly repair the one in service and bring it back to the plant.

Wrapping up, Florek suggests that perhaps the best way to combat shortages is to simply shorten the supply chain—which is what Millennium Power Services is doing by bringing what you need closer to home. Plus, it provides precision and flexibility to give you repair options even when you feel your hands are tied.

European Hrsg Forum

www.europeanHRSGforum.com

Eighth Annual Conference

The eighth IAPWS European HRSG Forum (EHF), held virtually May 17-19, 2022, connected 140 participants from 26 countries. This annual event is conducted in association with the US HRSG Forum (HF), and the Australasian Boiler and HRSG Users Group (ABHUG).

EHF 2022 featured 17 technical presentations, participant questions, active discussions, and answers from users and experts. Consulting Editor Steven C Stultz prepared the following highlight reel from presentations the editors believe of greatest interest to readers of Combined Cycle Journal.

Global issues

Thermal transients remain the paramount cycling concern worldwide. As one presenter put it, "We are now the weather-dependent power source that compensates for fluctuating solar and wind capacity, and operates with frequent starts and stops." A perspective shift for some, perhaps.

Thermal transient damage

In 2019, Combined Cycle Journal reviewed a 10-year global analysis of thermal transient damage impacting gas-turbine/HRSG/steam-turbine plants (CCJ No. 61, 2019, p 44). Key items in that report included attemperator design and operation, superheater and reheater drain systems, ramp rates and pressure-control-valve erosion, among others. The surveys and assessments are ongoing.

Bob Anderson, Competitive Power Resources and EHF co-chair, updated attendees on these and other issues at EHF 2022. Data-gathering began in 2009, he explained, and continues, tracking 31 key issues for 58 plants featuring five gas-turbine OEMs, 10 steam turbine OEMs, and 20 HRSG OEMs from around the world.

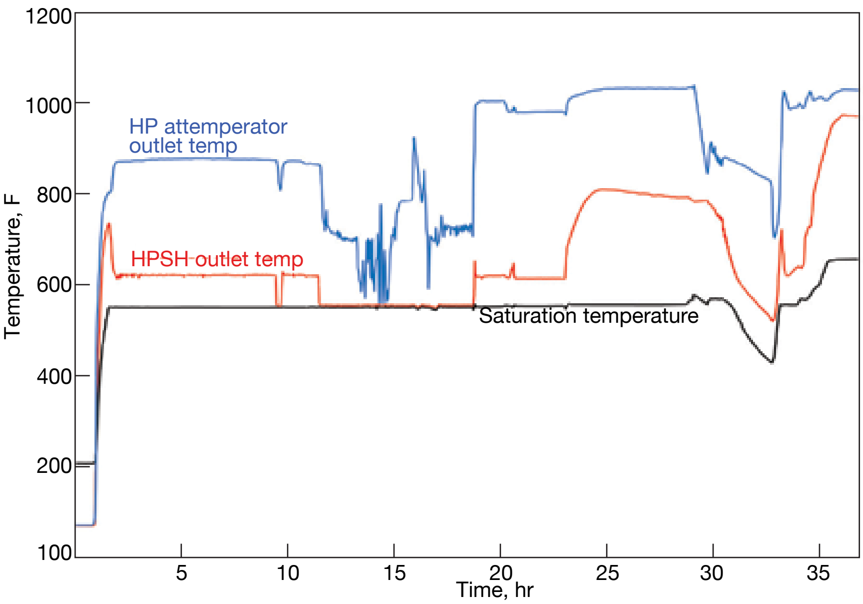
A few factoids from recent surveys:

- Management at 31% of the plants surveyed allows operators to manually manipulate attemperator controls, leading to quench cracking of downstream pipework.
- Only 16% perform routine inspection of attemperator hardware.
- 84% experience spray water leaking in sufficient quantity to appear in DCS operating data.
- 96% use master control/martyr block spray valve logic (accelerates leakage).
- HPSH (high-pressure superheater) and RH (reheater) drains fail to adequately remove condensate in 63% and 68% of the plants surveyed.
- 90% have no management policy for identifying the root cause of tube failures.

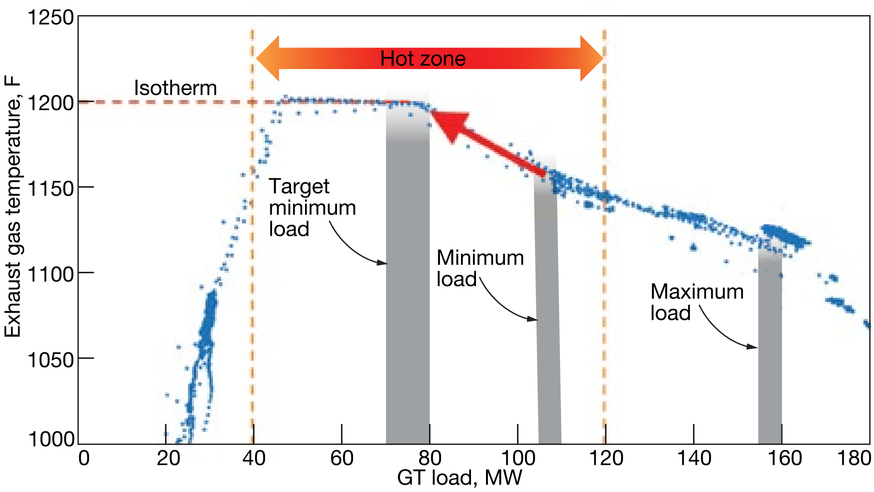
Negative recent trends were noted for inappropriate attemperator operation and monitoring, master control/martyr block-valve logic, and tube-failure root-cause programs.

Take, for example, inappropriate attemperator operation (Fig 1). Damaging actions include manual manipulation of set point or control valve, spraying too early during startup, spraying too late during shutdown, and using only attemperation to match cold steam-turbine metal temperatures.

A second example is HP bypass valve erosion. See CCJ report on ABHUG 2021 discussing warming steam flow for cold lag starts (No. 69, 2022, p 62). "We know the solutions, but seem to be going in the wrong direction," Anderson stressed.



1. Inappropriate attemperator operation has increased by 22% to 31% in the plants surveyed



2. Hot zone featured in exhaust-gas temperature versus GT load

The significance of thermal transient issues was discussed throughout this conference.

A search for improved turndown

Dan Blood, Uniper Engineering, and Anderson reviewed an ongoing case history for a specific 2002-vintage F-class plant that switches between maximum and minimum load to avoid startup penalties. They highlighted startup, shutdown, and layup as primary long-term concerns. The GE gas turbines

3. HP attemperator liner cracks are in evidence from borescope inspection

are capable of 50% turndown without modification.

The survey began with thermal transient reviews, causes, and corrective actions. The findings:

- Leaking attemperator spray, aggravated by piping design and protective control logic.
- Attemperator overspray and impingement on pipework, aggravated by piping design and attemperator hardware.
- Variability in startup/shutdown practices, typical of highly manual operation.
- Inconsistent performance of control logic.
- Inability to consistently drain the HPSH/RH during startup, typical of both early designs and manual operation.

What followed was a thorough review of preferred actions, selected from a total list of 18 to achieve acceptable low-load operation:

1. Repair or replace existing spray block valves and add tandem block valves in units without attemperator piping drains.
2. Modify spray-valve protective logic; change to master block/martyr control.
3. Establish spray leak detection and annual valve/nozzle maintenance.
4. Troubleshoot and correct control-logic anomalies.
5. Modify startup practices and attem-

perator control logic to eliminate or minimize overspray.

6. Replace existing integral control valve/nozzle attemperators (direct replacement of mast-nozzle assembly and an external control valve).
7. Automate HPSH/RH drains.

Discussion followed on reducing load into the *hot zone*, apparent on a plot of exhaust-gas temperature versus GT load (Fig 2). "This conflict is a direct consequence of the heating-surface layout with respect to attemperator position. It limits the turndown capability of the HRSG," stated Blood.

This presentation walked through details of several strategies, highlighting the pros and cons. First, however, the *must-do* was to upgrade the interstage attemperators. This was not a solution, but was considered an essential prerequisite, preventing both off-load and on-load spray leakage.

The plant chose direct replacement of mast-nozzle assembly and an external control valve. But this would not resolve the conflict between overspray and final steam-temperature control at reduced minimum load.

Beyond this, there are two short-term options: Reduce HP operating pressure (not possible if in sliding-pressure mode), or fire the duct burners (subject to burner capability and emissions compliance). Neither was recommended.

Longer-term strategy options were considered: Retrofit and use air attemperation at low load (dilute GT exit gas with ambient air), and GT upgrade (inlet-guide-vane control modification). Both represented high potential costs, but would be considered for detailed techno-economic assessment.

Blood and Anderson completed the review by walking through other model results of relevance that included HP economizer steaming, steam flashing across the IP level control valve, acid dew-point deposition on cold-end structures and pressure parts, and risk of flow- accelerated corrosion (FAC) in some areas.

The project is ongoing.

Clamp-on leak monitoring

Duke Energy operates 14 combined-cycle sites with 39 total units, powered mainly by GE and Siemens F-class gas turbines. The triple-pressure HRSGs were sourced from multiple OEMs. A presentation by Eugene Eagle focused on HRSG interstage-attemperator concerns.

A key issue is block-valve leak-by attributed to poor maintenance frequencies and quenching during startup and shutdown. Most interstage attemperators are ring-style with mechanical spray nozzles.

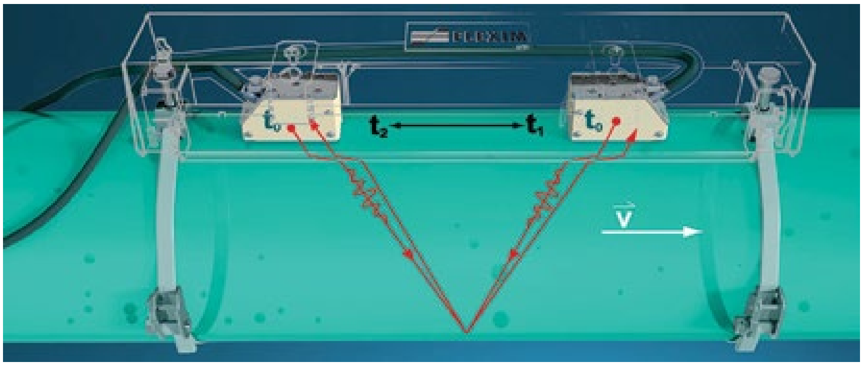
"For all practical purposes," said Eagle, "SH and RH outlet temperatures are functions of gas-turbine exhaust conditions, which means they cannot be controlled without attemperation." And without this control, downstream components could overheat.

Typical setup is operation with a block valve/temperature control valve combination. Wear on the block valve can lead to leak-by which has detrimental effects on the attemperator, internal liner, steam piping, and surrounding components. Thermal quenching is likely.

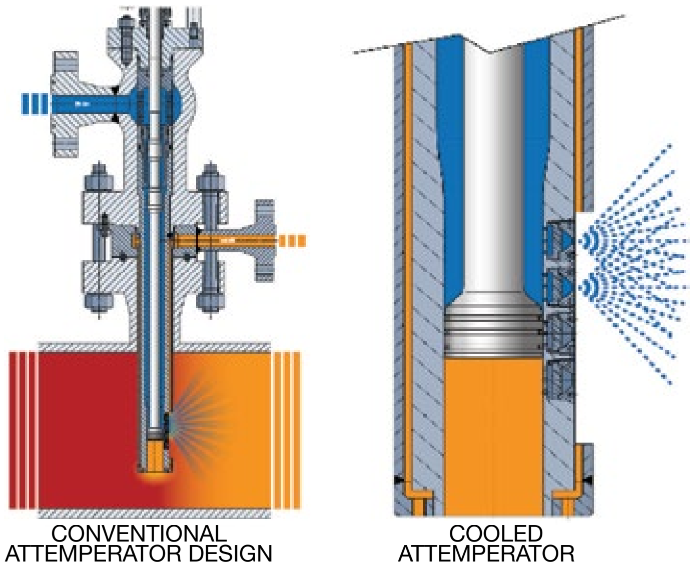
For Duke Energy, many units have had attemperator steam pipes/liners replaced (Fig 3). Plus, two units had the entire attemperator and downstream loop piping replaced—both projects were expensive.

Leak-by monitoring history. To detect leak-by, Duke looked at existing differential-pressure flowmeters, but found a non-linear relationship between differential pressure and flow, rendering the meter useless for trickle-flow detection.

Engineers also looked at thermocouple comparisons downstream and upstream of the attemperators, but determined this also to be inaccurate measurement for low-leakage flows.



4. Measurement principle for the Flexim system is transit-time difference



5. Cooled attemperator, installed a decade ago, eliminated thermal-stress failures

They considered acoustics, but current technologies only gave noise signatures, not actual flow rates.

Enter the Flexim portable ultrasonic flowmeter. The F601 model was placed on field trial. Eagle explained: "Two ultrasonic transducers are externally mounted on the pipe with a defined distance between them. By sending sound signals alternating with and against the flow, a transit time difference can be measured. This corresponds to the flow velocity."

Testing has been completed at three sites on HP and RH spray lines.

Installation of the Flexim F721 system (Fig 4), also covered, provides leak detection down to 0.01 m/s, zero-point stability, high turndown, accurate factory-calibrated measurement, non-invasive retrofit (no pipe work needed), and easy maintenance (no moving parts or contact with spray water). While not needed on spray-water pipes, a solution for flow measurement on high-temperature pipes (up to 1165F) is available.

This allows measurement at very low and previously undetectable leakage rates to enable repairs before pressure-part damage occurs. It also provides better accuracy than the DP meter at low spray flow rates.

Duke's first permanent installation was completed at a 3 × 1 plant in early 2021. It has been adopted as the fleet standard.

Nozzle head improvement

Cor Pauws, Advanced Valve Solutions (Netherlands), presented a multi-nozzle spray-type desuperheater as an alternative to the traditional radial spring-loaded type. The former provides small droplets (good for primary atomization), was said to work well at all loads, and needs only low system requirements for secondary atomization. His examples employed Weber number as a measure for secondary atomization.

"The traditional nozzle head connection becomes the weakest point," he explained, "so we have designed this as one piece."

Advanced Valve Solutions chronicled a case study of a combined-cycle plant in the UK that experiences more than 250 start/stops per year. The OEM attemperator nozzle heads failed after about six months. "Thermal stresses were the main issue." The solution was to cool the lance (Fig 5). The first cooled attemperators, installed at Marchwood Power Station in 2012, remain in operation after 10 years, with more than 2250 stop/starts.

All materials degrade

Low-cycle fatigue

A 1200-MW combined cycle in Turkey, commercial since 2017, experienced significant reheater failures (Fig 6). The cause: Low-cycle thermal-mechanical fatigue attributed to cycling operation and condensate quenching. Basically, the HRSG pressure parts suffer periodic mechanical movements excited by excessive temperature gradients associated with cycling.

Tugrul Basaran, Limak (Turkey), walked attendees through a detailed root-cause analysis— including metallographic examinations, operational data, failure histories (locations), and piping arrangements (design).

Ongoing solutions include attemperator PID control parameter adjustments, and tube-stub replacement/upgrades. "In this particular case, the attemperator operates smoothly after control parameters are adjusted," he said. He then showed P91 stub replacements with stubs of increased wall thickness (Fig 7)—an ongoing project.

Discussions included the possibility of oxide growth/exfoliation, and a recommendation to add thermocouples for monitoring. Plus, consideration of an HRSG sidewall baffle examination.

Remaining life

Raphael Stevens, John Cockerill Energy Solutions (Belgium), presented "Remaining lifetime assessment—where an HRSG health checkup meets material sciences." His go-to quote: "Small streams make big rivers." Example given was for a combined cycle in Peru, which highlighted the HRSG, gas turbine, electrical generator, steam turbine, and condenser.

6. P91 reheater failure was caused by cycling-induced thermal-mechanical fatigue and condensate quenching

7. P91 stubs were replaced with ones of increased wall thickness

- Creep-fatigue interaction.

The R&D cooperative project covers the time period 2018-2022. Material considered is P92, and a significant study incentive is unit cycling.

Findings and results will help guide future revisions of European design codes, as well as improved methods for fatigue and creep-fatigue assessments. The final report, funded in part by the German Ministry of Economic Affairs, will be in German.

To understand remaining lifetime analysis, he said, you must first recognize that "material degradation will always occur, even with perfect design, excellent operation, and state-of-the-art maintenance, and you need to build bridges among pressure parts, steels, operation, and maintenance."

Degradation is natural, and material science teaches us there are two main factors:

- Number of hours the pressure parts are operated above 842F (450C).
- Number of cold, warm, and hot starts.

The two key degradation types, creep and thermal fatigue, were explained in detail. Next, the speaker covered "critical points" (welds, etc), testing methods, and collection of operating data (temperature, pressure, and time) for lifetime analysis and failure prediction.

First words from VGB

Jurgen Rudolph, Framatome (Germany), presented the first public communication on a collaborative R&D project, "VGB calculation methods—including perspectives on updates of the European standard on calculation methods." VGB is the association of German powerplant operators with a charter similar to that of ASME.

Work-package contents of this seminal public release included:

- Component tests.
- Thick-walled components, non-elastic stress calculation.
- Welds and weld assessment.
- Low-cycle fatigue assessment.

