CPV St. Charles Energy Center

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INDEPENDENT VOICE OF THE GAS-TURBINE-BASED GENERATION SECTOR

SUMMER USER GROUP CALENDAR

D5-D5A Users Group
June 3-5

26th Annual Conference and Exhibition, The Yarrow (DoubleTree), Park City, Utah. Details/registration at https://www.501d5-d5ausers.org. Contact: Gabe Fleck, chairman@501d5-d5ausers.org.

Legacy Turbine Users Group
June 16-19

Third Annual Conference and Vendor Fair, Hilton Minneapolis, Minneapolis, Minn. The Frame 5, 6B, and 7EA Users Groups comprise LTUG and meet independently. Details/registration at www.powerusers.org. Contact: SV Events, planning.team@sv-events.net.

AOG (Alstom Owners Group) Users Conference
July 14-17

Eighth Annual Meeting, Sheraton Niagara Falls, Niagara Falls, NY. Details/registration at www.aogusers.com. Contact: Ashley Potts, ashley@aogusers.com.

HRSG Forum
July 21-25

2025 Conference and Vendor Fair, The Woodlands Waterway Marriott Hotel, The Woodlands, Tex. Details/registration at www.powerusers.org. Contact: SV Events, planning.team@sv-events.net.

ACC Users Group
July 29-31

2025 Conference, Lake Granbury Conference Center, Granbury, Tex. Details/registration at acc-usersgroup.org. Contact: SV Events, planning.team@sv-events.net.

HA Users Group
August 4-7

Eighth Annual Meeting, Hyatt Regency, Greenville, SC. Details/registration at www.powerusers.org. Contact: SV Events, planning.team@sv-events.net.

Power Users Annual Conference: Combined Cycle Users Group, Steam Turbine Users Group, Generator Users Group, and Power Plant Controls Users Group, and the Low Carbon Peer Group
August 25-28

2025 Conference and Vendor Fair, Marriott Marquis, Washington DC. Details/registration at www.powerusers.org. Contact: SV Events, planning.team@sv-events.net.

Combustion Turbine Operations Technical Forum (CTOTF)
September 21 – 25

50th Anniversary Conference and Vendor Fair, La Quinta Resort & Club, Palm Springs, Ca. Details/registration at www.ctotf.org. Contact: Christine Doyle, chrisdoyle@ctotf.org.

HRSG and Boiler Forum: América Latina
September 23-25

First Annual Conference, Blue Tree Premium Morumbi, São Paulo, Brasil. Details/registration at www.hrsgamericalatina.com. Contact: Bianca Carreira, bianca@hrsgamericalatina.com.

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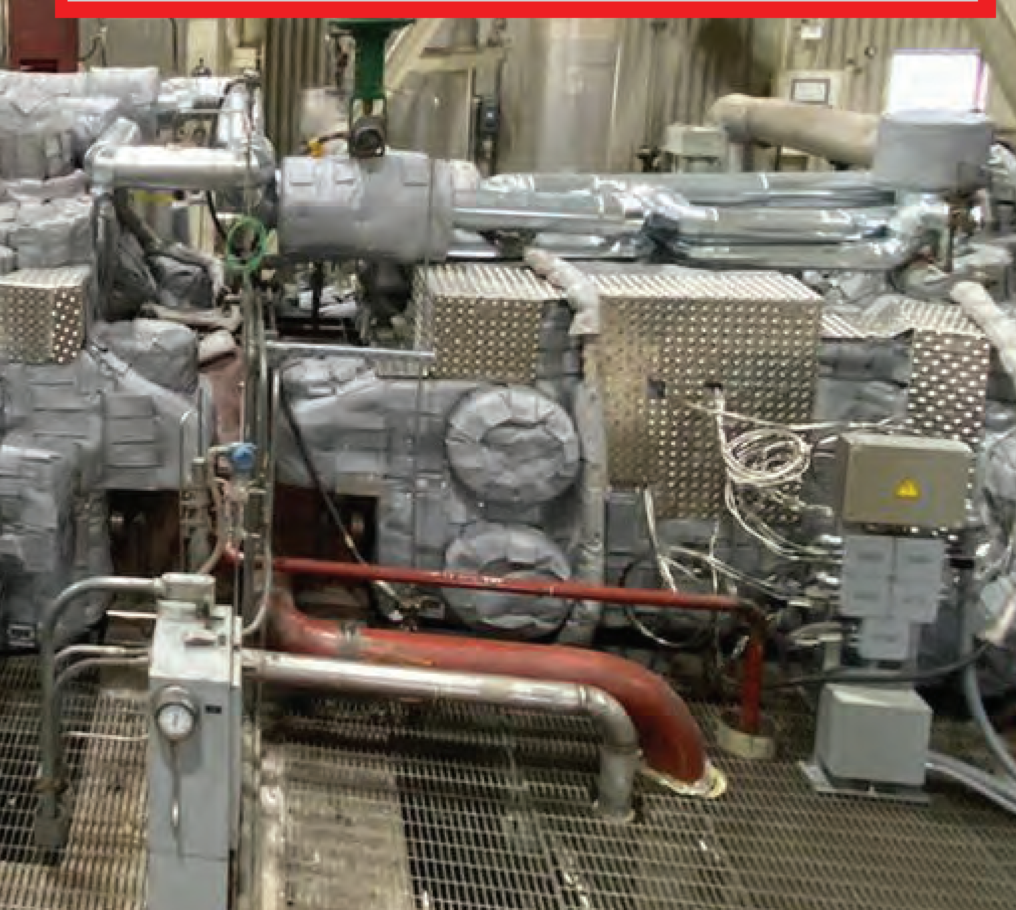

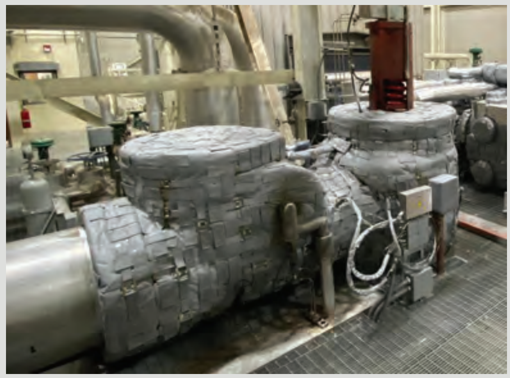

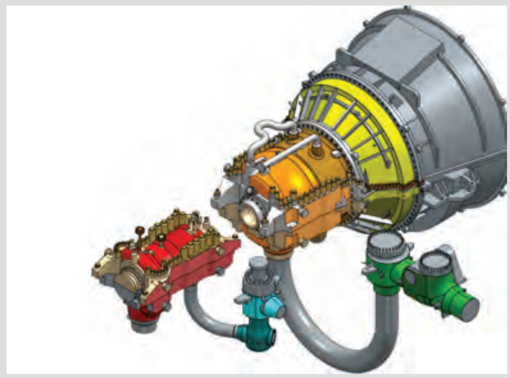

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GROUP

7F Users Group

2025 Annual Conference and Exhibition May 19-23 • Birmingham, AL

35 years serving 7F owner/operators

The 2025 7F Users Group Annual Conference brings together the largest gathering of 7F gas turbine owner/operators in the world. This year's event promises a comprehensive and collaborative forum focused on technical knowledge-sharing, hands-on solutions, and the evolving role of the 7F fleet in the energy landscape. Scan the QR code to access the latest official conference details at the Power Users website (www.powerusers.org). Here's a look at what attendees can expect throughout the week:

Monday – Technical kickoff and vendor networking

The conference opens with a strong user-focused agenda. The day kicks off with a general session featuring welcome remarks from the 2025 Steering Committee Chair, followed by a powerful user presentation recounting a remarkable generator fan blade liberation and outage execution over the Christmas break. A "Generator 101" overview from TECO Energy rounds out the morning.

A series of Vendor Solution Sessions follow, with industry experts discussing key topics like compressor vane looseness, HGP repair developments, varnish contamination, instrument calibration, flange leak detection, and more. These sessions provide a deep dive into evolving technologies and practical improvements. The day concludes with the first of two lively Vendor Fairs, offering users a chance to connect one-on-one with solution providers.

Tuesday – Upgrades, extensions, and user insights

Tuesday begins with remarks from the steering committee followed by a dedicated session from PSM, which will feature special sessions on rotor life extension and the company's growing experience with their suite of gas turbine upgrades F-class users: GTOP™, FlameSheet™, and FlameTop™. The afternoon centers on upgrades and life extensions, including presentations from KOSPO, FPL, and Southern Co. These sessions explore unit lifetime extension strategies, user experiences with the 7FA.04-200 upgrade, and real-world rotor findings.

Later, the Turbine Session takes center stage, featuring a technical discussion focused on component durability and field solutions. The day again wraps with a Vendor Fair, continuing opportunities for peer and partner engagement.

Wednesday – Deep dives into systems and root cause analysis

A jam-packed Wednesday opens with sessions on auxiliaries and controls, including a case study on a lube-oil loss event during start-up. Generator-related discussions follow, with insights into H2 vent line relocation and the retrofit of tilting-pad bearings.

The afternoon shifts into detailed Compressor and Combustion sessions. Users explore findings from major inspections, compressor retention key improvements, and recent combustion incidents—including a burn-through event tied to TIL 2552 and challenges surrounding black smoke emissions during liquid-fuel operation. A special evening outing at the Barber Vintage Motorsports Museum, hosted by MD&A, adds a social break after an intensive technical day.

Thursday – GE Vernova takes the stage

Thursday is entirely dedicated to collaboration with GE Vernova, beginning with the 2025 keynote address, "Our Time Has Arrived." GE leaders will share market outlooks, operational shifts, and strategies for reliability, revenue, and risk management. Key sessions include a 2024 recap and updates from Commercial Operations, Quality, Parts Fulfillment, and Repairs, followed by a forward-looking presentation on 2025 supply chain strategies and field services.

The afternoon features three rounds of simultaneous breakout sessions with targeted technical content. Topics range from combustion fundamentals and compressor/turbine performance to emerging AI/ML solutions, auxiliary system reliability, and root cause analysis strategies. The day ends with closing comments, a user feedback session, and a GE-hosted social event at Dread River Distilling Co.

Friday – Masterclasses and closing reflections

The final day begins with a synchronous condenser breakout, offering two sessions exploring conventional and clutchless approaches, featuring use cases from Dominion and FPL. The Combustion Turbine 401 masterclass follows—designed for seasoned professionals seeking advanced strategies and deep technical insights.

To close the week, the CT Outage Windows panel shares lessons learned from recent outage cycles and offers expert strategies for planning and executing work in volatile environments. The event concludes with final thoughts and the highly anticipated grand prize drawing.

The 2025 7F Users Group Conference offers unmatched access to practical knowledge, fleet data, vendor innovations, and peer collaboration—all in service of keeping the 7F fleet at the forefront of reliable and flexible energy generation. CCJ

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Presenters:

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7F Upgrades Global Sales Leader
GE Vernova

Jason Shaffer
7F Gas Turbine Product Manager
GE Vernova

Jason Bowers
Steam Turbine & HRSG Upgrades Global Sales Leader
GE Vernova

Eunica Garza
Sr. Regional Application Engineer
GE Vernova

GT11N/N2 & GT24 USERS CONFERENCE:

Date: June 24-26, 2025
Location: Baden, Switzerland

EVENT HIGHLIGHTS:

- Meet and hear from many of the experts who are working on and supporting your fleets.
- Listen to dedicated presentations covering technical updates about your gas turbines, generators, and control systems.
- Tour the GE Vernova factory in Birr, Switzerland including the blading repair and new make facility, the rotor and generator manufacturing facility, and the gas turbines learning facility.

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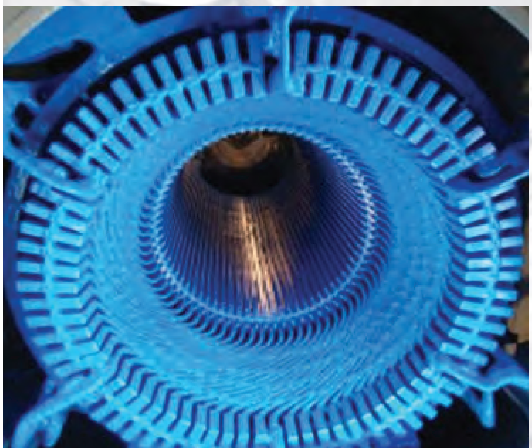


7F Users Group

Frustration mounts as users take more control over their machines' destinies

Relative to what was presented at previous meetings, the matrix of issues facing users expanded and the sentiments about the OEM didn't get any kinder at the 2024 7F Users Conference, held in St. Louis, MO, May 20-24. Those wishing a refresh on earlier conference summaries can refer to CCJ, No. 74 (2023) and CCJ No. 70 (2022) available in PDF at www.ccj-online.com/archive/.

Emblematic of the frustrations are the following near-verbatim quotes from users during the various sessions. Note: More than one user noted that OOEMs and major GT service industry players are facing similar challenges:

- We're going to have idle units because of supply chain issues
- Our recent ST/G outage highlighted the importance of improved collaboration and execution alignment with the OEM because of numerous avoidable issues
- There appears to be an opportunity to strengthen communication between OEM executive leadership and field operations teams to promote better outcomes
- Site engineers from the OEM would benefit from additional field experience to better support complex site activities
- Post-outage, we've observed recurring tube leaks, underscoring the need for enhanced quality assurance during OEM departures
- It takes too long to publish a TIL (technical information letter) after it has been initiated
- Lead time for critical spares is up to six months
- In-shop work is a black box when it comes to communication
- We're seeing opportunities to improve accuracy in parts fulfillment and ensure alignment with site specifications
- QA/QC sign-offs on some hardware, such as bolts, could be more thorough to ensure installation integrity
- Our last outage extended from 70 to 140 days due to stator bar issues, pointing to the need for tighter process controls
- We've noticed consistent resistance when addressing certain issues with the OEM, and see potential in fostering more collaborative problem-solving
- After replacing a bearing twice annually, we recently discovered through the 7FUG that a long-term OEM solution already exists
- There's a lack of clarity on the operational history (starts and hours) of R4P parts, and greater transparency here would enhance confidence and planning

You didn't have to read between the lines to note the OEM, during its OEM Day (summary follows), acknowledged many of the user frustrations but struggled to offer satisfactory responses for the here and now, while deflecting to new processes, procedures, and investments expected to remediate user concerns going forward. One OEM representative acknowledged that "we've been humbled regarding quality."

As always, the user presentations, summarized here (most posted online and available to members at www.powerusers.org), share invaluable lessons learned, experiences, updates on recurring issues, new issues to monitor, and post-mortems of safety events which enrich the entire community. It's clear that larger owner/operators (O/O) continue to exert more control over their machines' destinies by taking more responsibility for inspections, conducting more oversight of repairs, working with EPRI to solve problems, and collaborating even more with other users.

CHECK FUEL DELIVERY HEADER VENTS!

Nothing is worse than hearing of loss of life at a plant. Folks who come to user conferences to share so that similar accidents elsewhere can be avoided deserve the highest praise. Representatives from owners of a plant with eight simple cycle 7FAs reported on the failure of a high-pressure (HP) gas-vent-pipe ball valve on a fuel delivery header which took the life of a worker.

The failure occurred after the GTs were isolated and workers were relieving pressure in the system. The worker opened the top vent valve first, but the bottom vent failed. Post-incident assessment showed that the wall thickness of the vent pipe was not suited to the service and a 90 deg elbow in the vent line created a thrust load which was not counter-balanced with bracing. The vent valves had been exercised several times before.

Further review showed that what was installed was not what was called for in the design. Hundreds of workers walked past that vent and no one caught the off-spec install. Other vents at this site were similar. Subsequent walkdowns of every site and every vent in the owner's other GT plants revealed multiple locations requiring modification.

Weaknesses identified in the processes and procedures are (1) lack of oversight of the fuel delivery system compared to the GTs and (2) no standardized operating guide was available for clearing energy in the piping. Presenters cautioned that trying to establish a LOTO clearance in this part of the process created new safety issues.

Presentation slides are not available at the Power Users site, so network with your friends to access the details.

COMBUSTOR ISSUES

Some of the newer F machine issues appear to be focused in the combustor area.

Inner support rings. Four 7FA.05 machines with dry low Nox (DLN) 2.6+, advanced gas path (AGP) tech package, and 32k hr hardware (COD 2020) experiencing one to two starts per day are suffering from combustor fallout, or oxidation flaking, caused by inner support ring (ISR) failures. The ISR supports the stage 1 nozzles. "Massive amounts" of debris end up on the transition pieces (TP) downstream of the combustor crossfire tubes.

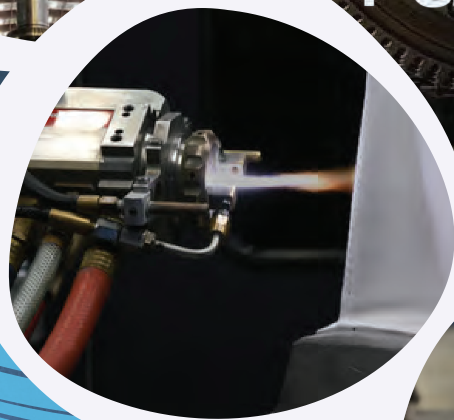
Flaking was observed after 5000 hours and 350 starts in 2021 and progressively got worse over the next two years. ISRs were replaced in kind in 2022 with no improvement, replaced again in 2023, and replace a third time with "upgraded materials." Replacing ISRs entails full removal of the combustor.

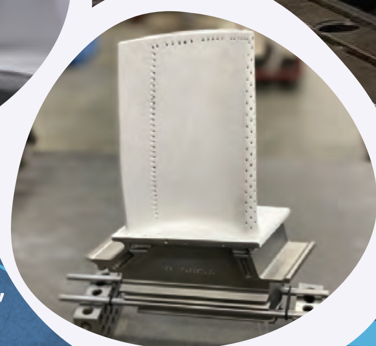
Photos of the site show an outdoor laydown area dotted with "unserviceable" TPs. Across the four units, 61 TPs have been replaced since the plant came on-line. Only seven made it to the 32k hot gas path (HGP) major. The presenter lamented that the OEM insisted that the .05 machine could handle this level of cycling and that no satisfactory answer has been offered, although an RCA is in the works. TIL 2364 addressing the situation was issued in the second half of 2022.

When the audience was asked if anyone had similar experience with .05s in high cycling service, no one responded. Excellent photos available in the on-line slide deck show the extent of the damage, as well as collateral issues, such as cracks across the PM1 fuel nozzle tip and across the effusion plate faces.

Combustor casing bolt washers. Washers seem so "elementary" until they are not. A large fleet owner/operator (O/O) reported on loose combustor casing bolts in 7F

DOOSAN





units with DLN 2.6+, initially observed in one unit after only three years operation. Some bolts had "spinning" washers, others were "backed out."

Loose bolts create leakage pathways and elevated compartment temperatures. Subsequent evaluation showed that the design material was inadequate – it softens over time - and the washers were not properly torqued.

The O/O worked with the OEM to find a modification, resulting in TIL2484, which applies to several dozen machines in the fleet. At conference time, six units had new Inconel (ASTM A437 GRB4B) washers and the bolts' torquing pattern and sequence was updated for all the units. The bolts are more expensive and the revised install procedure adds a shift-man of work to an outage. Each unit has 910 of these bolt/washers.

Several in the audience noted that they have had forced outages or delayed operations as a result of this issue and others noted that they experienced elevated compartment temperatures, which were resolved after addressing this bolting issue. The TIL recommends replacing these bolts and washers at the next outage opportunity.

The presenter reminded the audience that the TIL applies to all 7F 2.6 and 2.6+ transition pieces in your inventory, including new and repaired versions. A slide in the deck details the new torquing procedure.

Liquid fuel flame detectors. Straddling the line between combustion and I&C, user explained how a large fleet owner/operator resorted to use of NOFD (non optical flame detector) software for nine dual-fuel simple cycle units upgraded with 2.6+ AGP and enhanced compressor between 2017 and 2023.

Original flame detectors and upgraded versions kept fouling during liquid fuel combustion (though no problems were seen during gas firing), causing units to trip. Even after TIL2098 was issued, which called for changing the positioning of the detectors by shortening the length of the support tube assembly, the units still had problems. Detectors would "drop out" after a few hours once water injection was initiated. Other maladies are described in the slide deck.

7F-fleet top issues include poor-quality repairs, inexperienced service personnel, aging units, and a continuing stream of Technical Information Letters on the OEM's latest products—such as DLN 2.6+

TIL2428 was then released documenting issues with sensing degradation caused by water and fuel spray patterns fouling the detector lenses (slides offer clarity as to the level of fouling). The TIL recommends that sites apply NOFD software, a data-driven algorithm, to prevent trips during liquid fuel ops.

The rest of the slides elaborate on the software and logic, and experience with its use, summarized as "mostly good." If you're suffering from similar maladies, you won't want to skip the slides on custom control and troubleshooting screens developed by one of the site's engineers.

HOT GAS PATH

The following summaries underscore how owner/operators (O/O) are conducting their own QA/QC and RCA activities as oversight on the OEM.

Stage 1 buckets. Presentation began with a review of S1B design changes from the 7FA through the 7FA.05/AGP. O/O Specialists now conduct post IA, precoat, and final inspections for all repaired S1Bs and final inspections for new S1Bs.

One recent finding was that broken reamers from the thermal barrier coating (TBC) process were discovered inside internal cooling channels of repaired S1Bs – the OEM apparently failed to do x-ray or borescope inspection of the final product before shipping. After returning the set, the OEM borescoped 92 blades and 22 had to be replaced with new.

Another finding was shot-peening grit inside the cooling channels of new S1Bs, which could not be removed by air flush. Masking during shot-peening apparently failed to prevent the grit from entering the holes. Again, the OEM did not perform x-ray or borescope inspections before shipping to the site. After they were returned, the OEM did x-ray inspection of 92 blades and 11 had to be replaced with new.

An audience member asked if they had to "push" GE to do x-ray inspection of the returns and the answer was yes. Another added they also discovered reamers in the cooling holes of sets of S1Bs from 2021, an issue that had been on-going for years. A third noted that they were seeing mid-span tip indications and cracks after weld repairs of single crystal blades after 900 and 2400 operating hours.

Defects in R4P S1Bs. Simple-cycle dual-fuel 7FA units with DLN 2.6+ and R4P parts, including modified .03 S1Bs, AGP-Tech S1N, AGP-Tech S1S, modified .03 S2B and S2N, began to experience leading edge damage after 300+ FFS and 3000+ FFHs. To pre-empt issues at the next outage, the O/O sent S1Bs in inventory out for x-ray inspection of the tip caps. Prior to late 2023, the OEM did not do x-ray inspection of tip caps.

Slides include photos from inspections but the list of findings include: internal cracks as long as 0.867 in., backwall strikes from foreign objects, push-through on internal walls from electrical discharge machining (EDM), and small cracks on trailing edges.

As a result of these inspections and RCA work, the OEM now performs x-ray inspection of all R4P S1B replacements and changed the tip-cap replacement process to (1) include new gages to ensure correct angle of weld prep and (2) more accurately locate the internal ribs to assure the correct cut of the tip cap over the ribs for welding.

Presenter stressed that they don't yet know whether these changes will prevent leading edge damage caused by tip cap burnup. The first set of blades was installed in spring 2023 and were scheduled for BI in the fall of 2024. An audience member asked if there were any limitations on starts between BIs and the answer was no.

The presenter, in wrapping up, noted that the set of R4P S1Bs taken from a fall 2023 outage showed additional damage, including platform cracks on 12 pieces. RCA is on-going.

Blade vibration trip RCA. User experienced a vibration-initiated trip of a 7FA.03 which, upon investigation, resulted from a mass loss event when the 3rd stage blades all failed catastrophically. The unit had 130k+ operating hours at the time of failure. The failure is associated with creep degradation, clearly shown by the dark gray/blue boundary on one of the fractured blades, and faulty repair methods.

The repair was "years ago" and the O/O still doesn't know the root cause. However, eddy current indications were noted by the OEM at the time of repair but were not shared with the O/O in the final report. Bottom line: O/O no longer uses S3Bs from the OEM repaired more than once. Three audience members reported experiencing similar failures, with one noting it happened three times in a row.

GENERATORS

Leakage in water cooled generator. User recapped assessment of moisture, dust, and oil ingress and its impact on the insulation of the water-cooled generator rotor. During heavy rains and high humidity, the insulating capability drops to levels which can trip the unit on rotor ground fault. Site lost over $1-million in revenue in 2023 as a result of this issue.

A variety of actions were taken to prevent this situation, including beefing up frame-to-base sealing joints, adding external heaters, upgrading an undersized mist eliminator, relocating the generator bearing filter outside the "load tunnel," adding steel strip overhangs to reduce moisture ingress, revising generator insulator trip settings, and running the unit on full spin no load for several hours to help restore the insulating levels. See slides for photos showing where the hardware modifications were made.

One audience member noted that they had a similar issue and to be careful with the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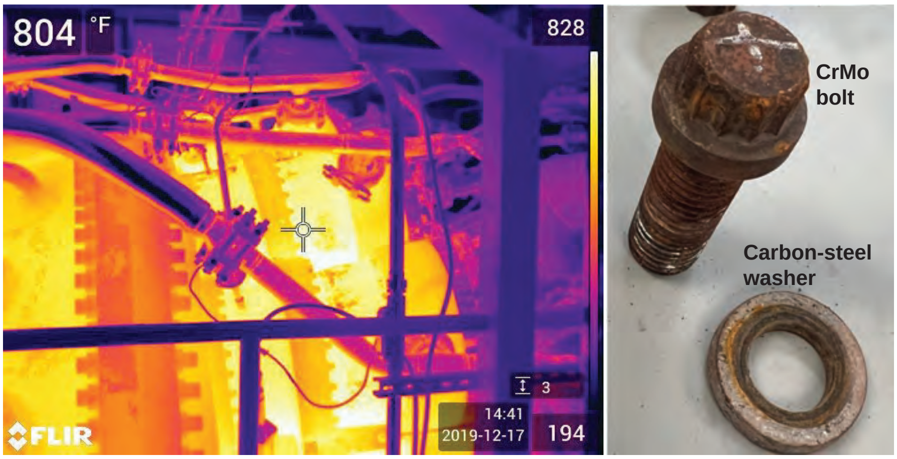
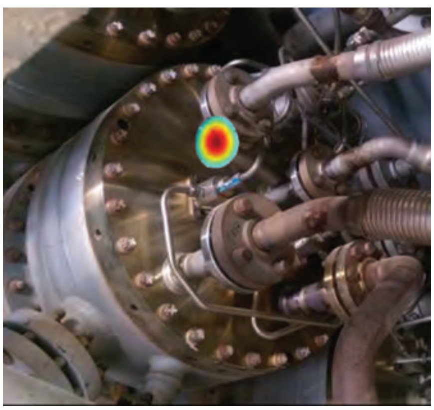
New first-stage blades were delivered with shot-peening grit inside cooling channels. Air flush was ineffective

Revising generator-rotor ground alarm and trip settings may help mitigate trips on rainy days

Leading-edge burnup on S1B airfoils prompted a change in the tip-cap replacement process and follow-on inspection



Elevated compartment temperature issue (left) attributed to loose DLN 2.6+ combustion-can bolts (right) was resolved by replacing carbon-steel washers with ones of higher yield strength and increased temperature resistance (TIL-2484)



Detection of a fuel-gas leak is challenging after a major outage, given the scores of hoses and flanges to check (photo indicates a leak in the PM2 hose of one combustor). There are at least five ways to detect a fuel leak that you might consider

Debris from oxidation flaking of the inner support ring for the first-stage nozzles ends up downstream

Responding to a low casing-pressure alarm on a hydrogen-cooled generator, plant personnel increased gas pressure. Hydrogen consumption increased dramatically over the next few weeks. Cause was a failed bushing

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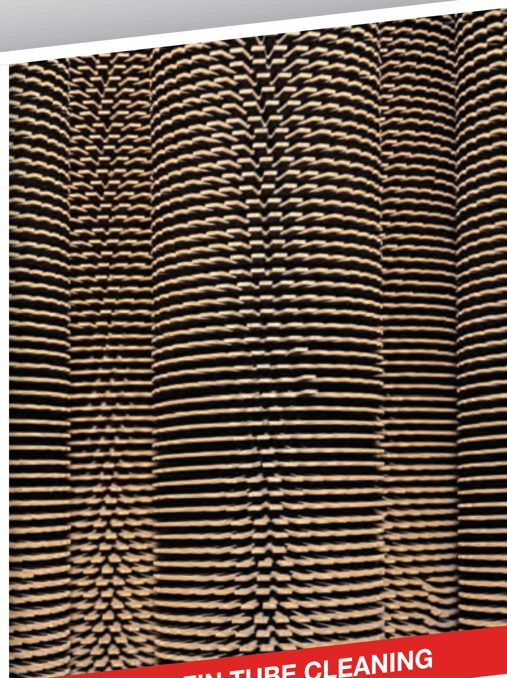


HRSG FIN TUBE CLEANING

changes to the insulator trip settings. Another referred to a 10-page document from the OEM addressing this issue.