Film formers

Film Forming Substances (FFS) was a hot topic at EHF 2022, expanding both experience and information on the subject. Co-chair Barry Dooley, Structural Integrity and IAPWS, directed this portion of the program, updating attendees on the application of FFS—both amine (FFA)- and non-amine (FFP)- based. Overall, the applications illustrate reduced corrosion-product transport and general protection in water-touched circuits, but questionable film formation in steam circuits.

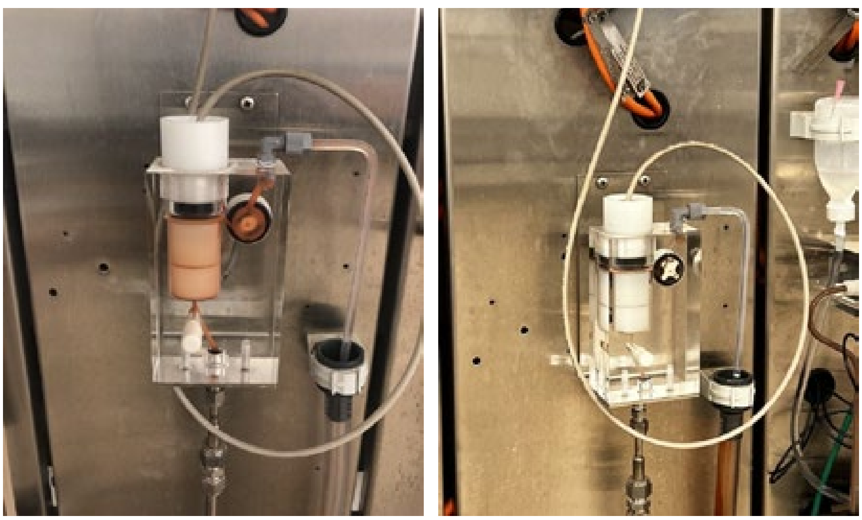
Participants were provided the key pre-application procedures required to achieve optimum results and prevent problems of under-deposit corrosion and gunk formation. To dig deeper, read the 2022 FFS meeting report elsewhere in this issue.

Anodamine HPFG

An in-depth and optimistic review of Anodamine HPFG for two-phase corrosion control was presented by Ondrej Soukup, CEZ Group (Czech Republic), who explained FFS application and chemistry optimization at an 888-MW 2 × 1 F-class plant, commissioned in 2014, with GT upgrades in 2020. The plant has experienced up to 193 starts per year.

Original chemistry applied at this particular plant is ammonia for pH control in feedwater and condensate, and trisodium phosphate for pH control in drums (the latter stopped in 2021).

During operation, corrosion was not fully controlled and some flow-accelerated corrosion (FAC) was present. No additional measures were taken for shutdowns. After 21 days, water had to be refreshed completely because of corrosion impacting system integrity, water consumption, cost, and unit availability. At the same time, cycling requirements were increasing.



May 2019 (before Anodamine application) 2022 (after Anodamine application)

8. Skid sampling shows oxides before and after Anodamine application

Chemistry enhancement strategies were planned in 2019 with these requirements:

- Steam cation conductivity must remain below the OEM guideline of 0.2 µS/cm.
- Non-toxic.
- Compatible with applied treatment program.
- Easy to handle and dose.
- Good and credible reference projects (experience).

Anodamine HPFG dosing was selected and began in September 2019. Discussion at EHF 2022 focused on the following online analyzers:

- Conductivity (specific, cation, and degassed).
- Silica.
- Sodium.
- pH.
- Phosphate.

These analyzers are trended by the DCS. No anomalies have been detected on any of the instruments. Note that a turbidity analyzer also was installed to monitor corrosion-product transport.

A key result of the FFS program was reduced online turbidity, where the startup peak virtually disappeared after two months of application on both warm and hot starts. Anodamine.com reports similar data for cold starts.

Soukup reviewed annual inspections with conclusions: "The system

9. Closed cooling water system, air-cooled (blue pipes), is the preferred arrangement. Chillers (white) provide extra cooling during summer. Yellow section at right heats gas before it enters the turbine

is much cleaner given less corrosion products, and two-phase FAC locations are transferring to hematite-protected locations. Surfaces that were showing blank metal have turned red (dull and hematite colored)."

In the sample skid, for example, the orange deposit of oxides at the oxygen sensor (Fig 8 left) has almost completely disappeared (right).

Annual inspections focus on cleanliness (quantity of oxides), color of protective hematite layers, history of FAC locations, and visual checks for hydrophobicity.

Again from Anodamine.com, "Two-phase FAC was drastically mitigated, along with reduced maintenance cost, shorter startups, and removal of costly shutdown methods of nitrogen blanketing and dehumidified air. Results were validated using total iron digestion analysis, Millipore filter tests, online laser nephelometer, and physical equipment inspection."

Anticipated future improvements include reduced blowdown of the drums, no phosphate dosing, potential cost saving on demineralized water, and reduced makeup requirements.

Changing the amines

Yitzak Nussbaum, EZOM (Israel), discussed use of FFS in a closed-circuit cooling-water (CCW) system. This was said to be the first application of this type presented to the industry. A key result was the ability to change the film forming amine.

The CCW discussed serves a range of components and processes. It is a closed loop of water with no blowdown and no evaporation, and a range of dissolved oxygen values. There are many systems (*clients*) from many manufacturers, with no single specification or maintenance guide. Piping system diameters and flow velocities vary.

Clients served include the gas and steam turbines, seawater sampling system, feed- and condensate-pump bearings, air compressor and vacuum pumps. All are potential points for leaks.

Thus, corrosion in the CCW is a major concern, and the target for EZOM's review of traditional treatment versus FFS. One target was the main air-cooled system (Fig 9), with piping sizes between 0.5 and 10 in. and temperature range between 30 and 37C/86 and 99F.

In 2018, the move was made from sodium nitrite to Cetamine. In 2022, a further move was made to Odacon. Long-term details were given for all CCW components.

The conclusions:

- Anticorrosion protection of FFS (Cetamine, Odacon) is verified by field tests in five different CCW systems.
- FFS (Cetamine, Odacon) can replace the anticorrosion treatment of nitrite and borate in CCW.
- Such replacement requires patience and control in the earlier stages, working with small doses.
- CCW with Odacon treatment was successful after a seawater leak into the system.

During the open discussion segment at the end of the presentation, Dooley commented: "Results are encouraging for conventional plants changing FFAs. IAPWS will add this to its recent experience changing an FFP."

A quiz, a puzzle, etc

Due diligence and a quiz

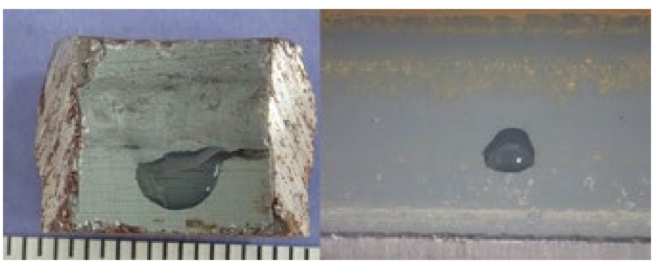
David Addison presented on the due diligence and planning that should precede the use of film forming substances. Get the details in the 2022 FFS conference report elsewhere in this issue.

One of Addison's key points was to use caution when relying only on visual evidence to gauge hydrophobicity. Fig 10 illustrates why. This is a complex science, poorly understood by the majority of managers and engineers responsible for powerplant operation and maintenance and often an incorrectly applied "metric" for assessing the effectiveness of FFS dosing.

Addison said that failure to undertake proper due diligence can lead to one or more of the following:

- Suboptimal FFS selection for the application.
- Incorrect application of an FFS.
- Failure to obtain the benefits of an FFS.
- Plant issues—including equipment failures.
- Excessive application costs with no additional technical benefits.

A deep dive into the science of hydrophobicity—including its value in assessing the effectiveness of FFS alternatives—is under consideration for publication as an IAPWS Technical Guidance Document. To learn more about how you can benefit, at no cost, from the work being done by the International Association for the Properties of Water and Steam to support the electric-power industry, go to www.iapws.org.



10. Caution is urged when relying only on visual evidence for hydrophobicity. Reheater tube at left was dosed with Anodamine, the one at the right was not

11. Complete roof module features upgraded cold casing and penetration seals

The puzzle

Dekomte analyzes and provides both fabric and metal custom-engineered expansion joints and replacements throughout the powerplant. For retrofits, the starting point is proper inspection.

The company's Jake Waterhouse stressed the use of thermal imaging to assess thermal expansion at joints throughout the HRSG—specifically the roof casing and penetration seals. "Visual and thermographic inspections create condition reports on all existing joints in the plant," he explained. "The goal is to understand the existing conditions and develop tailored long-term reliable performance resolutions."

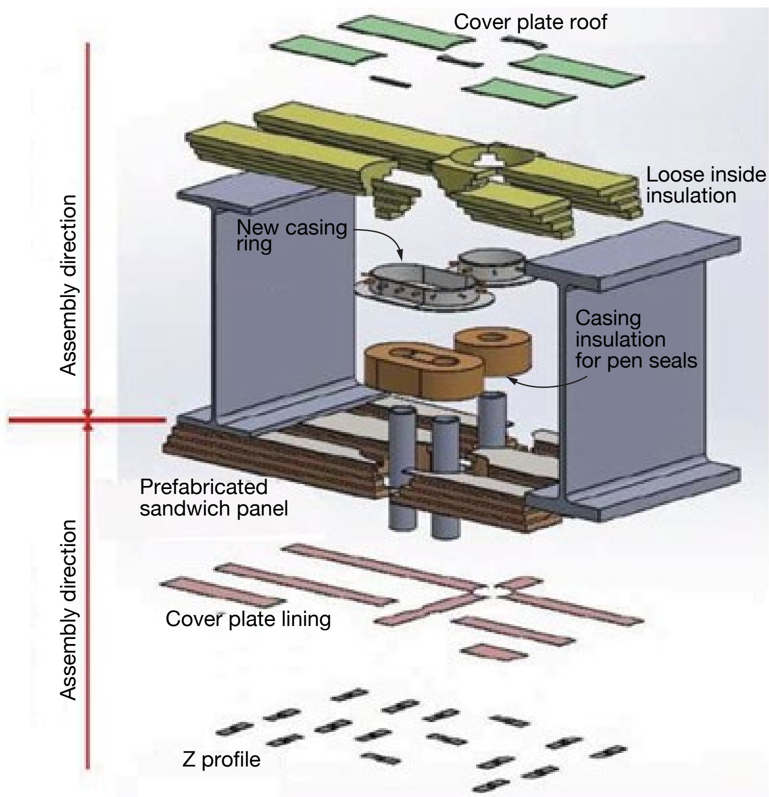
To illustrate his points, Waterhouse used the case study for a 552-MW 2 × 1 F-class combined cycle commissioned in 2001. Visuals walked attendees through the gas-turbine outlet and HRSG inlet joints, front-wall mechanical seals, metallic bellows in the roof HP and IP sections, among others, including front-wall mechanical seals.

Roof-casing and penetration-seals discussions then revealed a complex retrofit (Fig 11). This part of the retrofit solution (Fig 12) included 18 4-in. roof seals, 18 4-in. plus 4-in. combined seals, three 6-in. roof seals, six 4-in. front wall seals, and six 4-in. plus 4-in. combined seals— repeated 51 times per unit.

Site photos showed the complete retrofit, performed over 37 single-shift days within a 60-day outage.

Safety note: The thermal imaging reviews launching the retrofit should also lead to investigations of adjacent elements in the plant—to look for corrosion, cracking, distortion, and any direct personnel safety issues.

A participant comment at the end: "Impressive. Quite a puzzle."



12. This retrofit/rebuild became a complex project

Other presentations

Not all presentations could be covered here. Other topics included a root cause often ignored for high SCR ammonia use, updates on cycle chemistry control, PressureWave+ deep cleaning, HP bypass valve erosion, bypass valve damage, and desuperheater lifetime case studies.

Organizers and sponsors of EHF 2022 were IAPWS, ABHUG 2022, HRSG Forum, Advanced Valve Solutions, HRST, Mettler Toledo, Precision Iceblast Corp, Reicon, and Veolia. Sponsors made short presentations during the conference.

Arrangements and activities were handled by MECCA Concepts Pty Ltd and Combined Cycle Journal.

Co-chairs for EHF 2022 were Barry Dooley, Structural Integrity, and Robert Anderson, Competitive Power Resources.

EHF 2023. The ninth EHF Conference will be held in-person May 16-18, 2023 in Florence, Italy. Details will be available at www.ccj-online.com.

Clean turbine fluids promote trouble-free operation

Brent Converse, the plant engineer at Old Dominion Electric Cooperative's Wildcat Point Generation Facility (Sidebar 1), has three decades of experience in the operation and maintenance of powerplant equipment—including advanced-class gas and steam turbines. Among the most important lessons Converse has learned over his career: "Stay ahead of the curve" on things having a significant impact on reliability and performance, and pay close attention to detail.

The editors asked Converse to share an example during a telephone interview. He chose the lube- and hydraulic-oil conditioning systems for his plant's three turbine/generators. Background: Wildcat Point's Mitsubishi Power 501GAC gas turbines have separate sumps for control and lube oil—the former 150 gal, the latter about 6900. Both systems are charged with Idemitsu's Daphne Super Turbine Oil MG32.

The Alstom steamer has a nominal 6600-gal combination sump for control and lube oil; the Alstom hydrogen-cooled generator a separate sump for seal oil. The fluid common to both systems is Mobil DTE 746.

Converse, who has been at Wildcat Point since before commissioning, said the first oil conditioning systems installed were C.C.Jensen Inc's off-line (a/k/a kidney loop) HDU fine-filter solution for the gas-turbine control-oil sumps (Fig 1).

The plant engineer monitors control oil quarterly, judging its condition primarily based on the results of RPVOT, RULER, and acid-number tests. The HDU can mitigate fluid degradation conducive to the formation of acids and insoluble oxidation products that could impede the operation of components critical to turbine control.

However, antioxidant depletion makes it necessary to replace control oil every two years, or so. "Having had no unit trips attributed to control/lube-oil issues since commissioning, such attention to detail has paid dividends," said Converse.

The plant engineer's familiarity with the Jensen system was a catalyst for a discussion with the company's technical manager, Axel Wegner, at a user group meeting. The result was two-fold: Installation of Jensen's varnish removal unit (VRU) on both gas turbines and its PTU-type Filter Separator on the steam turbine.

More recently an HDU-type Fine Filter, similar to that serving the gas-turbine control-oil system, was installed on the ST generator seal oil system. The major difference between the two is that the latter is explosion-proof.

Why kidney loop

Kidney loop or offline filters benefit users because they are independent of the fluid system and always in service at an optimal flow rate—thereby avoiding pressure fluctuations and other disturbances that might otherwise negatively impact rotating equipment. Plus, they achieve very fine filtration. As Fig 1 shows, turbine fluids are withdrawn from the lowest point in

1. Wildcat Point

Wildcat Point Generation Facility, located in Rising Sun, Md, and owned by Old Dominion Electric Cooperative (ODEC), is a nominal 1000-MW 2 × 1 combined cycle. The gas turbine/generators are Mitsubishi Power 501Gs (air cooled); the supplementary-fired heat-recovery steam generators and steam turbine were supplied by Alstom.

The oil/gas-fired project began commercial operation in April 2018. Transcontinental Gas Pipe Line Co, a subsidiary of Williams Partners, supplies gas to Wildcat Point via its 11-mile Rock Springs expansion project.

Cycle heat rejection is via a 16-cell counterflow mechanical-draft tower. Cooling water is supplied via a 5-mile supply/discharge pipeline connected to the Susquehanna River.

Plant site is near the Maryland/Pennsylvania border and adjacent to The Carlyle Group's Rock Springs Generation Facility, which is equipped with four GE 7F peakers. Power is delivered to the PJM Interconnection via a 500-kV switchyard at the Rock Springs site.

2. How to determine the ISO fluid cleanliness rating

Fit the counts in the right-hand column of the sample lab analysis (table at left) to the appropriate range of particles per milliliter (ml) in the table at the right to determine the Range Number defined in ISO 4406.

Example: The sample has 1752 particles larger than 4 microns (the first number in the series), 517 larger than 6 microns, and 55 larger than 14 microns. The Range Numbers from the right-hand table expressed in ISO convention are 18/16/13.

Keep in mind that turbine journal bearing and hydraulic servo-valve clearances dictate the need for clean oil. Excessive bearing wear and servo-valve sticking can result if tight cleanliness standards are not maintained. Turbine OEMs offer specific guidelines on recommended cleanliness levels, typically 16/14/11. Best practices suggest that ISO cleanliness testing be conducted quarterly or more frequently depending on service duty.

Sample particle count

Particle size, microns	No. of particles larger than size at left
4	1752
6	517
10	144
14	55
20	25
50	1.3

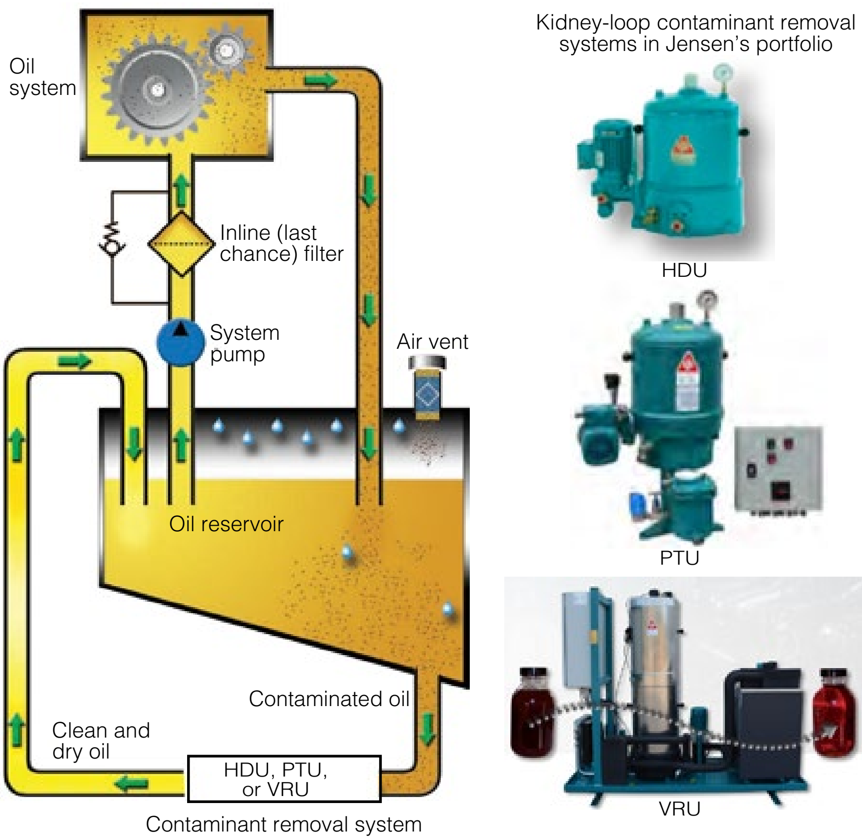
1752 particles per ml larger than 4 microns

517 particles per ml larger than 6 microns

55 particles per ml larger than 14 microns

ISO cleanliness rating (Range Number)

More than this no. of particles per ml	Up to an including this no. of particles per ml	Range Number
80,000	160,000	24
40,000	80,000	23
20,000	40,000	22
10,000	20,000	21
5000	10,000	20
2500	5000	19
1300	2500	18
640	1300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10
2.5	5	9
1.3	2.5	8



1. Kidney-loop contaminant removal systems from C.C.Jensen Inc rely on a stack of filter disks to eliminate particulate matter, water, acidity, and degradation products from lube, hydraulic, gear, transformer, diesel, and other oils used in powerplants. Composition of the filtration medium varies depending on the duty

2. Filter disks are effective in removing varnish

the oil reservoir, removing sediment in the process.

All of the Jensen offline filters installed at Wildcat Point—HDU, PTU, and VRU—are arranged in this manner. Likewise, all are designed to (1) remove particles 3 microns absolute and larger, (2) absorb up to 1 gal of water per filter insert, and (3) remove insoluble varnish. This performance is achieved by a stack of two or more filter inserts, such as those shown in Fig 2, made primarily of compressed wood cellulose and cotton linters.

Composition of the filter inserts may vary from the standard Jensen offering where special requirements warrant. This has not been necessary at Wildcat Point. Wegner notes that independent laboratory tests show the Jensen filter inserts do not affect the phenolic and aminic antioxidant additive packages typically used in hydraulic/lube oil formulations for powerplants.

Applications. The HDU and its standard filter insert are designed for use in applications except where water ingress is expected. Special inserts are available for acidity reduction, dissolved-water removal, and soluble-

3. Varnish factoids and turbine-fluids best practices

- There are more than 30 different kinds of varnish; some are colorless. When in doubt, add an ultra-centrifuge (UC) test to your MPC (membrane colorimetric patch) analysis (Fig A). Recall that the MPC patch is made by isolating and agglomerating insoluble by-products associated with varnish, the color of the patch being a measure of varnish potential. By contrast, the "g" forces imposed on the oil sample in the UC test extract insoluble contaminants too small for normal particle counting.
- Varnish can be dissolved, insoluble, or cured, and its state depends on temperature and contact with air (Fig B). Varnish can cover surfaces immediately when it becomes insoluble.
- Hundreds of machine inspections and oil analyses have shown that (1) critical concentrations of varnish can be present with generally acceptable antioxidant levels, and (2) oil can be varnish-free with completely depleted antioxidant levels. Oil cleanliness is the determining factor.
- To assure accurate test analyses for varnish, take oil samples when the machine is running and in thermal equilibrium. Testing of cool oil will give lower-than-actual concentrations of varnish.
- Testing for particulate contamination can be by the optical or pore-blockage methods. In the former, the oil sample is passed through a beam of light. Anything that interrupts that beam is counted as a "particle." The calibrated mesh screen used in the pore-blockage method captures only hard particulates. Thus, there can be a significant difference between the two results, depending on the presence of water, soft contaminants, and/or insolubles.
- A sudden high-pressure alarm from your kidney-loop filtration system likely is caused by water ingress.
- When using a C.C.Jensen Inc kidney loop system, the company recommends scheduling your annual filter insert changes when the oil is coolest–for example, at the end of an outage–before the system is returned to service and the oil heats up again.

MPC value: 1 UC value: 4

A. That some varnishes are colorless is in evidence here with the MPC test showing pristine lube oil (MPC value of 1) and the ultra-centrifuge result on the same sample having a UC value of 4 (scale is 0 to 8)—a varnish level of some concern

B. Same turbine oil in the left and center bottles. At 140F (left), varnish is dissolved in the base oil. At 40F (center), it is insoluble—meaning the saturation level of the varnish in the oil exceeds its solubility at the fluid temperature. Varnish is "cured" and no longer soluble in the base fluid when "baked on" hot surfaces (thrust bearing shoe at right)

varnish removal.

The PTU is used mostly with steam-turbine lube-oil systems (and diesel-oil filtration systems) because of its ability to remove large quantities of water from the turbine fluid and discharge it automatically.

Wegner says the PTU has advantages over dehydrators often used in ST control and lube-oil systems for this application—including lower capital and operating costs, ability to remove particulates and varnish, and faster water removal. However, dehydrators may be beneficial in systems charged with fluids having poor demulsibility (don't shed water easily). Centrifuges, a third alternative for water removal, are limited in their ability to work reliably over long periods and to reduce moisture levels to the 20 ppm often recommended today.

Jensen's VRU typically serves on large gas and steam turbines where large amounts of soluble varnish must be removed from lube oil. A specially designed filter insert removes dissolved and suspended soft contaminants by polar attraction and alerts on varnish saturation by high pressure. The varnish-free oil produced cleans all system components it comes in contact with, ultimately reducing the level of varnish in the full charge of fluid to near zero.

Jensen recommends that its filtration systems run 24/7/365 and that the filter inserts be changed annually, when the pressure drop across the filter exceeds the recommended limit, or when oil analysis requires a change—whichever comes first.

A high pressure drop requiring new filter inserts can be caused by a leak exceeding the water holding capacity of the filter or by a high concentration of particulates in the turbine fluid. Wear and tear of mating parts and rusting of carbon steel components—such as the oil reservoir—contribute to the latter. Wildcat Point avoids rust to the degree possible with oil sumps made of stainless steel.

Regarding control of particulates,

Wegner says that begins when the oil is purchased. He urges filtering new oil or specifying a required ISO cleanliness level at that time to avoid receiving a fluid that may be dirtier than that called for by manufacturers of servos and other hydraulic control components.

Based on his experience, you can expect an average contamination level of about 19/17/14 unless you write a tighter spec. Go to Sidebar 2 to refresh your knowledge of ISO cleanliness ratings.

Sidebar 3 offers best practices on turbine fluid systems and varnish.

Extended warranties and service. There's only so much plant personnel can handle today given busy schedules, new operating regimes, etc. Converse said Wildcat Point opted for Jensen's extended warranties and service to keep equipment running the way it should, maintaining turbine fluids within recommended specifications.

Jensen changes out filter elements annually and performs all PMs called for in its O&M instructions. Any interim issues are responded to in timely fashion and there have been no delays in service and in the receipt of necessary parts. As noted earlier, "no failed starts" is the objective and the fluid systems for the principal rotating equipment at Wildcat Point continue to meet these expectations. CCJ

STUG
STEAM TURBINE USERS GROUP

The Steam Turbine Users Group officially launched at its first meeting in Richmond, Va, August 2014. In its infancy, the all-volunteer organization focused primarily on the GE A10 and D11 steam turbines used in combined cycles. Today, it covers steamers for combined cycles made by all the leading OEMs.

The 2022 meeting will be the group's second visit to San Antonio (2016). It also has met in St. Louis twice (2019 and 2021) and once each in Louisville (2018), Phoenix (2017), Orlando (2015), and Richmond. There was a virtual conference in 2020.

2022 conference overview

Sessions are *user only,* with this exception: Representatives of companies exhibiting at the vendor fair on Monday can sit in on the Tuesday morning presentations. Presenting vendors are allowed in the room only when it is their time to present.

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

Monday, August 29. The first-morning training session for steam-turbine users focuses on a topic of interest to many owner/operators today: Evaluating equipment and/or component upgrade considerations. The program will be conducted by Team EPRI. It will begin with the question, "What pain points are users experiencing regarding equipment replacement considerations?" Takeaways will include guidance on how to build and solicit an effective bid specification, the importance of quality oversight and execution, and questions to consider asking during a design review.

The afternoon session features user presentations and roundtable discussions. Two of the topics available at press time: Turning-gear maintenance and failure, and two failure modes for crossover bellows.

Tuesday, August 30. The morning is devoted to presentations by leading vendors: C.C.Jensen, EthosEnergy Group, Oilkleen, Advanced Turbine Support, Cutsforth, and Independent Turbine Consultants. The titles:

- De-mystifing varnish analysis and mitigation.
- In-situ repair and upgrade of LP turbine blades.
- Keys for a successful transition to a new turbine fluid.
- Steam-turbine cycling risks.
- Condition-based turbine monitoring.
- Steam-turbine valve maintenance.

First half of the afternoon session will be conducted by Siemens. Topics include erosion monitoring and corrective actions, troubleshooting rotor vibration, and a replacement steel blade for the existing titanium L-0 fleet.

User presentations and roundtable discussions are scheduled following the refreshment break. A topic that should be of great interest to attendees is "Pinned L-0 buckets: Variability in UT inspection results and pin removal."

Wednesday, August 31. MD&A takes the reins for the first half of the morning session, advising users on what to focus on during their first, second, third, and later majors. Discussions on long-term planning and lifecycle management follow. Inspection and maintenance of Rexroth actuators for turbine valves takes the group to the mid-morning break.

GE steps to the podium after refreshments and holds the mic until closing at 5:30. The lineup of topics:

- Recent TILs and top issues.
- Importance of insulation and indicators of concern.
- Service best practices.
- Water-induction impacts and potential root cause.
- Outage planning and forecasting emergent work based on fleet experience.
- Improving outage OTD (FieldCore).
- Upgrade experience.
- Combined-cycle steam-turbine outage 101.

Thursday, September 1, is devoted to user presentations and roundtable discussions until the meeting concludes at noon.

Steering committee, 2022

Eddie Argo, *Southern Company*
Jake English, *Duke Energy*
Jay Hoffman, *Tenaska Virginia Generating Station*
Connor Hurst, *Teco Energy*
Mark Johnson, *FPL*
John McQuerry, *Calpine*
Matt Radcliff, *Dominion*
Lonny Simon, *OxyChem*
Seth Story, *Luminant Generation Services*

2021 user presentations

LCC 15 Spring 21 outage HP/IP, LPDF, valves

Results of the spring 2021 outage—findings and repairs/replacements—are presented in bullet-point fashion for this 2 × 1 M501F-powered combined cycle with 40-in. titanium L-0 blades. Service history: 67,000 hours; 475 starts. Rubs, clearance/alignment issues, erosion, LP exhaust-hood vibration, etc, were addressed. Turning gear was replaced and the original repaired and put into inventory.

Bearing vibration increased from pre- to post-outage but remained below the action limit of 4 mils and considered acceptable for long-term operation. Eccentricity also increased from pre- to post-outage from -1 to -2.5 mils but the cause was not determined. However, the eccentricity is steady and has not impacted operation.

Journal- and thrust-bearing metal temperatures post-outage remained below the action limit despite all the drive-train adjustments made during the outage.

ST valve maintenance issues

Review of steam-turbine valve maintenance issues encompasses units serving in both conventional steam plants and combined cycles. The many cutaway drawings of valves might prove valuable for training purposes.

Presentation highlights include the following:

- Recommended maintenance intervals.
- Technical bases for maintenance intervals.
- Technological differences among valves from different manufacturers. Plus, areas considered most likely subject to degradation.

Taft Cogen cooler maintenance

Personnel at this 800-MW 3 × 1 combined cycle noted that generator hydrogen usage was increasing over time to maintain purity. Hydrogen leaks appeared after about two years of service; cooler seals were leaking from the bottom. Cooling water was sourced from the closed cooling-water system; its rubber-seal life expectancy was eight years.

During a recent inspection, the floating ends of the coolers were checked and oil was found weeping from the seals, indicating a possible hydrogen leak. Also observed: Several of the lantern-ring retaining plates were bent. Overtorquing of bolts was believed the cause.

After cooling lines were disconnected and lantern rings disassembled, staff found oil and debris around the cooler sealing area. Housekeeping, seal maintenance/replacement, and straightening of the lantern-ring retaining plates were among the corrective actions taken.

Balance shot on a hot rotor (D11 steam turbine)

The speaker declares at the outset that this is not a presentation, rather it is a quiz. Whatever, it's worthwhile accessing the slide deck. He begins with the question: After you identify high vibrations, what do you do? And then lists the three things he did to move forward. Next question: What special tools do I need? Then: Where do the weights go? Photos and a cross-sectional diagram of the turbine assist in understanding the approach taken.

What balance-weight options are available? Three choices: Normal, overhung, and super-overhung. The speaker acknowledges that old-school heavy weights are no long used given the belief they came out at speed, in at least some cases.

The rotor is hot: How long can you be off-gear? Some say no more than 10 minutes with a hot rotor, although others have been off longer. "Listen for rubs when you re-engage" was a suggestion. What's the best way to roll the rotor, given there's not enough control with the turning gear? There are several alternatives, including a pipe threader and air ratchet/drill.

Next question: Any tricks for making balance-shot removal possible? You'll have to review the slides to get this answer, as well as to see the results of a two-day plot of eccentricity.

HP/IP rotor end-of-life concerns

This case study reports the findings of a KN steam-turbine major on a 2003 unit purchased from the original owner in 2017. History: 76k operating hours and approximately 1900 starts, which translates to about 124k EOH according to the OEM's calculation. The HP/IP rotor was sent to Siemens' shop for a complete technical evaluation.

It revealed rotor hardness levels at the HP and IP inlet grooves were less than previously observed by the OEM for other steamers inspected in the KN fleet. A table giving inspection results estimated remaining life at 11 rotor locations given the reduced hardness properties. Most troubling was that at the IP second-stage blade groove, 78% of rotor life had been consumed with respect to localized creep-fatigue—99% considering material properties with reduced hardness values.

Options for dealing effectively and economically with the findings were evaluated and rotor replacement in 2023 offered the best balance of reliability and risk avoidance given the operational flexibility the owner sought in both unit dispatch and turndown.

Industry L-0 erosion issues

Presentation begins with an overview of erosion issues on 40-in. L-0 blades for a nominal 500-MW Toshiba four-flow steam turbine which photos show to have exceeded the level of damage expected. Measurements taken to assist in corrective action, erosion findings for other units in the Toshiba fleet, and options for refurbishment or replacement are given.

Next, photographic evidence of erosion of last-stage blades from Alstom, Mitsubishi, and GE show this to be an industry problem—generally speaking.

Final slides in the deck offer a summary of technologies for inspecting installed blades—both reaction and impulse types. Simplified illustrations make this material, based on EPRI research and test results, easy to comprehend.

Considerations for cyclic operation

An overview of recommended maintenance intervals, and the technical basis for them, gets the reader involved quickly. A risk-informed approach to interval optimization provides users a road map and includes a table of equivalent-hours calculations and target hours for valves and turbine majors for machines manufactured by Alstom, GE, Hitachi, Mitsubishi, Siemens, Westinghouse, and Toshiba.

Examples of different OEM steam-turbine designs and degradation areas are of particular value to owner/operators with a mixed bag of turbines in their fleets. Example: Areas of concern for the D11 include steam-path SPE, diaphragm dishing, HP and IP inlet sealing, N1/N2/N3 gland casings, rotor bow, low-cycle fatigue at wheel-inlet transitions, and N2 creep deformation.

Tables of high- and low-temperature steam-turbine high-impact risks benefit all those with responsibilities for steamers. Among the high-temperature risks evaluated for impact, drivers, traditional detection, and monitoring potential are the following: rotor and blade-attachment creep-fatigue, casing distortion, rotor deformation, and diaphragm dishing.

Low-temperature risks evaluated include rotor-shaft high-cycle fatigue, L-0/L-1 attachment and pin fatigue/stress corrosion cracking, L-0 blade HCF, and L-0 leading- and trailing-edge erosion.