Shorted field end-turns. Vintage 2003-2004 7FA generators in combined cycle (CC) service were experiencing shorted turns, defined as the migration or breakdown of insulation in the coils, allowing electrical contact between turns and potentially leading to a forced outage. This user noted such issues in the 2B field in one unit in 2022 and planned to replace it in 2024. Then, similar issues cropped up in the 2D field in 2023, and then in the other two fields in early 2024.

Ultimately, all four fields were exchanged for new ones in mid-2024. Other options, in order of cost, included rewind (limited shop slots), exchange with used copper (longer lead time), exchange fields (short lead time, if ones are available), or buy new fields (not available at that time).

User offered these bullet points for addressing shorted turns:

- Take flux probe readings every six months to a year
- Trend vibration and field current
- Limit cycling of the unit
- Plan well ahead for a field exchange, and investigate the OEM's shop time, slots, and available fields.
- Plan to visit the shop – it's an invaluable learning experience and good QA/QC practice.

7FH2 generator H2 leak. A petrochemical site with 7FA.03s in cogen service experienced an H2 leak from a 2005-vintage 7FH2 generator several months following a major outage. Slides describe where and how the leaks were detected and the failure of a high-voltage bushing which led to the incident.

HMI/CONTROLS

The inner workings of a 7F control and automation system can seem like a maze of mystery and magic, unless you are a controls specialist. Thankfully, the 7F conference program has included at least one detailed presentation on the subject over the last few years. To paraphrase the presenter, there's not one person who understands both the turbine control system and the plant control system.

This year's account, in today's parlance, included a number of "hacks" and workarounds to address what were termed "original issues" with the OEM's approach, enhance the user experience, and save money. The presenter cautions that many of them involve LTSA challenges and you should expect the OEM to "push back on everything."

Areas covered include:

- Trips caused by condensation in exhaust pressure switches
- Trips caused by lack of turbine compartment ventilation
- Shortening cool-down sequences re: aux seal oil pumps and forced cooling
- Helping operators with routine tasks like valve stroking and tests to ensure machine readiness
- Tuning the water injection curve for liquid fuel firing while complying with emissions limits (spoiler: repurposed fuel nozzles came with plastic caps embedded inside)
- Mitigating Auto-tune combustion dynamics monitor (CDM) probe failures
- Managing the end of support from Microsoft for Windows 2012 R2 (noting that the OEM's alerting of its customers was within a "less than optimal timeframe") and replacing HMIs, network switches, and simulators

Regarding the last bullet, this O/O, with a huge portfolio of machines, decided to buy its own PCs and network switches and configure the HMI and switches themselves, working with their internal I&C, field support, and IT security departments. They also built their own simulators. This allowed them to take the mystery and magic out of the equation and greatly reduce reliance on the OEMs for troubleshooting and fixes.

GENERAL MACHINE ISSUES

Safety incident review. Safety incidents always deserve the undivided attention of the user community. A 2x1 7FA with D11 ST/G was in outage for BOP scope and BIs and NDEs of the major equipment. Slides review an injury caused to a contractor pressure-washing HRSG stacks in prep for repainting. A stack elevator struck the manlift basket occupied by the contractor, the pressure wash wand fell out of his hands, whipped around, and injured his face and arm. Another worker was trapped in the elevator.

A thorough response timeline and post-incident review was conducted for worker performance and corrective measures. In the future, stack elevators will be in LOTO when work is conducted in that area, workers will be in two-way radio communication, and station leadership will conduct pre-job briefs with contractors.

Axial vibration RCA. A 7FA.03 exhibited high axial vibration after coming out of its first major inspection outage which included the following: Enhanced compressor package 3, 3rd party stage 17/exit guide vanes (EGV), 3rd party combustion and HGP parts, and Mark VI to VIe conversion. The vibration worsened during low load operation. Five months later, the unit took a forced outage on excessive axial vibration.

The subsequent RCA, detailed in the slides, concluded that active thrust bearing shim needed grinding after a flatness test showed the shim had "sprung." According to the presenter, a shim "with a 0.02 in. spring should never have made it into the unit." Actions include a witness/hold point to ensure thrust shim flatness before installation and stricter QC over future thrust shim grinding.

IGV throttling, post AGP upgrade. User upgraded with DLN 2.6+, AGP Tech Package, AutoTune MX, extended turndown valves, and new hazardous gas system, then experienced unusual inlet guide vane (IGV) response post-commissioning. New model-based controls imposed "all sorts of new limits," especially for rotor protection. Upshot was that the upgrades led to poor compressor efficiency.

Fleet trip reduction study. Mid-sized O/O undertook a study of fleet-wide forced outages (FO) to determine common causes and remedies. The initial effort led to a reduction from 592 to 444 annual trips.

Not surprisingly, valves were found to be the largest contributor to FOs, 2x higher than any other component or factor, with the largest sub-category being actuators. New planned maintenance tasks were instituted to achieve more consistency in calibration, assembly, overhaul, and soft goods inventory around valves.

For 7FA fleet trips specifically, a single point vulnerability study was conducted to determine if logic and control changes could eliminate a trip, convert a trip into an alarm, add time delays to a trip, or substitute a runback instead. This effort led to 29 recommendations, with several examples included in the slides. Conclusion: There's lots to find in the logic which can be modified to avoid unnecessary trips.

Inertial mode operation. Asian O/O needed to add more inertial capability into its system following addition of large increments of renewable capacity. A 7FA unit was selected, which had little room for the installation of a clutch. Engineers elected to create new logic which would allow the gas turbine and the generator to provide inertial energy (in the clutch situation, only the generator provides the inertial energy).

Added advantage was that the schedule could be significantly shortened. Addition of "inertial operating mode" was successful and the O/O is now evaluating different inertial energy options for other GT/CC sites.

Turbine compartment leak detection. At a huge power complex in the Middle East, engineers addressed gas leakage after major outages. Identifying leaks requires multiple attempts and machine re-starts. The OEM's detection and protection logic and trip limits are described as "conservative" and its off-line detection procedure impractical.

For one, there are no isolation valves for gas flow into the fuel nozzles and the leak test requires the installation of blinds to carry out a hydrostatic pressure test (there are 56 hoses and 112 flanges), then conducting the snoop test at hoses, flanges, and plugs.

Slides cover the evaluation of five alternative on-line and off-line gas detection methods, with the one chosen being the use of ultra-sound imaging at crank speed (when the compressor discharge pressure is around 0.9 to 1.3 psi). Leaks were found to have a frequency range of 30-50 KHz. Using this method, and paying more attention to

QC during flex hose installation reduced the number of leak incidents after HGP inspections from 6 to 0 in two years.

Borescope inspection program. One of the country's largest fleet owners describes the formation and activities of an internal borescope inspection (BI) team serving all the GT assets. For those who are, or may be, building internal capabilities or want some good info for oversighting BI contractors, the slides offer valuable data and evidence in the form of team size and capabilities, prep and overage areas by region of the machine, list of TILs with associated BI requirements, findings rates, percentage of planned maintenance vs emergent activities, intervals between BIs, and average times to conduct a BI, write a report, and brief plant staff.

BOP 101 -CCGT BOP with GT operation. Slides include handy 7FA assembly and construction diagrams, including the cooling and sealing air systems; CC and simple cycle startup graphs; rules of thumb on GT and ST performance; list of typical performance issues, and critical parameter graphs (exhaust temperature, MW output, inlet bleed heat, and others).

Of particular note is coverage of potential BOP deficiencies following a GT upgrade, including ST and GT bearing loads, turbine compartment and exhaust plenum and frame conditions, HRSG operating temperature points, safety valve set points, boiler feed and condensate pump capacities, and HP and IP drum separator capacities.

2024 VENDOR PRESENTATIONS

Day 1 of the conference was devoted to a tour of the MD&A turbine/generator repair facility in St. Louis (morning), and a content session with six MD&A specialists (afternoon). These presentations are summarized below, followed by the other vendor material organized under the headings turbine, generator, rotors, controls, HRSGs, and balance of plant. Most of the slide decks are available to Power Users members at www.powerusers.org. For those not there, check with that vendor's sales rep for your facility.

MD&A: Blade tip rejuvenation of 7FA.04 first-stage blades involves removing cracks and damage, welding with Rene N4 material, and machining to prepare for new tip cap installation—restoring structural integrity and extending service life

MD&A SESSION

7F outage planning & solving issues. Highlights of this presentation by Richard Rucigay on developing a quality outage RFQ (request for quote), are NDE inspection requirements, especially TIL-related items; a very detailed bullet list of NDE inspection considerations categorized around the type of outage (BI, combustor/HGP, or major); description of a portable in-situ air flow test stand (PATS) which can replicate shop air flow bench testing in the field; and a compressor stator vane hook fit wear solution called vane pinning. PATS offers users additional data on fuel-nozzle assembly health.

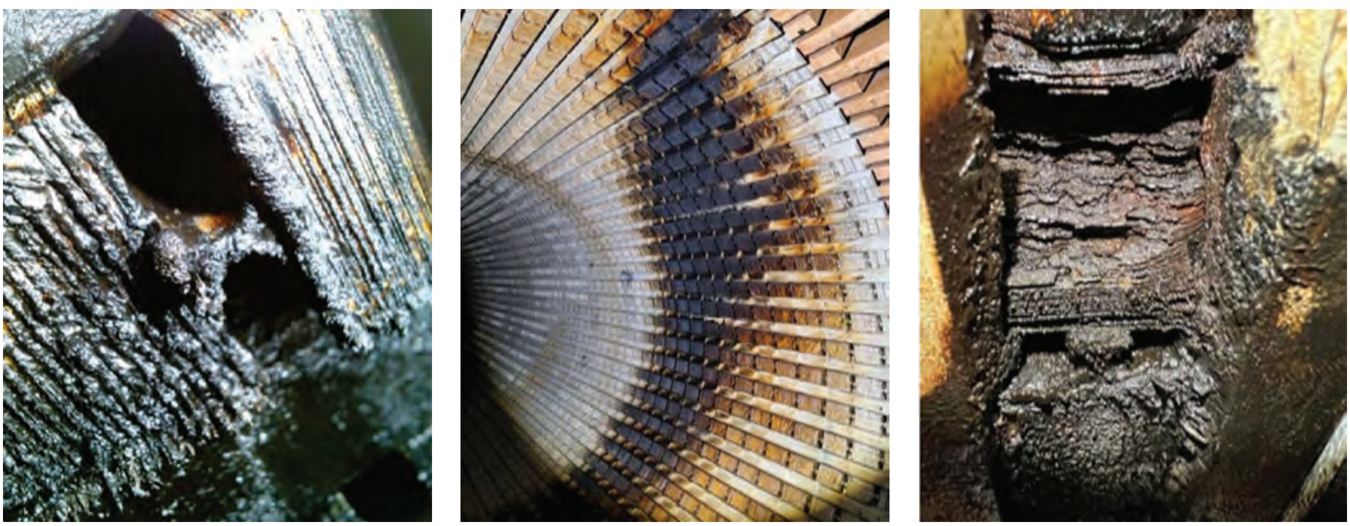
Pinned vanes are said to avoid a compressor casing replacement and a longer outage and have shown negligible effect on resonant frequencies. No failures have occurred in 200 installations (at conference time) and the fleet leader exceeds 100k operating hours.

7F rotor life assessment and extension. Mark Passino says if your rotor is approaching the 5000 start/144,000 hour threshold (per GER3620), you'll want to consider a complete rotor life assessment (RLA), which MD&A says can be accomplished in 12-16 weeks, as well as MD&A repairs, modifications, and enhancements. The RLA covers known 7FA rotor issues, including these major ones covered in the slides: compressor blade dovetail cracking in rows 12-17, turbine disc cracking, and design enhancement for the 1-2 spacer, labeled a particularly high risk component.

7FA RLE standard plan and supporting parts. It takes up to two years to replace a rotor, as there are long lines for forgings, according to David Fernandez. In lieu of replacement, you can consider rotor life extension (RLE - reusing the rotor with added maintenance and inspection outages or reusing the rotor with modifications. MD&A maintains a strategic inventory of all critical forged components, including compressor blade spacers, bolting hardware, and R1-R17 components. At conference time, R0 parts were on order.

Gas turbine parts repair and solutions. Thanks to an EPRI-sponsored demo program, single crystal components are "fully repairable" using MD&A procedures, and you can expect performance improvements to boot. Jose Quiñones' slides focus on 7FA.04 shroud tiles, with a two-layer abradable coating; row 1 blade tip restoration, inspection, and coating; 1st and 2nd stage nozzles; and row three blades (with no internal cooling), for which a repair process is said to be "elusive." MD&A uses a high-cobalt alloy for blade restoration instead of Inconel 650.

7FH2 step iron liberation. Early 7FH2 generators have an iron liberation defect acknowledged by the OEM (TIL2260) because the units were torqued to a lower threshold (2000 ft-lbs) than later units (3000 ft-lbs). Peaking duty leads to added thermal



MD&A: Greasing, contamination, and step iron damage was discovered after a challenging in-situ robotic inspection of an early vintage 7FH2 generator

stresses and risk of liberation as units age.

This presentation by James Joyce covers the discovery of step iron liberation during a challenging in-situ robotic inspection of a 1996-vintage unit (204.5 kVA), an assessment of repair options, and the subsequent partial restacking and full stator rewind.

Specifically, MD&A:

- Stripped existing windings and removed the core compression flange (CCF) and three full packs of core iron
- Cleaned all stator components of ferrous material deposited during operation
- Replaced core iron and compressed the CCF to the recommended threshold
- Performed core loop test and thermally seasoned core to remove oil and ensure that the torque values were adhered to.
- Applied low-weeping epoxy to the newly installed core iron laminations
- Performed full stator rewind

MD&A recommends that lower serial number 7FH2 generators with high number of starts get a key bar torque test.

Control strategies for life extension. "Obsolescence is not the end," says Vince Hilaire, and he's not referring to a line from an apocalyptic film. Contrary to what the OEM may claim, you can recommission a legacy control system and upgrade it with MD&A's IBECs integrated solution.

Recommissioning services include check/adjust power supplies, verify I/O is properly connected, investigate and clear nuisance alarms, conduct loop checks, calibrate instruments, and consult on unit operations. IBECs features native drivers and open source protocols, alarming and pattern recognition, time synchronization, redundancy and change replication, sequence of events recorder, high-speed trending and data historian, and remote access and monitoring.

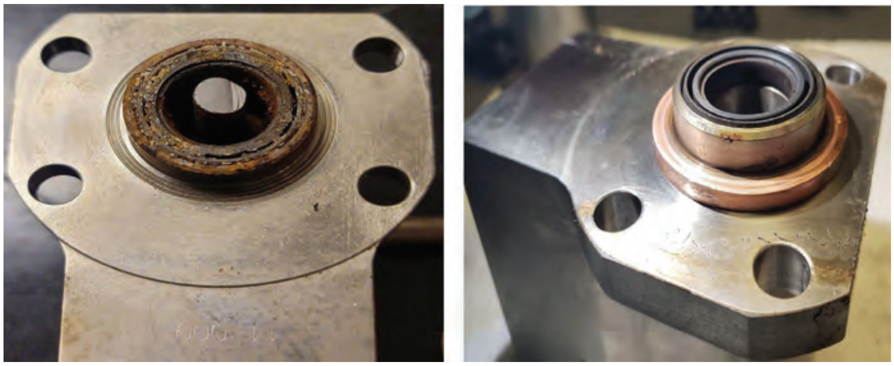
TURBINE

Interpreting borescope reports

TG Advisors LLC

Jason Neville

Why conduct Borescope Inspections (BSI)? According to Neville, BSIs allow you to trend turbine wear and specific issues for better risk management. They lead to evidence-based, educated decisions on machine issues, replacement hardware, TIL compliance, repair resources, and downtime. In addition to regular intervals (minimum annually), BSIs should be conducted after abnormal engine behavior, combustion spread events, vibration step changes, wheel space and exhaust temperature shifts, precommissioning, and post overhaul. Specific slides offer handy lists of inspection areas by section – compressor inlet, compressor, combustor, turbine, and exhaust.



JASC: Side-by-side comparison shows significant degradation after one year with non-water-cooled steel versus improved seal integrity after four years using 3rd Gen stainless steel water-cooled valves

GE 7F DLN 2.6 fuel nozzles

APG

Jeremy Clifton,

Slides review fuel nozzle basics (parts descriptions) and inspection and repair processes. Emphasis is placed on rebuilding bellows for pre-mix nozzles and fuel distribution valves, and new stiffener design, featuring three centering slotted spaces instead of two, for liquid fuel cartridges.

Engine-ready advanced TBC coatings for IGTs

Honeywell/Liburdi

Josh Smelzer

Smelzer hones in on two versions of a low-k (thermal conductivity) thermal barrier coating (TBC) now under long-term testing. The dense vertically cracked (DVC) version is for rotating parts, a porous version for stationary parts. These TBCs are said to be 10-30% lower in thermal conductivity than the industry standard 7YSZ and phase-stable to 3100F, 500 deg F higher than standard.

Slides include microstructure photos, thermal k data, cyclic testing results, and bond cap tensile strength values. Long-term testing includes four years in the field, shop, and lab. Phase 2, from 2022-2026, comprises parts installed in a commercial 7FA.03 GT with flared compressor, and steam-injected combustor operating at 2350F. Photos of early results are included.

AGT Services: When robotic inspection is not feasible, borescope-aided visual inspection through simple end cover removal enables cost-effective access to critical generator components, including endwindings, main leads, and turn insulation

Understanding the impact of BOP equipment on liquid fuel system reliability

JASC

Schuyler McElrath (RIP)

The esteemed McElrath, who passed away early in the year, reviewed JASC's 3rd generation fuel system improvements which seek to maintain seal integrity and prevent leakage in the liquid fuel, purge air, and water injection piping and valves. Included in this iteration are heat sink clamps on fuel lines in the turbine compartment and stainless-steel valve housings.

GTOP4 and FlameSheet: alternatives to advanced OEM designs

PSM

Kevin Powell, Katie Koch, Andrew Ascala

Results from the first GTOP4.1 upgrade installation should be available this year. PSM says it is AGP (advanced gas path)-compatible, includes more durable materials than the OEM's, and has better seals. Presentation covered redesign and upgrade details for R1 nozzle technology, 1st stage buckets, R1 shroud blocks, R2 nozzles, R2 buckets, and R3 buckets. Multiple sets of these parts had already been sold at conference time.

Also covered was Flamesheet, PSM's homegrown combustor technology now featuring the unique dual recirculation zones and incorporating micro-mixing technology. GenVII Flamesheet, which addresses the Gen VI distress modes revealed in early operation (discussed in detail), has been applied across the F- and E-class turbines, with frame 5 and 6B in development. Ten FA units with Gen VI Flamesheet were in operation at conference time.

GENERATOR

Generator robotic inspection – benefits, challenges and contingencies

AGT Services

Jamie Clark

Industry resources for major work on

the 3000+ generators built since 1995 are constrained. Clark gives scheduling tips for planning major and minor outages and inspections, especially how far in advance to lock in resources since repair durations can take from one to seven weeks depending on scope. Clark reminds users that the catch phrase, "robotic inspection," refers to many different robotic devices and generators with different core lengths, air gaps, wedge depths, etc.

Generator stator end-winding vibration operating deflection shape confirms global resonance

IRIS Power-Qualitrol
Aaron Doyle

For a 72.25-MW 2-pole generator, modal analysis and bump test identified an elliptical mode shape of concern near 2x line frequency, which was confirmed by installing fiberoptic accelerometers to monitor end-winding vibration.

Generator monitoring for safety, efficiency, and risk mitigation for now and beyond

Environment One Corp
Christopher Breslin

Machine age increases risk and condition monitoring helps manage risk. Company's GCM-X core monitor, described in detail, immediately detects generator overheat and insulation degradation by sensing particles in the hydrogen coolant stream, verifying their presence, collecting them, and triggering alarms for operators.

ROTORS

Rotor end of life

TG Advisors
David Butz

GER3620 and TIL1576 state that 7F rotors pose an elevated risk of failure at 144K FFH (factored fired hours) and/or 5000 FFS (factored fired starts). However, this doesn't mean they are unusable. Slides present an overview of the F-class rotor (reminding that there are three different sizes) and the key areas of interest at end of life. One notable slide states the good, bad, and ugly of Inconel 706 (primary rotor material); another lists common stator and field issues with the 7FH2 rotor. Options compared include continue to use as is, replace with a refurbished or used rotor with remaining life, or replace with new.

HRST: Weld geometry at the pipe-to-endplate joint created a stress riser, leading to fatigue cracking and liberation. Combined with cyclical thermal and pressure stresses, this design flaw was a root cause of the repeated failures in this HRSG

Rotor life extension by design

EthosEnergy
Jeff Schleis

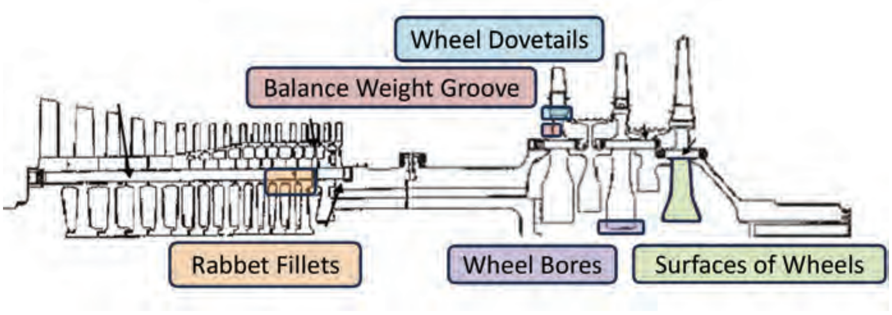
After intro material on market conditions leading to greater machine cycling, TIL1576, and industry solutions, focus of Schleis's slides is enhancing rotor design, (1) by selecting replacement alloys to match actual stress data and (2) through minor geometry alterations which are still fully compatible with original parts. Dubbed the Phoenix, it is a certified new rotor at reduced capex. One Phoenix and one new rotor were installed at a plant in March 2024 with (at conference time) no issues for either.

GT rotor life risk assessment with cycling and load swinging in a renewable energy support function

Structural Integrity Associates
Matthew Ferslew

Over time, frequent starts and stops create mechanical (rotational speed) and thermal gradient stresses which then can initiate and propagate low cycle fatigue (LCF) cracks; load swings propagate cracks beyond danger thresholds. The key to being able to swing load safely is frequent inspections inside and outside the rotor using techniques such as magnified borescope, surface penetrant (FPI/FPT), ultrasonics, and eddy current, depending on the alloy, location features, etc, especially in the highest risk areas.

During the Q&A, Ferslew highlighted the flat slot bottoms of rotors in production before 2004, after which the OEM switched to round slot bottoms. The flat variety is a safety issue but is not generally included during normal inspections. Compressor stages 16 and 17 are areas of particular interest.



TG Advisors: Regions of high stress critical to safe, reliable rotor function are not accessible without disassembly. Wheel bores cracks are safety critical. Wheel dovetail cracks propagating to failure may risk a turbine wreck but are less of a safety hazard

HRSG

Effects of GT operational changes on HRSG pressure components – case studies

HRST Inc
Souvan Chakirov

After a review of industry challenges affecting HRSG O&M (especially aging of the fleet since the 2000-2004 bubble period), Chakirov outlines two case studies of component failures which all users should take note: high-pressure superheater end-plate failures and reheater manifold bowing.

After 2261 starts, an end plate in the subject unit failed and multiple fatigue cracking of end plates was discovered. Further investigation revealed that most of the end plates had ID initiated cracks. HRST developed and applied an innovative weld repair, then developed a new test method after another end plate failed. In all, 24 end plates were replaced at this plant.

In case 2, poor drainage of condensate and feedwater buildup caused bowing of the secondary reheater tube panel at multiple sites. HRST offers recommendations to address the drainage issue.

BALANCE OF PLANT

Turbine oil & life cycle management – developing a tactical plan to mitigate varnish

Shell Lubricant Solutions
Chris Knapp

Not all lube oils are equal even if they meet specs. Slides review basics of turbine oil formulation, varnish chemical composition, and oxidation of lube oil to varnish. The tactical plan includes selection of the oil, testing and analysis, managing baseline varnish potential, partial and full oil changeout, and managing increasing vanish potential.

Key tests include MPC (measures levels of varnish components, TAN (acid number -indicates varnish buildup), RUER (antioxidant level remaining), and RPVOT (remaining life with respect to oxidation potential).

Air filtration and extreme weather

Donaldson Filtration Solutions
Bob Reinhardt

The extremes under scrutiny here are snow and ice, wildfire smoke, extreme heat, and high humidity and coastal locations. Bulleted topics included are pulse system, snow hoods, heat tracing and vanes, success

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HARD WORK
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GTS provides comprehensive, turnkey solutions spanning technical services, mechanical & welding expertise, scaffolding & insulation, and specialist engineering support.
"Very high caliber group. They have been put in difficult situations with tight deadlines and have been able to execute the projects. I will continue to use them for large scale complex projects."
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Dekomte: Proven flex seal frame design ensures gas tightness and thermal stability under high cycling, reducing adjacent equipment risks and extending maintenance intervals

of HEPA filters with smoke, watertightness, and preventive maintenance, including pulse system checks, pre-filter changeout, evaporator cooler tuning, and hood treatments.

Flex seal solution for high cycling and gas tightness

Dekomte
Jake Waterhouse

Do you consider your flex seals a consumable or a long-term solution? Slides argue that, given potential issues with the OEM's original seals, you have three options: A standard OEM solution (three-year life), an advanced seal (six-year life), or Dekomte's 15-year solution. Details for five applications (GT inlet, GT exhaust, HRSG inlet, HRSG outlet, and boiler penetration seals) and case studies are provided.

Turbine overhaul to overhaul reliability

ExxonMobil
James Hannon

Slides cover Mobil's turbine oil triage strategy to mitigate varnish, including basics on varnish chemistry and formation, varnish tests and limits, and oil replacement options. Consequences of varnish are sticking valves, wear and higher than desired temperatures on bearings, and H2 seal failure. Details on company's Solvancer™ and System Cleaner products and its proprietary valve varnish rig test are provided. Data from the rig are "more relevant than glassware tests."

The role of the owner's engineer in outages

Gulf Turbine Services
Joe Mitchell

Benefits of owner's engineers (O/E) extend beyond their traditional role in project oversight, says Mitchell. They can assist in pre-outage planning activities, augment on-site staff, and plug knowledge gaps when experienced staff members retire or leave. Examples cited include a flange-to-flange upgrade of a 7FA.02 to .03, flange to flange upgrade of a 7FA.05, diverter damper overhaul, project management of a steam turbine major outage, and O/E for a 2x7FA.02 and D11 steam turbine triple major.

CONTROLS

Performance evaluation and instrument calibration

AP4
John Downing

Downing reminded the audience, essentially, to sweat the small stuff which can often lead to unit trips, i.e., the instruments, sensors, valves, transducers, transmitters, and all of the associated components which comprise the control system. The GT is a finely-tuned machine and out-of-calibration instruments degrade performance. Thermocouples start to drift with operating time. For example, there are 12 data points used directly to raise and lower load, but there are 42 other data points associated with them. The control scheme is based on critical reference parameters and constants which need to be accurate.

Transducers in the control loops are often located in areas susceptible to vibration and high temperatures. Older machines tend to have old cables whose insulation may have deteriorated or are interfering with electrical equipment. Lots of issues have surfaced with compressor bleed valves and inlet bleed heat, inlet guide vanes, fuel gas valves, cooling and sealing air, and other subsystems.

Embedded in Downing's delivery is a plea: "Do your performance checks, make sure instruments are not neglected during outages, pay attention to cybersecurity threats, and stay updated on what your insurance carrier is requiring (such as compressor discharge pressure transducers to detect stall).

Best Gas Turbine in the World – with "issues"

At the 2024 7F Users Group Conference, held shortly after GE Power officially transitioned to GE Vernova (GEV), users and GEV representatives gathered to explore challenges, share updates, and discuss the future of the 7F gas turbine fleet.

With "ver" symbolizing green and "nova" meaning new, GEV introduced its refreshed identity and recommitted to supporting plant-level performance. Yet, as many attendees noted, execution in the field still needs to catch up with the promise of innovation.

GEV Day opened with a candid acknowledgment from a 7F User Board member: "It's the best gas turbine in the world…but it has issues."

That sentiment encapsulated the day's discourse—recognition of a strong foundation tempered by a call for better reliability, communication, and support.

USER-IDENTIFIED PRIORITIES

During a closed-door session the previous day, plant operators and engineers outlined their top five concerns:

1. Component repair quality
2. Field services performance
3. Aging fleet units, particularly from 1997–2004
4. Proliferation of TILs for new technologies like DLN 2.6+ and 7FA.05
5. Supply chain limitations

GEV addressed each of these areas throughout its presentations, aiming to provide clarity and highlight tangible improvements. As GEV presentation materials are not available with the rest of the 7F conference content, you'll have to request details from your GE site representatives or access through your customer portal.

FOCUS AREAS

After a brief corporate review, GEV reps listed some of the accomplishments of the pre-

ExxonMobil: Varnish in 7FA engines leads to valve sticking, increased bearing wear and heat, and hydrogen seal failures—impacting turbine performance and reliability

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At Sulzer, we deliver when you need it. Every job is a challenge. Nothing is as it seems. Pick the team you know will flex with them and meet them head on.

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In a difficult moment, you need to have the best option. Come see why the industry chooses to grow with Sulzer. TOGETHER.

vious year in the areas of technology development, corporate culture, outage services, and safety. GEV's "Live Outage" approach had "pockets with fantastic outcomes, and pockets which were not," according to one specialist.

The top drivers of unreliability in the 950+ machine fleet worldwide are, in this order, combustion system, cooling and extraction air, fuel system, controls, and exhaust system. Users with the 2.6+ combustion system are "sharing reliability improvements." Sub-components mentioned specifically as affecting reliability stats are flame detectors for combustion, compressor bleed valves for extraction air, gas control and safety relief valves in the fuel system, and exhaust thermocouples (TC) and communication links in the controls.

The company has been making large new investments in new rotor manufacturing and rotor repair capability to the tune of over $350M.

QUALITY METRICS

The presenter on quality metrics acknowledged that GEV needs to get better. In field services, crew quality and planning were listed as the top issues, with parts availability, field services scheduling, and work quality rounding out the top five.

The company is "pursuing zero defects relentlessly." Some of the new programs supporting the goal include:

- Stop work actions to address defects – 50% increase in stop-work situations to identify and address systemic sources of defects
- Strategic focus on third party parts - the designated supplier quality program (DSQP) is in place at over 100 suppliers and a Parts Failure Modes and Effects Analysis (PFMEA) has been "implemented across the top 40 risk areas." The DSQP rep resides at the supplier site but is trained by GEV.

The goal is to shift from reactive to preventive with respect to defects in part because "we've been humbled regarding quality." Part of that humbling was increased supplier quality incidents and nearly two dozen new Technical Information Letters (TIL) released since the 2023 conference.

RCAs and recent TILs. The root cause analysis (RCA) process at GEV follows the "Eight disciplines" methodology for identifying, solving, and eliminating problems. Presenters stressed that RCAs take time, and GEV is trying to improve on this "top user concern" with greater visibility into the process. Bi-annual webinars have been instituted to address RCAs and users can now access an "RCA Fleet Dashboard" with the status of each item. Users responded positively to these new initiatives.

In a field services update, the presenter mentioned GEV's field engineering program to "establish a pipeline for recruiting and training entry-level workers," recognizing that "it is difficult to get new people." The 100 "live outage" events last year are characterized by five key pillars – core crews, simplified procedures, sequencing, material flow, and tooling.

Site workers are supported by a remote outage support team (ROS), comprising 35 seasoned experts (level 3 and 4) who answer questions and act as mentors for the field crew. Users also have access to the Power Answer Center (PAC) portal and can escalate matters with an Emergency Response (ER) case.

"WHAT WE HAVE HERE…

…is a failure to communicate," an oft-quoted line from the film Cool Hand Luke, which summed up much of the users' frustrations during one open roundtable session.

One user complained that it often takes 3-4 days to get a response to an ER and another noted that "communication between the customer service lead (CSL) and the PAC died" on multiple occasions during an HGP. In a show of hands, more than half the room had experienced 2+ day delays for PAC responses. GEV responded by emphasizing proper escalation processes and noting their high case volume, though users expressed a clear desire for more responsive, plant-focused support.

Users also questioned or commented on: Getting consumables to the site for outages, why engineering responses were always associated with commercial aspects, difference in repair outcomes between Singapore shop and Greenville shop, inconsistent notification and publication of TILs, consistency in tools supplied to each site, retention of GEV technical assistants, difficulty getting shop representatives on the phone, and lead times of up to six months for critical spares.

GEV has responded by implementing a series of targeted initiatives to strengthen communication, reliability, and service quality for 7F users. These include refining ER escalation protocols through improved tagging, real-time monitoring, and automated alerts to ensure faster response times; assigning dedicated contacts from the Remote Outage Support team to improve continuity and execution during outages; and expediting the release and visibility of Technical Information Letters (TILs) through a new user portal with subscription-based notifications.

To enhance operational consistency, the OEM is developing regional inventory buffers for critical spare parts and tools and working closely with logistics partners to streamline delivery. A renewed investment in field service talent emphasizes training, mentorship, and retention to support long-term technical continuity at user sites.

Lastly, GEV is launching a comparative quality initiative across its repair centers to improve transparency, standardization, and user visibility into repair processes and outcomes. These improvements reflect a continued commitment to responsiveness, accountability, and collaborative progress.

COMPRESSOR, TURBINE

The following is a laundry list of topics and associated TILs covered in a session on compressor and turbine:

- **Inlet guide vane (IGV)** actuation system inspection (TIL2363-R1).
- **S17 Gen V new shroud material** (TIL1850-R3 but four others may be associated with it) – this is a long-lead time item and parts need to be procured at least a year in advance of installation. The parts enable migration to "next gen S17" and supersedes existing mechanically attached bushings a la Gen II, III, and IV.
- **7F.03/04 RO compressor blade removal.** Procedures were updated in 2024 based on RCA learnings.
- **Wet-operation-related compressor fouling.** Multiple 7F surge events are driven by fouling. Although high silica content in fogger system water was referenced, one user noted that they don't have foggers and the fouling may stem from thermal barrier flaking during normal water washing.
- **7F.04 stage 3 tip shroud distress** (TIL2045 revision). Internal creep voids can initiate cracks and lead to shroud liberation. Affected parts and spares should be sent to a service center to receive cooling hole modifications. Parts not modified should undergo fluorescent penetrant inspection (FPI) every 4000 FFH until removal.
- **7F AGP flex S1N distress investigation.** Trailing edge distress on S1N from oxidation and material loss has been observed on nozzles. RCA is in progress including material analysis. Users asked whether this was observed on multiple units, and answer was that it is considered unit-specific for now. Users also asked what the service profile was for the affected unit and the answer was ~15,000 FFH, with first observation at 11,000 FFH.
- **AGP S1B tip oxidation and cracking distress.** Pre-2019 vintage AGP tip repairs were based on Haynes 230 alloy for tip rebuilding but the material was shown to have worse oxidation resistance than the base alloy. GEV is rolling out and qualifying Haynes 233 for this repair. Additional cooling holes and tip trench may be necessary to reduce temperature.

These updates emphasize the need for timely guidance and consistent part upgrades to address fleet-wide challenges.

GEV's vision for improved support, service, and a more resilient energy future was on full display. But as the sessions revealed, the user community remains focused on execution: timely communication, consistent quality, and dependable field service. By continuing to listen, adapt, and act on user feedback, GEV and the 7F fleet can evolve together to meet today's demands and tomorrow's opportunities. CCJ


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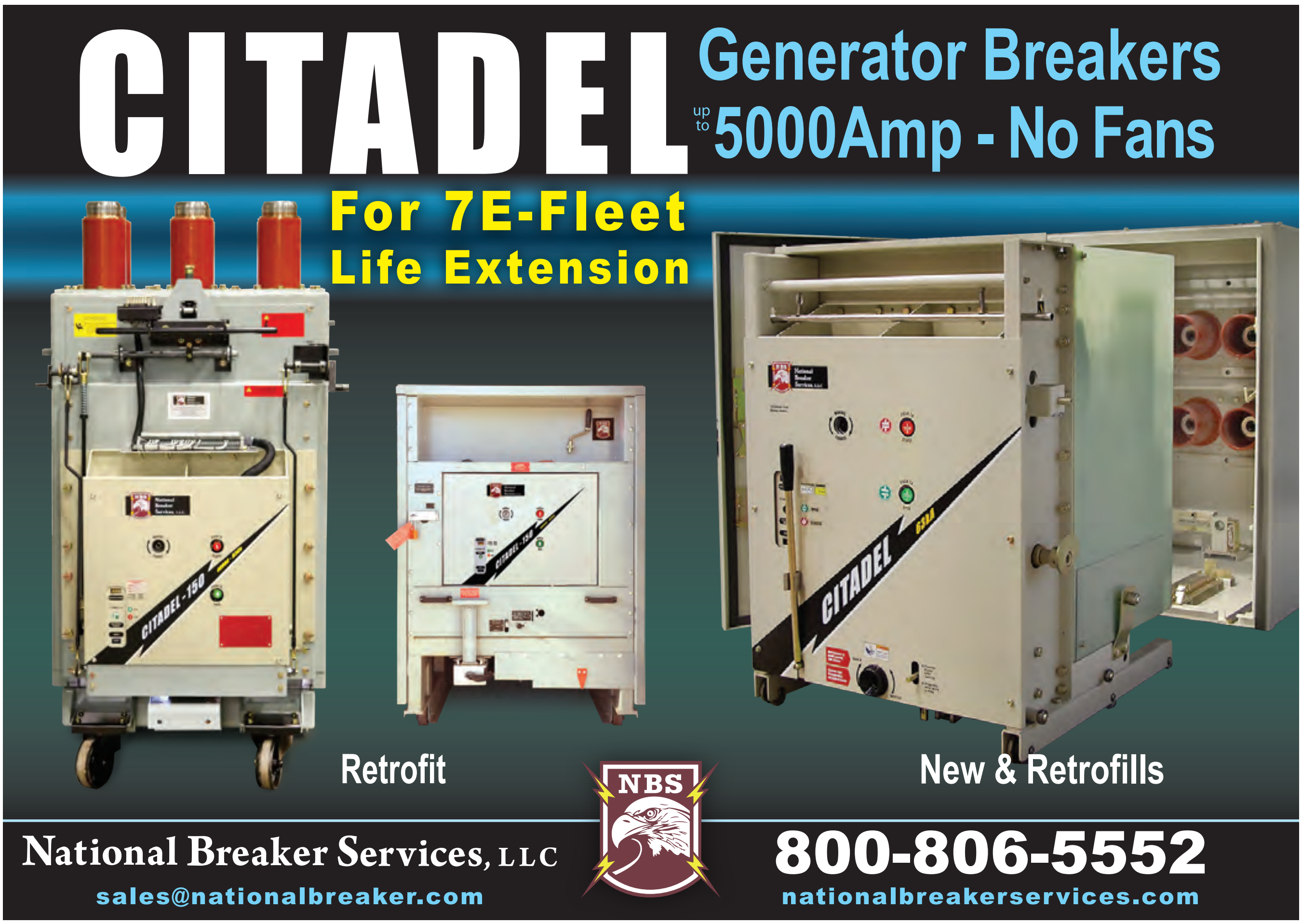
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2025 Annual Conference and Exhibition
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Legacy in motion: Advancing Frame 5, 6B and 7E together

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The Legacy Turbine Users Group (LTUG), part of the Power Users suite of end-user networks, returns this June with its highly anticipated 2025 conference, gathering Frame 7EA, Frame 6B, and Frame 5 owner/operators, OEMs, and independent service providers for four days of collaborative learning, solution sharing, and fleet updates.

Held at the Hilton Minneapolis, this year's event delivers a content-rich agenda designed to inform, engage, and equip attendees with actionable insights for improving performance, reliability, and lifecycle planning of their mature gas turbine assets. Scan the QR code to access the latest conference details and registration page or head over to the Power Users website (www.powerusers.org) for more.

This year's conference is structured around two parallel tracks—one dedicated to the Frame 7EA fleet and the other serving the Frame 6B and Frame 5 community. Each track features targeted technical sessions, roundtable discussions, OEM briefings, and valuable breakout tracks, with enhanced focus this year on outage execution, combustion upgrades, parts repair strategies, and digital solutions for operational efficiency.

DAY 1: FOUNDATION AND FORWARD THINKING

Kicking off with foundational courses, attendees can participate in the "GT Intro Short Course (101)" led by John F. D. Peterson, followed by his more advanced "Next Level Course (201)," ideal for those wanting a refresher or a deeper dive into gas turbine theory and maintenance.

These technical overviews are balanced with practical application sessions in the afternoon, including Integrity Power Solutions' 2025 update on exhaust frame and aft diffuser R3 upgrades—an especially timely topic given rising concerns over exhaust frame reliability.

Safety takes center stage next with MD&A's "Safety Differently" presentation, exploring proactive organizational learning models. Allied Power Group's talk, "The Upgrade You Really Didn't Need…" questions common assumptions about component enhancements, challenging users to align upgrades with real operational benefit.

Baker Hughes also takes the stage Monday afternoon, providing a comprehensive suite of presentations tailored to Frame 5 units. Topics include:

- FR51 product overview and power enhancement kit options
- Fleet updates and maintenance intervals
- Combustion system emissions controls
- Repair network capabilities at Houston service center
- Latest TILS and best practices

These sessions are critical for users evaluating upgrade options or needing guidance on emissions compliance and maintenance planning.

DAY 2: A LOT OF MEAT AND POTATOES

For Frame 7EA users, key sessions from various solutions providers include:

- Interpreting borescope reports
- Value of independent outage oversight
- Compressor vane looseness
- Fuel flexibility and emissions technology
- Generator controls and lifecycle planning

For the Frame 6B users, GE Vernova, led by product line manager Erik Hilaski, starts the day with its fleet updates and leads into the following key topics:

- Core asset rejuvenation

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- Rotor life extension strategies
- OEM component repair practices

The OEM afternoon breakout series allows attendees to tailor their learning with deep dives on topics like:

- HGP and combustion components
- Controls modernization
- Auxiliary systems and BOP end-of-life planning
- Mid-life asset rejuvenation

Meanwhile, the 7E afternoon general session delivers timely presentations from Voith on torque converter optimization, Doosan on parts durability, and AP4 Group on DLN tuning. MD&A's discussion on 7EA lifetime extension caps the day with practical upgrade considerations.

The evening vendor fair features nearly 100 exhibitors and provides users with the chance to engage directly with solution providers in a relaxed networking environment.

DAY 3: MORE ROUNDTABLES, OPEN DIALOGUE

The third day dives into user experience and collaborative conversation for the Frame5/6B groups with sessions on inlet/compressor maintenance, flame scanners, exhaust systems, control system reliability, and the evolution of key repair methodologies.

In the afternoon, EthosEnergy presents on risk-based rotor life extension, while National Electric Coil provides insights on stator winding CTQ elements. A must-see PSM presentation on the evolution of the FlameSheet combustor is slated for an extended slot following the afternoon break.

On the 7EA side, a full day of GEV kicks off with product line manager Jay Bryant and team providing updates on:

- TILs and RCA learnings
- DLN1+ hydrogen combustion projects
- Asset rejuvenation and field service improvements

The fleet overview leads to specialty GEV-hosted breakout tracks that include:

- Peaker and cogen roundtables
- "Live Outage" support
- Combustion systems and 7E 101
- Generator and controls deep dives

The day concludes with the well-regarded "Ask GEV Anything" session—a candid Q&A where users can voice feedback, share concerns, and seek clarification directly from OEM representatives.

DAY 4: MAINTENANCE MASTERY AND WRAP-UP

The final day keeps momentum with practical technical content. PSM returns to explore post-outage tuning and combustion optimization, followed by AGT Services' in-depth "Generator Maintenance 101" workshop—spanning both AM sessions.

Roundtables cover generators, turbines, auxiliaries, and controls, fostering peer-to-peer dialogue and reflection. This day is especially helpful for site-level personnel seeking take-home maintenance tips and troubleshooting perspectives from fellow users.

WHY YOU SHOULD ATTEND

The LTUG 2025 Conference is more than a meeting—it's a collaborative forum where legacy fleet owners come together to strengthen operations and influence the future of support for aging gas turbines. With OEM participation from both GEV and B-H, alongside expert voices from MD&A, Doosan, PSM, and others, users will gain high-value insights into emissions compliance, life extension, outage planning, digital upgrades, and evolving fuel flexibility—including hydrogen integration.

Whether you're facing rotor refurbishment decisions, navigating combustion tuning challenges, or working through auxiliary reliability issues, LTUG offers an unmatched opportunity to find solutions, compare notes, and grow your professional network. **CCJ**

LTUG 2025 EXHIBITORS

As of April 21

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AGT Services
Allied Power Group
Alta Solutions
Ap4 Group
Baker Hughes
Baseload Power
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Young & Franklin

Main story lines at LTUG24 reveal how to recover after taking a punch

To some, here's the distinction between reliability and resiliency: Reliability is avoiding a punch; Resiliency is recovering as quickly as possible from a punch. Aging assets, such as those with older turbine models, are likely going to take more punches than they avoid because the resources to avoid the punch are devoted to newer, more critical assets.

The third annual Legacy Turbine Users Group (LTUG), held in The Woodlands (Houston area), Texas, July 15-18, 2024, once again brought together under one roof owner/operators of Frame 5, 6B, and 7EA machines. With more users hesitant (for good reason) to propagate their machine experiences beyond trusted members of their own community, it's becoming more and more difficult to gain much material benefit from the LTUG "after the fact".

The value of attending extended beyond the hallways and breakout sessions of the hotel. LTUG 2024 hosted a full suite of shop tours, taking advantage of the conference's proximity to Houston, the global epicenter of gas turbine repair. Users were treated to behind-the-scenes looks at the growing, impressive capabilities of Allied Power Group, Baker Hughes, Doosan Turbomachinery Services, and Sulzer Turbo Services.

Most slide decks for the 7EA and Frame 5 and just a few for 6B are posted at www.powerusers.org, where the three organizations reside online. More time is being allotted for roundtable discussions, less for formal user presentations. OEM day slide decks are not posted but can be accessed via your GEV Customer Portal.

Finally, vendor-led presentations are displacing user-driven ones. The real-time discussions are where the action is, and, like most things in life, you get out of them what you are willing to put into them.

However, there were several outstanding user presentations, one a post-mortem and root cause analysis (RCA) around a control system backup battery charger failure, a second describing an alternative to a diesel motor starter, and a third an RCA of a 7EA compressor failure. All three illustrate how these plants recovered quickly from the punch. A fourth covered the upgrade and overhaul of a 1970s-vintage peaking plant.

FIRE IN THE CABINET!

Moral of this story is to assess old control system battery pack chargers, especially if you are migrating from Mark V to Mark VIe and you've retained the old chargers and I/O. Or just take some time to assess them period, including your fire suppression system.

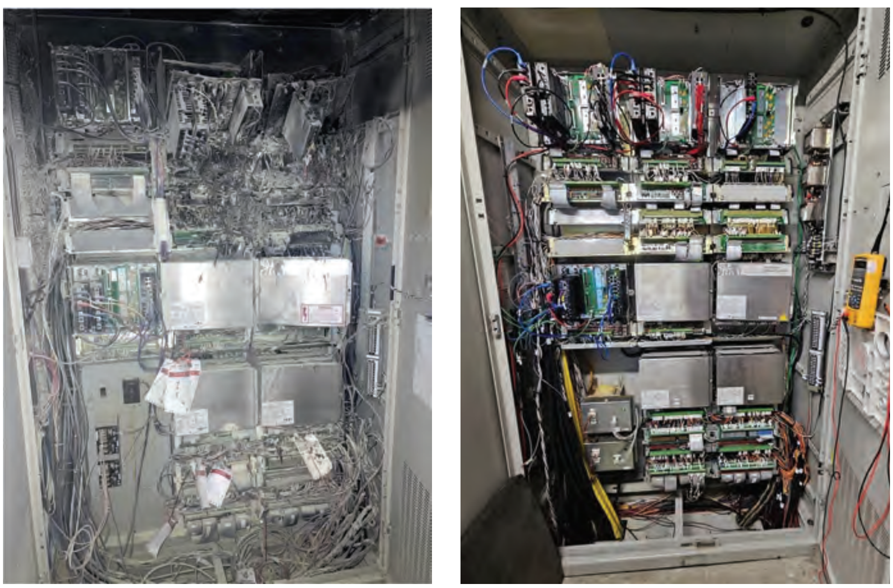
A user with five dual fuel, standard combustion, 7EA machines commissioned in 1994 experienced a fire (dubbed an "unplanned combustion incident") in the battery pack and charger cabinet (Fig 1) in February last year while the unit was in outage for a major inspection (MI). The plant had upgraded to the MKVIe MMV in 2016, but left the original battery charger in place. Batteries had been replaced in 2010. Photos reveal the extent of the smoke during the fire, and substantial damage to the cabinet.

Subsequent RCA revealed a flood of diagnostics and alarms from the subsystem, beginning in November the previous year, which would clear in milliseconds while the unit was off-line. This happened for "days and days when the unit was off-line." It had "probably been years" since the unit was operated at its high voltage shutdown (HVSD) threshold of 150 VDC.

Lead theory of cause was that the charger was not charging the batteries and the DC voltage was cycling between low and high, which could lead to high heat conditions. An alternate theory, however, that could not be ruled out was that AC had gotten into the DC circuits via the failing battery charger or external source in the field.

Other RCA findings were that a planned maintenance (PM) strategy didn't exist for the MKVIe MMV hardware and I/O, the only DC power to the MKVIe MMV was the batteries (no DC-to-AC converter, or DACA, also known as the transformer assembly, existed, which was "uncommon" according to the OEM and AP4 Group, who was assisting the plant)), and the wrong kind of fire extinguishers were stationed (not Class C CO_2) in the area for this type of fire.

After evaluating options, the plant's post-incident actions included correcting the gaps in PM and fire suppression, replacing original battery chargers, adding high/low DC voltage and other alarms, and establish voltage monitoring in PI and graphics in the MKVIe MMV.



1. Recovery from fire in the charger cabinet, originating in the battery pack, was accomplished in two months

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AP4 agreed to rebuild the cabinet in two months while others, including the OEM, proposed schedules up to eight months. The slide deck includes photos of the cabinet rebuild and rewiring (during which the "sins of the past" were fixed), schedule, and ancillary tasks. Aside from a ground fault in the DC system and a damaged exciter card, which was inspected, cleaned, and returned to service, there had been no other incidents of note, nor any failed starts or trips.

An audience member noted that his plant had found oscillating charger voltages months before an "event" and that the chargers were "acting weird." A second suggested that these components should be on a monthly NERC PM check. Best practice noted in the room: Make sure you have properly refurbished control cards on the shelf.

HYDRAULIC MOTOR STARTER SAVES DAY

A facility with Frame 5 units in far north Plains country (i.e., really cold in winter) lost its aged diesel starting motor at the beginning of 2023. The unit had to be on-line by June 1, it was impossible to get parts for this Cummins machine. Multiple service vendors would not engage with the project because of "difficulty dealing with this particular starter package." Thus, the owner/operator opted for a replacement skid consisting of a large electric motor plus a variable displacement piston pump (Fig 2).

Focal points for the presentation were (1) the need to "weld in and weld out" to extract the diesel motor from inside the gas turbine housing in two pieces through the roof, without pulling the top off of the turbine, and (2) making sure new equipment in the gearbox room (designed for "someone four-foot tall") was compatible with the components which were reused, such as the clutch.

Regarding the second, a repurposed carrier bearing was added inside the torque converter to the middle of the shaft. A stub shaft was also added to make a 2-in rotor on the motor side compatible with the 3 in rotor on the clutch side. Both affected the weight

2. Hydraulic motor starter package, comprising an electric motor and variable displacement piston pump, replaced an aged diesel-based skid, for which parts and services were unavailable

and structural design parameters. The new clutch "spins freely in one direction, engages in the other."

Cold weather design points are particularly salient here. The facility required an insulated housing. Hoses had to be wrapped with heat tape. A separate start sequence had to be programmed into the controls, during which the pump motor is first run in neutral to warm the lube oil while limiting amp draw to maximize torque. When the pump hits full stroke, it is closed to light off the turbine.

The vendors involved with the project, ST Cotter Turbine Services and HPI Energy Services, reported that they rescued the facility "with a luxury yacht instead of a tug." While they've completed hundreds of starters for FT4s, FT8s, and other machines, this was the first frame 5. Cummins is now said to be recommending the duo to customers in similar situations.

Other issues to consider:

- You need a specialist for the controls.
- Make sure the concrete pad for the skid can handle potentially higher vibration levels, which may also affect complying with sound level limits.
- Local codes for black start may require a soft start or variable frequency drive (VFD) set up.
- Motors up to 400 hp have been used, although this site required a 300-hp unit. Larger motors come with a larger footprint.

- Make sure you have enough fuel for multiple starts during commissioning.

The project schedule for the new starter was four months from finalizing paperwork to a fully commissioned skid. Actual installation took 7-10 days. At conference time, the unit successfully handled 21 starts. Plant is looking at obtaining additional hardware (larger valves, for one) so that two GTs can be started with the one unit.

Slide deck includes a more detailed description of the machine train and clutch assembly, an excellent series of project photos and a handy list of considerations for those contemplating a similar project.

INLET BELL MOUTH BOLT 'BOLTS'

A 1981-vintage, 7001E dual-fuel peaking unit at a Pacific Northwest coastal site, with almost 30,000 fired hours, close to 1500 manual starts, and 161 emergency trips, was down for a planned outage at the beginning of October 2023 when staff observed significant inlet guide vane (IGV) and compressor blade damage and missing split line bolt head. See the slides for photos showing details. Bolt piece was later recovered in the 5th stage extraction port of the compressor lower section.