Combined journal and thrust bearing

This presentation features photos of thrust axial position keys as found, thrust pedestal condition as found, new hardened key design, bearing-support repairs, and L-0 blade arch binding on 40-in. steel airfoils. However, the slides offer virtually no written explanation, so if you're not a steam-turbine expert it's unlikely you will gain much from this PowerPoint.

2021 vendor presentations

Considerations for reducing trailing-edge erosion, *Siemens Energy*

Trailing-edge erosion, attributed to moisture droplet impacts, has been observed on the suction side of some L-0 blades near the base of the airfoil (Fig 1). This easy-to-understand, comprehensive, presentation with excellent graphics explains the damage mechanisms and sources of moisture, with a focus on spray-system considerations. Conclusion: Poorly coordinated, configured, and/or maintained spray systems can lead to elevated rates of trailing-edge erosion.

SMART Seals™: An advantage in today's challenging steam-turbine environment, *EthosEnergy*

Reason to review this presentation on the Power Users website: Audits indicate that around 70% of steam-path losses can be attributed to operating with excessive seal clearances. On a 300-MW steam turbine this can equate to about $300,000 in fuel cost and a $1.2-million loss in annual generation—while increasing CO_2 emissions by up to 25,000 tons/yr.

One area of focus is labyrinth seals which contribute to reduced turbine performance when they suffer mechanical damage and thermal distortion. Retractable packing and brush seals mitigate losses, attendees were told. Better blade tip seals also can help reduce losses caused by leakage between stationary diaphragms and rotating blades.

Other sealing solutions described include the following:

- Articulated inlet seals to replace conventional snout rings, which control steam leakage at the turbine inlet between the inlet pipe and outer and inner shells.
- Anti-swirl packing rings that reduce steam-whirl destabilizing forces, significantly increasing rotor stability margin.
- HP/IP midspan joint leakage at the N2 packing box is minimized by using improved materials, a double-nut arrangement, and increased preload (Fig 2).

The benefit of upgrading shaft and tip seals and snout rings to the EthosEnergy SMART seal™ designs is said to be a reduction in heat rate of from 2% to 4% and an increase in output of from 4% to 7%.

Advanced rotor-straightening technology, *EthosEnergy*

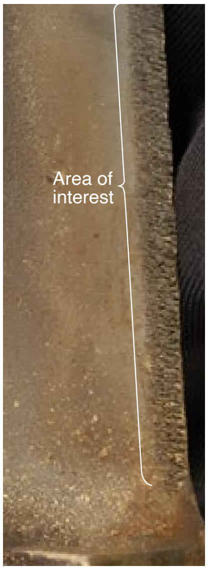
The first few slides review (1) the root causes of rotor bow (including rubbing during startup, water induction, and foreign object damage) and (2) traditional rotor straightening methods. EthosEnergy's advanced rotor straightening technique (Fig 3), said to have been applied successfully on more than 150 rotors—including some with bows exceeding 200 mils—is detailed in the remainder of the presentation. A case history is included.

Metallographic analysis, magnetic particle inspection, FEA, and engineering all play a role in the success of the technique, well described with diagrams and photos.

Advanced single-layer turbine warming system, *ARNOLD Group*

Pierre Ansmann opened his presentation on "the most advanced turbine insulation combined with a high-performance heating system to improve startup flexibility," by summarizing its value proposition thusly:

- Increased in-market availability.
- Lower startup costs.
- Reduced thermal fatigue and longer mean time to repair for critical components.



1. Trailing edge erosion, associated with moisture-droplet impacts on some L-0 blades, can lead to crack initiation and possibly airfoil liberation

■ Increased operating flexibility.

The ARNOLD system features interlocking high-performance blankets which conform perfectly to the turbine surface. High-quality materials and manufacturing, and long-term high-temperature resistance, allow the company to guarantee reuse of its insulation system for 15 outages without a decrease in efficiency.

Dozens of thermocouples, strategically located on the turbine, ensure proper heating. Each of the 18 or so heating zones has t/cs installed on the heating wires to double check that the zone is responding correctly and at the specified temperature. Below every heating zone, multiple t/cs are mounted on the casing to confirm even heating of the turbine (Fig 4).

A properly maintained ARNOLD insulation system is said to maintain your turbine in a hot-start condition for at least four or five days after shutdown. No preheating of the unit is required prior to a start within this time period, reducing startup fuel consumption and auxiliary power.

A case study attests to the value of this warming system for a 100-hr shutdown. Results are the following:

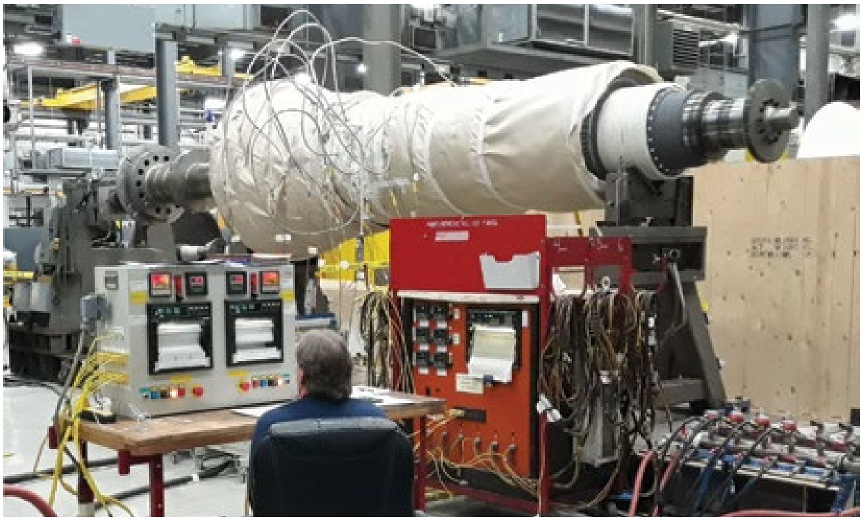
■ Temperature control setpoint, 750F.
■ System cooled naturally from 1000F to 750F where the casing upper-to-lower differential reached only 40 deg F; previous shutdowns the differential had reached as high as 100 deg F.
■ The warming system maintained 750F casing surface temperatures for over 100 hours and reduced the upper-to-lower casing differential from 40 deg F to around 10 deg F during that time.
■ Differential expansion limits never were exceeded, and the turbine restart was normal and comparable to previous starts.

2. Upgraded N2 packing can help maximize the value and extend the life of your steam turbine

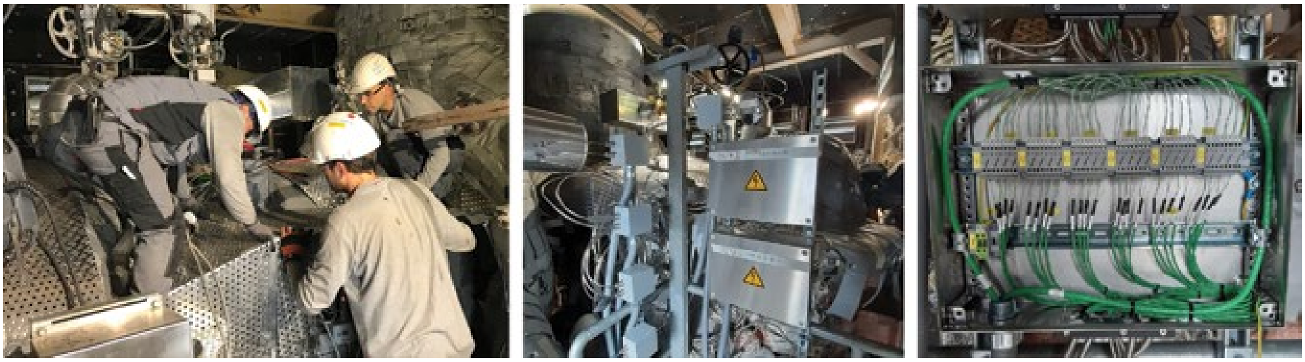
Solid particle erosion on combined-cycle units, *Independent Turbine Consulting*

This case study reviews main-stop-valve damage on a D11 steam turbine, discovered during the spring 2020 outage and determined to be related to solid particle erosion (SPE). It covers discovery of the problem, investigation (including the sources of the particles), and solution—including mitigation strategies. The nominal 200-MW turbine, an integral part of a 2 × 1 combined cycle, was approximately 10 years old and had accumulated about 53,000 hours of service and nearly 600 starts.

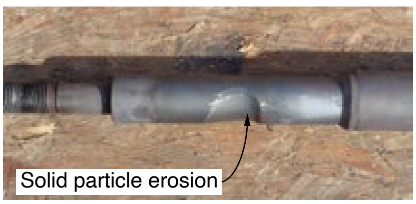
Severe SPE was found on the valve stems as shown in Fig 5. Exfoliation of HRSG tube material was the source of



3. Advanced rotor straightening method developed by Ethos Energy is a proven technique that has been used successfully on more than 150 rotors, some with bows exceeding 200 mils



4. Single-layer insulation and step-protection system from Arnold is installed at left. All electrical connections, center and right, are moved away from the casing



5. Damage to main stop valve for a D11 steam turbine, discovered during an outage, was attributed to solid particle erosion

6. Drop-in solutions have been performed by Doosan in more than 30 locations worldwide

the particles. Solution: Improve water chemistry.

Guidelines for dealing with the aftermath of SPE are covered in GE's Technical Information Letter 1739.

Repair approaches for aging steam-turbine rotors, *Doosan Turbomachinery Services*

Come up to speed on Doosan's capabilities by accessing this presentation. It begins with a short overview on the parent company's activities in the power industry and beyond. Highlights include drop-in replacements for major steam-turbine sections, such as the HP/IP, as shown in Fig 6.

Next is a review of Doosan Turbomachinery Services' capabilities in Houston—including gas- and steam-turbine component repair, rotor inspection and assessment, welding, heavy mechanical work, parts, onsite services, etc.

The meat of the presentation is two detailed rotor-repair case studies with many drawings and photos to make them easy to understand and expand your knowledge of the processes involved. Both rotors began commercial baseload operation in the second half of the 1960s and had been transitioned to peaking service.

The first case is about a 360-deg circumferential crack in the midspan balance-weight groove of a nominal 400-MW unit—confirmed by mag particle inspection with follow-on ultrasonic inspection to estimate crack depth and develop a repair approach. There had been no operational indication this crack existed prior to rotor teardown and inspection.

Repairs described were successful and the rotor and diaphragms returned to the plant on schedule. There were no major issues on reassembly and restart was described as "smooth." Following one test run that revealed vibrations were better than pre-outage and upwards of 10 MW was recovered, the unit was released for service.

The second turbine, rated a nominal 500 MW, also gave no indication of issues during operation. However, a shop visit for inspection was motivated by previous corrective work on HP/IP rotor cracks requiring major weld repair as well as borescope inspection results that showed nozzle-block retention hardware was failing and foreign objects were lodged in the first reaction-stage stationary blading.

Indications were characterized, a machining plan developed, and geometric mods performed before final NDT of the complete rotor. Planned repair schedule was maintained and unit reassembly and restart were generally smooth.

Steam-turbine valves, *MD&A*

Presentation is a primer on the inspection, repair, and reassembly of steam-turbine valves that offers guidance on specific repairs, as well as repair options, for several types of steamers serving in combined-cycle plants (Fig 7). Strainer baskets, control-valve seats, and steam chests and their rebuild are covered. This slide deck is worth reviewing each time valve inspection and repair are required.

7. Repair of steam-turbine valves is an MD&A specialty

2021 OEM presentations

GE Day was Thursday, August 26. It opened with an hour presentation by Mike Jones and Matt Foreman on recent Technical Information Letters and top issues. L-0 fleet lessons learned was next with Jason Crowe at the podium. Dave Welch followed with two presentations after the break: "Proactive maintenance to prepare for increased cyclic operation" and "Rotor end-of-life/assessment." Crowe concluded the morning program with "Alignment and clearances."

Welch started the afternoon with a presentation on turbine valve maintenance. Jason Bowers was next with "Upgrade experience: ASP and next-gen valve." Open discussion followed until the session concluded at the afternoon break.

The GE presentations are not available on the Power Users website. Access them on the OEM's MyDashboard website at https://mydashboard.gepower.com.

Siemens Energy participated in the STUG meeting with the following three presentations on Wednesday morning (August 25):

- "Improving capability and flexibility of existing combined-cycle powerplants through plant assessments," Jim Badgerow.
- "Applying advanced digital applications to empowering traditional fossil power stations to operate with the demands of the 'new normal' in the ever-changing North American power market," *Galen George.*
- "Blade erosion reduction strategies," *Steve Radke.*

Only the third presentation is available in the STUG sector of the Power Users website. For the first two, go to the Siemens' Customer Extranet Portal (https://siemens.force.com/cep). If your organization owns and/or operates Siemens power-generation equipment and you do not have access to that portal, use the link to request it. Or contact the Siemens representative for your company/plant.

7EA Users Group

Legacy Turbine Users Group

The 7EA Users Group has been serving owner/operators of GE Model 7EA, A, B, C, and E gas turbines for more than a quarter of a century. Today, the OEM refers to this group of units collectively as 7E, which can be confusing to some. Rumor has it that the naming convention will be clarified at the 2022 conference, August 29 to September 1, at the San Antonio Marriott Rivercenter.

A bit of history. The first two Frame 7 package power plants (PPP)—the lingo used by GE decades ago for its gas turbine/generators "packaged" for rapid deployment where power was needed—were ordered by Long Island Lighting Co and installed in the summer of 1971—one at the utility's West Babylon plant, the other at its Shoreham Plant (a/k/a Wading River).

The nominal 52-MW distillate-fired units were still in standby service and equipped with their original Mark I Speedtronic™ control systems when the editors contacted National Grid, the current asset owner, last year.

Today, there are roughly 1200 7Es (new GE designation) in service worldwide—three-quarters of them are 7EAs.

2022 conference overview

Monday, August 29. Owner/operators attending the 7EA meeting have two options for the opening morning's training sessions: Tour MD&A's gas-turbine parts manufacturing and repair facility (transportation provided if you reserve a seat at the registration desk) or participate in a short course on legacy engines designed both for newcomers as well as experienced users who could benefit from a refresher.

The afternoon session kicks off with Mike Hoogsteden's (director of field services for Advanced Turbine Support) not-to-miss annual presentation, "State of the 7EA fleet." Key topics include the following: Issues identified across the fleet during recent inspections, rotor-blade/stator-vane clashing, in-situ compressor- and turbine-blade blending advancements, new TILs, and generator robotic inspections.

Presentations by vendors take up most of the time remaining until the vendor fair—covering anti-condensation measures for metal-enclosed bus, 7EA root-cause analysis process, and exhaust-frame mods and upgrades.

Tuesday, August 30. The 7EA meeting traditionally has been one to focus on presentations by vendors. Those participating this year: PSM, Sulzer, MD&A, GTC Control Solutions, SVI Industrial/SVI Dynamics, AP4 Group, Veracity Technology Solutions, AGT Services Inc, and National Breaker Services.

The topics: Hydrogen combustion in B/E-class gas turbines, no-leak seal for the DLN primary fuel nozzle, rotor life assessment, lessons learned during controls upgrades, common problems with exhaust systems and silencers—a case study, OEM versus non-OEM controls, quantifying corrosion pitting using advanced NDE, 7EA generators and how minors turn into majors, reducing thermal stress on GACs.

Wednesday, August 31, is GE Day, featuring presentations and breakout sessions until the gavel comes down at 5 p.m. The breakout roundtables cover the waterfront: cogeneration, peakers, repairs, controls and software, asset management for casings and rotors, field services, generator recommendations, accessories and balance-of-plant tips, repairs/field services.

Thursday, September 1. Vendor presentations on extending the service lives of gas-turbine components, and full-rejuvenation heat treatment of GTD111DS, are included among several user presentations and roundtable discussions not firmed up at press time. The meeting concludes at noon for all not interested in joining the MD&A tour of the company's gas-turbine parts manufacturing and repair facility. This is the same tour that was offered on Monday.

Steering committee, 2022

Dale Anderson, *East Kentucky Power Co-op*
Joshua Coots, *Duke Energy*
Tracy Dreymala, *EthosEnergy Group, San Jacinto Peakers*
Jeff Hansen, *Old Dominion Electric Co-op*
Guy LeBlanc, *IHI Power Services Corp*
Tony Ostlund, *Puget Sound Energy*
Mike Vonallmen, *Clarksdale Public Utilities*
Lane Watson, *FM Global Chemical Operations*

2021 user presentations

Lessons from the field: Circuit-breaker maintenance practices

Breaker events profiled in this slide deck include the following:

1. New breaker failure at a 7E simple-cycle plant.
2. Vacuum-bottle failure at a hydro plant.
3. Catastrophic breaker overheating.
4. Single-pole failure of a 115-kV breaker.

The takeaways from these events provide valuable "lessons learned." For the first, the presenters' experience confirmed that modern relaying can be of considerable helping to speed-up the troubleshooting time after an electrical trip. The second showed vacuum bottles have a finite life. More specifically, dc hipot/bottle integrity tests do not give an indication of future life.

Takeaway from No. 3, illustrated with circuit and logic diagrams, and photos of damage: Breaker forced-cooling apparatus is important if it's applied. Action items: Act on alarms, check runback levels, maintain cooling fans, and correct failing switches. Important: Spare breakers can be a life-saver.