The RCA concluded that the #3 right-side bolt on the air inlet fractured at the head radius and entered the compressor, causing domestic object damage to the blades, mostly the first four rows. Failure mechanism was that hydrogen-induced cracking caused long-term corrosion combined with elevated material hardness level.

Although 43 years of continuous exposure to the coastal environment and normal aging were likely responsible, overtorqueing during installation could possibly have played a role.

Compressor, turbine, and rotor were sent to APG's shop in Texas, where the unit was destacked, inspected, repaired, rebucketed and rebladed, rebalanced, tested, and returned service by January 5.

THAT 70S SHOW

Oil-fired frame 5 peaking units in the Midwest, commissioned in 1976, were overhauled and upgraded with project deliverables of 98% start reliability, 98% availability, and remote operation. The control system upgrade gives an even better idea of the vintage: from Mark II to Ovation.

Slides, in outline form, review scope items and division of responsibility, multi-contract approach, as-found plant description, and other project aspects. Among the challenges faced were lead times for the control system, inflation (budget was from 2019), and no-bids received from some service firms because of market demand.

Added scope items may be revealing to those with similar vintage units and upgrade ambitions: Inactive thrust bearing mod (TILs 533, 1019 and 1038), bearing and oil deflectors, starting motors, torque converters, exhaust casing, casing alignment and dowlings, stage 9 hook fit (TIL1304), and miscellaneous parts.

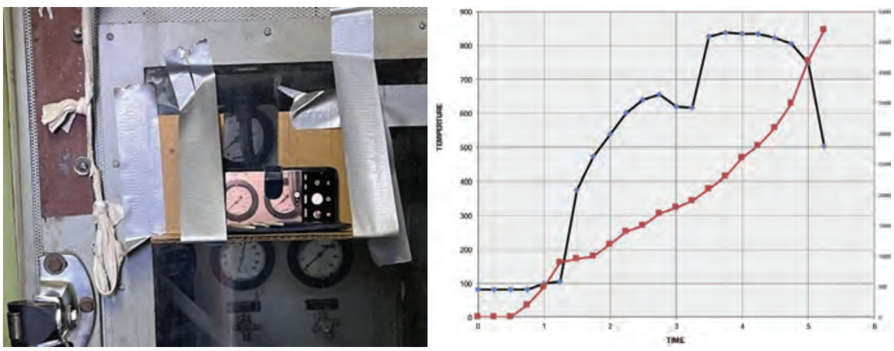
TROUBLESHOOTING REFRESHER

Cutting across the 7EA and Frame 5 sessions was Dan Melsheimer, GT-DLM LLC, an industry veteran who delivered a refresher on troubleshooting. Those new to the industry should find the deck invaluable. What may seem to veterans like common sense items are, sadly, easily forgotten, especially when in the throes of trying to recover from an incident.

Learning the origin of the word "troubleshooting" alone is worth checking out the slides. If that doesn't grab you, the photo of a fuel regulator trend graph (Fig 3) made with video data from three different iPhone should!

Melsheimer points out the technology gap with today's technicians. Why? Most of today's technicians were in high school when legacy machines were designed and installed. New technicians have trouble sorting through the notes on the original drawings.

While alarms are the key to tracking down issues, "you need your mind more than the alarms." Causes of trips are often hidden in



3. Graph of exhaust temperature and speed was created by converting iPhone recordings of analog readouts into troubleshooting data

the drawings. On the other side of the equation, owners outsourcing maintenance lose control over the skills necessary.

Approaches to troubleshooting fall into three buckets:

- Shoot from the hip. Fix the first thing that comes to mind, which can be up to 95% effective if the people involved have experience.
- Shot gun – fix everything you can think of which might have gone wrong, even if it doesn't identify the root cause and can induce other problems.
- Step by step – the preferred approach, of course, which involves lots of documentation and can be guided by forms and methods you can create. A sample is provided in the slide deck.

Being prepared for incidents before troubleshooting is critical. Have all drawings and documentation for the machine organized and easily accessible in one place. Set up files to record trends in the control and monitoring system. Make sure technicians are trained on the OEM drawing system, analog data collection, and devices you can use for analog data collection.

One user noted that their operators on shift are required to follow an RCA procedure sheet and email it to everyone regardless of shift. Another responded that if an incident can't be fixed within four hours (which usually is the case), then a team-based step-by-step methodology is put into action.

CONTROLS ON MAIN STAGE

Across the three parallel user group sessions, controls sucked up a good deal of the oxygen in the rooms, including the lead presentation in this summary. Here are others.

John Downing, AP4, made the rather startling observation in the 7EA track that life extension to 2065 is now being discussed. It takes little imagination to understand the impact of that on a facility's control system. Digital control technology is arguably the fastest evolving area of plant components. Yet some plants have 30-40 year old thermocouples and pressure and temperature transmitters.

Downing suggested that plants create a book of all instrumentation and associated components, along with their calibration procedures. Dozens of parameters measured by these aged sensors are the basis for the automated instructions for the GT, such as raising and lowering speed and load. A dry low NOx combustor tuning sheet has 50+ data points. The reference temperature estimator at the inlet to the first stage nozzle is used to make all DLN operating changes. This is a calculation based on measured parameters.

In other words, there are critical control parameters and their associated measurements and *information-only* measurements. Downing recommends calibrating all instrumentation at least one a year and instruments involved in critical parameters twice a year. Also, there are "dozens of little gremlins addressed by the Technical Information Letters (TILs).

Emerson's David Cicconi offered plenty of tips to the Frame 5 attendees on how to plan and manage a turbine controls upgrade. Slides run through scope definition which may include enhanced turbine control features; solving combustion system issues like unit turndown, trip system performance, flame detectors, and generator metering; and upgraded auxiliaries like fuel valves, generator controls, and speed measurement.

One point of emphasis was what to do with existing drawings, which are often inaccurate at best, non-existent at worst. When the OEM's control system is replaced, other drawings are affected. You should consider a pre-outage audit to investigate discrepancies in drawings and other documentation, or at least add time to the schedule for field checks to drawings.

Cicconi noted a best practice to match existing wire numbers and signal names in the upgraded system using digital editing, i.e., colored lines, to clearly define scope and responsibility at contract stage, and to avoid replacing existing cables and devices and retain wiring loops.

Expect 12 months from purchase order to equipment shipment, and up to four weeks for site work.

Users responded during the Q&A with issues to be aware of, such as fire protection system integration into the upgraded controls and voltages compatibility with the new excitation system.

Young and Franklin presented on fuel gas electric valve upgrades for a Frame 5 unit. Y&F has been in the business over a century as a job shop to GE. In 2006, they began developing their own electric valve design to replace hydraulic models which leak and develop varnish. A typical Frame 5 has 10-12 of these valves, while a 7F could have close to 300.

Each valve comes with a digital motor controller (DMC), the "brains," and is said to require minimal logic changes. Diagnostics from the DMC and USB connectivity ease troubleshooting and provide real time data to ascertain valve health. In response to a user question, the Y&F speaker noted that junction boxes could be mounted as far as 200 ft but with an arrangement where the junction box is "in the middle," distance could be extended beyond 300 ft.

Users speak out on I&C. The following bullet points were gleaned from the 6B I&C roundtable discussion session:

- There is no Mark VII control platform in the OEM's planning cycle
- No one responded when asked by the facilitator whether they've had negative experiences with the VIe platform.
- Some firms will rebuild valves otherwise thought to be not serviceable – including gas control, inlet guide vane, and safety relief.
- "Everyone" has issues with servo valves – keeping varnish quantities low is critical. One tip: let oil circulate for a couple of days after an outage to flush out debris. They are difficult to service, so are generally just replaced.
- Compressor bleed valve solenoids are a "perennial problem" because they pull in 700F air if you have a leak.
- Needle valve on the fill/drain torque converter is often incorrectly set.
- If you have a diode failure in the brushless excitation system, replace it as soon as possible. Make sure exciter diode replacements weigh the same as the old ones, shave off some copper if necessary, or make sure they come from the same supply source. The OEM gets them from different suppliers.

MAINTENANCE STRATEGIES: PEAKERS

Being old is one thing. Being an old peaking unit requires a different type of maintenance strategy. Attendees were treated to a roundtable discussion on this topic for Frame 5. Keep in mind that these users are commenting from different perspectives – island locations, unmanned units, remote locations, etc.– and different machine vintages.

Users reported different schedules for starting the units as a checkout. One said they started every 4-6 weeks, two users said once a month unless the unit was called to run, a third said start up to crank speed once a month, and to breaker speed every quarter (minimum, no load). Operator "rounds" are conducted every week, said multiple attendees, in one case by rotating technicians.

Ratcheting got good air time. Schedules vary from once a day for eight hours to once a day for fifteen seconds. A user with 1970s-vintage units said they experience "no problem with the turbines themselves." User, mentioning their Ovation system, said their units ratchet once a day, and an alarm sounds it if doesn't. Another said that operators trend and verify pressures and timing, and take the unit to maximum ratchet pressure during the weekly rounds.

Others noted that the oil system stays on 24/7 to be ready for startup, lots of issues crop up with starting systems, the turbine compartment is kept at 95F to prevent condensation-driven corrosion of blades (which did occur over several years), and peakers are running more in winter than summer. Upgrades mentioned include switching to modern relays and adding instrumentation to the starting motor.

A user asked if anyone had removed the liquid fuel atomizing air blower for duel-fuel units. They tend to fail, this user noted, questioning what they contribute, and are costly to maintain. Others cautioned that the unit could "smoke" without the atomizer, or lead to coking on the crossfire tubes. Lots of condensation passes the atomizer during startups, warned another.

Inlet guide vanes are borescoped (BS) annually by a service firm, said a user, to check for bushing clearances (among other things) and eddy-current-inspect row 1 (looking for oil leaks). They have to pull four nozzles because the BS plugs are "useless."

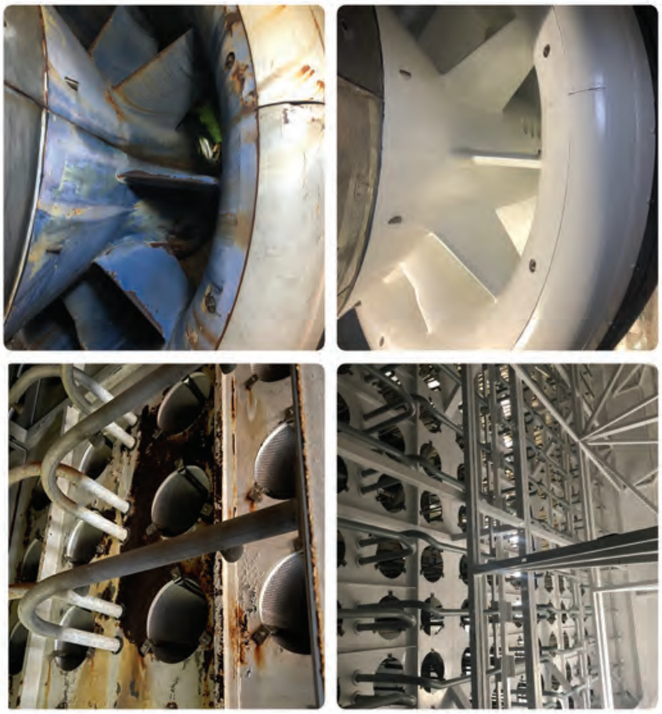
Other experiences include a fire in an unmanned unit when hot gas from a small leak in the exhaust contacted leaking oil dripping on debris left from some inappropriate contractor work involving sound cladding and grout. Staff didn't know the unit was on fire until the fire department called. Users noted that raccoons often nest in remote units and pigeons get in the mufflers of the diesel starters.

Finally, a user conceded that the maintenance strategy is driven by "what bit them last time," which led to a discussion of corrosion issues with lube-oil coolers (fins breaking off, among them), and replacing shell and tube heat exchangers.

BUCKETS AND CASINGS

Here are the more salient points emanating from the 6B turbine discussion:

- Dozens of users will be lining up for new casings
- Non-OEM casings are not yet available; there's not enough demand
- One user reported their casings have been patched up four or five times already
- Is there a good abradable casing coating that can last a major operating cycle? No, said one user. Some don't last a year. You have to remove the coating every repair cycle. One user applied titanium paste to casing cracks; they've lasted a year and a half so far.
- Take care of the rotor and the casing at the same time; it's more expensive to buy them separately.
- 1st stage bucket rock was solved by coating the area on either side of the cooling passage. One user was "in favor" of thermal barrier coating on the 1st stage nozzles, but not for buckets, suggesting they be discarded because the cost of refurbishment is so high.
- General rule of thumb: When you run parts longer, you repair more after.
- Make sure water or air is run through cooling holes of new or repaired buckets and send someone to the repair shop to make sure work is done correctly.
- One user favors x-ray inspection of 2nd



and 3rd stage buckets.

- User reported that "angel tip wings" on 3rd stage shroud block wore out after 30K hours.

VENDOR PRESENTATIONS

EXTENDING SERVICE LIFE OF 7EA COMPONENTS

MD&A
José Quiñones

Every option for replacing 7EA components poses risk, whether new or repaired from the OEM, repaired by a non-OEM service provider, or obtained from another user. Consider this: Sometimes, 50% of repaired components are scrapped because they were damaged during repair! MD&A manufactures parts with improved alloys that can significantly enhance operating life and going-forward economics. Numerous examples of damage mechanisms, testing procedures, repair techniques, and advanced alloys are included for 2nd and 3rd stage blades and 1st stage nozzles (Fig 4).

ROTOR LIFE EXTENSION MANAGEMENT – USER CASE TRENDS AND RECOMMENDATIONS

GE Vernova
Taylor Williams

Some 6B machines have been "out there" for 45 years. Users were cautioned that the 200,000 factored fired hours or 5000 factored starts limits (signaling end of rotor life) are "not conservative values." To drive home the risk of continued operation, presenter cautioned that the "blast zone" for throwing a wheel is two miles because the casing is not strong enough to contain wheel liberation. Presenter reviewed TILs1049, 1382, 1576, GER3620, and PSSB20240307A and recent updates.

COMPRESSOR STATOR VANE LOOSENESS

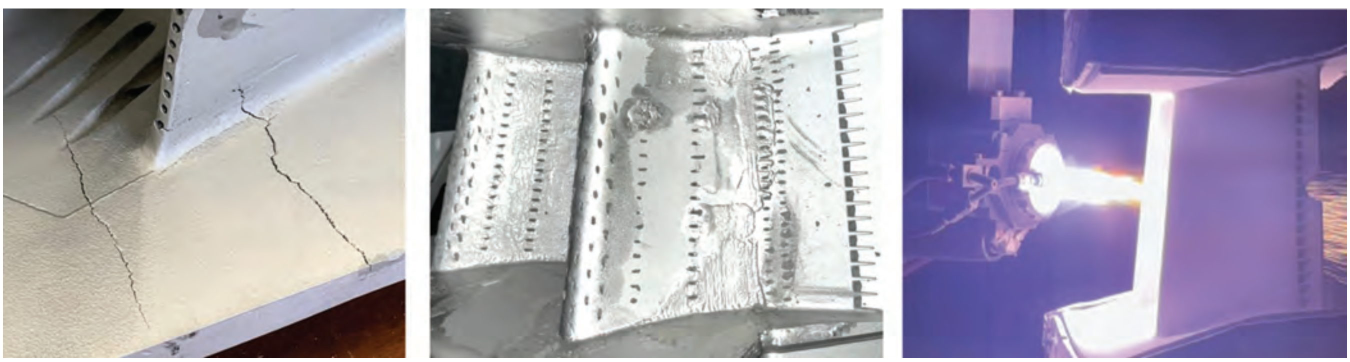
CTTS
Rich Armstrong

There have been multiple crashes across all legacy (and current) turbine models with square-based stator vanes. Message here is that the OEM's "big foot" solution for loose stator vanes "doesn't work," and that an optional solution, applied to four units (at conference time) this year alone (and dozens of units over two decades), is available. Slides review evidence of shim and vane damage and fretting, tip rock, measuring vane looseness, explanation of the phenomenon, and details of the vane-pinning alternative.

AIR FILTRATION AND EXTREME WEATHER

Donaldson Filtration Solutions
Bob Reinhardt

Bulleted options are listed for these extreme weather events: snow and ice, wildfire smoke, extreme heat, and high humidity and coastal locations, along with preventive



4. Severely cracked and oxidized 7EA nozzles are repaired via welds, FIC cleaning, and vacuum brazing. Restored wall thickness and structural integrity are finalized with APS coating and post-heat treatment for improved durability and thermal protection maintenance tasks.

EOP-012-2 EXTREME COLD WEATHER PREPARATION FOR GOS AND GOPS

Entrust Solutions Group
Rachel Williams

Slides cover basics you'll want to know about (1) new requirements issued by the North American Electric Reliability Council (NERC) in EOP-012-2 (update from EOP-012-1), cold weather preparation standard, and (2) being able to demonstrate that you can operate at the extreme cold weather temperature (ECWT) conditions. Now you have to calculate your unit's ECWT, and document critical components, specific freeze protection measures, and cold weather constraints, as well as develop and implement a corrective action plan (CAP) to address deficiencies. If you need an incentive, the penalties are as high as $1-million per day per violation.

IMPACTS OF INCREASED CYCLING ON CRITICAL COMPONENTS

EthosEnergy
Ravi Annigeri

Greater cycling significantly affects turbine operation, performance, and life of components. Ethos has solutions to address turbine bucket rocking, a primary impact of cycling. Its EcoMax Combustion Tuning system can optimize performance during starts and load cycling. Digital Twin model, fined tuned with field reports and data, serves as a basis to analyze rotor components and address known issues and failure modes, improve stress/life, and maintain interchangeability and compatibility.

TORQUE CONVERTERS IN STARTING PACKAGES: LONG TERM WEAR AND FAILURE MODES

Powerflow Engineering Inc
John Baciak

Slides outlines fundamentals of torque converter (TC) design and operation and reviews primary damage and failure modes such as piston wear, external oil leaks, worm/gear shaft failures points, anti-friction bearing failures, thrust and journal bearing wear, overrunning clutch wear and failure, cavitation erosion, and others (Fig 5). Among best practices noted: If you have multiple units, have no spare TC, and don't know the condition of the TCs you have, overhaul one to determine the likely condition of the others.

5. Catastrophic failure occurs when overrunning clutches are run far beyond service life—sprag wear, corrosion, or pin shear can lead to total loss of torque application, scoring, and fractured housings, severely impacting turbine startup and shutdown operations

TECHNOLOGY AND APPLICATIONS OF TURBINE COATINGS

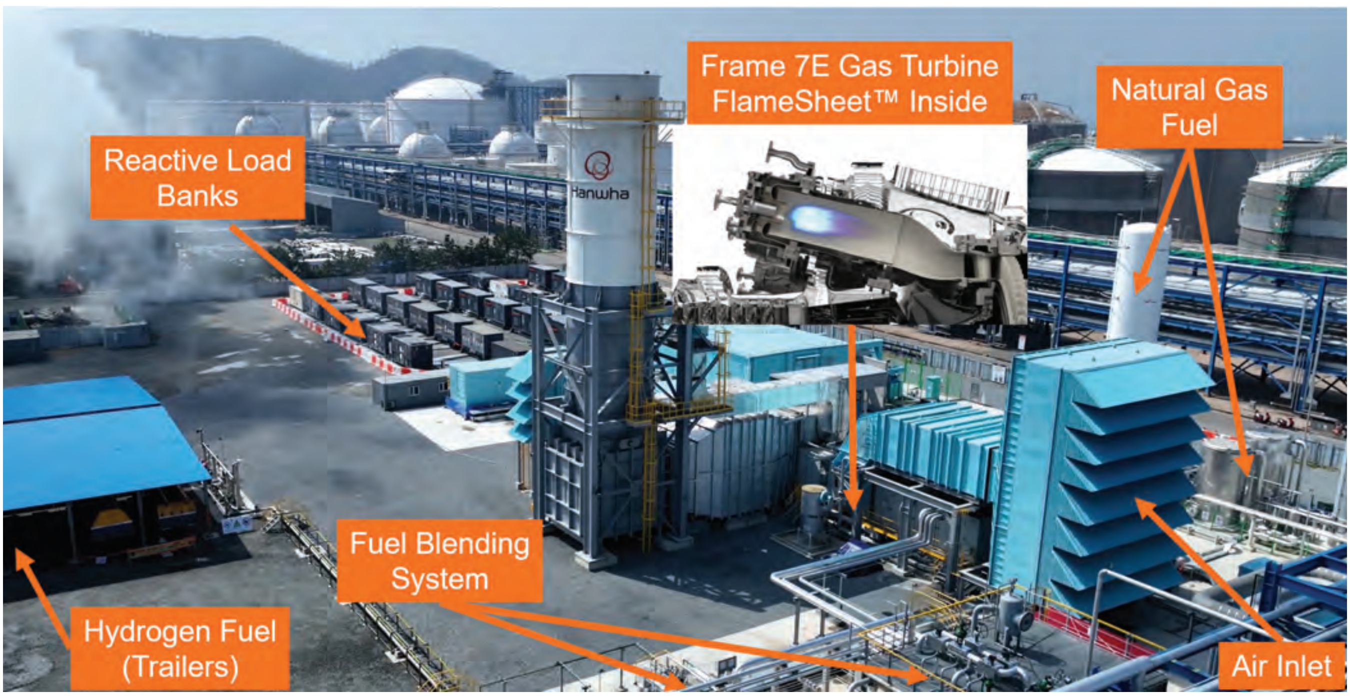
Liburdi Turbine Services
Doug Nagy

Extensive primer covers cold and hot-side turbine components and the coatings used to protect their surfaces, coating deposition and application processes, selection criteria, types of coatings for various locations, compositions and microstructures, as well as advanced technologies, including nano-structured materials, suspension plasma sprays, cold sprays, low conductivity thermal barrier coatings (TBC), and degradation mechanisms.

DECARBONIZING THE GAS TURBINE FLEET: UPDATE OF CURRENT COMBUSTION OFFERINGS

PSM Thomassen Energy
Mark Kooister

Slides review PSM Thomassen's global footprint in services and units, it's strategic plan in providing technology and options for decarbonization, 6B product line, Frame 5 upgrades, waste gas and high-hydrogen combustion technologies (Fig 6), FlameSheet retrofit platform, commercial adoption of H2 retrofits, and scaling challenges with a Frame 5 FlameSheet, among other topics. A 100% H2-fired Frame 5 demo is due to start operating in 2026. CCJ



6. Technologies for H2/fuel gas blend combustion, including a 7E turbine with FlameSheet, are being demonstrated at the Hanwha H2 validation facility

Borescope inspections often more important than ever

Condition awareness is the first step toward outage optimization

With all the sophisticated gas-turbine inspection technologies available today—including ultrasonic, eddy current array, and phased-array ultrasonic—one might think the borescope had lost a step in status.

Nothing could be further from the truth.

Borescope capabilities have improved dramatically over time and they put your eyes right into the guts of critical plant equipment—to warn of existing and impending problems. Mike Hoogsteden, director of field services for Advanced Turbine Support LLC, drove home this point during a recent CCJ interview.

Periodic inspections are highly recommended, he said, because they allow owner/operators to chart gas-turbine condition over time and to identify damage caused by rubs, foreign objects in the gas stream, corrosion pitting, deposits, cracks, coating loss, and component wear, movement, or loss.

Having this information prior to an outage is a big help in planning, budgeting, and scheduling. Plus, some users are using the results of borescope inspections to make condition-based maintenance decisions and dispense with the traditional hours/starts-based paradigm.

Most facility managers would agree that an annual inspection is "table stakes" in the plant reliability game. Hoogsteden's not so sure. That might have been the norm a few years ago, he says. Today, he's inclined to suggest two inspections yearly because of what he calls recent "unusual significant findings" (Sidebar). One inspection would be a "deep dive," the other a "look/see." Think of your dentist here: One semi-annual visit for a cleaning and visual check; the other for x-rays and dental work.

An experienced borescope team, Hoogsteden continued, has a solid value proposition in troubleshooting. It often can identify the cause or causes of such things as high vibration, deviations in exhaust-temperature spread, NOx compliance issues, and unit trips.

Experience is one of Advanced Turbine Support's defining characteristics and why it is widely considered one of the industry's top inspection companies. Powerplant veterans may recall that Rod Shidler and Rick Ginder founded the company 25 years ago (2001) and continue to serve on the front line.

Over the years, the firm's team of more than 20 inspectors has gained the intimate knowledge of the various gas-turbine models—frames and aeros—required to find and characterize problems. Sticking a borescope in a unit and finding blades missing after a catastrophic failure is easy. Locating the failure initiation sites and identifying the symptoms that led to the failure is much more difficult.

Tom Christensen, senior VP, Strategic Power Systems, supported Hoogsteden's assessment of today's equipment challenges in a recent industry presentation. SPS has been gathering powerplant operating data for four decades and well respected for the accuracy of its information.

One of the key themes of Christensen's talk was the increasing demands placed on existing power infrastructure. Over the past decade, he said, powerplants have been required to operate for longer hours because of the increased demand for electric power, delays in new plant construction, and market fluctuations that encourage the maximization of existing assets.

In many cases, Christensen noted, annual operating hours per plant have increased by 20% to 50%, pushing some facilities beyond their original service requirements. This has accelerated the wear and tear on critical components, leading to an increase in forced outages and unplanned maintenance.

Christensen identified several factors contributing to these disruptions, including aging infrastructure, regulatory uncertainty, supply-chain issues, and extreme weather events. He particularly highlighted the growing frequency of transformer failures, turbine malfunctions, and control system breakdowns, which can take months to repair if replacement parts are not readily available.

One of the most pressing concerns he raised was the rising cost and duration of forced outages. Traditionally, maintenance schedules were carefully planned to minimize downtime, but recent industry shifts have made it increasingly difficult to adhere to these schedules. As a result, many powerplants are experiencing prolonged outages—months in some cases—significantly impacting grid reliability and operational costs.

Plant reliability is everyone's concern. It behooves plant personnel to learn as much as possible about their equipment when an inspection team is on-site. An important step in this effort is to review beforehand the OEM's advisories pertaining to the borescope inspections that will be conducted. The list of Technical Information Letters (TILS) for GE 7FA machines that follows may be of help to some readers. It was compiled by colleagues at a major utility and presented at an industry meeting several months ago.

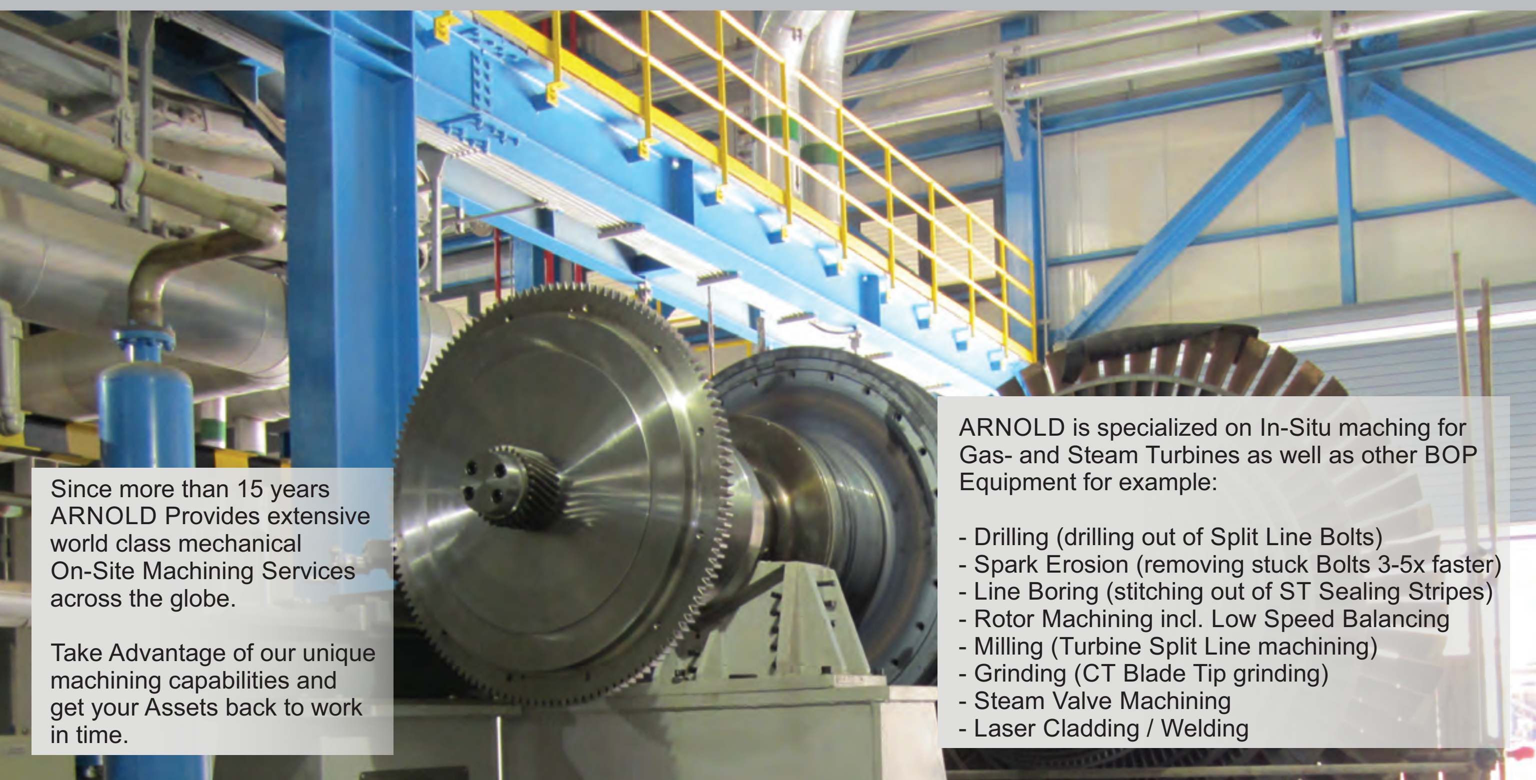
- Inlet section (inlet door)
  - 1794, Water wash nozzle pins
  - 2049-R2, IGV rubbing
  - 1068-R3, IGV bushing migration
  - 1509-R4, R0, S0, and R1 inspection
  - 1796-R1, R0 blade staking
  - 1870-R2, Blade staking
  - 1562, Shim migration
- Compressor plugs
  - 1769, Aft stator rock
  - 1502-R1, Aft compressor rubs
  - 2286, S5 vane inspection
  - 1850-R2, S17 stator bushing
- Lift oil
  - 1582-R2, Lift-oil hose inspection
- Combustor (upper manway)
  - 1850-R2, S17 stator bushing
  - 2423, TP hardware
  - 2302, R1 nozzle bolting
- Combustion
  - 1724-R1, Quaternary fuel annulus
- Turbine plugs
  - 1182-R1, Bucket inspection
  - 2377, R1 damper pin
  - 1108-R1, R1 turbine nozzle
  - 1858, R2 bucket inspection
  - 1859, R2 bucket inspection
- Exhaust door
  - 2343, Exhaust baffle seal

Mechanical On-Site Machining Services

Milling
(e.g. Split Line)

Rotor Machining
(e.g with Low-Speed Balance)

Valve Machining
(e.g. Governor Valves)



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Take Advantage of our unique machining capabilities and get your Assets back to work in time.

ARNOLD is specialized on In-Situ maching for Gas- and Steam Turbines as well as other BOP Equipment for example:

- Drilling (drilling out of Split Line Bolts)
- Spark Erosion (removing stuck Bolts 3-5x faster)
- Line Boring (stitching out of ST Sealing Stripes)
- Rotor Machining incl. Low Speed Balancing
- Milling (Turbine Split Line machining)
- Grinding (CT Blade Tip grinding)
- Steam Valve Machining
- Laser Cladding / Welding

ARNOLD GROUP

UNUSUAL SIGNIFICANT FINDINGS

Advanced Turbine Support's Mike Hoogsteden, director of field services, shared some examples of what he considers "unusual significant findings" identified during recent borescope inspections of GE gas-turbine Frames 5, 6B, 7EA, and 7FA running harder and cycling more frequently because of changes in power-market dynamics.

1. Separated fuel nozzle in 7EA photo A is something that had not been seen previously by an Advanced Turbine Support inspector. Photos 7EA B and C show disengaged and protruding S2 knife seals contacting S2B. In B, the seal is behind the trailing edge of the second-stage; in C, the seal and bucket are in contact

2. Damage here resulted from the failure of a 7FA third-stage bucket. The fix was believed to require a hot-gas-path inspection at a minimum

3. Series of photos shows R17 migration in a 7FA

4. There were seven S17 liberations in this Frame 6B

5. Rotor dropped in this Frame 5 causing extensive compressor damage. A bearing failure was the assumed cause early in the investigation. Photos 5C and 5D, show the large number of seventh-stage stator vanes and rotor blades, respectively, lost in the accident


1A


1B


1C


2A


2B

3A

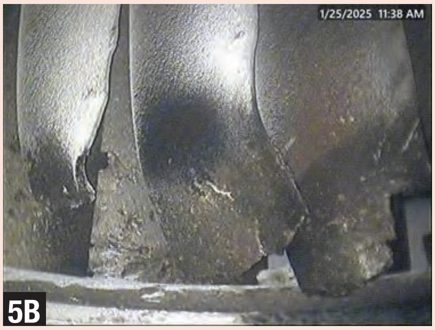

3B


3C


3D


4

5A



5B

5C

5D

2025 Conference and Exhibition
July 21-25 · The Woodlands, Texas

A key element to the HRSG Forum that differentiates it from other user groups…All sessions on all days are open to all Forum participants: users, vendors, consultants and exhibitors. No sessions are restricted but are moderated by Bob Anderson (Competitive Power Resources) and Barry Dooley (Structural Integrity, UK) to ensure fruitful presentation and discussion outcomes. That includes training, a unique blend of practical and academic, on day 1.

CATALYSTS

Monday morning sessions covered CO and SCR catalyst system design, operation and maintenance.

Andrew Toback, Environex, Inc., launched the training day with *SCR and CO/VOC system training – a practical workshop for HRSG operation and maintenance*.

Environex (Malvern, PA) is a team of chemical engineers, scientists and laboratory technicians specializing in selective catalytic reduction (SCR) and oxidation catalysts of all types. They offer expertise in SCR/CO lifecycle management, catalyst testing, catalyst design, ammonia injection grid (AIG) tuning, troubleshooting and specialized training.

Below is a brief overview and selected details of what was covered:

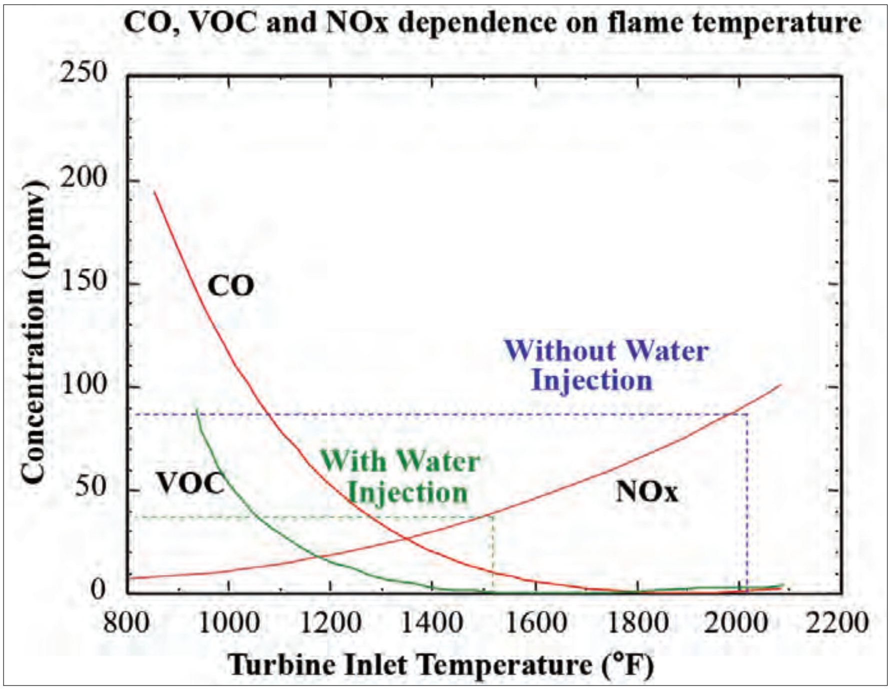
OPERATIONS

Toback began with this: "You are operating a power plant, not an emissions factory. So, let's talk about plant operations."

He first offered a primer on NOx, explaining how it is formed principally when N2 reacts with O2 at temperatures above 2500F during fossil fuel combustion. He added that carbon monoxide (CO) and volatile organic compounds (VOCs) are formed from the partial combustion of carbon-based fuels. When CO competes with VOCs for free radicals, CO wins.

Looking forward, Toback added that formaldehyde is a specific partial combustion product "new on the docket" that is now being studied and regulated (40 CFR Part 60).

He then offered a look (Fig T1) at what he called a "NOx vs CO/VOC tradeoff" explaining how CO, VOCs and NOx are dependent on flame temperature. As he explained, CO and NOx work against each other.



T1. NOx vs CO/VOC tradeoff

This led to a chemistry review, and an interesting temperature chart depicting the fundamentals (Fig T2).

He spent a lot of time on ammonia slip and its relationship to inlet NOx explaining that:

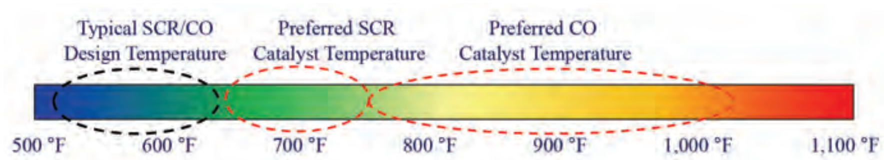
- Higher inlet NOx generates more ammonia slip.
- Ammonia slip limits NOx conversion efficiency.
- Reducing inlet NOx can reduce ammonia slip and increase catalyst life cycle.

Therefore, turbine exit NOx matters. Again, the fundamentals:

- Higher turbine exit NOx emissions need more complicated SCRs.
- Ammonia distribution (grid) operation and maintenance are critical to meeting permit levels.

He then turned to alternative fuels and today's hot-button topic, hydrogen, along with renewable natural gas. Problem areas include:

- Hydrogen:
  - Transport (higher leakage rate than natural gas).
  - Storage concerns.
  - Higher combustion NOx.
- Renewable natural gas:
  - Issues with transport.
  - Siloxanes that can poison both SCR and CO catalysts.



T2. SCR/CO temperature profile

PIC
PRECISION ICEBLAST CORP

info@precision-iceblast.com
(906) 864-2421
www.precision-iceblast.com

INDUSTRIAL CLEANING, COATINGS & SURFACE PREPERATION

Our Mission

Our mission is to drive ROI and improve key performance indicators that matter most to power plant managers and stakeholders.

Through our patented, proprietary HRSG cleaning solution, we capture over 90% of power-robbing scale, significantly boosting power output while reducing downtime. We are committed to maximizing plant efficiency, extending equipment life, and minimizing energy input, helping plants operate at peak performance with measurable results.

Delivering industry leading ROI thorough our proprietary deep cleaning

Our proprietary method reaches 95% of the heat transfer surfaces, Lowing back pressure, increasing efficiency and improving power output.

Minimizing downtime and operational disruption

PIC's cleaning requires minimal involvement from plant staff and significantly reduces downtime compared to other methods, allowing for more operational hours.

Extending HSRG unit lifespan

PIC's cleaning ensures less wear and tear on equipment, increasing the lifespan of the towers and reducing the need for frequent cleaning or costly repairs.

PIC's HRSG Deep Cleaning™ Dry ice blasting technology combined with patented deep cleaning tools, ensuring:

- No secondary waste generated.
- Safe, easy cleanup with no damage to pressure parts.
- No risk of CO2 buildup- 30 years with zero safety concerns.

Back Pressure Reduction

Achieve at least a 50% reduction in back pressure, with many clients reporting **80 - 90% reductions.**

Improved Heat Rates

Significant drops in heat rates, with reductions of up to **300 BTU/kWh.**

Emission Reduction

Reduced plant emissions by lowering NOX and CO2 output by thoroughly cleaning all the heat transfer surface area allowing for optimal absorption of the flue gas resulting in **cleaner exhaust emissions.**

Increased Turbine Output

Boost gas and steam turbine output, with some clients reporting **35 MW** post-cleaning.

Before

Before cleaning 8th row of tubes

After

After cleaning 8th row of tubes

30 + Years Delivering Unbeatable ROI

Gas Turbines

PIC proven dry ice blasting is a highly effective method for cleaning gas turbines offering numerous advantages over traditional cleaning techniques.

Catalytic Reduction Natural Gas Plant SCR/CO units:

High-Volume low-pressure air lancing and vacuuming thoroughly removes rust , insulation ammonia salts from honeycomb catalyst in natural gas SCR/CO units. Delivering exceptional ROI through optimal efficiency.

Boilers, HRSG Units, and Heat Exchangers

PIC's dry ice blasting service provides a highly effective and non-invasive solution for removing stubborn deposits in boilers and heat exchangers. This method uses dry ice pellets that sublimate upon contact, breaking down tough buildup without damaging sensitive surfaces or generating secondary waste. This approach keeps boilers and heat exchangers operating efficiently, minimizing downtime and extending the lifespan of critical components

Generators & Substation Equipment

Generators and Substation equipment are highly susceptible to contamination from dirt, debris, and residues, leading to critical operational issues.

- Circuit breakers
- SCR/CO catalysts
- Compressors
- Field frames
- Insulators
- Rotating equipment
- Rotors
- Silos
- Hammer mills
- ID fans
- Inlet cooling houses
- Thermal oxidizers

30 + Years Of Experience

Founded in 1993-1088 HRSG

Units cleaned, across five continents and thirty countries. Greatest Megawatt recovery of any method or company

Stellar Reputation

Our success is wholly based upon delivering, on time, on budget, we do so safely with zero environmental impact and minimal disruption for our clients.

We Stand Behind Our Work

As a leader in numerous markets with an impressive client list. We understand that we succeed because we deliver for our customers.

Proprietorial & Patented Technology

Precision Iceblast is proud to be the world leader in dry ice blast cleaning. We invented and built our best-in-class equipment, no other company can deliver comparative results because no other company has our equipment.

Resources & Reach

PIC has a large pool of well-trained and experienced crew members and the largest fleet of dry-ice blasting machines in the industry to tackle any size project in any location. We are completely self-contained and do not burden customers on job sites.

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He added that ammonia itself is considered a fuel, but produces high NOx and requires significant retrofit to the SCR system.

Toback then reviewed dual function catalyst configurations, pros and cons.

This was followed by factors that lead to non-ideal catalyst performance including non-uniform distribution and catalyst poisoning. "The most important factor," he said, "is the distribution of ammonia to NOx."

More specifically, plant operations leading to non-ideal performance include moisture exposure (some catalysts), poor or damaged seals, poor ammonia control, bypass, and load changes. "Low loads can reduce catalyst life," he said. Catalyst deterioration factors include poisoning by K, As, Na, Ca and SO2; fouling by dust or insulation; and thermal phase changes.

He also covered duct burner impact and offered field experience on turndown.

CATALYST TESTING AND LIFE CYCLE

This section offered helpful visuals on how catalysts deactivate, with the following caution. "By the time you see ammonia slip escalate, it's too late. You need periodic inspection and core sampling," he said.

Catalyst core sampling has both pros and cons:

- Pros:
  - Can be taken directly from bulk catalyst.
  - Multiple sample locations possible.
  - Works with any honeycomb catalyst
- Cons:
  - May not follow vendor's guidelines.
  - Ladder or scaffolding required (Fig T3).

T3. Core sampling requires ladder or scaffolding for access

He stressed the benefits of multiple sample testing.

He then reviewed commercial CO catalyst designs and plugging issues, including platinum migration.

This ended with a discussion about on-site rejuvenation of oxidation catalysts: wash catalyst modules, rinse clean, dry without damaging wash coat, and reinstall.

Questions at this point covered outage times (including CO catalyst wash), locations of core sampling, sampling frequency with cycling operation, and specifics of ammonia slip calculations.

MAINTENANCE

Ammonia system maintenance covered the flow control unit, riser deposits, and plugging of grid and nozzles.

He began by stating that the vaporizer is the alarm, but rarely the root cause. With hot gas recirculation (HGR) or electric heaters, the sizing margin is tight to reduce parasitic load. When the ammonia flow exceeds design, the heat is not available to vaporize the ammonia and water.

He then stressed monitoring for elevated ammonia flow, which can be caused by one or more of the following:

- Bypass around the catalyst.
- Insufficient catalyst activity (poisoning or a high temperature event).
- Masking/fouling of SCR catalyst face.
- Injection grid plugging.
- Poor distribution.

As he explained, injection grid cleaning reduces backend cleaning frequency. Optimizing the ammonia-to-NOx ratio reduces ammonia slip and the resulting ammonia salts downstream.

SCR catalyst maintenance and troubleshooting began with a review of catalyst types, elements and geometries. Catalyst seals and allowable bypass followed, along with a discussion on additional sealing to minimize bypass. Catalyst plugging and some effects were reviewed including:

- Increased backpressure.
- Performance loss due to fouling/plugging.
- Possible catalyst shifting.

This ended with a discussion on SCR catalyst cleaning to reduce backpressure and increase system efficiency.

The bottom line: Catalyst cleaning lowers pressure drop and increases fuel economy (Fig T4).

"Every inch of backpressure is megawatts you are losing," he stated. A secondary benefit of clean catalysts, he added, is reduced tube cleaning.

He concluded with an overview of ammonia injection grid tuning, including the pros and cons of permanent AIG grids and vertical probe ports.

Questions covered a variety of topics including restoration of old catalysts, the trend toward gluing blocks together, and on-site storage of catalysts for future use. One interesting point: storage can have an impact on warranties.

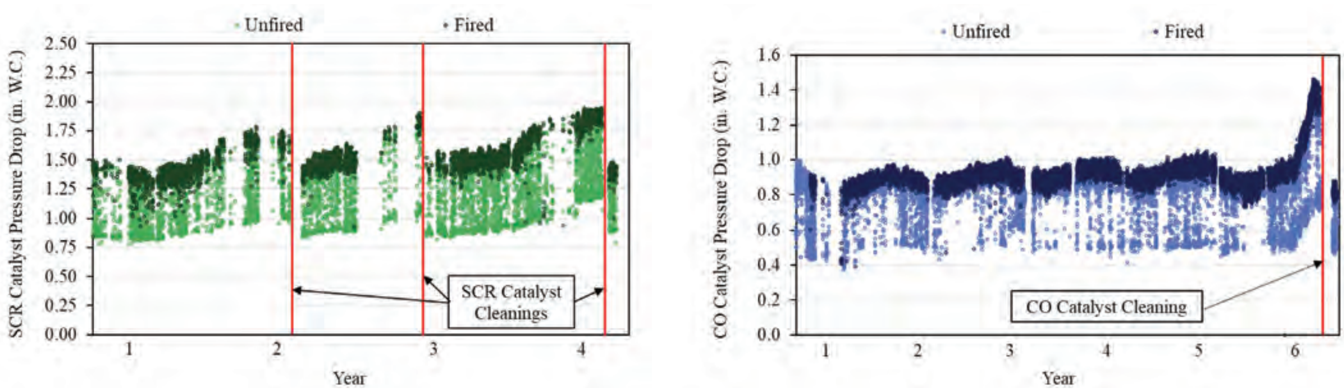
BOILER FEEDWATER PUMPS

Loyal Fischer, KSB SupremeServ North America, offered a two-part class on feedwater pump fundamentals (Part 1) and boiler feedwater pumps (Part 2). This topic had been suggested at HRSG Forum 2023. Barry Dooley stated immediately that this topic was a "first-of-a kind at these industry conferences, even globally."

Fischer began with a "useful review" of high-energy pumps, including a primer on fluid dynamics.

Centrifugal pump design history dates back to the late 1860s, in Germany, and Fischer took us through the development and use of various pump types and designs, then focused on centrifugal pump types while interjecting the fundamentals of conservation of mass and energy, including conservation of linear and angular momentum for these "kinetic energy machines."

He then took a deep dive into various centrifugal pumps, performance curves, volumetric losses, and system efficiency.



T4. Catalyst cleaning decreases total backpressure


umicore
Catalysis
Smarter catalysts: two in one
Better emissions compliance
Clean air is our business. The GTC-802 (NOx/CO-VOC) "Dual Function" catalyst will help your plant meet stricter emission standards while improving performance and profitability. **GTC-802 combines two catalysts in one, delivering both superior NOx reduction and outstanding CO and VOC oxidation.** Lowest pressure drop, near zero SO_2 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

Part 2 was specific to boiler feed pumps for combined cycle plants, covering types, designs, operation, installation, maintenance, and repairs.

He posed the question: "What are the two most important consideration for selecting a boiler feed pump?"

- Reliability:
  - Pump construction.
  - Installation.
  - Operation.
  - Maintenance.
  - Support from the OEM.
- Cost of reliability:
  - Energy (net present value).
  - Price.
  - Repair costs.
  - Lost opportunity cost.

An interesting point: "Pump installation and startup is the highest risk point in the life of the pump," he said. "Proper operation has a big impact on the life and maintenance requirements" going forward. He also recognized "support from the OEM (Fig T5)."

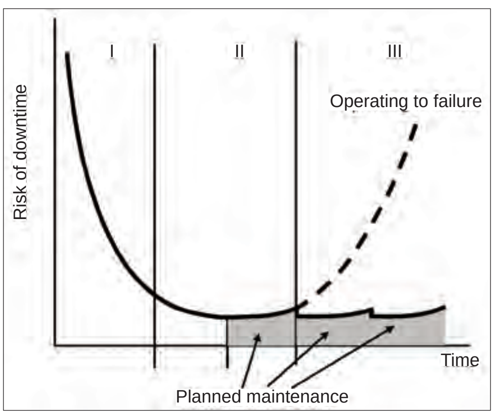
Fischer then focused on the types of multistage pumps (Figs T6-T8):

- Horizontal split design (BB3).
- High pressure ring section (BB4).
- Barrel pump design (BB5).

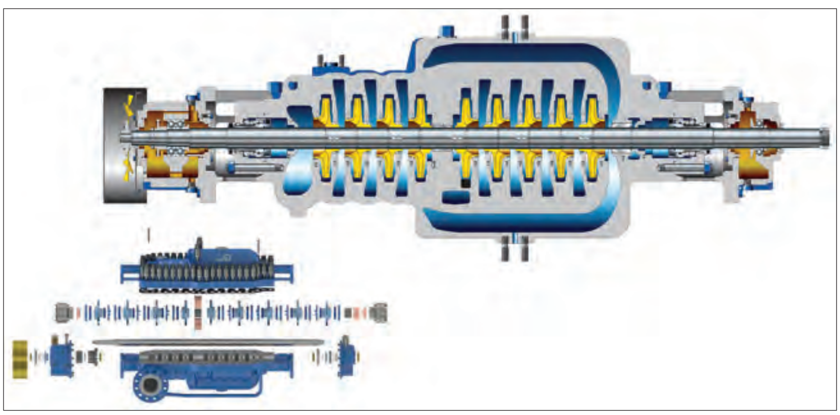
Ring section and barrel pumps can be nearly the same, he explained. Both can share the same bearings/balancing, stage casings/hydraulic performance and pressure range. The difference – the barrel has cartridge removal. Ring section is the most common boiler feed pump design in the U.S. for combined cycle plants.

Fischer launched into design details including hydraulic design (shaft, diffuser and impeller), multistage pump casings, and impeller and diffuser vane combinations, including manufacturing tolerances.

He then covered casing wear rings (standard and profiled), rotor support, and bend lines.



T5. Reliability over time boiler feed pumps



T6. Horizontal split case pump (BB3)

He followed with "gravity and sagging of rotors," and adaptation to the shaft bend line (Fig T9). "The adapted casing," he said, "keeps the rotor within its clearances which reduces contact during startups and shutdown."

Axial thrust balancing and balance disc wear were next, followed by bearing systems and seals.

Questions at this point included coal vs combined cycle use, upsets during turbine cycling, reasons for losing pump pressure over time, and pump exterior flow losses.

Casing discussions covered forged vs cast casing components and ring section and barrel casing designs.

Operating flow rates and their impact on pump reliability were discussed including zero flow, low flow and hot shutdown, with specific examples and details. "Zero flow can destroy a pump in seconds, and operation at low flow will cause chronic and premature pump wear," he said.

Installation discussions covered critical speeds, pump and driver alignment, and nozzle alignment.

Selected details: A solid foundation is fundamental, and it is best to align at ambient temperature based on calculated thermal growth.

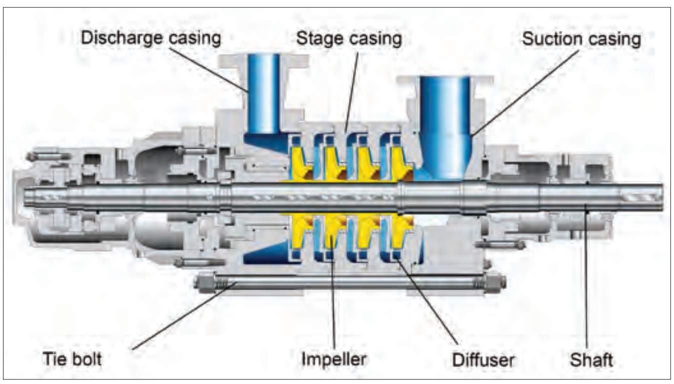
For maintenance, in the samples shown, Fischer pointed out that all wear parts except casing wear rings are easy to access. This allows easy replacement of shaft seals, bearings, and balancing devices.

For checking wear parts during on-site maintenance (Fig T10), Fischer discussed:

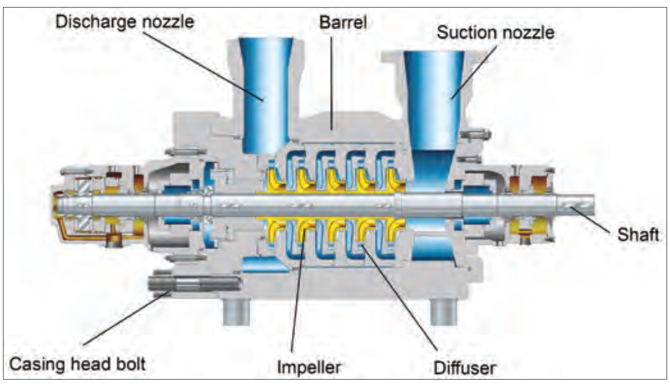
- Lube oil, cooling, vent and tapping piping removal.
- Bearing removal.
- Shaft gland and mechanical seal removal.
- Rotor lifts to check internal clearances.
- Removing casing nuts/lifting cover.

Repair problems focused on incorrect third-party material composition (improper heat treatment) and sagging issues.