High-side/substation breaker reliability is critical, attendees were told. Ensure the plant, or transmission utility, is providing proper maintenance and upgrades.

Review your Generation Interconnection Agreement regarding responsibilities, if your plant has one. In any case, proper and regular maintenance must be performed on all components to ensure reliability.

Guidance on the maintenance required is provided, along with the timing of tests, what good results look like, and data interpretation. Bear in mind that roughly half of all breaker performance failures are attributed to lubricant degradation, improper selection, and/or misapplication.

A lunch-and-learn session in the plant break room might be in order to familiarize staff with breaker assembly and components, troubleshooting, spare parts, the importance of proper bolt torquing, and where to find the breaker manuals when they're needed.

In-situ fuel-nozzle flow testing

Presenters describe positive results in using a portable air-flow test stand (PATS), a/k/a portable flow bench, to conduct fuel-nozzle testing in-situ rather than removing fuel nozzles from the gas turbine and sending them to a shop for that purpose. Important point: This owner has a fleet of well over a hundred gas turbines.

The PATS was said to provide a direct measurement of the engine's fuel-nozzle characteristics, with the ability to isolate the problem to a single combustor position/circuit and possibly eliminating fuel-nozzle flow as a cause of the issue being dealt with. Several slides describe how PATS works and the infrastructure support required to conduct testing—for example, more than 80 cfm of clean, dry air.

Case studies are summarized for the following engines:

- 501FD2 (DLN)—high blade-path spreads, with cold spot.
- 7F (DLN 2.6)—high exhaust spreads after an outage, with cold spot.
- 7EA—high exhaust spreads after a liquid-fuel run, with cold spot.
- 7EA (DLN 1)—high exhaust spreads after an outage, with no hot/cold spot.

In closing, the speakers shared what challenges colleagues might encounter with in-situ flow testing, including these:

- Access to air of the quantity and quality required.
- Possible limitations of PATS given ambient-air characteristics where used (not a controlled repair-shop environment).
- Not all combustion issues can be solved with flow testing.
- Easier when fuel-nozzle flow targets are available to compare to "spec."

2021 vendor presentations

What we are seeing in the 7EA fleet during our inspections, *Advanced Turbine Support*

The 2021 version of this annual presentation by Mike Hoogsteden, the company's director of field services, which is of significant value to plant personnel for its many illustrations, highlighted GE Technical Information Letters (TIL) users should become familiar with, in particular—including the following:

- TIL-1854, "Compressor Rotor Stages 2 and 3 Tip Loss," suggests blending and tipping to mitigate the impact on availability and reliability of Row 2 and/or R3 tip loss.
- TIL-1884, "7EA R1/S1 Inspection Recommendations," addresses the need to inspect R1 and S1 airfoils for possible damage caused by

clashing—the unwanted contact between the leading edges of S1 stator-vane tips and the trailing edges of rotor blades in the platform area.

- TIL-1980, "7EA S1 Suction Side Inspection Recommendations," advises users to inspect for crack indications on S1 vanes made of Type-403 stainless steel, regardless of whether clashing damage is in evidence on S1 and R1 airfoils or not.
- TIL1562-R1, "Heavy-Duty Gas Turbine Shim Migration and Loss," informs users on the need to monitor the condition of compressor shims and correction actions available to mitigate the risks of migrating shims.

Compressor stator-vane looseness: What to look for and what to do, *CTTS (a/k/a Core Tech)*

Pinning is a relatively low-cost and quick solution for gas-turbine owner/operators challenged by compressor stator-vane looseness. More than 200 engines have been "pinned" in the last 20 years, avoiding engine damage and saving thousands of vanes (Fig 1).

The pinning technique, developed by Rodger Anderson, who began his career as a member of GE Frame 7 compressor design team, has been the subject of several CCJ articles over the years. What to look for during your next compressor inspection in terms of shim migration and vane looseness/damage is described in the slide deck along with the likely causes.

1. Loose ring segments in compressor stages S17, EGV1, and EGV2 are secured as shown using spring pin dampeners

Emergency rotor support services—a case study, *Sulzer*

The borescope inspection of a simple-cycle 7F unit revealed severe damage in compressor rows 14 through the exit guide vanes (Fig 2 left). The owner/operator needed the unit back in service ASAP. Slides detail the steps taken to assure proper corrective action—from inspection to rotor disassembly to parts replacement with shop-manufactured components to reassembly (Fig 2 right) to rotor balancing to preparation for shipment to the plant—in only 36 days.

Details presented in the slides provide a valuable learning experience for the plant team.

The second part of the presentation gives details on Sulzer's capabilities, repair history, shop capabilities, rotor life assessments, and field services.

Analysis of inspection protocols for S-1/R-1 clashing, *Veracity Technology Solutions*

The goal of an inspection protocol should be to provide the highest sensitivity for flaw detection and determine an inspection frequency that gives the inspector the most opportunities to detect a flaw before the defect becomes catastrophic.

In the example given, two units were undergoing their annual NDE inspections to satisfy the requirements of TIL-1884 (see first item above). The units were equipped with C450 stators, which exhibited signs of corrosion lockup in the lower half after nearly 11,000 fired hours and 2000 starts. An eddy-current inspection was specified; a fluorescent penetration inspection was conducted as well to validate the findings.

Many indications were identified and are shown in the slides. Analysis revealed the cracks emanated from shallow surface discontinuities which experts believe were caused by one or more of the following: environmental conditions, possible stress corrosion cracking, and high-cycle fatigue (from stator lockup in the vane carrier).

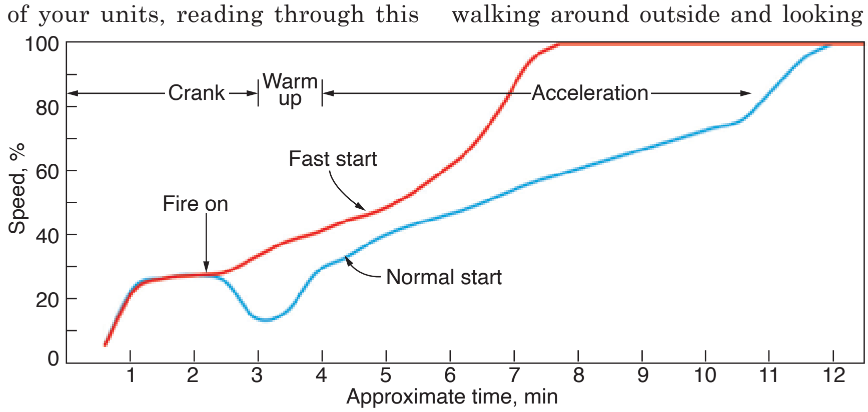
Conclusions: The use of traditional penetrant methods may not be effective for detecting the types of cracks found. Only after the stators were removed and sent to the shop did the inspection team identify all of the flaws using its proprietary inspection

2. Compressor damage as-found is at left. Repaired, stacked, stretched compressor rotor is married to the repaired turbine rotor at right. A unit rotor balance was done before progressive blade/balancing of the turbine section technique.

It's important to note that swapping out of the C403 stainless-steel stators installed on older machines with C450 components recommended by the OEM may not provide the level of asset protection desired. The bottom line: It's imperative to be diligent on your inspection protocol.

Getting your 7EA ready for increased run time, *Emerson*

If you're looking for a checklist of action items to improve the run times of your units, reading through this presentation is a good place to start. It focuses on controls mods, generally far less costly than hardware changes, to consider. Example: Control mods can enable the transition from normal to fast starts (Fig 3).



3. Controls modifications reduced a normal 12-min start to about 8 minutes fairly easily for the 7EA example shown: start to purge speed now is less than half a minute, the purge 1.5 minutes, ignition and warmup to reach 25% speed less than half a minute, acceleration from 25% to 100% about five minutes, and synchronization about half a minute

Bus maintenance in action, *RMS Energy*

Bus duct is relatively easy to maintain. Keep it dry, clean, and cool, the RMS Energy experts say, and your problems will be minimal. But how many plant personnel do you see walking around outside and looking up? And even if they were, the upper portion of the duct remains out of sight.

The presentation begins with a list of critical bus-duct components: Flex/bolted connections (current carrying), expansion bellows/joints, insulators and mountings, seal-off bushings, grounding, and insulated joints. Fig 4 shows some of the damage one can expect without a rigorous monitoring/inspection plan.

Monitoring equipment/techniques suggested include these: Thermocouples and infra-view camera to monitor components remotely and initiate alarms. Electromagnetic signature analysis (EMSA) is a valuable online diagnostic technology that can support maintenance decisions based on real-time operating conditions. It can save critical shutdown time by eliminating the need for offline testing.

Several case studies with before/after photos are instructive.

The GTC quick solutions package, *GTC Control Solutions*

Five case studies encompass this presentation; four are explained below.

The first describes a single point of failure. Problem: A high differential among ambient-temperature thermocouples (t/cs) was causing a "not ready to start" situation. There were two compounding issues: The first was sub-optimal location of the t/cs. This second: A "no high differential" was a start permissive—that is, a high differential would result in a "not ready to start" condition.

The fix: Two t/cs were relocated to prevent erroneous temperature measurements. Plus, the "no high differential logic" as a permissive to start was changed to "two out of three t/cs failed." The latter assures that if one t/c fails, operators receive an alarm but will still remain ready to start; two failed t/cs interrupt the start sequence.

Case 2 involved an LM5000, which has two speed pick-ups per shaft. Originally, the "Hi-Select" determined speed. Thus, one failed hi-detector trips the unit. Solution was to check inputs and reject "out-of-limit" values.

Case 3 involved an LM2500 with very hot starts. Over-temperature trips occurred during startups. Diagnostic alarms indicated a loss of P2 pressure feedback. Solution was a logic change to "IF on temperature control during startup THEN trip."

Case 4 described problems with a 7B gas turbine equipped with torque converter, jaw clutch, and limit switch that experienced starting difficulty. Clutch disengaged at 47% speed; however, logic required clutch to remain engaged until 50% speed. Torque converter degradation was the problem and the logic was changed to permit clutch disengagement below 50% speed.

Gas-turbine operability challenges in an unstable grid environment, *EthosEnergy*

Please find a precis of this presentation on p 29.

7EA turndown solutions: How low can we go? *PSM*

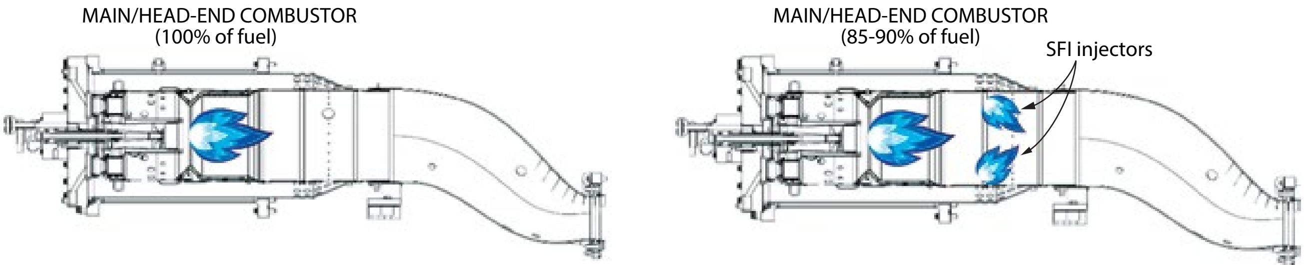
Presentation is a good review of PSM's tools for extending engine turndown. It begins with a review of the company's LEC-III™ ultra-low emissions and LEC-NextGen combustion systems and refreshes your recollection of its inlet bleed heat and exhaust bleed solutions.

PSM's latest turndown solution—Sequential Fuel Injection (SFI)—specifically engineered for 7E (that is, Models 7B through 7EA) LEC and DLN 1 combustion systems is the presentation's focus. SFI is said to leverage prior sequential combustion experience with the company's FlameSheet™ product, to achieve comparable results with SFI without major changes to existing combustion hardware (Fig 5).

Recall that low-emission combustors are sized for optimum NO_x emissions at baseload and "lean-out" as load is reduced; CO spikes as the Minimum Emissions Compliant Load (MECL) is approached. With SFI, the main/head-end combustor is sized for CO at MECL, and SFI fuel is added proportionally as load is increased from MECL to baseload (up to 15% of the total).

SFI fuel reacts with hot excess air from the main/head-end combustor, holding the temperature rise in check, thereby minimizing NO_x production while also maintaining low CO.

4. Some things to look for when troubleshooting bus duct: Cracked laminations caused by vibration or air flow (left), damaged flex braids caused by rubbing and/or abuse (center), and damage attributed to improper bolting and/or lack of maintenance at connection points (right)



5. PSM's Sequential Fuel Injection solution completed full-scale validation testing in 2020 and achieved a significantly greater reduction in turndown compared to LEC-III results. Diagram at left explains operation from startup to MECL (about 35% baseload with IBH), at the right MECL to baseload

6. Distribution-grid plate that failed (left) was replaced with one of new design to facilitate installation (right). It was delivered to the site within three days of taking field measurements

Remote operations for simple-cycle GT sites, *Emerson*

Lots of things to think about if your simple-cycle unit is not yet equipped for remote operation. Presentation's stated goal is to help users leverage digital transformation to save O&M and increase earnings.

Using flow net modeling to optimize fuel-nozzle calibration and flow testing, *Trinity Turbine Technology*

New ideas for optimizing combustion-system air and gas mixing to reduce emissions and temperature spreads. Results have been promising; work continues.

Emergency material and design support, *Schock Manufacturing*

Slide deck focuses on Schock Manufacturing's ability to respond quickly to customer problems—such as expansion-joint blowout, exhaust-liner sheet failure, diverter damper seat and landing-bar failures, failed trash screens, stack corrosion, failure of silencer panels, etc (Fig 6). Customer testimonials are included.

Generator testing: What the tests mean and how they are resolved, *AGT Services*

Jamie Clark, well known to owner/operators for his meaningful presentations at user-group meetings, had a simple objective here: Identify standard tests and inspections—electrical, mechanical, and visual—that plant personnel should be familiar with to avoid operational surprises and to assure the highest level of equipment reliability possible. He provided examples of both bad and good test results, and offered recommendations and corrective actions to achieve the stated objective.

Here's the lineup of components Clark recommends inspecting:

Stator winding: Endwinding support system, wedge system, gas-gap baffle studs, rubber baffles, and bushing box for hydrogen-cooled machines.

Stator core: Tightness, iron migration, damaged/overheated laminations, and vent duct blockage.

Field (rotor): Cleanliness, arcing between wedges, hot spots on tooth tip at wedge joints, retaining-ring condition, borescope survey under retaining rings, collector-ring condition, fan damage, and copper dusting.

This is a good presentation, in the opinion of the editors, for a lunch-and-learn in the plant break room. Details are at a minimum, photographs are excellent.

Considerations for the fleet management of gas-turbine lubricants, *EPT Clean Oil*

EPT Clean Oil specializes in ion-exchange-based lubricant treatments and oil testing in critical applications. It maintains an on-going R&D program focused on advancing the science of lubricant management.

Peter Dufresne's goal was to help owner/operators see the value in treating their lubricants as an asset, rather than as a consumable, and to understand and use the tools at their disposal to manage that asset. Here's an "executive summary" of the plan he suggests users follow. Details are in the 49-slide PowerPoint.

- Complete oil analysis done to ASTM standards.
  - Track and monitor rates of additive consumption.
  - Predict end of lubricant life well in advance.
- Use a conditioning system to manage oxidation.
  - Eliminate potential for varnish and reduce rates of additive consumption.
- Purchase high-quality oils from a reputable manufacturer/supplier.
  - Consider an annual 5% top-up.

Other presentations available on the Power Users website from the 2021 conference include these:

Predictive analytics to improve gas-turbine power forecasting and maintenance practices, *Camfil*

Breaking down the run-to-failure strategy: Why proactive bus-duct maintenance is critical, *Electrical Builders*

Legacy Turbine Users Group

Frame 6B Users Group™

Steering committee, 2022

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*

The 6B is a familiar GE gas turbine in cogeneration systems at process plants where staff typically is challenged to keep legacy assets operating on a low O&M budget, often without the support of a corporate engineering staff. The presentations and discussions at annual meetings of this users group provide know-how and proven solutions to help owner/operators achieve that goal.

These engines also are found in simple- and combined-cycle arrangements for electricity production only. In fact, the first Frame 6 (Model A, which preceded the 6B) was commissioned July 15, 1979 at Montana Dakota Utilities Co's Glendive Power Plant. The 41-MW, dual-fuel-capable, simple-cycle unit was still in service a year ago.

2022 conference overview

Monday, August 29. The morning training session is a short course on Frame 6B engine details that impact operation and maintenance. Presenters are John F D Peterson, PE, and Zahi Youwakim, two long-term members of the Frame 6B steering committee; Peterson, now retired, was one of the group's founders. The program is designed both for newcomers as well as experienced users who could benefit from a refresher. The afternoon program opens with a safety roundtable and accompanying case histories. A presentation on gas-turbine train alignment is next, with the Turbine Auxiliaries Session to follow. The latter runs until the meeting concludes for the day at 5 p.m. The vendor fair opens at 5:30.

Tuesday, August 30, is GE Day. The morning presentations: Fleet updates, monitoring and diagnostics to increase reliability, interval extensions, refresher on combustion technology, hydrogen experience and the path forward, and rotor life extension.

The afternoon program consists of three breakout sessions designed for maximum interaction between users and GE's experts. Each session features three of the following discussion topics running in parallel: Combustion technology Q&A, rotor end-of-life discussion, generator and excitation maintenance, maintenance interval extension Q&A, repair technology updates, and controls, upgrades, and instrumentation.

Wednesday, August 31. The morning program features roundtables and user presentations on the air inlet section of the engine and the compressor. Between the roundtables is a vendor presentation, "Mobil™ Solvancer®: Improving turbine reliability and reducing the cost of operation through advanced technologies."

Combustion and turbine sessions are in the afternoon, along with vendor presentations on the current and future capabilities of the 6B burning hydrogen, and combustion system optimization.

Thursday, September 1. Two roundtable sessions (I&C and generator/exciter) and two vendor presentations ("Combating the effects of increased cycling" and "Rewinding HV generator stators") conclude the meeting by noon.

2021 virtual meeting

No formal user presentations were on the 2021 virtual conference agenda. Rather, users shared their experiences via four roundtable discussion forums: compressor, I&C, combustion, and turbine, each chaired by a member of the steering committee. You can access these and other presentations cleared for release in the Frame 6 section of the Power Users website (www.powerusers.org) under the "Conference Archives" tab.

Important to note is that copies of each slide deck and an unedited recording of each discussion are available to registered users. These are superior training aids for O&M personnel, both experienced hands who might benefit from a refresher as well as newcomers.

Highlights of the compressor roundtable include the value of hydrophobic HEPA filters to engine performance, the need know the nature of blade deposits and before you water-wash to avoid pitting corrosion, and when to/when not to fog.

A highlight of the I&C presentation was what to know before you consider upgrading from a Mark IV to Mark VIe control system. It's a big undertaking, despite what you may have heard to the contrary. Space constraints may be a challenge difficult to overcome.

Support documentation focusing on O&M safety available from the OEM is highlighted in the sidebar.

Two vendor presentations are available on the Power Users website, both concerning generators:

- "Generator cycling concerns," W Howard Moudy, National Electric Coil. Presentation's primary intent is to develop awareness of cycling-related concerns and affected components. It covers speed and load cycling.
- "When a robot won't fit," Jamie Clark, AGT Services Inc. Focus is on generator minor inspection techniques and their limitations.

The third leg of the Frame 6B conference stool, conducted by the OEM on the second day of the meeting consisted of four sessions, each running about 30 minutes. The subjects: Covid experience, condition-based parts management, decarbonization, and compressor and hot-gas-path Q&A.

The highly experienced presenters included the following:

- Patrick McConnell, EHS leader for North America.
- Patrick Bowling, parts life chief engineer.
- Mike Cocca, Alberto Schirmer, and

Safety TILs affecting 6B gas turbines

- TIL-2101, Modification of manual lever hoist for safe rotor removal.
- 2044, Dry flame sensor false flame indication while turbine is offline.
- 2028, Control settings for GE Reuter Stokes flame sensors.
- 2025, GE Reuter Stokes FTD325 dry flame sensors, false flame indication.
- 1986, Braid-lined flexible metal-hose failures.
- 1918, 6B Riverhawk load-coupling hardware and tooling safety concern.
- 1838, Environmentally induced catalytic-bead gas-leak sensor degradation.
- 1793, Arsenic and heavy-metal material handling guidelines.
- 1713, 6B, 6FA, 6FA+E, and 9E false-start drain system recommendations.
- 1709, 6B load-coupling recommendations.
- 1707, Outer-crossfire-tube packing-ring upgrade.
- 1700, Potential gas-leak hazard during offline water washes.
- 1633, Load-coupling pressure during disassembly.
- 1628, E- and B-class gas-turbine shell inspection.
- 1612, Temperature degradation of turbine-compartment light fixtures.
- 1585-R1, Proper use and care of flexible metal hoses.
- 1577, Precautions for air-inlet filter-house ladder hatches.
- 1576-R1, Gas-turbine rotor inspections.
- 1574, 6B standard combustion fuel-nozzle body cracking.
- 1573, Fire-protection-system wiring verification.
- 1566-R2, Hazardous-gas detection system recommendations.
- 1565, Safety precautions to follow while working on VGVs.
- 1557, Temperature-regulation valves containing methylene chloride.
- 1556, Security measures against logic forcing.
- 1554, Signage requirements for enclosures protected by CO_2 fire protection.
- 1537-1, High gas flow at startup—Lratiohy logic sequence.
- 1522-R1, Fire-protection-system upgrades for select gas turbines.
- 1520-1, High hydrogen purge recommendations.
- 1429-R1, Accessory and fuel-gas-module compression-fitting oil leaks.
- 1368-2, Recommended fire-prevention measures for air-inlet filter houses.
- 1275-1R2, Excessive fuel flow at startup.
- 1159-2, Precautions for working in or near the turbine compartment or fuel handling system of an operating gas turbine.

Paul Daiber, each a senior application engineer.

- Kevin Elward, 6B system engineer.
- Mihir Lal, 6B senior combustion system engineer.

The Covid presentation explained why customers would experience far fewer disruptions related to the disease in the future. Reasons include continual refinement of travel best practices, conducting in-person meetings only when necessary, and more rigid sub-crew separation.

The speaker stressed that the company's primary goal is to keep employees and customers safe, relying on GE Health Services to continuously monitor indicators that encourage better work habits. Priority Two is to improve the OEM's ability to execute outages in more timely fashion. Minimizing the number of cross-border deployments and reducing quarantine time by way of judicious resource assignments will help in this regard.

The Covid pause enabled management and staff to rethink how business was being conducted and to improve safety and work processes. For example, FieldCore now mandates that employees not take a call while driving. The use of two 10-hr shifts instead of 12-hr shifts promotes good health by avoiding the need for in-person shift turnover. Also, strict tool control procedures have been implemented with a requirement that all tools be sanitized before their return to the field.

Bowling began his presentation by reviewing the evolution of maintenance practices since the 1930s when reactive maintenance was practiced. From about 1960 to 1985 preventive (scheduled) maintenance was the focus. That transitioned to predictive maintenance, incorporating reliability- and condition-based maintenance, plus prognostics/diagnostics (real-time M&D). Intelligent health management is on the horizon, whereby controls are integrated with condition-based maintenance/prognostics.

Repairs were the next topic. Components may not be repairable, partially repairable, or fully repairable. The goal is to make repairs that extend component life. CCJ

Shock waves *deep-clean* HRSG tube bundles

Twenty years ago, few people probably thought that a tube cleaning technique for HRSGs attached to gas-fired turbines would be adapted from those used for solid-fuel boilers. Yet that's where we are today. Carl Wise, Thompson Industrial Services, and Vince Barreto, PowerPlus Cleaning Systems, showed attendees at the HRSG Forum Supplier Workshop, last fall, that such a system can be elegantly designed and operated even if it's dislodging and removing tons of material stuck on HRSG tubes.

The technology, originally called PowerWave+ when introduced by GE in 2006 as an online system for solid-fuel boilers, was converted from a sound-wave- to a shock-wave-based process, then acquired by PowerPlus in 2014 and adapted to offline cleaning. Simply, the *acoustic* driver attached to a sound horn, was replaced with a *combustion tube* to create a pulsed detonation cleaning device.

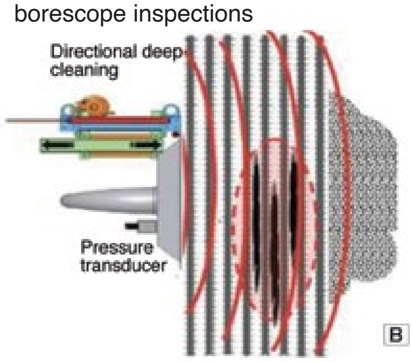
PowerPlus calls it Extraction Pressure Impulse Cleaning (EPIC). While the recording of the Forum presentation gives more details about the technology, what you really want to experience are the videos, available at https://HRSGforum.com/recordings, which show how the device is engineered into a "navigation rig," temporarily installed in the lanes between the tube bundles, and moved remotely from location to location while a technician monitors the cleaning on a 50-in. screen.

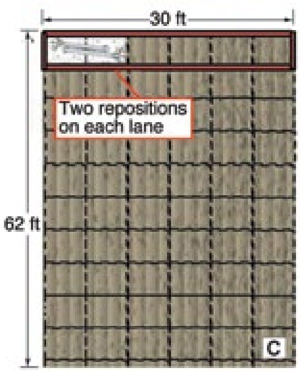
The rig is arranged for the HRSG being cleaned, which can be vertical or horizontal, and can accommodate baffles, which one astute attendee asked about. If sky-climber ports are not available for rig support, they must be added, although Barreto noted he's only encountered one unit that was not so equipped. Another attendee wondered if the blasts would dislodge material on the *ID side* of the tube and the answer was "no"; the shock wave energy does not reflect *through* the tube wall.

Two of the key benefits of this technique over dry-ice blasting and open detonation, say Barreto and Wise, are avoiding scaffolding or sky climbers and providing the capability to deep clean "every square foot of the heat-transfer surface." Tube sections are subjected to the shock waves from the lanes on both the upstream and downstream sides.

Several case studies were presented with dramatic total tonnages of material removed, several inches of differential pressure restored, and 1-2 MW of output recovered. CCJ

Directionally focused, rapidly repeated shock waves penetrate into and around tube bundles to dislodge material on tube and fin surfaces. Rig is moved remotely between the lanes. Results are verified with subsequent borescope inspections





Legacy Turbine Users Group

FRAME 5 Users Group

The GE Frame 5 is likely the most popular gas turbine ever produced for power and industrial applications. The first unit in this model series shipped 65 years ago from the OEM's Schenectady (NY) shops and Frame 5s are still being built today—albeit by manufacturing associates abroad and at ratings about two and a half times those of the 12-MW models installed in the late 1950s and early 1960s.

Although more than 3000 of these machines have been sold over the years, the editors cannot find records of any formal user group meeting conducted since the millennium with the Frame 5 as its focus.

Power Users believes this engine has value as a critical peaking asset and is supporting the launch of the Frame 5 Users Group as part of its Mega Event at the San Antonio Marriott Rivercenter, August 29 to September 1.

2022 conference overview

Monday, August 29. The morning training session is a short course on GE legacy engine details impacting O&M. Presenters/discussion leaders are two highly experienced power/process engineers—John F D Peterson, PE, and Zahi Youwakim.

In the afternoon, the following vendor presentations are scheduled:

- The Frame 5's future as a critical peaking asset, *Allied Power Group*.
- Wet low-emissions technology to comply with New York State's NO_x abatement program for Frame 5 turbines, *Petrotech*.
- Machine alignment, *Cascade Machinery Vibration Solutions*.
- Combustion-system optimization, *Sulzer*.
- Methods to improve operational performance of gas turbines, *Schock Manufacturing*.

Tuesday, August 30. The morning program features one vendor presentation, "Decarbonization: Hydrogen and the current gas-turbine install base" (PSM), and three roundtables (compressor, combustion, and turbine; safety and I&C; and auxiliaries and generator).

Baker Hughes conducts the afternoon program. Technical content includes the following: Frame 5 historical perspective, service engineering (stats, TILs, lessons learned, outage optimization), Houston Service Center and the BH repair network, turbine upgrades, certified renewed equipment, LT-16 brownfield replacement of legacy Frame 5s, hydrogen fuel capabilities, and additive manufacturing.

Wednesday, August 31. The final day of this user-group meeting features three very practical training workshops: generators (Jamie Clark, AGT Services Inc), controls (Abel Rochwarger, GTC Control Solutions), and turbine rotor (Paul Tucker, FIRST). Each runs for an hour and three-quarters. User presentations and roundtable discussions fill the remaining time on topics such as maintenance strategies and equipment aging.

Thursday, September 1. No Frame 5 program is scheduled. Attendees are welcome to attend any of the other user-group sessions.

Steering committee, 2022

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

The importance of Frame 5 inspections

Frame 5s are, in a manner of speaking, "beasts," and many don't run very often. But that doesn't mean they are immune to the problems found in more advanced machines that stop/start regularly and run at higher temperatures.

In fact, sitting idle may not be a good thing at all. Consider the call to CCJ's offices a few years back from a user responsible for a Frame 5 at the end of a sub-transmission line to provide grid support if needed. The unit was located in a remote area subject to very high humidity for several months annually. It was started remotely each month and run for an hour to prove it would operate if called upon.

One day the unit failed to start. The caller said he found the exhaust section had collapsed and wanted to know if the editors could point him to a vendor that could help. The exhaust section had "rusted to death" over the years and could no longer support its own weight.

Enter Mike Hoogsteden, director of field services for Advanced Turbine Support, an industry leader in the conduct of borescope inspections to determine the condition of gas turbines and other assets. He is well known in the user-group community for insightful presentations on fleet-wide inspection results that can help owner/operators avoid emerging issues or at least be better prepared to deal with them (see 7EA Users Group article in CCJ No. 70, p 78).

Hoogsteden is not on the Frame 5 agenda (but he is the opening speaker

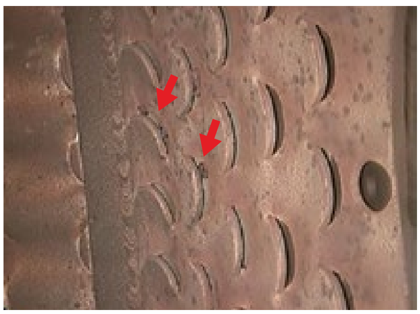
1. The thin ligament at the 10th-stage extraction slot may be weakest point in the Frame 5 compressor (left). It is susceptible to cracking, which can cause major damage if it occurs. Photo at right shows how: The hook portion of the casing simply "peels" away, allowing vanes to work free and go downsream

2. Inlet guide vanes, pressure side shown, were liberated from the tip shroud (arrow)

3. A section of the inner shroud is missing (arrow). Note the impact damage to the trailing edges of the inlet guide vanes (suction side)

4. Two S0 vanes liberated at the 6 o'clock position

5. A ninth-stage rotor blade also liberated from Engine B



6. Debris was found on several combustion caps

7. Impact damage and material loss was found on several first-stage buckets in the turbine section

on the 7EA program Monday afternoon and all San Antonio user registrants can attend), so the editors asked him to share some highlights of what Advanced Turbine Support inspectors were seeing in the Frame 5 fleet.

He began by saying a large majority of Frame 5 operators don't perform semi-annual inspections, as do the large gas turbines running regularly. Depending on the run profile, a full compressor/combustion/turbine borescope inspection every one to two years probably makes best sense for many of these units.

Also recommended, and depending on unit designation, is an eddy-current inspection of all IGVs (fixed and variable) and the stage S0 or S1 stator vanes (first row of vanes). The EC scan would identify any cracks in the vanes.

Another location for a careful inspection is at the ninth-stage hookfit, where component separation can be an issue. Recall that the thin ligament at the 10th-stage extraction slot forms the hook that holds one side of the ninth-stage stator vanes in place. It is susceptible to cracking that could allow one or more vanes to work free and go downstream causing major compressor damage (Fig 1).

If you are unfamiliar with how best to prepare for a Frame 5 borescope/EC inspection, contact your service provider. A couple of things Hoogsteden recommends: (1) For the combustion section inspections, provide access to every other one of the 10 cans via removal of the fuel nozzles; (2) gain access to the second row of turbine blades by availing access into the stack.

Hoogsteden then provided a flavor of what might be found with a borescope by sharing findings from three recent Frame 5 inspections. Engine A was a Model M, B a Model P, and C a Model N.

Engine A. The inlet section was found in relatively good condition, but there was rust and debris on the inlet

8. Engine C was found with dings on 13 R0 rotor blades

9. Stator-vane hook-fit separation in the ninth stage ranged from 32 to 68 mils between the case material and vanes

10. Corrosion and material loss in the exhaust section was significant

floor. Inspector's recommendation was to prep the floor for a two-part epoxy coating capable of withstanding regular water immersion.

The compressor section, accessed through the inlet bellmouth initially and later through the removed upper case, revealed partial liberation of the IGV tip shroud, causing significant downstream damage (Figs 2 and 3). An engineering review was recommended before repairing and restarting the unit.

The combustion section was in good condition; water wash residue was visible on the hardware. Combustion liners were accessed through the fuel nozzles in cans 3 and 7.

The turbine section, accessed via the combustion liners, also was in good condition. The exhaust section was not inspected.

Engine B. Rust and debris was found on the inlet floor of this unit as it was in Engine A. Inspectors accessed the compressor section through the inlet bellmouth, finding two stage S0 stator vanes had liberated at the 6 o'clock position (Fig 4) along with one R9 rotor blade (Fig 5). Result: Extensive damage throughout the compressor.

Combustion liners were accessed through the fuel nozzles, the turbine section via the liners and exhaust section. The combustion section was found in good condition except for some debris found in the combustion-cap air slots (Fig 6). Impact damage and material loss was suffered by a majority of the first-stage turbine buckets (Fig 7). Condition of the exhaust section was "good."