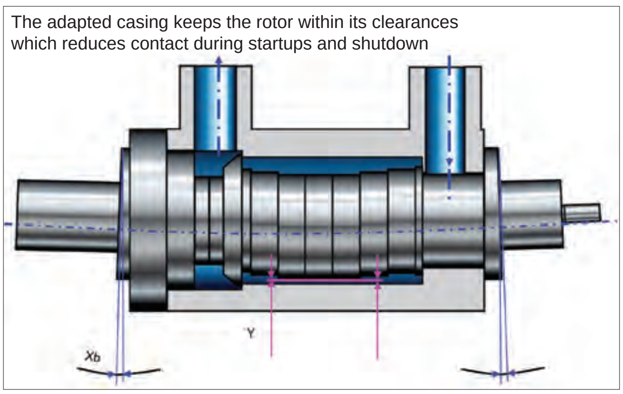
His bottom-line recommendation: Read your manual, and work with the OEM.



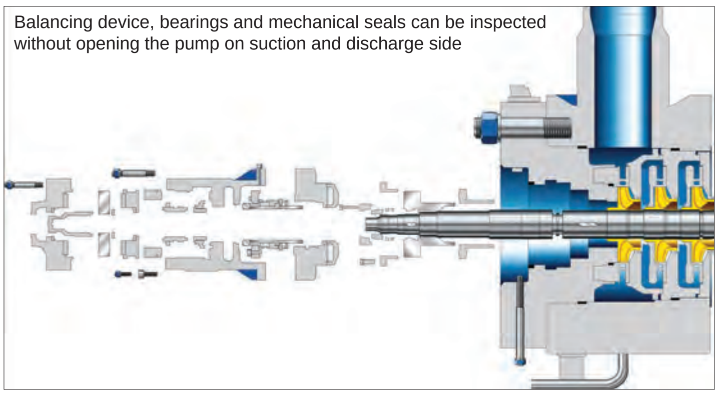
T7. Ring section design (BB4)



T8. Double casing barrel pump (BB5)



T9. Adaptation to the shaft bend line



T10. Checking wear parts

HRSG FORUM GENERAL SESSION COVERS ALL THE BASES

Following the first day of training on catalyst systems and boiler feed pumps, conference sessions began on Tuesday with opening remarks by Anderson, who introduced co-chair Dooley and the steering committee.

The 300 attendees represented end users/operators, HRSG manufacturers, service providers, specialized consultants, and a wide range of equipment designers and fabricators.

Anderson stressed the following: "At this year's event, unique to North America, you will find a balanced combination of presentations that provide practical information, question and answer sessions, and facilitated spontaneous discussions on issues of interest. You will learn more about HRSGs, how to maintain and operate them better, how to improve their design and performance, and you will share your own expertise and experiences with others."

This was only the second in-person event since the impact of Covid-19. Noting the alignment with HRSG forums in Europe and Australia, Anderson announced that 12 countries were represented this year in St. Louis, and more than half the participants were attending in person for the first time.

The HRSG Forum requires no membership or credentials, just an interest in learning more about HRSGs and their operation.

Selected presentation highlights for days two and three follow.

THE DEMAND FOR POWER

A recurring topic in presentations and discussions was the growing demand for power, both in the US and throughout the world.

Peter Van Allen, project manager at Arizona Power Service Company (APS), offered a concrete example of owner/operator programs to keep the power flowing. His agenda topic: *HRSG considerations and analysis before GT upgrade*.

He began by highlighting the massive electricity demand growth in Mariposa County, AZ, driven largely by the booming computer industry. "One new operating data center is the same energy load requirement as operating 300 Walmarts," he explained. Mariposa County has seen some of the highest annual population gains in the US since 2016, and coal plants in his state will be retired by 2031.

Along with this growth, he stated, "extreme weather has become the norm. In 2023, Phoenix experienced 55 days above 100F." He reminded participants that existing combustion turbines can derate on extremely hot days.

"Therefore, current and long-term electric reliability is paramount," he continued. "We have 8000 MW of new resources in the near-term action plan and more than twice that over the 15-year planning horizon. Natural gas is a critical part of this energy program."

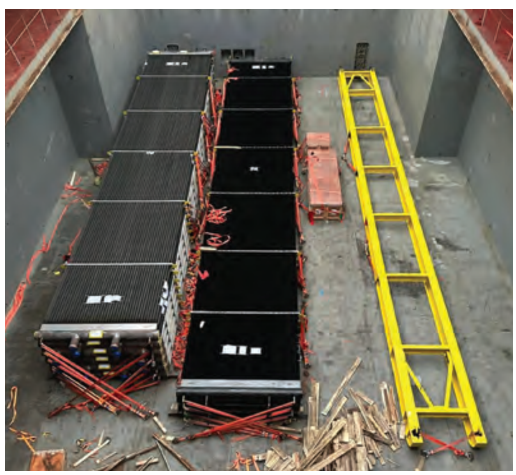
Case history *West Phoenix CC5 thermal performance upgrade project*, recently back on line.

The objective: 55 MW capacity increase for the 5A and 5B combustion turbines (Fig GS1). Scope included HRSG and other balance-of-plant improvements to support these CT upgrades.

Greg Rueff, Vogt Power International, joined to discuss the HRSG work details. Work packages included:

- Heat transfer components – 28 harps (Fig GS2).
- Harp structural supports.

GS1. West Phoenix CC5 power block



GS2. Harps loaded into bulk vessel for transport

- Cold reheat piping and flow elements.
- Gas baffles.
- Steam drum separators.
- Duct work casing, liners and insulation.
- HRSG piping.
- Attemperators (resized).
- Valves (safety, control, IP)
- Drain pots.

Project benefits included:

- Final 58 MW increase.
- Increased mass flow to HRSGs.
- Turbine NOx reduction from 20 to 10 ppm (reduced ammonia consumption).
- HRSG backpressure reduced by 6 in. WC (largely by blast cleaning).

Presenters ended with the topic "How to rerate a boiler" and had a strong suggestion for owner/operators facing such a project challenge: "The Authorized Inspector is an important part of the team," they stressed.

Questions/discussions reviewed installation details, new component design life, and carryover testing frequency.

MEGA TRENDS

Tom Freeman, GE Vernova, also highlighted increasing demand as he discussed "Mega Trends" in what he called "The great awakening: Make my plant run to 2065."

In an interesting industry overview, Freemen walked through the four primary mega trends of load growth rate, asset age, decarbonization, and grid emergencies. He explained that we are now in a third gas turbine industry bubble (the last was 1999 to 2005).

Quoting Scientific American and others, he continued: "The dawning Artificial Intelligence boom could use a shocking amount of electricity."

He then offered the example of *Buying a Ford F-150*. Each Google search can use 0.3 watt-hours of electricity, he explained, such as a search for: "What is the appeal of a Ford F-150 truck?"

Using ChatGPT4 for "What about Ford F-150 trucks for post midlife individuals living in the suburbs?" uses 3 watt-hours. Creating an image (ChatGPT4) of a person contemplating buying a F-150 truck consumes 10 watt-hours.

His message: More computer thinking means more energy consumed. We can't build power generation fast enough, and interconnect (grid) issues for PJM and ERCOT are staggering."

MORE CYCLING

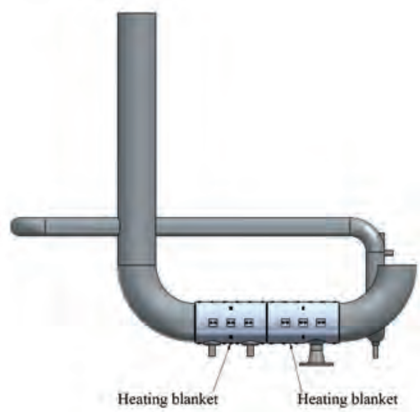
Prewarming system options for startup was presented by Joe Schroeder, J.E. Schroeder Consulting.

A cooperative team of Bob Anderson (Competitive Power Resources), Schroeder, Norm Gagnon (Arnold Group), Eugene Eagle (Duke Energy), and Bill Carson (EPRI) has been studying methods of reducing temperature and pressure issues of system startup using warming systems.

He began with a turbine heating blanket overview.

He then added downcomer heating blankets stating that "electrical heating offers several advantages over steam sparging" and discussed a specific field trial at Duke Energy (Fig GS3).

Eugene Eagle, EPRI, joined to review testing and results.



GS3. Testing of an HP evaporator heating blanket

Selected summary details:

- The test proved that downcomer heating blankets can maintain drum pressures and keep the unit in a warm standby condition.
- Heater installation was quick and simple.
- Adding heat to HP, IP and LP evaporators may be better than adding to HP alone.
- The tested unit had less severe tube differentials and no large quenches or tube temperature down shocks during startup compared to the unheated twin unit.

One summary point: control panels were installed as a temporary system, operated locally at the HRSG. This demonstrated that the concept would work, and calculations for heating requirements were accurate.

A large, permanent power supply for these warming systems will be required. Analysis is ongoing and a final report is pending.

Questions/discussions included project duration (5 days), use of thermocouples, heater design life (20 years), stack temperature profile, and impact on relief valves.

THERMAL TRANSIENTS AND CHEMISTRY

Barry Dooley provided global updates on both thermal transients and system chemistry, noting that failure mechanisms keep happening although they are clearly understood.

He offered his list of repeat cycle chemistry situations that he has closely monitored since 2008. Stressing the commonality, he noted that these situations and damage details are based on operations, not on a particular HRSG OEM.

Chemistry impact on HRSGs can fall into some general categories:

- Chemistry-influenced tube damage and failure mechanisms.
- Corrosion product transport.
- Steam turbine deposits/damage/failures.

He then focused on single-and two-phase flow accelerated corrosion in combined cycle/HRSG plants, and ended with a detailed list of Technical Guidance Documents available at no charge through The International Association for the Properties of Water and Steam (IAPWS).

During discussions, Bob Anderson, who works with Dooley on these surveys, added an interesting comment: "Tube-to-header failures are generally caused by thermal events, not by manufacturing errors. Metallurgical analysis of the failure site is critical for finding the failure mechanism needed to determine the root cause."

HYDROSTATIC TESTING

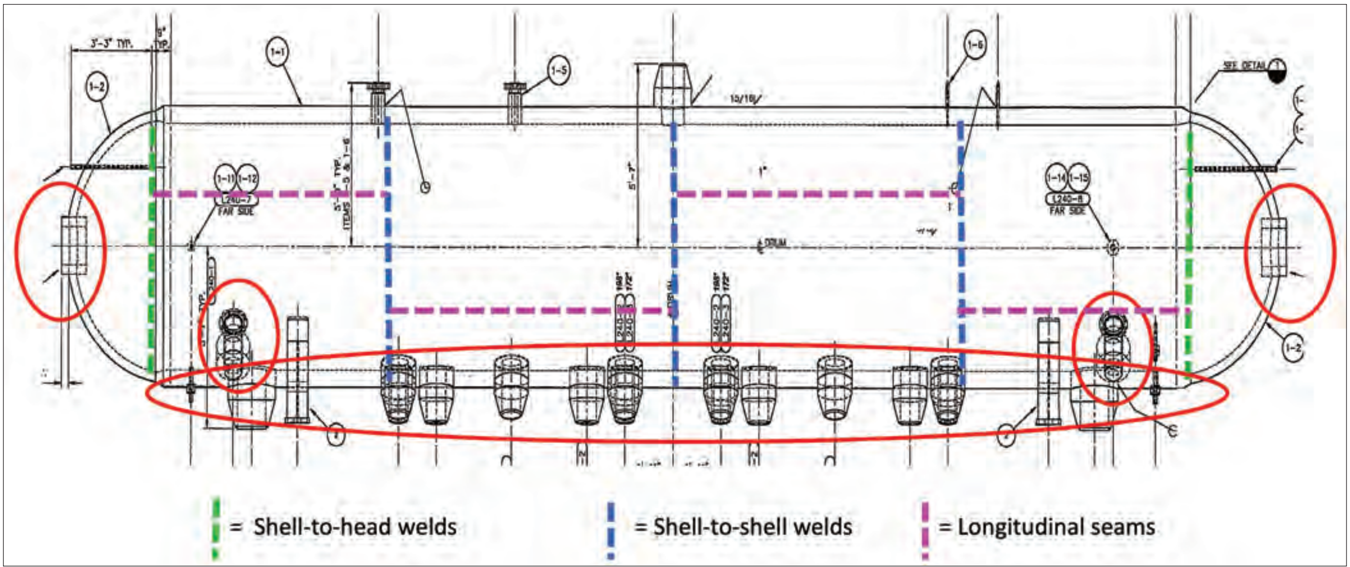
Ian Perrin, Triaxis Power Consulting, focused on *Hydrostatic testing: what, why, and when?* This topic was first discussed at the most recent EPRI Boiler Reliability Interest Group (BRIG) meeting in December 2023.

Hydrostatic testing (aka hydrotest) is system pressurization with water (an incompressible fluid) to test for workmanship, leaks, strength and system integrity. It is governed by ASME Section 1, PG-99, and is traditionally part of the commissioning process. The standard is 1.5 times the maximum allowable working pressure (MAWP) of a system.

An important note: Post-commissioning at less than 1.5 times MAWP is a pressure test, not a hydrostatic test. The terms are often mis-applied. Normally, pressure testing is below 1.5 MAWP and is often below operating or working pressure.

Perrin then cautioned that there are numerous "myths" about hydrostatic testing, which he labeled "Nonsense you can read online."

One example: "The Claim: Pressure or hydrostatic testing will allow for determination of remaining useful service life, or continued safe service life." This is a myth, suggested Perrin. "Hydrostatic testing or pressure testing tell you absolutely nothing about remaining useful service life, fitness for service, or continued safe service life," he stated. He added that "very large cracks can pass hydrostatic testing but may propagate in service (due to fatigue or creep)."



GS4. Nozzle and shell weld cracking

Thermal-stress-driven failures will not be addressed or detected.

Most HRSG damage issues are from thermal events, and locations of high thermal stress may not coincide with locations of high stress due to pressure.

Perrin offered past examples of catastrophic failures that have occurred during 1.5X hydrostatic testing.

Post-commissioning, your authorized inspector (AI) may require a 1.5X hydrostatic test, but this is not recommended, he concluded.

A lot of interesting discussion followed including use of flaw grooves for testing (ID and OD), ultrasonics in lieu of hydro, magnetite fracturing, chemical cleaning, 1.5 hydro on low pressure boilers, lack of industry standards on pressure testing schedules, acoustic listening devices, and jurisdictional rules and inspector approvals.

INSPECTION AND MAINTENANCE

Jeff Henry, Applied Thermal Coatings, offered *The value of metallurgical analysis of failures*, or how to extract the necessary information from an analysis to support plant operation. Access the nearby QR for more detail on the topic from Henry's HRSG Forum 2023 welding workshop.

Proper metallurgical analysis is "an important component of any root cause investigation," he stressed, "and is necessary to prevent repeat failures."

Done properly it provides information regarding both primary and secondary damage mechanisms. It explains the damage within the context of equipment operation so that the root cause analysis can focus on information relevant to the failure sequence, avoiding unproductive diversions into non-relevant issues.

"The failure analysis is not the root cause analysis," he explained. "It is a critical component of the RCA."

Going deeper: "It is not just the academic background of the analyst that is important – if, at some basic level, the analyst does not understand how the equipment was designed, how the component was manufactured and how the system in which the component was installed was intended to operate, then it is unlikely that the results of the analysis will be of any real benefit to the plant in preventing future failures."

Discussions included the value of knowing the sample location, and improper assumptions of oxygen as a cause for failure.

Lester Stanley, HRST, then offered *Drum weld inspection experience and lessons learned.*

Stanley raised two key points (among others):

1. On-off cycling creates stress in thick pressure parts due to the thermal transients within the components (e.g. HP steam drums).
2. Searching for drum weld cracks often results in stress on the people involved, expensive repairs, and missed planned outage dates.

GS5. PAUT is performed to size the cracks and determine the depth

He first focused on steam drum locations to inspect (Fig GS4) for nozzle and shell weld cracking, outlining the principal areas where stresses occur: downcomers, risers, manway rings, and shell-to-head welds, among others.

He then walked through some visual and phased array ultrasonic testing inspections (Fig GS5), critical crack size assessments, monitor/repair decisions, and a variety of lessons learned.

Stanley's summary:

- Perform thorough HP drum weld inspections to catch problems early.
- Complete pre-outage drum shell ASME minimum wall thickness calculations.
- Perform "Critical Crack Size" analysis of the larger HP drum welds.
- Plan ahead for drum internals surface preparation actions.
- Develop a precise drum weld inspection map to keep track of findings.
- Utilize critical crack size graphs to make fast decisions on "repair or monitor" if weld cracks are found.
- Carefully document the location, size and depth of cracks, especially if the cracks are adjacent to other cracks, due to interaction concerns.

Questions/discussions included weld prep cleaning, quantitative predictions, inspections above and below the water line, inside vs. outside inspections, informing the jurisdictions, weld repair experiences, chemistry monitoring, and knowing the geometry.

Stellite Richard Laukam, Valv Technologies, presented *Avoiding Stellite® delamination in high temperature steam valves.*

Laukam gave an informative overview:

1. Much work by EPRI and others has been put into researching the phenomena of delamination of hard-faced weld overlay (HFOL) Stellite in valves for steam.

2. Separation into layers has been observed in valve components at the Stellite/steel interface and in the weld dilution zone formed between the steel and clad.
3. Ultimately, disbanding/liberation/delamination of the weld hardfacing from the valve body occurs, resulting in collateral damage to components in the plant.

This topic would be continued by EPRI during Day 4 of Forum 2024.

Common delamination areas are high-pressure stop and unit isolation valves and hot reheat isolation valves.

The principal concern is turbine damage caused by foreign objects (Fig GS6). In the worst cases, Stellite pieces find their way to the steam turbine, causing turbine blade and other damage (12,000 to 80,000 hours).

He offered a case study of in-situ repair for reducing delamination. The recommendations:

1. Qualify a proper welding procedure.
2. Apply a butter pass of Nickel Alloy 625 to the substrate, separating Stellite and F91 material and preventing formation of an undesirable metallurgical condition in the weld zone between the two metals.
3. Properly control the heating and cooling during the welding process.
4. Thoroughly inspect the freshly welded area with periodic inspections during outages.

And how can delamination be avoided?

He explained that chromium carbide is becoming an option over Stellite. This has the potential to perform better, especially with the coming higher operating temperatures.

He also covered valve seat and disc designs and offered positive results for a 700 MW combined cycle plant operating for 10 years with 2500 cycles.

Discussions included castings vs. forgings, procedures for both, fatigue cracking, and cycling guarantees.

Robert Russell, Veolia, discussed how a *Power plant optimizes influent water treatment by changing the coagulant* (for improved demineralizer operation).

He outlined the steps involved in influent clarification: coagulation (neutralizing electrical charges), flocculation (bringing destabilized particles together), and sedimentation (settling to the bottom of the clarifier).

His case study was a field application at a northeast US combined cycle plant, highlighting increased filter throughput, direct chemical costs, and related savings including sludge/landfill reduction by 50 percent. Coolers also now run with lower conductivity water, translating to cleaner combustion turbines.

Details included particle destabilization, testing, and the impact of seasonal variations.

Discussions included dissolved vs. suspended solids, reverse osmosis vs. polishing systems, and evaluation of source water conditions.

Mike McCartney, Shell, offered *In-service steam leak mitigation* in a petrochemical steam system. Such systems, he explained, often use a common steam source that is distributed throughout many operating units for varied purposes. In a refinery operation, this can include hundreds of miles of piping and associated equipment, and unit operation in one area can impact operating decisions throughout the facility.

He went on to explain the common leak repair methods of crimping and clamping, with direct references to ASME PCC (pressure equipment and piping) Articles.

ASME and owner/operator policies govern the use of crimping and clamping, McCartney explained, and some leaks may be extremely complicated. Both piping size and location matter. Metallurgy is also a critical factor, as is thermal expansion during operation. He offered various application examples.

His base message: safety is paramount, and is "the ultimate decision driver."

Discussions included similarities of boiler failure mechanisms, condensate issues, and resource limitations on site.

REPLACEMENT PARTS

Viking Vessel Services' Marshall Hicks and John Null provided an interesting update on the product known as Tuff Tube Transition and related solutions for tube repairs and replacement header installations. The topic: *TuffTube update: Regulatory acceptance and header replacements.*

The purpose: More than 90 percent of HRSG tube failures occur at the tube-to-header connection, in the heat affected zone (HAZ) of the tube (base metal), at the toe of the weld. See Fig GS7. The Tuff Tube Transition (TTT) product line now includes the Tuff Tube Header Connection (TTHC) shown in Fig GS8.

The product provides a 40 to 60 percent stronger tube-to-header connection in HRSG boilers (based on FEA analysis) and an estimated 50 percent savings in project downtime over conventional installations. US and international patents are pending.

The new Viking Vessel product line also includes the Tuff Tube Purgeless Sleeve (TTPS) shown in Fig GS9 for tube-to-tube connections featuring self-aligned fit-up, elimination of butt welds, and no requirement for radiographic testing.

Hicks and Null also discussed the Tuff Plug for purge-free pipe and tube terminations.

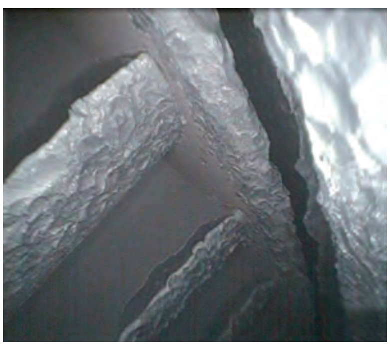
Case study On a recent project, more than 150 tubes were removed to address tube-to-header failures at the center of the tube bundle. Using TTPS eliminated the need for 150 butt welds and radiography, and all welding was completed in 2.5 shifts. Summarizing, "In this emergency repair, the TTT product line allowed the plant to save up to three weeks of down time."

"The TTP HIP (Header Integrity Program) is our engineered solution for replacing old, damaged headers," they explained. "Most HRSGs in the US are more than 20 years old and have been heavily cycled, far beyond OEM recommendations. TTHC-lined headers can be installed in as little as 10 percent of the time it would take to install a conventional stubbed header.

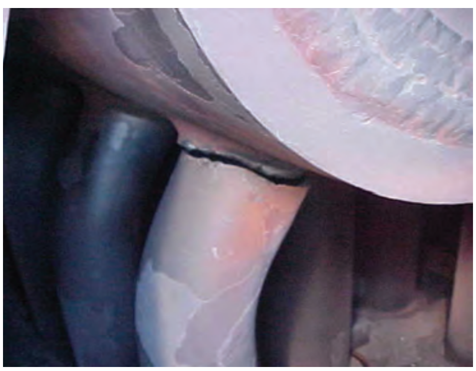
They offered a case history for three RH1 lower headers, removed and replaced with TTHC-lined headers. The complete removal and install took only four days, providing an estimated 85 to 90 percent savings in downtime for the plant.

These headers (See Fig GS10) were manufactured using the GTAW welding process.

As this is fairly "new" technology, a number of questions and interesting discussions followed including discussions on water-touched versus steam-touched tubes, flow disruptions, tube dimensions and wall thicknesses, condensations issues, and the

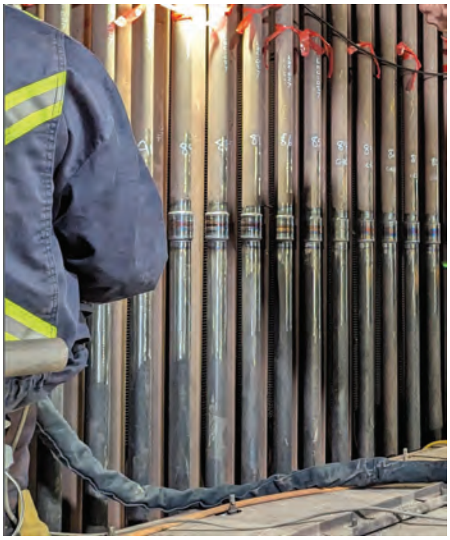


GS6. HP steam turbine blade path damage caused by liberated Stellite



GS7. HRSG Tube separated from header

GS8. TTHC connection on location



GS9. Tube-to-tube connections on site

GS10. TTHC header in shop

heat affected zones.

VALVES

IMI's Ory Selzer then presented *Specifying replacement bypass valves*. The fundamental: A turbine bypass is a steam conditioning system that reduces pressure and temperature while bypassing the steam turbine.

In a typical combined cycle plant, this includes valves for:

- High pressure (HP) to cold reheat (CRH).
- Hot reheat (HRH) to condenser.
- Low pressure (LP) to condenser.
- HP to condenser.

Common reasons for replacement are unreliability (noise, vibration, failures), age (materials and lack of maintenance support, particularly P91 from the early 2000s), or a gas-path upgrade (capacity increase over original design). The greatest challenge to pumps is thermal transients.

Selzer discussed design conditions including high pressure drop, sizing and operation, shutoff/actuation, and temperature compensation.

He added: Don't assume in-kind replacements are appropriate. Any plant changes could require updates.

For replacements, he recommended:

1. Use a proven upgrade design with a large installed base; demand reference list with at least five years of operation experience.
2. Avoid complex valve internals with an excessive number of parts that can fail; simple trim design is better!
3. Make sure you have a serviceable valve with a removable seat (quick change).

He then offered various supporting case studies and stressed the increasing occurrence of "non-OEM parts failures."

Discussions included inspection frequency, turndown operations, the dangers of forced cooling, fast startups, and operations during lead and lag unit starts.

Jeroen Bakker, Advanced Valve Solutions, offered a review of challenges associated with *HP bypass valves in cycling power plants*.

His overview: In base-load operations, HP bypass valves traditionally served specific functions:

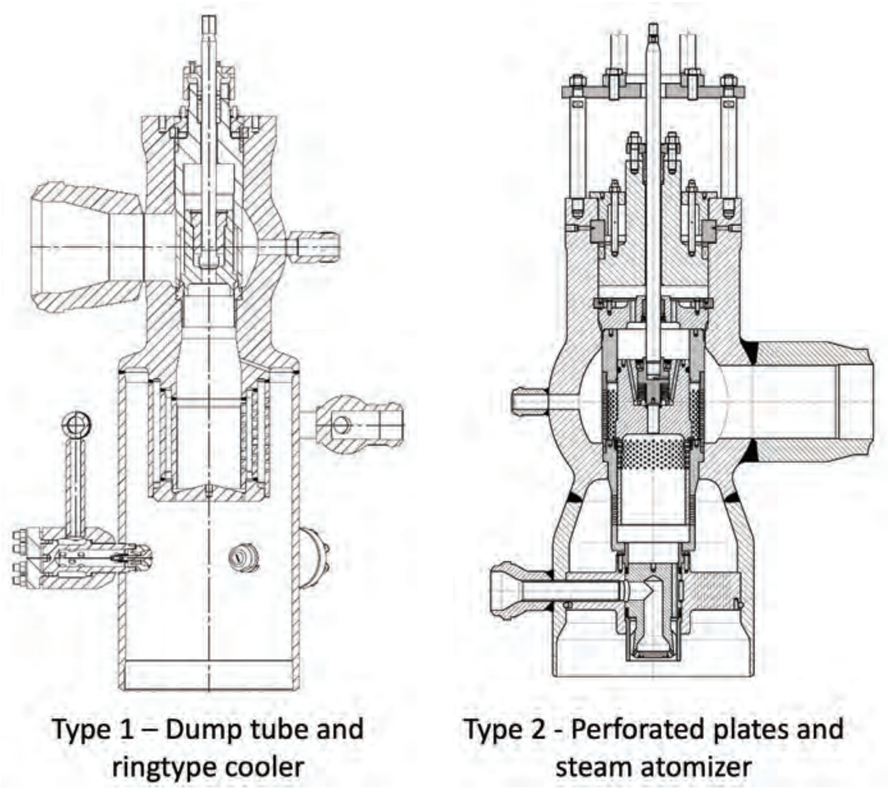
- Open to 80 to 100 percent during steam turbine trip.
- Bypass HP steam during HRSG startup and shut down, performed a few times per year.

"But today," he said, "these valves face more frequent operation, impacting reliability and system integrity."

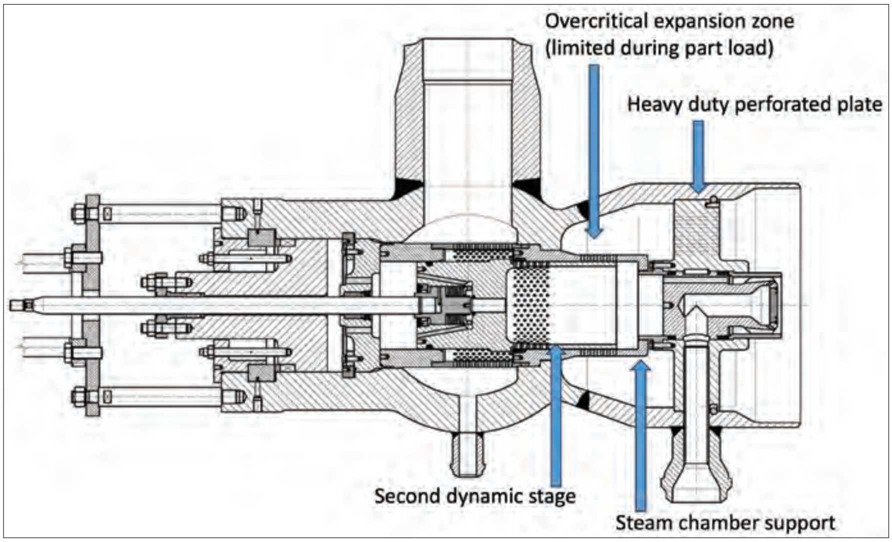
There are two principal types of bypass valves: those with integrated dump and ring-type coolers, and those with perforated plates and steam atomizer (Fig GS11).

Transitioning from base load to start-stop operation has revealed recurring issues with Type 1 (dump tube) valves:

- Failure of dump tube integrated in the valve body.
  - He covered dump tube failure due to water impingement, high frequency vibration at full steam flow and part load.
- Cracking of nozzle at steam line weld (continuous thermal stress regardless of steam flow).
- Thermal stress in downstream piping



GS11. HP bypass valves, Type 1 and 2



GS12. HP bypass valves in cycling power plants

leading to cracking and deformation (primarily at high steam flows).

He suggested how to prevent dump tube failures (Fig GS12):

This would support dump tube or steam chamber after first stage at the bottom.

1. Introduce a second dynamic pressure stage to prevent overcritical expansion and minimize turbulence (oscillation).
2. Eliminate dump tube, replacing it with heavy duty perforated plates.

He then suggested how to reduce thermal stress in the downstream line and nozzle weld:

1. Replace perpendicular spring-loaded nozzles by axial spray injection through steam atomizer.
2. Insulate spray water supply line by use of an inner liner.

He summarized: "Make it a storm, not a hurricane."

To paraphrase his overall message, sometimes we need to step out of our comfort zones to revise designs. We can do this with valves, and should do this for other plant components with high thermal stress and turbulence issues.

Discussions included code requirements, drip leg size, interstage drains and sloped piping.

Also, throughout the conference, previously submitted questions were discussed as time allowed.

EPRI TECHNOLOGY TRANSFER DAY

As is the custom at HRSG Forum, the fourth day is dedicated to the latest HRSG/HEP research and case studies conducted by the Electric Power Research Institute (EPRI), and open to all conference attendees.

This full-day event was presented by:

- Bill Carson – Program Leader, HRSG.
- Eugene Eagle – Senior Technical Leader, HRSG.
- Tom Sambor – Program Leader, Power Plant Piping.
- John Siefert – Program Leader, Materials.

Eugene Eagle opened with the *Heat Recovery Steam Generator (HRSG) Program Overview*. The mission: Provide best practices and technology to enable high HRSG reliability with limited resources.

Eagle's background on EPRI included:

- Examples of current research.
- HRSG-specific research areas and reports.
- Damage mitigation initiatives. 2024-2026 focus:
  - Erroneous attemperator operation.
  - Component damage mechanisms and avoidance strategies.
  - Thermal transient evaluations.
- Improved performance programs and troubleshooting guides. 2024-2026 focus:
  - Gas turbine upgrade impact on HRSGs.
  - Improving turbine exhaust gas flow distribution to HRSG coils.
  - Improving HRSG thermal performance.
- Life management.
  - When, where and how to detect damage.
  - Disposition of damage.
  - Damage tolerance.
  - Tools and methods to support an integrated approach to fitness for service.
- Flexible operation. 2024-2026 focus:
  - Purge procedure improvements to reduce startup time.
  - Best practice operation strategies to reduce impact on components.
  - Reducing gas turbine impact on HRSGs during flexible operations.
- HRSG innovations. 2024-2026 focus:
  - New methods of steam conditioning beyond traditional attemperation.
  - Novel gas turbine exhaust attemperation concepts.
  - New materials and features (e.g. dissimilar metal welds).

He followed with a list of project updates with detailed status reports.

STATE OF THE INDUSTRY

Tom Sambor then presented a valuable reminder on the current *State of the industry: summary of challenges*.

In general terms, the perspective on energy transformation can be classified as:

- Increasing:
  - Flexible operation.
  - Material complexity.
  - Supply chain challenges.
  - Alternative repair solutions.
  - Fitness for service (continuing to run).
- Decreasing:
  - O&M budgets.
  - Awareness of Codes and Standards.
  - Service provider expertise.
  - In-house engineering and support staff (owner/operators and OEMs).

The stark summary: "We are all being forced to do more with less," he emphasized. Sambor supported this with recent news headlines on workforce reductions within the industry.

The underlying message was the relevance and value of EPRI and its ongoing research. Much information is available to the public. For more extensive access, those without an EPRI account can go to https://enroll.epri.com or askepri@epri.com.

Sambor then presented EPRI's Integrated Life Management Strategy, a "rigorous approach focused on mechanics, metallurgy and nondestructive evaluation" leading to component life assessment.

Looking at a comprehensive list of industry issues, Sambor explained that the remaining time in this technology transfer day would offer various details including flat-end closures, intersections (tees), and developments with creep strength enhanced ferritic (CSEF) steels.

He noted that EPRI Report 3002005846 contains a comprehensive list of industry issues and includes suggested life management strategies.

FITNESS FOR SERVICE (FFS)

John Siefert then presented EPRI's comprehensive knowledge on *Fitness for service of power generation components*.

He reviewed the history of EPRI work related to fitness for service, and on the growing need for FFS methods. Many specific and detailed examples of projects and case studies followed covering examples with Grade 22 and 91 materials. Current "hot issues" dealt with cracking and repairs in 1CrMoV HP steam turbine casings and a Grade 91 replacement forged valve body, among others.

The summary: FFS is becoming more critical as the need for power keeps increasing. Detailed analysis is critical. Siefert emphasized that "EPRI research is helping utilities limp along, buying time (when needed)."

END CAPS

Siefert and Sambor then turned to "emerging problems," specifically end caps.

They noted that "run, repair, replace decisions are vital to a plant that has dozens of at-risk end caps or fleets that have hundreds."

An interesting set of slides focused on dispelling myths and rumors associated with end cap damage and failures.

DISPELLING MYTHS AND RUMORS

Each of these myths was discussed. **All are false**:

- End cap damage/failures are a new industry issue.
  - Examples were given back to 1991.
- All sections of the HRSG are equally susceptible to damage failures.
  - Known service-related damage/failures have all occurred in high-temperature sections, e.g. HPSH and RHTR sections.
- Risk of end cap damage/failures can be mitigated with NDE alone.
  - Examples: confirmation of improper root pass material is only possible through sampling; creep damage is not detectable with linear phased array.
- Damage/failures in end caps are all associated with fatigue.
  - In a list of six well-documented cases, four were due to creep, one due to fatigue, and one unknown, complicated by a previous weld repair.
- Damage/failures in end caps are all associated with improper fabrication.
- Damage/failures in end caps are all associated with normal operation.
  - Elevated temperatures and/or severe transients were reviewed.
- Damage/failures in end caps are all associated with one style of end cap.
  - Plug, relief radius, plate and offset caps were reviewed.

Subsequent slides addressed each of these.

The truths in summary:

- End cap damage and failures are not new
- Different styles of end caps are vulnerable.
- End caps are susceptible to creep and/or fatigue damage.
- Fabrication flaws are generally not the cause of damage/failures.
- This is a safety concern; end caps can and have become projectiles.

The suggestion from EPRI Report 3002011049 is to implement a risk-informed assessment program for flat end caps.

TEE INTERSECTION DAMAGE

Sambor continued with an update on high-temperature tee intersection damage research. An EPRI Industry Alert was issued in February 2023: *Seamless tee intersections*, available by accessing the nearby QR code.

The basic alert: Applies to any modern plant constructed with a Grade 22, 91 or 92 piping system, typically including:

- All CCGT plants built after 1998.
- All supercritical coal-fired plants built after 1998.

More specifically, this applies to:

- Grade 22, 91 and 92 steels (and X20).
- Main steam and hot reheat systems.
- Operations above 1000F (540C).
- Failures in as few as 35,000 hours with many in the range of 50,000 to 70,000.
- Cracks and leaks in crotches and girth welds.

A single powerplant unit generally may have four to eight at-risk tees.

Risk mitigation, in general, was addressed by Sambor as: "Reduce uncertainty through implementation of a comprehensive life management approach and targeted replacement for optimized tee intersections."

Case studies followed focusing on:

- HP to process steam tee.
- Main steam to turbine stop valve tee.
- Main steam combining tee.

An overview: the damage mechanism is consistent and comes down to creep damage mechanism, not fatigue.

Sambor explained in detail the EPRI screening technologies used, as well as repair and replace options.

The bottom line: This is another safety issue and is not going away.

ALTERNATIVE GRADE 91 WELD REPAIRS

John Siefert then addressed EPRI's comprehensive knowledge on *Alternative weld repair research and applications*, primarily focusing on installed Grade 91 components. In the US, nearly 1200 combined cycle plants have Grade 91 steel, primarily in the highest temperature locations including HP/Main Steam and RH/Hot Reheat systems.

He drew some conclusions from experience in the UK:

- ~5 percent of the total girth weld population was susceptible to Type IIIa or Type IV in-service cracking before achieving intended design life.
- On a plant basis, the susceptible girth weld cracking population was 10 percent.
- On a system basis, the population was as high as 30 percent of the main steam girth welds.

He then covered alternative weld repairs in Grade 91 in combined-cycle and fossil plants.

Siefert presented five end-user case studies, and listed a total of 14 end-users from the in-depth EPRI database, stating that there are more than 10,000 alternative weld repairs in operation (and ~6 known repair failures), with most in high temperature and cycling operation. "Sustained EPRI support from industry is not a trivial exercise," he stated. "It is essential!"

BACK-END FOULING

Eugene Eagle then returned to discuss *Proactive and reactive approaches to back-end fouling*, beginning with the reactive.

Recent EPRI research includes pressure wave, detonation cord and foam-based cleaning methods for HRSG gas-side tube cleaning. Guidance is available in EPRI report 3002007881 and others.

Eagle then continued with the proactive: *Mitigating back-end corrosion and deposition*.

Typical strategies include staying above the dew point, good layup practices, correct use of exhaust gas dampers, and regular catalyst cleaning. Eagle also addressed potential future research activities, including tube coatings, gas conditioning (sulfur removal), and economizer redesign/materials changes.

HARD-FACING FAILURES

John Siefert then concluded the sessions with EPRI's comprehensive knowledge on **Co-base hard-facing failures (in valves)**. He called it "an endless odyssey with failures galore."

"The consequence of liberated hard-facing transported to the steam turbine is in the millions (of dollars) and will reduce sealing contact in safety-critical valve applications," he said. "Despite attempts to raise awareness, failures are still occurring throughout the industry."

For more on delamination of hardfacing and how to avoid it, access the nearby QR code.

He then reviewed recent field tests and microstructural validations.

His summary:

- The development of integrated solutions validated by service experience typically takes ten years of sustained research.
- A Ni-base butter layer should be implemented as best practice for any hard-facing applied to an Fe-base substrate regardless of application, location or operating temperature.
- A Ni-base butter layer must be implemented for Fe-base components operating above 900F and/or if upstream of steam turbine.

Hard-facing delamination remains a major issue in the industry today, and studies are ongoing. CCJ

From wear to repair: Managing exhaust-frame health

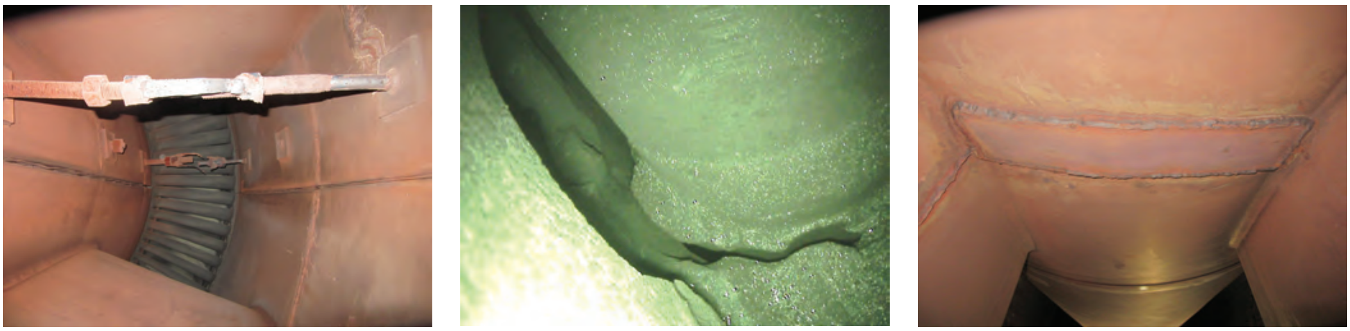
The exhaust frame faces several critical operational and maintenance challenges primarily because of cyclic, variable, and minimal load operations. No matter the turbine model, end users and solutions providers are reporting more frequent inspections and maintenance on this vulnerable equipment.

Here, David Clarida of Integrity Power Solutions (IPS) reviews his recent experience at a Texas CCGT facility faced with a challenging operational profile dealing with high demand for electricity coupled with renewable resource intermittency.

"Keeping a watchful eye on the exhaust frame is paramount to effectively plant maintenance," stresses Clarida. Key issues include high and increasing repair costs, materials degradation, inadequate longevity of current repairs, and cooling-air loss resulting in operational inefficiencies, increased temperatures, and potential structural risks—such as casing cracks. Fig 1 illustrates typical issues identified during inspections.

According to Clarida, solutions range from partial, targeted repairs, such as those shown in Fig 2, when outages are short or limited, through comprehensive shop or onsite refurbishments, to complete replacements involving all upgrades. The last is optimal when internal alignments are already required.

The case study of a 7F exhaust frame shared here illustrates a multi-year progression of inspection, evaluation, and maintenance efforts aimed at preserving long-term reliability.



1. Inspections are critical to managing exhaust-frame health. Examples of findings: Parting-joint separation and cracked shop welds are in evidence at left, along with turnbuckles remaining from a previous outage; borescope image in center reveals cracked airfoil internals; cracked shop welds and previous repair are at right

The timeline began in June 2020, when a scheduled exhaust inspection revealed early indicators of component wear and degradation in the airfoil channels. These initial findings prompted a more targeted borescope inspection in November 2020, which provided detailed visuals confirming the need for corrective action. Based on those results, the plant proceeded with airfoil tail and channel replacements, plus a diffuser repair, in May 2021, effectively addressing the most pressing concerns.

Finally, with the next major opportunity for intervention, a comprehensive exhaust-frame field refurbishment was carried out by IPS in March 2024 (Fig 3). This allowed the customer to restore structural integrity and performance while minimizing downtime, marking the culmination of a carefully planned and executed long-term maintenance strategy.

This refurbishment demonstrated significant operational improvements, including reduced cooling blower load and elimination of redundant blower operation, confirming the effectiveness of the upgraded solutions. CCJ

2. An advantage of partial, targeted repairs is the ability to get your plant back in service quickly. Photos stacked at left show an airfoil crack and past repair at the top and IPS upgraded repair at the bottom. An airfoil internal crack is at the top right and IPS internal repair below

3. IPS field refurbishment was performed in less than 40 days and with the rotor in place

Problem areas to keep an eye on

- **Flex-seal failures:** Early designs frequently fail, causing significant cooling-air leaks and maintenance demands. Upgrading to improved flex-seal retention assemblies has proven successful in extending seal life and reducing maintenance.
- **L-seal-block cracking:** Frequent axial and circumferential cracking. The upgraded Monoblock L-seal design reduces cracking significantly by simplifying the structure and minimizing weld points.
- **Parting-joint issues:** The joint often experiences separation, cracking, and leakage of cooling air. An upgraded robust tongue-and-groove design effectively mitigates these problems, substantially decreasing leakage and structural distress.
- **Airfoil issues:** Airfoil channels and tails frequently crack and lose insulation integrity, elevating risks such as high wheel-space temperatures. Robust airfoil upgrades—including improved welding, integrated spines, and upgraded internal channels—reduce stresses and extend service life.
- **Insulation-pack failures:** Insulation cracking and loss lead to increased risks of component distortion and cooling hole blockage. Enhanced insulation packs eliminate traditional clips, improve attachment, and increase insulation density, significantly improving durability.
- **Aft diffuser concerns:** Shell and flange cracking at stress-concentration points indicate severe structural stress and degraded material. Upgraded diffuser designs reduce these structural concerns.

OT vs drum HRSGs: Selecting the right design for operational flexibility

The energy sector is undergoing a transformative shift, driven by the growing need for cleaner, more flexible, and more efficient generation technologies. As renewable energy sources such as wind and solar continue to grow—projected to account for 80% of global net capacity additions by 2050—gas-fired power plants remain essential in ensuring grid reliability and stability.

In this evolving landscape, HRSG technology plays a critical role, particularly in combined cycle power plants (CCGTs) that demand high efficiency and operational flexibility. A recently published paper by GE Vernova (GEV), accessible via the nearby QR code, presents a comparative study of water chemistry performance in once-through (OT) and drum-type HRSGs, highlighting key operational findings derived from commissioning and fleet data collected from the GEV global fleet.

As the power generation industry integrates increasing levels of intermittent renewables, the demand for flexible, fast-ramping thermal generation remains strong. OT HRSGs offer high efficiency and startup responsiveness suited to dynamic grid conditions, while drum HRSGs remain a reliable alternative for applications prioritizing simplicity and robustness.

This study compiled by Maneka Roger, Mariah Couzzi-Carneiro, Markus Heitzmann, and Mirco Colombo compares water chemistry behavior and steam purity in GEV's OT and drum HRSGs, using real-world operational data from multiple global H-Class (HA) plants over a 10-year period.

The focus is on degassed cation conductivity (DCC) as a key measure of steam purity during start-up and long-term operation. Results show both HRSG types consistently meet GEV's DCC targets, with OT HRSGs achieving startup DCC thresholds more rapidly, offering enhanced responsiveness without compromising steam purity.

These findings reinforce the suitability of OT HRSGs for high-cycling applications and validate their water chemistry performance as equivalent or superior to traditional drum HRSGs under proper feedwater conditions.

The GEV OT HRSG is highly advantageous for new plants where operational flexibility, rapid response, and efficiency are critical, though it demands advanced controls. Drum HRSGs remain a reliable and simpler alter-native, suitable for plants with less dynamic operational requirements, prioritizing ro-bustness and operational simplicity (Table).

OT HRSGs offer several operational advantages, particularly for facilities needing

Track 4A in Malaysia, a 9HA.02, 2x1 CCGT with GE Vernova OT HRSGs

CONSIDERATIONS FOR YOUR NEXT HRSG

Parameter	Drum HRSG	OT HRSG
Startup time	Slower ramp rate to heat the HP drum and establish natural circulation due to thick drum wall and large water inventory.	Fast startup due to continuous flow, and less water inventory, which allow for rapid heating.
Flexibility	Some limitations due to the need to protect the magnetite layer in the HP drum.	Highly flexible: can efficiently handle varying loads and quick changes.
Control complexity	Simpler, more forgiving in handling fluctuations.	Increased complexity, requiring precise control of flow and temperature.
Efficiency	Typically operates at lower steam pressures and temperatures, leading to lower thermal efficiency. Continuous and intermittent blowdowns remove impurities but result in water and energy losses.	Operates at higher steam pressures and temperatures, improving thermal efficiency at base load. Minimizing desuperheater spray flows at part load and off design operating conditions results in higher thermal efficiency.
Water Treatment	Can handle low water quality due to separation in the drum – reduces scaling issues.	With high purity water, scaling and corrosion is prevented.
Applications	Common in a wide range of power plants, including industrial applications.	Used in high efficiency power plants, and applications requiring rapid load response and frequent cycling. Offers superior off-design and part-load performance, making them ideal for markets with high fuel costs.

rapid startup and high operational flexibility. They feature faster ramp-up times due to continuous water flow and minimal water inventory, which significantly cuts down startup durations. Their ability to handle varying loads without concerns about thermal stress on drum components provides excellent operational agility. Furthermore, OT HRSGs operate at higher steam pressures and temperatures, resulting in enhanced thermal efficiency, especially noticeable at partial loads where desuperheater spray flows are minimized.

Water chemistry management is simplified in OT HRSGs because steam purity directly correlates to feedwater quality, eliminating the need for additional chemical treatment or blowdown at steady-state operations. Consequently, OT HRSGs consistently produce higher-quality steam and achieve desired steam turbine admission criteria more swiftly. Their design proves particularly beneficial for high-cycling operations, such as plants supporting renewable energy integration, where frequent starts and stops are common.

However, the OT design does present certain drawbacks, including increased complexity in system control, necessitating precise instrumentation and advanced automation. This type of oper- ational precision can potentially raise maintenance complexity and frequency, particularly related to control systems and critical instrumentation.

Conversely, drum HRSGs offer a robust, reliable alternative. Their large water inventory and inherent natural recirculation make them tolerant of operational fluctuations, providing a forgiving and stable environment. Control and operation are generally simpler and less demanding, which can reduce initial investment and complexity. Drum HRSGs are also more forgiving regarding feedwater quality variations due to their effective impurity removal through blowdown procedures.

Nonetheless, drum HRSGs have limitations in rapidly changing operational environments. Their larger thermal mass results in longer startup times and lower responsiveness to load changes. Operational efficiency is generally lower due to the need for regular blowdowns to manage water purity, leading to higher energy losses. Furthermore, the thermal stresses imposed on drum components can restrict operational flexibility and rapid load variations, potentially making them less suitable for frequent cycling. CCJ

7HA & 9HA USERS GROUP

2025 Annual Conference and Exhibition August 4-8 Greenville, South Carolina

Supply chain woes converge with lingering and emergent issues

If you have an HA machine in your future–close to 70 worldwide are in the pre-COD (commercial operating date) phase–and you haven't already, now's the time to get engaged with the folks who have been operating 110 of those units globally. And the best, and only, place to do that is by attending the HA Users Group Annual Conference, where over 100 users collaborate among themselves (and through membership in www.powerusers.org), vendors actively supporting the fleet, and with GE Vernova (GEV) to solve problems.

Why now? Because you are likely to experience many of the same issues associated with these machines since they were first introduced to the industry in 2016. As both the user and vendor material from last year's conference reveals, despite progress being made on many fronts, several of the major, and original, issues still lack consensus on a root cause and what could be labeled a "permanent" or long-term solution.

Compounding the situation is that the advanced-class GT industry in the aggregate has been facing global supply chain disruptions; deficiencies in skilled and trained labor for shop and site work; constraints on sharing information because of confidentiality agreements between user and vendor; and general frustrations among vendors, users and insurers.

Easiest way to access the material you're going to need on your HA unit journey is to become a member of the Power Users Group (www.powerusers.org), all of whom have access to HA User Group conference content posted at the site. GEV-related material is only accessible through the customer portal platform.

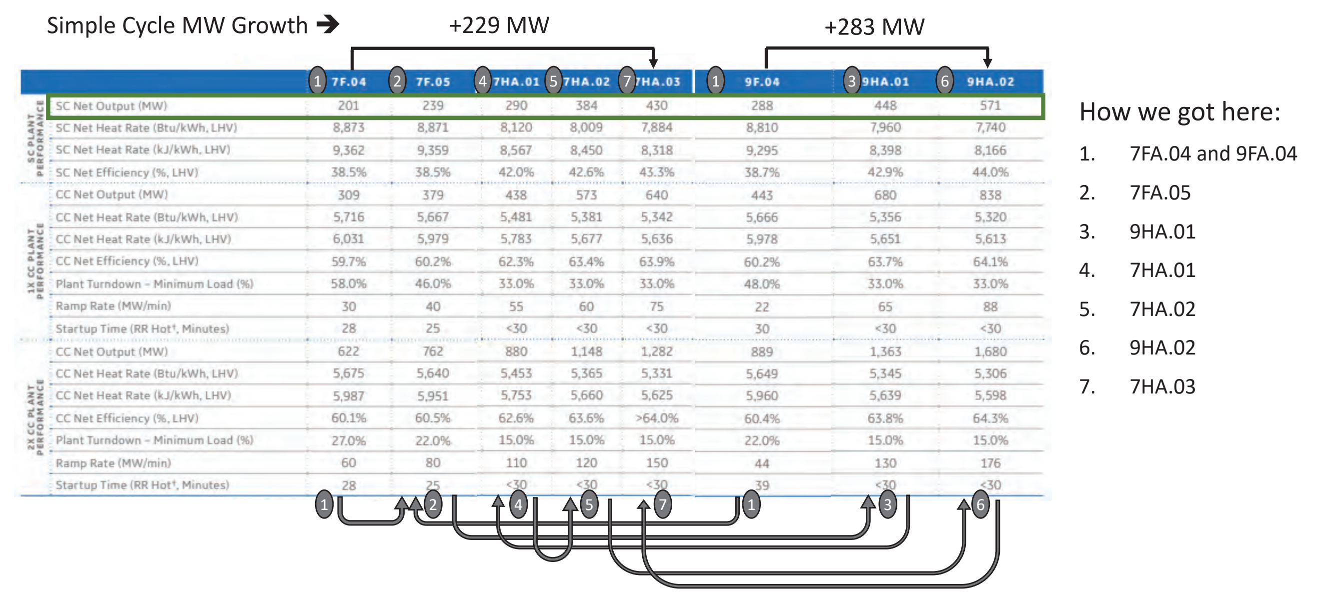
However, the most valuable information you'll access is through the private conversations and user-only discussions following the slide presentations at the conference. The rule of thumb these days is the value of content is inversely proportional to the number of people who might see it. The 2025 edition will take place in Greenville, SC, from August 4-8 and you can register through the QR code above.

In abiding by today's confidentiality restrictions, what follows here are only highlights of what went down at the conference.