Engine C. Access (1) to the compressor section was through the inlet bellmouth and the ninth-stage air extraction, (2) to the combustion liners via fuel nozzles and crossfire tubes, and (3) to the turbine section by way of the combustion liners and exhaust section.

Impact damage was found at the leading edges of 13 R0 rotor blades (Fig 8), the debris causing minor damage throughout the compressor. Stator-vane hook-fit separation was evident in stage 9, where the gap between the case material and stator vanes ranged from 32 to 68 mils (Fig 9).

The combustion and turbine sections were in good condition; however, there was inner-barrel corrosion with material loss and cracking in the exhaust-section diffuser vanes (Fig 10). CCJ

COMBINED CYCLE Journal

CCJ No. 71 (2022)

Index to advertisers

Coming of age with the electric power industry

Editor's note: It's unusual for someone to contribute productively to a given profession for seven decades and still be a go-to person when challenging questions arise. After all, that someone must be nearing the century mark in age, when physical and mental capabilities likely are in decline.

Generator expert Clyde V Maughan, who turned 96 in July, faced the challenges of age realistically and four years ago closed his consulting business, which he had been dialing back for years. However, The Clyde, as he is known to close associates, still takes calls from the CCJ editors to help us avoid making inaccurate statements—to the degree possible.

The electrical (and mechanical) engineer remains sharp as a tack mentally, despite two strokes over the years. He's certainly not as fast afoot as he was a decade ago, but still gets outside the assisted living facility where he now resides to tend a community raspberry patch and flower bed.

So, you ask, "Who is this Clyde guy anyway, and why does he warrant a biographical sketch in CCJ?" The editors believe Clyde, our most prolific contributor over the last dozen years or so, is a unique individual whose life experiences can offer valuable lessons for others.

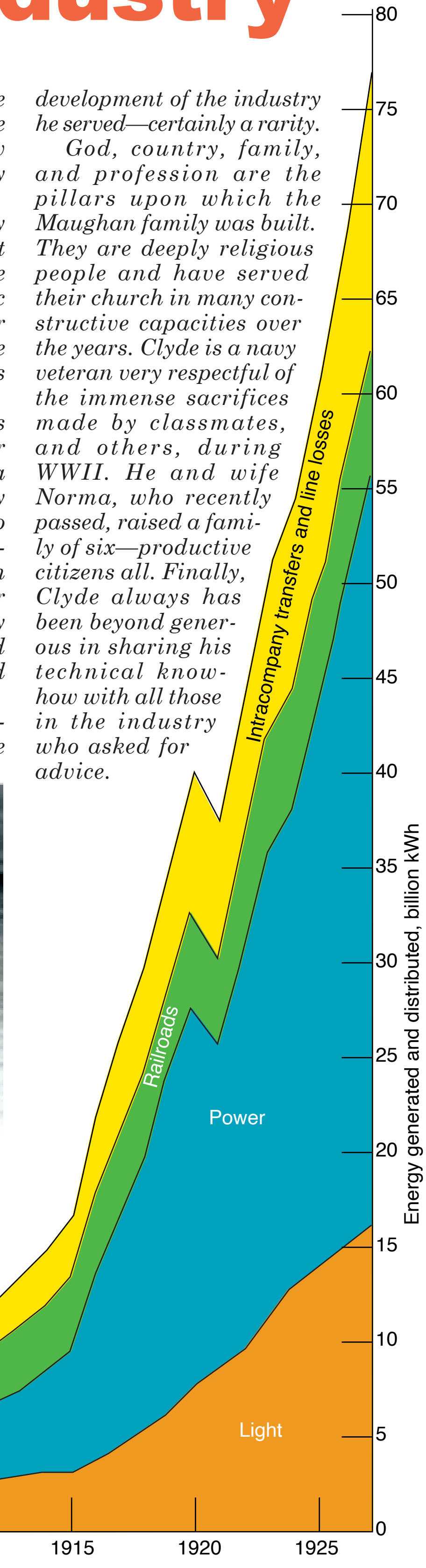
He was born in 1926, several years before the fledgling electric-power industry turned 50 and more than a decade before the Maughan family farm had an electrical connection to central-station power. Clyde graduated from the University of Idaho with a degree in electrical engineering after serving in the US Navy, was hired by GE in 1950, and proceeded to spend his entire professional career tethered to generators.

Thus, Clyde's life and career progression have been in lock-step with the development of the industry he served—certainly a rarity.

God, country, family, and profession are the pillars upon which the Maughan family was built. They are deeply religious people and have served their church in many constructive capacities over the years. Clyde is a navy veteran very respectful of the immense sacrifices made by classmates, and others, during WWII. He and wife Norma, who recently passed, raised a family of six—productive citizens all. Finally, Clyde always has been beyond generous in sharing his technical know-how with all those in the industry who asked for advice.

Clyde V Maughan is a member of the Greatest Generation—those who experienced the depression, survived WWII, and contributed to the country's economic development for the benefit of all

Before electricity everyone in farm families labored, generally from the time they could walk. Here's Clyde, the last of nine children, age four, feeding the animals



1. The dramatic growth in electric production during the industry's first two generations (refer to Fig 2) tracks an e^x success curve. Data are provided until 1926, the year Clyde Maughan was born

	1882	1907	1932	1957	1982	2007	2022	2032
Electricity sales, billion kWh	–	5.9	77.5	561	2125	3765	4116	NA
Installed capacity, GW	–	NA	34.1	129.1	649.5	995	1144	NA
Residential customers, million	–	NA	19.8	46.8	85	125	137	NA
Capital expenditures, million $*	–	NA	260	4050	30,270	70,000	140,000	NA

*For investor-owned utilities only, primarily data from Electrical World magazine

2. The electric-power industry in the US began, most would agree, on Sept 4, 1882 with the opening of the Edison Electric Illuminating Co of New York's generating plant at Pearl Street in lower Manhattan. Electricity for lighting was its primary purpose, as the company's name implies.

The industry's development is displayed in 25-year increments, typically considered a generation in human terms. Some highlights of each generation are presented below to offer perspective.

Gen 1, 1882-1907: First true central station, polyphase electric system, induction motor, first hydroelectric plant, first steam-turbine-powered generating station, first US diesel installation, General Electric Co incorporated.

Gen 2, 1907-1932: ASME Boiler Code adopted, Panama Canal opens as the world's largest electrical installation, the Great Depression begins, tungsten filament lamp introduced, WWI, USN launches first electrically propelled ship, asphalt/mica insulation systems developed for generators, appliance inventions included washing machine, vacuum cleaner, and household refrigerator, Clyde Maughan born into a world with limited access to electric power, the industry's technical giants who created the electric-power industry fade away (see accompanying sidebar).

Gen 3, 1932-1957: First commercial nuclear generating plant (Shippingport), first US generating plant powered by a gas turbine (Belle Isle), first mass-produced digital computer (Univac I), fluorescent lighting introduced, WWII, Clyde Maughan graduates from Univ of Idaho (BSEE) and joins GE, first supercritical steam unit (Philo), GE Frame 5 gas turbine introduced, gas-turbine powered trains begin service (Union Pacific).

Gen 4, 1957-1982: DOE formed, Arab oil embargos, Clean Air Act becomes law, EPA formed, Clean Water Act, first GE Frame 7 (model A) goes commercial (West Babylon), first GE Frame 6 (Glendive), first Westinghouse 501D gas turbine enters service, first GE electronic GT control system—Speedtronic™ Mark I—introduced, Three Mile Island accident, Public Utility Regulatory Policies Act opens the generation market to non-utility entities, LM2500 and LM5000 aeroderivative engines introduced by GE for land and marine service, improved generator insulation systems (polyester first, then epoxy) gain acceptance.

Gen 5, 1982-2007: Westinghouse and Mitsubishi begin collaboration on development of the 501F gas turbine, National Energy Policy Act allows access to electric-utility transmission lines, long-term service agreements (LTSAs) introduced, gas-turbine bubble of 1999-2004 adds 200,000 MW to the grid, Enron goes bankrupt, Western Turbine Users (WTUI) incorporates to serve owner/operators of GE aeroderivative gas turbines, LM6000 and LMS100 aero engines introduced, 18/18 (chromium/manganese) steel retaining rings recommended to replace 18/5 rings, Clyde Maughan retires from GE after more than 35 years of service and launches Maughan Generator Consultants.

Gen 6, 2007-2022 (2032): Carbon capture and sequestration added to the industry's lexicon, Fukushima accident, generation of electricity produced from wind and solar sources ramps up at a pace reminiscent of electric growth during Generations 1 and 2 as described in Fig 1, Clyde Maughan retires from consulting, WTUI and the 7F Users Group expand rapidly to become the largest organizations worldwide supporting owner/operators of GE aeros and 7F frame engines, respectively.

Clyde V Maughan was delivered in the Lava Hot Springs (Idaho) hospital July 5, 1926, unusual in that day, his eight older siblings having been born at home. The inventors, engineers, and businessmen who pioneered electric-power development got started long before Clyde came along and electric use was expanding rapidly at the time of his birth (Fig 1)—during what CCJ calls the industry's second generation. In this article, the editors chart the industry's growth in 25-year increments, typically considered a generation in human terms (Fig 2).

Gen 1 and Gen 2 (1882-1932) were defined by the tremendous progress made by gifted scientists in the discovery and understanding of the fundamental principles of electric power generation, and by outstanding engineers in the design and manufacture of generators and their prime movers capable of producing large quantities of bulk electric power (see Leaders sidebar).

Electricity use during the industry's first 50 years was promoted primarily in urban areas. Life on the farm was much different. In fact, rural living in that era would be difficult for most folks under about 65 today to fathom.

Clyde reflected: Farming through the ages changed very slowly. Little mechanization occurred in farming the fields until the development of the steel plow in the mid-19th century (the Maughans migrated to the US from England in the 1840s), and the development of quality lightweight gasoline engines in the early 20th century.

Clyde recalls that the power supply for the farm during his childhood was a Delco 24-V system, probably the only one in the community. It consisted of a small gas engine and dc generator, and a bank of wet-cell batteries. He remembers this system as marginal in every respect: "It could power only three or four small lightbulbs when the engine ran, but the batteries soon 'died' when the engine stopped."

Continuing, "In the evening my father knew just how much gasoline to put in the tank to drive the engine a selected amount of time with two bulbs burning in the house 100 yards away.

"But it was dangerous. I remember my father talking about the gas storage tank being on fire one evening while he was preparing the generator for operation. He put the lid back on the tank and the fire went out. It must have been winter. Otherwise, the shed, barn, cows, and hay all would have been lost. . .and maybe my father."

The Rural Electrification Act of 1936 was the game-changer. Within two years, the Maughan farm was supplied with electricity from the grid, with the following among the benefits:

- Milking machine. Clyde remembers that well, recalling, "You have no idea how cold your seven-year-old hands could get milking in a drafty barn on a windy winter morning."
- More eggs. Lights in the henhouse kept the laying hens awake 12 hours a day to increase egg production.
- Electric stove. He remembers how happy his mother was when an electric stove was installed; however, it never did function as advertised and required patience to use it.
- Water pump. Hand pumping of

Leaders of the electrical revolution

Pioneers in the development of equipment and systems to produce and distribute electricity for lighting and myriad other uses included gifted inventors, engineers, and businessmen. Most were deeply involved in technology development prior to the electric-power industry's first generation, as defined by Fig 1 in the main text—including the inventions of Dr Charles Francis Brush in dynamo-powered arc lighting and of Thomas Alva Edison in incandescent lighting.

The industry giants selected by the editors for this compendium all had made their significant contributions to electrification before the end of the industry's second generation. The thousands of engineers who followed them took their inventions to the next level—true commercialism—refining ideas and machines to increase output, reliability, efficiency, safety, etc.

Case Western Reserve University

A. Brain trust. Elihu Thomson, Frank J Sprague, Brush, Elmer A Sperry, and Edwin W Rice Jr (l to r), PhD's all, celebrate the 50th anniversary of a pioneer Brush dynamo in April 1928

Brush, Dr Charles Francis 1849-1929

This gifted Ohio farm boy was said to have been building batteries, static electricity machines, and electromagnets before entering high school. Brush is credited with the development of a superior dynamo and arc-lighting system, one widely adopted for street lighting and commercial installations (Fig A). His Brush Electric Co was purchased in 1889 by competitor Thomson-Houston Electric Co, which merged with the Edison General Electric Co in 1892 to form GE.

Coffin, Charles Albert 1844-1926

Coffin's business acumen, coupled with the engineering talent of Elihu Thomson and Edwin J Houston, enabled the trio to launch the Thomson-Houston Electric Co as a competitor to Edison's, with which later merged to form GE. Coffin was General Electric Co's first president.

Edison, Thomas Alva 1847-1931

A prolific inventor in many fields, he laid the foundation for the electric-utility industry with his Pearl Street generating station and its associated electric system (Fig B).

Insull, Samuel 1859-1938

Edison hired Insull, shortly before Pearl Street began commercial operation, to manage his personal and business affairs. Later he became an executive of many Edison companies. After Edison's merger with Thomson-Houston Electric Co, Insull left to become president of Chicago Edison Co. His talents were immediately apparent in the progressive expansion of that system, in development of rational rate structures, in advanced methods of marketing both electricity and securities, and in public policy.

Insull was a pioneer in bringing efficient central-station power to small suburban and rural communities, and built a large integrated electric system in the Midwest. In the witch-hunting atmosphere that followed the great depression, he was accused of mail fraud and other illegalities, but was acquitted.

Rice, Dr Edwin Wilbur 1862-1935

Starting as an assistant to Elihu Thomson, Rice became plant superintendent of the Thomson-Houston Electric Co, and later technical director of General Electric Co after those companies merged. He became president of GE in 1913, following Coffin's retirement. Rice, who was awarded more than 100 patents in his career, was said to have had a special talent for industrial organization and management,

water for the home and barn was eliminated, and indoor plumbing replaced the outhouse.

- Homework could be done with decent light, which was safer than candles and conducive to higher grades.

Clyde was on a roll in remembering the inconveniences of yesterday without electric power. Although the family farm was about 1200 acres, he says, only about 20% of that land was good for planting the crops required to sustain the large family.

Before hot water was available from the tap, bathing of children was done in a 3-ft-diam tub in the kitchen with only 6 in. of water. First one to bathe obviously had the cleanest water.

Home heat was supplied by a wood-burning stove in the kitchen and a wood-fired radiant heater in the living room. That was it.

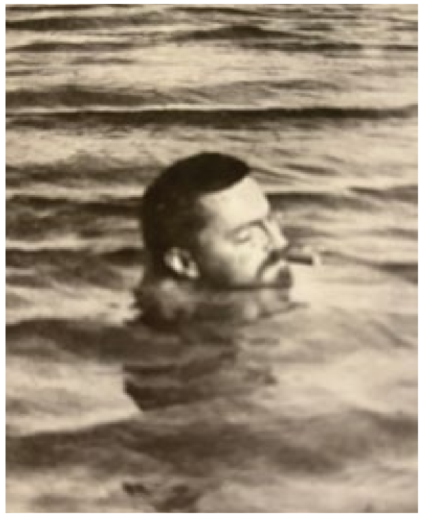
The foregoing slice of history may help one better understand why it's difficult to get Clyde or others of his generation to complain much about anything and why he dedicated his life's work to improving both the reliability/availability of electric generation equipment and the well-being of others.

Depression and WWII

Life was put on hold during the depression and war. Both impacted electric-power development—the former curtailing it, the latter expanding it (Figs 3 and 4).

Farm work was never-ending and the depression brought lean times. The family struggled with debt and some mediocre crops during those years, like most others, yet Clyde says he never felt "poor." The Maughans had a house and were warm, had adequate clothing, and good food. Many others were not so fortunate. Plus, all the children learned how to play a musical instrument. Clyde's specialty was the French horn.

B. **Thomas Alva Edison** (left) and Dr Charles Proteus Steinmetz examine porcelain insulators during Edison's last visit to Steinmetz at GE's Schenectady works. The year was 1922



General Electric Co

C. **Steinmetz rarely** was seen without his signature cigar. Here while relaxing one can only assume his incredible mind was running through equations of importance

and in directing the inventive skills of others.

Sprague, Dr Frank Julian 1857-1934
A pioneer in the design of electric motors, Sprague invented the constant-speed electric motor (according to Who's Who in 1928) and made important contributions to the development of electric railways and elevators. A graduate of the United States Naval Academy, he founded the Sprague Electric Railway and Motor Co in 1889.

Steinmetz, Dr Charles Proteus 1865-1923
He is recognized for his contributions to three major fields of ac systems theory: hysteresis, steady-state analysis, and transients (Fig C). Steinmetz derived the law of hysteresis loss, devised new and simplified mathematics for analysis of ac circuits, and was awarded over 200 patents. The Wizard of Schenectady worked for GE from its beginning until his death.

Sperry, Dr Elmer Ambrose 1860-1930
The Sperry Electric Machinery Mining Co was founded in 1888 to deliver power, and machinery designed and built by the company, into deep coal mines to increase fuel production. Two years later, the electrical engineer and inventor, launched the Sperry Electric Railway Co. Lessons learned from that business helped him equip cities in the Pennsylvania/Ohio region with electric trolleys capable of navigating hilly terrain. He also designed an electric automobile which led to patenting ideas later used in the development of lead/acid batteries. Perhaps Sperry is best known as the father of modern navigation technology, starting the Sperry Gyroscope Co in 1910 to pursue that line of business.

Tesla, Nikola 1856-1943
Inventor of the polyphase induction motor and the ac system within which it operates, a pioneer in high-frequency research.

Thomson, Elihu 1853-1936
Teacher, scientist, inventor, engineering statesman, he built the Thomson-Houston Electric Co and contributed to successor GE.

Westinghouse, George 1846-1914
Inventor of the air brake so important to railway safety, pioneer in natural-gas distribution, early proponent of ac electrical systems (Edison favored dc systems), and electrical-industry entrepreneur of genius and vision.

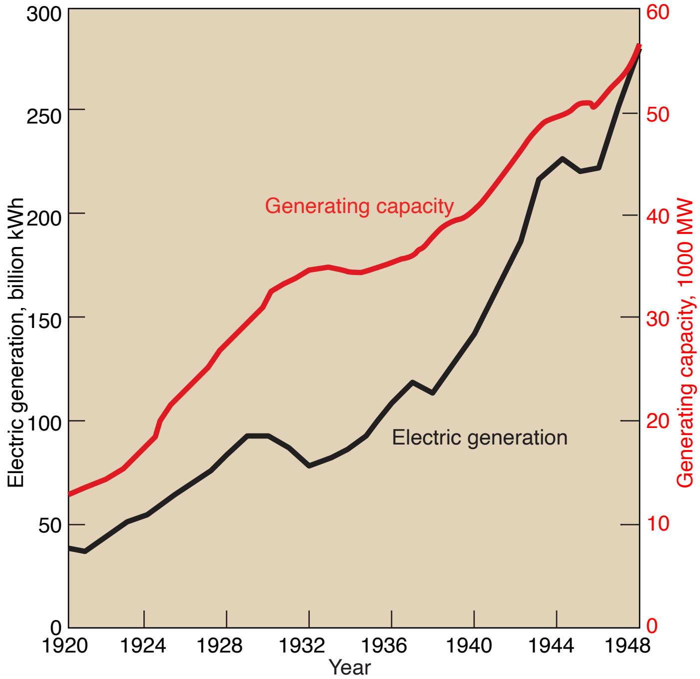
The first tractor, bought in 1929, had iron wheels and was "pretty useless" on hills. A Farmall F30, purchased at the end of the depression, "could do real work." Still, plowing, seeding, and cultivating the crops, and care of the pigs, cows, chickens, sheep, and work horses, was a full-time effort for everyone in the family. Clyde remembers that his dad always was planning to give the kids Saturday afternoons off, but important work almost always over-rode his good intentions.

The only "real" family trip he could recall was a visit to Yellowstone at about age nine.

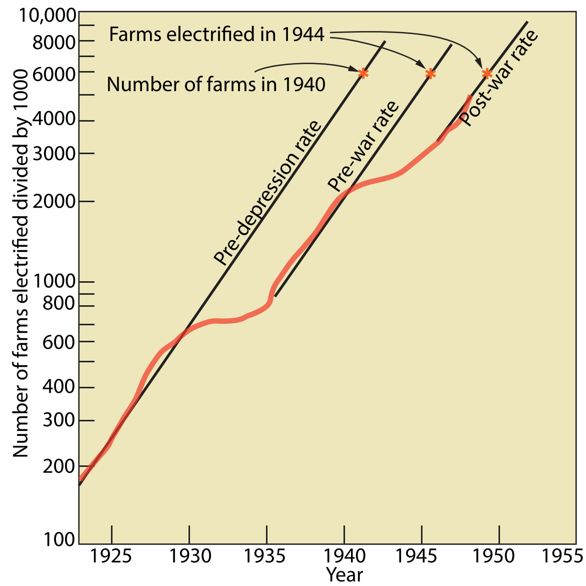
Portfolio growth was not something folks of that time were concerned with—or even heard of. Growth, financial or otherwise, was a challenge. Clyde's father bought the farm in 1917 figuring he could pay for it in three years. He might have, had there been three consecutive "good" years. But that was not to be, given the short growing season for a farm at 5200 ft elevation. It was still in debt when sold in about 1950.

Shortly after graduating high school and five days after turning 18, Clyde enlisted in the US Navy. It was a month after D-Day. He did well on the aptitude tests during boot camp and opted for the aviation electrician's school in Florida, moving to a naval gunnery school in Jacksonville after completing that course of study. Clyde says he must have been a good turret repairman given his promotion to Aviation Electrician's Mate 2/c in two years. He was discharged from the USN in July 1946.

Returning home, Clyde learned that of the nearly three-dozen Lava boys who had turned 18 from 1938 to 1944, at least one-third were killed in the war—a staggering price for a small rural town to pay. Never having been exposed to enemy fire, that reality tortured him for years. To honor



3. Growth in both electric generation and installed capacity suffered a setback during the depression years before rebounding dramatically during the WWII years



4. Rural electrification, not much more than a goal when Clyde Maughan was born, accelerated dramatically during his early years. Progress was stunted by the depression and rebounded during the war that followed. The Maughan family farm was connected to the grid in 1937

those who gave their lives to preserve our freedom, he helped organize a committee to design, build, and fund a suitable monument. It was dedicated in September 2000 (see Monument sidebar).

Off to college, then GE

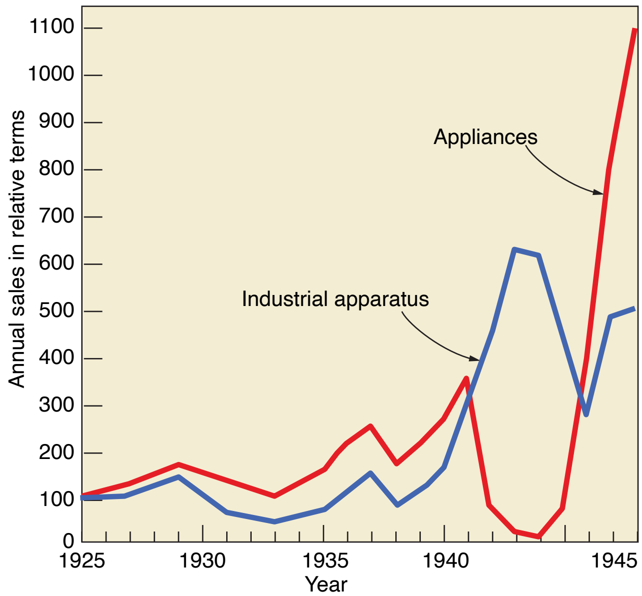
GI Bill in hand, Clyde enrolled in the engineering program at a small college in nearby Logan, transferring to the University of Idaho after two years. He graduated with a Bachelor of Science degree in Electrical Engineering in June 1950 and accepted GE's offer of employment at its world-class manufacturing facility in Schenectady, NY.

It was a good choice given the very positive impact electric power was having on the economy (Fig 5). Plus, sales of electricity had grown five-fold from when Clyde was born to when he joined GE, and gave no indication of slowing down.

Clyde squeezed wife Norma (they married in August 1947), son Bruce, and all their belonging into the couple's 1949 Plymouth sedan (bought with money Norma saved from her job at a bank), and headed east. The trip took five days on mostly poor roads.

Moving east was not an easy decision. Bannock County, where the Maughans lived, was the third most populous county in Idaho and had only about 41,000 residents, according to the 1950 census—slightly more than the number of people on GE's Schenectady payroll.

Clyde recalled that GE tended to hire farm boys because of their inclination for hard work and not making "waves." His talents and instincts fit the work well and he enjoyed engineering—even though four years earlier he hadn't the faintest idea what an engineer did and had never been in a factory of any sort.



5. Annual sales of electric appliances increased more than 11-fold from the time Clyde Maughan was born until he graduated from the University of Idaho with a degree in electrical engineering and began working for GE. According to NEMA, annual sales of electrical apparatus jumped five-fold during the same period

During Gen 3 (1932-1957), power generation was a "glamor" business. Large companies like General Electric were able to hire the best of the best engineers. Clyde recalls how fortunate he was to be able to work with, *and listen to,* these experts. Among them, he says, were a few "absolute geniuses"—men like:

- Dean Harrington of GE, a brilliant expert in electromagnetic design.
- Dave Willyoung of GE, an amazing man who could create an elegant and simple design to solve extremely complex problems.
- Neil Kilpatrick of Westinghouse, who thoroughly understood the huge metallurgical needs of the highly stressed rotating components and was able to help develop metals to meet those needs.

Of course, he continued, the electric utilities also had some excellent engineers. Among them:

- Jim Timperley of AEP, who thoroughly understood generator maintenance and led in the application of the powerful electromagnetic interference (EMI) testing of these machines.

Monument celebrates the lives of those killed in WWII

Almost all of the men between the ages of 18 and 35 who resided in Clyde Maughan's home town of Lava Hot Springs (LHS) served in the armed forces during World War II—11, possibly more, were killed in action. Their sacrifices were saluted at the dedication of a monument in their honor, Sept 30, 2000.

The idea for a monument resulted from conversations among graduates of LHS at a reunion in July 2000. At that time, considerable media attention was directed at locating a long-overdue national WWII memorial on the mall in Washington (DC). Clyde and his schoolmates believed recognition at the local level especially appropriate.

In her opening remarks at the dedication, the president of the LHS city council, Irene Bergendorf, credited Clyde with conceiving and designing the remembrance. The ad hoc committee formed to move the project to completion before Veterans Day was supported financially by anonymous contributions from 57 donors.

The left-hand stone at the top of the monument (photo) reads, "Dedicated to the sacred memory of these young men from Lava Hot Springs who gave their lives for their country in World War II, 1941-1945." The right-hand stone identifies those killed.

Engraved in the large stone at the bottom of the monument is the following dedication: "During World War II, the small Idaho village of Lava Hot Springs suffered exceptionally high loss of its young men. This monument is dedicated to these valiant young men. But it is also dedicated to their families and to their friends, who shared the sorrow of their ultimate sacrifice."

- John Demcko of APS, another engineer with deep knowledge of generator maintenance, plus deep expertise in complex excitation systems.

"From these men, and others," Clyde told the editors, "I was fortunate to accumulate massive amounts of knowledge on generator design, operation, and maintenance, which I have tried to pass on to others."

Clyde's first permanent job with GE, following the obligatory first year of three-month rotating assignments, was in large turbine/generators (more than 50,000 hp), with a focus on generator engineering. During that assignment, he wrote the first version of what became a common generator evaluation test. In the early 2000s that document (with minor revision) was still in use by GE.

Although the young couple's goal was to return to near where their families resided after two or three years, Clyde accepted a position in GE's field service engineering group in San Francisco—at that time (end of 1953), at least, a location preferable to Schenectady.

Field-service assignments were varied, as you might imagine, including work on both large stationary turbine/generators and shipboard turbines and electrical systems. The work was challenging and varied, and well-suited to Clyde's career goals in equipment maintenance and repair, but it involved much travel and time away from home.

After four years in San Francisco, it was back to Schenectady in generator application engineering. Three years later he was assigned to turbine/generator manufacturing, becoming the first generator engineer to work in that group. There Clyde spent four years training field-service personnel and helping to improve manufacturing procedures.

It was at this time that he learned how difficult it can be to bring about change in a large corporation. Case in point: A gremlin caused an insulation defect that was not being repaired correctly because lab studies had come up with a wrong answer. Clyde spent "a couple of frustrating years off and on trying with limited success to explain a correct answer to those responsible for repairs."

The problem was still around a few years ago, he says, adding facetiously that he considers himself the most knowledgeable person in the world on this particular problem. This caused him to recall the following aphorism: "Know more and more about less and less until you know everything there is to know about nothing."

Part of his manufacturing assignment was to train GE service personnel to replace stator windings in generators without the use of factory winders to guide them. He wrote detailed instructions, trained the crews and their supervisors, and rewound more than three dozen large generators without incident, in the process saving the company millions of dollars.

Next stop was back to engineering for eight years to work on the development of high-voltage insulation systems. The following 12 years were spent in product service, before retiring in 1986.

During Clyde's 36 years with GE, electricity sales in the US increased more than eight-fold. In sum, he had 11 jobs in engineering, manufacturing, and field service. Plus, he earned a Master's Degree in Mechanical Engineering. The knowledge and experience gained proved invaluable to the consulting business he would soon start.

Consulting?

While working for GE, Clyde had never considered consulting after retirement, and he never had heard of anyone retiring and becoming a consultant.

His plan was to take care of the farm he and Norma had purchased about 25 miles from their home and "fix toasters for little old ladies."

That idea didn't last long. About two months later he received a call from a user having problems with a small steam turbine. A former GE colleague had suggested that he call Clyde to get to the root cause of the failure. The rewards of that engagement, both professional and financial, encouraged him to pursue a second career in consulting. He wound up working from half to three-quarters of his time for the next couple of decades for Maughan Generator Consultants (MGC).

Every turbine/generator engineer understands "baseload," and for Clyde's blossoming business that was a retainer contract from GE for about half his time. He expected six months of work from the OEM, but that turned into six years. The balance of his available time was spent on utility consulting assignments.

For the OEM, his first assignment was to train and equip field engineers having generator responsibilities. He began this program with 24 untrained service personnel and built a team of 72 "pretty-well trained" engineers. In the process he also rewrote all of GE's rewind instructions—about 400 pages of documentation.

During his post-retirement time with the OEM, Clyde was involved in the correction of numerous significant engineering and manufacturing problems. He considers this period in his work career "exceptional, enjoyable, and rewarding."

Looking back, Clyde remembers doing well over 300 non-GE consulting jobs—some routine, others unique and quite interesting—during his second career. These gigs lasted from a few days to about two years and involved work on all types/sizes of old and new generators, from all manufacturers in the western world and Asia, at hydro, fossil-fired, and nuclear stations.

During his consulting career, Clyde resisted involvement in legal disputes, which he believes pretty much a waste of an engineering mind. Two caveats for this work: MGC would focus on finding the facts but not on "winning the case." Legal work was billed at a 20% premium over engineering hours.

Regarding bias, he had this to say: "I always tried to be unbiased in my work. I mostly worked for utility customers, and I told them that I would not use what I learned while working with manufacturers against those vendors. After all, I had worked 36 years for a manufacturer, and that's where my allegiance lies. That never seemed to bother anyone."

Watching the game clock as the 1990s drew to close, Clyde added another goal to his career plan: Help train the next generation of generator repair personnel. The foundation of this effort is his 240-page book on generator maintenance, aptly entitled, "Maintenance of Turbine-Driven Generators." The editors are not aware of a comparable handbook written by someone with Clyde's depth of experience and knowledge. You can access this valuable reference work at ccj-online.com or in the Resource Center for the International Generator Technical Community (GeneratorTechnicalForum.org).

He knew relatively few people would curl up with his handbook to learn what they needed to know to improve the performance of their generators. So, he developed an in-person seminar incorporating about 1500 slides for clients in North America, Asia, Middle East, and South Africa. The added value of having Clyde onsite was the Q&A, which typically took half or more of the seminar hours. He conducted about three dozen of these seminars over the years, reaching more than a thousand participants.

What about the owner/operators not able to afford a custom seminar or want to read the handbook? Clyde partnered with CCJ's General Manager Scott Schwieger to record a series of seven webinars, which, like the handbook, are available at ccj-online.com or in the Resource Center for the International Generator Technical Community (GeneratorTechnicalForum.org). Here's the lineup for "Generator Monitoring, Inspection, and Maintenance":

- Impact of generator design on reliability.
- Problems relating to operation.
- Failure modes and root causes.
- Monitoring capability and limitations.
- Inspection basic principles.
- Test options and risks.
- Maintenance basic approaches.

Technical papers, are, of course, another way to reach those wanting to learn. Clyde, an IEEE Fellow, has presented at nearly three-dozen generator maintenance conferences during his years as a consultant. Many of those have been repurposed as articles in CCJ. You can search for these on the CCJ website via its keyword search function or access all of his technical papers in the Clyde Maughan section of the IGTC Resource Center at GeneratorTechnicalForum.org.

The large number of gas-turbine user groups and no generator user group puzzled Clyde, so with help from NV Energy, CCJ, OEMs, and several consultant friends, he launched the Generator Users Group in 2015, now incorporated in the Power Users portfolio. Learn more at powerusers.org.

His latest effort to facilitate the sharing of information on generators at no cost to owner/operators was to promote the value of remote technical support during generator inspections and maintenance. It's not a panacea, but can conserve personnel resources and improve balance sheets. To illustrate: Clyde figurers he made about 450 onsite visits in his consulting career and that half of those could have been done well offsite with present technology.

Continuing, he says, with still better audio visual and communications technology, perhaps three-quarters, or more, of these jobs could have been done well remotely. There are many variables in this "equation," but certainly in the future many onsite visits can and will be replaced with remote assistance. Finally, the outcome of the onsite-to-offsite transition will depend a great deal on participation by all affected parties. Dig deeper by reading the Guest Commentary in CCJ No. 64 (2020), p 3.

Clyde's retirement in Gen 6 came as renewables were gaining favor. Interestingly, generators connected to the latest wind turbines have about the same output as the most advanced steam turbines did a century ago; PV panels, of course do not rotate. Renewables generation at the end of 2021 was more than 14 times that at the beginning of Gen 6 in 2007—growth rates in kilowatt-hour sales are reminiscent of those at the beginning of the electric power industry. CCJ