HA evolution

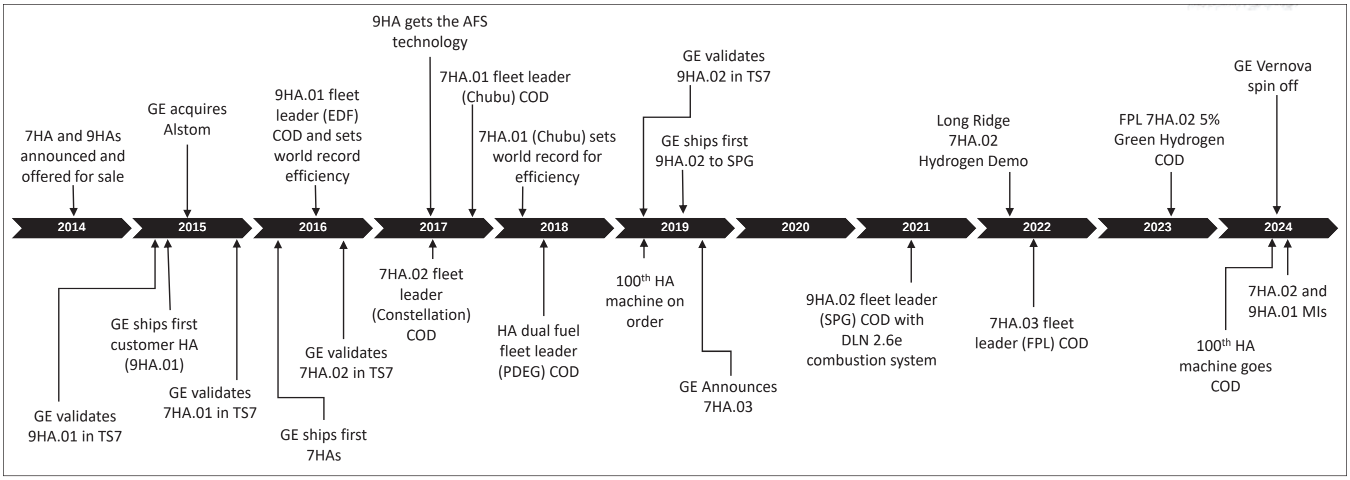
A late-1970s hit song by Talking Heads repeatedly asks the question, "how did I get here?" In a context-setting slide deck, one user representative and GE specialists reconstruct the evolution of the HA fleet from the 7FA.05 compressor, said to be the foundation of the HA design, to the latest models 9HA.02 and 7HA.03. Most of the machines operating or on order are of the 7HA.02 variety, but each of the units is related to the previous model.

For example, the newest 7HA.03 machine has more in common with the 9HA.02 version of the HAs than the 7HA.02, meaning the international user community has more to learn from each other than with the 7F and 9F users. One critical table in the slide deck compares the relevant design/performance data from the 7FA.04 and 9FA.03



		1 7F.04	2 7F.05	4 7HA.01	5 7HA.02	7 7HA.03	1 9F.04	3 9HA.01	6 9HA.02
SC PLANT PERFORMANCE	SC Net Output (MW)	201	239	290	384	430	288	448	571
	SC Net Heat Rate (Btu/kWh, LHV)	8,873	8,871	8,120	8,009	7,884	8,810	7,960	7,740
	SC Net Heat Rate (kJ/kWh, LHV)	9,362	9,359	8,567	8,450	8,318	9,295	8,398	8,166
	SC Net Efficiency (%, LHV)	38.5%	38.5%	42.0%	42.6%	43.3%	38.7%	42.9%	44.0%
1X CC PLANT PERFORMANCE	CC Net Output (MW)	309	379	438	573	640	443	680	838
	CC Net Heat Rate (Btu/kWh, LHV)	5,716	5,667	5,481	5,381	5,342	5,666	5,356	5,320
	CC Net Heat Rate (kJ/kWh, LHV)	6,031	5,979	5,783	5,677	5,636	5,978	5,651	5,613
	CC Net Efficiency (%, LHV)	59.7%	60.2%	62.3%	63.4%	63.9%	60.2%	63.7%	64.1%
	Plant Turndown – Minimum Load (%)	58.0%	46.0%	33.0%	33.0%	33.0%	48.0%	33.0%	33.0%
	Ramp Rate (MW/min)	30	40	55	60	75	22	65	88
	Startup Time (RR Hot†, Minutes)	28	25	<30	<30	<30	30	<30	<30
2X CC PLANT PERFORMANCE	CC Net Output (MW)	622	762	880	1,148	1,282	889	1,363	1,680
	CC Net Heat Rate (Btu/kWh, LHV)	5,675	5,640	5,453	5,365	5,331	5,649	5,345	5,306
	CC Net Heat Rate (kJ/kWh, LHV)	5,987	5,951	5,753	5,660	5,625	5,960	5,639	5,598
	CC Net Efficiency (%, LHV)	60.1%	60.5%	62.6%	63.6%	>64.0%	60.4%	63.8%	64.3%
	Plant Turndown – Minimum Load (%)	27.0%	22.0%	15.0%	15.0%	15.0%	22.0%	15.0%	15.0%
	Ramp Rate (MW/min)	60	80	110	120	150	44	130	176
	Startup Time (RR Hot†, Minutes)	28	25	<30	<30	<30	39	<30	<30

1. Turbine output has increased by over 220 MW (60Hz) and 280 MW (50Hz) in simple cycle through iterative design—from 7/9F.04 to latest 7/9HA models—driven by innovations in compressor scaling, firing temps, combustion systems, and turbine architecture



2. A decade of HA gas turbine evolution: over 100 units in operation, 2.5M+ hours logged, and continuous advancements in efficiency, hydrogen capability, and validation testing driving progress from 9HA.01 to 7HA.03

through the 7HA.03 and 9HA.02 (Fig 1).

One fascinating tidbit from these slides is that 100 HA units were on order only four years after the first 9HA was shipped, and less than two years after the fleet leader 7HA unit began operating (Fig 2). Clearly, owner/operators were not taking a "wait and see" attitude before ordering. At the time of the conference, the HA product line had amassed 2.5-million operating hours.

One important distinction made here is between the 7HA.02 (FL16) and the 7HA.02 (FL18), the latter having a double-wall compressor, provisions for stage 4 blade cooling, higher firing temperature, and tighter HGP clearances, among other differences.

Flex hose failures

One of the most significant learnings at the conference was that two 7HA.02 machines at different customer sites had experienced premature failures of inlet bleed heat (IBH) flex pipe/hoses. These failures occurred on the "dog legged" style design that was made available in 2022 after an "angular hose" design failed in the field the prior year. One user reported that the failure occurred after only 10,169 fired hours in July 2023 while the machine was running baseload. It took seven days to return the unit to service using on-site spares, available because of operating history with leaks. This site now plans to replace these hoses every 10k hours.

Ten months later, the second user experienced an IBH flex pipe failure (also at baseload) after approximately 16,000 fired hours and 52 starts. Both sites have expanded the safety perimeter around the machine to protect workers. After the second customer failure, GE revised the safety related recommendations in TIL 2299 based on the debris range and by urging from the customers impacted. Both customers urged the community to take a hard stance on an employee exclusion zone to protect employees.

GE's diagnosis is that the failure likely occurred from stress corrosion cracking initiated by sulfur attack (at a point experiencing higher stress than the rest of the hose), noting that one site was adjacent to a wastewater treatment plant where sulfur compounds could be present. However, the slide notes that, while the other site was not near a wastewater plant, corrosive compounds are "in the air."

GE continues to investigate the IBH hose failure root cause with customer hardware cut ups and data collected on an operating unit at one of the failed hose sites. GE found higher temperatures and believes this also contributed to the problem. TILs related to this problem are different for different models of HA. Users should watch for revisions to TILs 2299, 2354 and 2341 in 2025.

Common fleet issues

Conference goers were also treated to the results of an attendee survey, which will help those just embarking on the HA journey understand what they should be looking for and asking questions about. The HA user group steering committee uses this real time survey tool to prompt conversation and collaboration throughout the conference duration. This creates an engagement among the users and impromptu sharing of "war story" as well as opportunities to learn from the most veteran operators of these newest technology machines.

The results, reported here as general HA user experiences, must be understood with respect to the HA design evolution described above. Machine design characteristics vary, each site has responded to the various TILs in its own way, and the condition of every unit (following COD) depends on the operating modes (e.g., fired operating hours, starts, ramp rates, etc.) and O&M practices at each site.

Of the respondents, 44 were attending for the first time, while 39 are veterans of the conference. Five represent HA.01 machines, 62 HA.02, 11 HA.03, nine 9HA.01 and one 9HA.02. 66% are units in multi-shaft CCs, 25% in single-shaft CCs, and 9% simple cycle. When asked what their major concerns are, the attendees listed parts, HGP, rotor, and vibration most often.

Other relevant survey results:

- 16% of respondents have experienced a rotor swap, nine have access to a spare rotor, and twenty five wish they did
- 34% have experienced a forced outage (FO) of some sort, and 16% have experienced an outage resulting from foreign (or domestic) object damage
- 19 respondents have experienced stator vane rubbing, though 47 have not
- 34 have found loose or missing hardware in combustion assemblies, 33 have not
- Nine have swapped load frequency control (LFC) modules and the units are now load-limited
- 30 have observed the thermal barrier coating (TBC) eroding away on the GT blades (buckets)
- Nine have installed filters attached to the S1N cooling circuit and 32 others want them or need them
- 33 have experienced unibody spallation and have had to replace hardware early
- Six have experienced combustor inner diffuser cone (IDC) creep and 33 believe they will soon
- 52 have applied the TIL for the spacer 0 issue, six have a cracked spacer 0, fifteen have installed the rim seal (shim), and six are not happy with the shim
- Four have applied the phase 1 HPPS (high pressure packing seal) modification of the mid-shaft seal, 16 have applied the phase 2B HPPS and AIS (aft inducer seal) modification, and nine have noticed a reduction in MW output with the new seals
- 23 have measured excessive T2 vibration and 12 see it elevated past the first critical, 30 experience excessive T2 vibration run-to-run variation, 18 have generator frame resonance, eight require frequent re-alignment, and three experience large mid-shaft runouts
- Many have experienced numerous prob-

lems with journal bearings and thrust bearings

Attendees were also asked about GEV's collaboration with the users during the conference and they did not grade on the curve. Forty gave the vendor a grade of C or below, 23 three gave a B, and one gave an A. While numerous specific short, often pithy and witty, comments were also offered, common themes appeared to be more transparency, desperation for spare parts, and slow response times to issues.

7HA.02 fleet leader outage observations

Staff affiliated with an early 7HA.02 site, along with a life assessment consultant, reported observations on one unit there following a spring 2024 major inspection (MI) outage. Unit had over 48K hours and 162 starts. Worth noting is that the unit's original rotor was exchanged in 2021 for a refurbished rotor with 9K fired hours and 90 fired starts.

The slides offer a detailed account of findings, especially as each relates to respective TILs and GEKs, while noting that there are approximately 75 TILs associated with the GT, generator, and controls.

The high-level summary of the experience notes a lack of spare parts, variations in the engineering and technical dispositions from GEV, lack of rotor inspection accuracy relative to the TILs and GEKs, lack of skilled labor force expertise and planning, and gaps in tooling delivery and schedule integration. One slide notes that in some instances, the site had to settle for the "best of the worst" refurbished used parts available, likening it to having to maintain an HA junkyard for spares.

In addition, site staff posed significant challenges to GEV's interpretation of findings, observations, and remedies. Generally, it was noted that engineering responses are based on fleet data/knowledge and/or a perception of the customer's risk profile, parts availability, contract budget, liquidated damages, or access to available resources for remedies.

Specific machine observations listed are:

- Pitting on the inlet guide vanes (IGVs), variable guide vanes (VGVs), stator vanes, and rotor blades
- Deformed stator vane ring horizontal joint keys (TIL2135)
- Stator vane ring segment tab wear (TIL2333-R1)
- S1S TBC rubs and flaking (TIL2141)
- Stage 1 buckets TBC spallation and airfoil leading-edge region through-wall holes
- No cracks in the spacer 0 rim (shim install)
- Generator stator greasing, loose laminations
- GT and generator rotor and GT stator casing magnetism

9HA.01 fleet leader MI results

A user representing an early 9HA.01 site reported findings at the 2024 major MI point. Short history of the unit includes an unplanned outage for an S1B replacement (2018), HGP major with a 72-day outage to rectify the shaft line vibration issue (2020), T fairing and spacer 0 correction and a 23-day outage extension (2023), and an MI following an forced outage (FO) beginning in May 2024 and scheduled through January 2025.

Spacer 0 crack migration was observed on the GT rotor, reminiscent of 2023 spacer 0 findings. As there was no new spacer 0 replacement available, the site opted for installing the shim to close the gap between the spacer 0 and wheel 1.

Site also plans to migrate from the FL15 to the FL21 rotor design which reportedly addresses concerns enumerated in TILs 2244-R1 (T fairing distress), 2277 (compressor blade retention ring), 2330 (phase 2B seal package), 2147 (rotor life limit), 2445 (turbine rotor space 0 inspection), and 2333 (turbine cover plate inspection). Slides note that the compressor discharge casing

(CDC) requires trimming for the FL21 rotor assembly.

Combustor hardware impacts include hula seals burned or missing on seven of 16 nozzles in the fuel nozzle and cap assemblies, large cracks in the fuel nozzle casing, fretting of the flow sleeve piston ring grooves with loss of material (in the context of combustion dynamics), degraded combustor parts on junction links and cracks on some casings, large internal crack on a transition piece (TP) replaced in 2019, and TP side seal missing one year after an MI.

Finally, distress was noted on the compressor stator vane (TIL2322), resulting in a stage 9 upgrade to the exit guide vanes (EGV), which, the slide emphasizes, is still the "former" design, not the rings necessitated by the TIL.

Steam-turbine rotor defects were described. For the intermediate-pressure module (IP) – heavy rubbing of bucket tips, two locking blades heavily twisted and exhibiting shingling, several locking blades twisted out of spec, and missing J seal. No root cause has been determined and the rotors has been deemed not returnable to service as-is. For the high-pressure module (HP) – heavy rubbing and gaps at tip of buckets and rubbing increasing over time. Again, no return to service as-is.

Operational issues

An HA.02 site reported on general operational issues and steam turbine defects. Unit 1 at the site had 45K hours and 201 starts, unit 2 had 21K hours and 131 starts. In May 2023, unit 1 experienced a GT trip and took a forced outage following a BI. Vibration of the No. 2 bearing was greater than 1 in/sec accompanied by a sudden shaft phase change. Subsequent finding was the GT spacer 0 (covered in TIL2445R1) liberated, caused by high cycle fatigue (HCF). The unit was out of service for four months.

The site purchased and installed a new rotor (non LTSA), and replaced S1N, S1B, S1S, S2B, and S2S and plans to install the CAPA (corrective action, preventive action) kit during the 2025 MI. Report notes that there was no backup stock of rotors from GE, hot gas path (HGP) parts were in short supply, and the consumables took a few months to arrive.

Site also experienced combustion spread deviation alarms when the axial fuel staging (AFS) circuit was activated. Suspected cause was a V-shaped wire from a damaged gasket on the compressor discharge casing and a thin plate emanating from the unibody seal, both depositing in the combustor area.

Regarding the steam turbine, the last stage blades were Stellite-coated to mitigate erosion, moisture was absorbed into lube oil (caused by errant steam flow during startup while the oil condition monitoring system was working poorly), and the site plants to change out the main condenser tubes because of excessive leakage.

An LNG-fired 9HA.01 site operating between 15-100% load range with very low annual starts reported a forced outage for an S1B replacement in 2019, a planned outage to correct combustion wear on the piston rings in 2022 (which had earlier led to a forced outage), and two trips in 2021 and one in 2022.

During an MI in 2021, the site found several dropout nuts on the floor of the GT enclosure and several vertical flange bolts between the exhaust frame and diffuser. When personnel opened the sealing bracket, they found several failed metal plates and insulation. Subsequent borescope inspection (BI) indicated cracks and missing plates at every airfoil. Site also reports that GE is recommending replacing the entire exhaust frame with the new design but has not yet released it. The site prefers to repair it rather than replace.

Highlights from a more recent 9HA.01 installation with three gas turbines (natural gas with diesel fuel backup) include: (1) diesel fuel firing has been problematic in one GT since COD; liquid fuel combustors have been replaced, but GE is not sure how to correct; (2) frequent foundation fieldbus issues and loss of communication to the control room; (3) purge valve and digital valve positioner (with air conditioning) failures; (4) random hot air leaks from GT piping flanges inside the enclosure; (5) failure of valve positioners in the GT compartment; and (6) recent failure of a steam turbine low-pressure admission control valve.

While the first combustor inspection (CI) on one unit was successfully completed, GE's support with respect to manpower, parts, and tools was "questionable." Other comments include GE completely ignored cybersecurity during commissioning of the controls and monitoring systems, and the DCS prematurely reached the end of "extended support." At conference time, the plant continued to run primarily on gas only while liquid fuel (LF) issues of one GT was yet to be resolved.

Vendors to the rescue

Several vendor presentations were interspersed throughout the user-led discussions, many of which featured collaborative experiences between users and solution providers. As the HA fleet expands, so too does the network of third-party vendors supporting it. The user community has shown a growing openness to these partners, particularly when it comes to resolving long-standing operational challenges.

A prime example: vendors like Cutsforth have been addressing collector ring issues on SPL generator frames for years, and the majority of 7HA.02 users have now adopted a vendor solution for A042 leak containment.

The HA steering committee received more presentation proposals than they could accommodate for the 2024 conference. They carefully selected vendor presentations that addressed common fleet-wide challenges, emphasizing solutions-oriented content while screening out those with a "sales pitch" tone. The summaries that follow offer brief overviews; for full slide decks, visit www.powerusers.org.

Back to basics – generator testing

Jamie Clark – AGT Services

This roundup covers standard electrical, mechanical, and visual tests and inspections for large generators, with examples of bad vs good test results, what sub-components to inspect, and recommended corrective actions. Included are Kelvin Bridge/DLRO (digital low-resistance Ohmmeter) for winding resistance, Megger for insulation resistance and polarization index, DC leakage for controlled over-voltage (including the IEEE95 Appendix A graded method), Hi-Pot for high voltage, electromagnetic core imperfection detector (El CID), and bump test for end winding resonance frequency. More specialized stator tests include surge, partial discharge, corona camera, AC HiPot, EMI, robotic inspection, acoustic surveys, AC impedance, pole balance, and shorted turn test. A fun but instructive highlight is understanding why tuning end-windings is like playing the guitar.

3. Proper cleaning and tuning of the ammonia injection grid (AIG) is critical to maximizing SCR catalyst performance and reducing chemical usage

Pro-active SCR/CO system management for lower emissions and operating costs

Andy Toback - Environex Inc

Factors affecting SCR system performance include non-uniform gas and reagent flows and temperatures, catalyst deterioration, and certain plant O&M factors. Photos show examples of ammonia grid deposits, CO catalyst pressure damage, brick shifting (common with extruded ceramic catalyst), and other maladies. Regular cleaning of the ammonia injection grid (AIG), catalyst surfaces, and ammonia salt deposits from the economizer will maintain good back-pressure levels and save you a substantial amount of money relative to the cost of cleaning (Fig 3).

Complete cycle solutions for all GE H-class plants

Pierre Ansmann and Norman Gagnon - Arnold Group

Slides focus on the design and benefits of state-of-the-art insulation and warming systems for gas and steam turbines and, with EPRI funding, field testing results from latest warming and insulation system designs for HRSGs. D11 steam turbine case study reveals a start-time reduction from 266 to 149 minutes and 25% lower high-pressure (HP) rotor low cycle fatigue life consumption, along with attendant improvements in emissions and fuel consumption. A 250-MW unit will require a max of ~200 kW parasitic power and ~50 kW to maintain temperatures at shutdown. Install times are ~30 days.

Results from testing HP evaporator downcomer heating blankets at Duke Energy's Buck facility Unit 12 showed (1) that HP drum pressure could be maintained at 20 psig for several hours, (2) lower tube temperature differentials, and (3) no large quenches or shocks during startup compared to the unheated Unit 11. There were extenuating circumstances typical of a field test, such as issues with instrumentation and components not built to commercial specs. Warming could be an alternative to steam sparging for reducing stress on pressure parts, but a large, dedicated power source would be required. Total install time is estimated to be 3-5 days with a 300-kW maximum power need, and ~100 kW to maintain temperatures at shutdown.

Accompanying photos and 3-D renderings show all aspects of insulation and warming system design including insulation thickness, support structures, joints and attachments, blanket shapes, blanket materials, and thermocouples. Commercial installations would require use of Arnold field services for removal, inspection, and re-installing insulation and heating elements to maintain warranty. Note that many of the 9H and newer 7H units come equipped with such systems because of superior quality and maintenance benefits (Fig 4).

4. Arnold insulation system enables 60–80% of blankets to remain in place during outages, cutting reinstallation time and cost while allowing rapid turbine access by removing only essential sections like split lines, bolts, flanges, and jack rings

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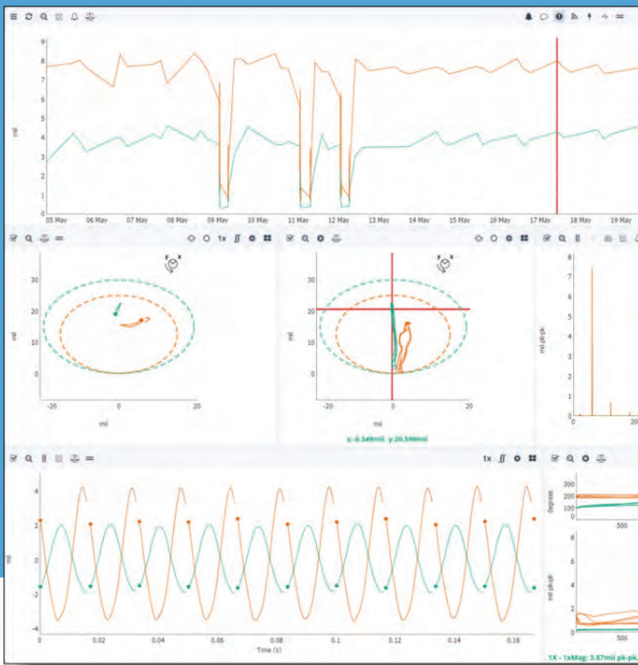

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HVTS for casing corrosion mitigation
Eric Duvekot - Integrated Global Services

A proprietary superalloy applied using a high velocity thermal spray (HVTS) has shown to be effective in mitigating the flaking and spalling from unprotected low-chrome surfaces exposed to high-temperature oxidation in the compressor and combustion regions of the turbine. This debris damages fixed and rotating gas turbine (GT) components, plugs cooling passages, and erodes thermal barrier coatings (Fig 5). The material can be applied on-site in 6-10 days in a temporary, completely enclosed space.

5. Iron-oxide debris causes severe damage to blades and vanes, resulting in clogged cooling paths, erosion of coatings, and costly off-cycle replacements

Since 2022, 11 GTs of various frames and outage configurations in baseload and peaking service have been clad, with subsequent borescope and IGS eddy current inspections showing zero coating degradation.

Vibration information – more is better!
Chuck Requet - Cutsforth and Meredith Neal - TVA

These two companies have partnered to apply wireless vibration sensors, data collection, and analysis (using Cutsforth's InsightCM platform with "industry standard" viewers) first at TVA's nuclear plants, and now at eight CC plants and one simple cycle plant. Case studies from the nuclear plants include a gland seal exhaust fan and bus duct cooling fans. Objective is to use data from the wireless system acquired every eight hours to prompt off-cycle data collection from handheld devices when warranted. Wireless can reduce the install cost of vibration monitoring by up to 70% for a large fleet deployment (35,000 sensors) and cut the break-even point by half.

Oh no! Turbine part damage – RCA planning and thoughts
Matthew Ferslew, Structural Integrity Associates

So, you've observed damage or failure of one or more GT components. What do you do next? Obviously, that's complicated and very site- and component-specific, but this set of slides guides you along the trajectory towards answers. One critical situation to avoid is the root cause analysis (RCA) process "owner," or the individual/company controlling the "story," having an "agenda." Slides are very detailed and packed with useful information, especially for those who are not materials specialists.

Critical actions for site personnel include making sure hardware under RCA is in your possession, and not lost or damaged; collecting data and alarm trip logs from the controller before they become archived or otherwise difficult to access, or disappear; taking photos of as-found components after disassembly; talking to outage craft team members who may recall unusual observations; and taking extreme care in preparing the affected components for shipping. Section on "metallurgical and damage mechanisms and inspection/observation 101" includes slides on fatigue; creep; dwell time fatigue; overload/tensile strength; wear, erosion, and fretting; corrosion and oxidation; and embrittlement and crack propagation.

1. **A 7HA CC unit can lose close to $250,000** annually with every inch (water column) of higher backpressure in the GT exhaust back end
2. **Key RCA steps, items, and actions**

begin with damage observations and ends with verification of the corrective actions taken

Nice to meet you. The first-ever vendor fair for the HA fleet was held in a small, focused setting that fostered meaningful conversations between users and solution providers. Vendors were hand-selected from a highly competitive pool of applicants, as interest exceeded available space. Feedback from participants was overwhelmingly positive—more than half indicated they plan to engage with a vendor as a result of the fair. Encouraged by its success, the HA steering committee will make the vendor fair a regular feature of future conferences, with plans to expand both the capacity and the diversity of offerings for the growing HA user community.

Looking to 2025

The user community stays in close contact with the HA steering committee—reaching out as they bring units online or to share valuable lessons learned from the field. The committee remains dedicated to amplifying user voices and offering support, especially when challenges feel overwhelming. While users consistently praise the high efficiency and robust performance of their HA machines, the size, complexity, and advanced technology of these units come with a learning curve that can be steep.

Looking ahead, the committee is already preparing the agenda for the 2025 HA Users Conference. In partnership with Power Users, this August 4-8 will undoubtedly be the largest and most impactful HA gathering to date. A major focus will be increasing transparency and collaboration, with more shared experience sessions featuring the OEM and vendor partners—highlighting real-world problem-solving and actionable insights.

To accommodate expanded content and deeper discussions, the committee is extending the conference from three to four days. The 2025 event takes place in Greenville, SC—GEV's backyard—providing an ideal opportunity to attract both new and returning users operating all HA models from across the globe for a truly collaborative and solutions-driven experience.

CUSTOMER-CENTRIC APPROACH LEADS TO MARKED ENHANCEMENTS ACROSS HA FLEET

As of the 2024 conference, GE Vernova (GEV) reported the cumulative sale of approximately 164 HA gas turbines, with 104 units in commercial operation. With the current GT demand boom, expect a significant jump in these numbers over the next few years. The HA fleet has collectively amassed over 2.6 million operating hours, the clear front-runner in the advanced-class GT fleet.

The 7HA fleet achieved availability of about 92.12% and reliability of around 97.76%, while the 9HA fleet reached approximately 92.89% availability and an estimated 98.91% reliability—both showing marked improvement since the last conference due to resolved engineering challenges.

Supply chain and shop capacity expansion

GEV strives to prioritize customer feedback and reporting to help improve its products. Since their first conference appearance in 2019, GEV has taken and is continuously taking steps to improve their HA units based on customer feedback and data.

During a presentation and Q&A session with Shane Long, VP of global supply chain, he addressed continued support to its customers as a standalone entity and highlighted some of the marked improvements to both 7HA and 9HA units over the last five years.

Notably, there has been ~60% increase in rotor repair capacity and around 30% re-

6. Hollenbeck shares a history of vibration RCA history, dating back to 2018

duction in repair cycle times, with ongoing efforts to enhance these metrics further. Upward trends in these areas are due to substantial investments in the global supply chain in response to user concerns.

Long also noted an upward trend in HA HGP growth for buckets, nozzles, and shrouds from 2022 onward. A concerted effort in fine-tuning operations for over 90% of these hot gas path components across 10 lean lines has resulted in about a 24% increase in turbine output year over year. This trend is projected to continue into 2025.

In addition, combustion and HGP hardware repair cycles have decreased from 12–15 months to approximately six months for most components. Coated hardware repairs still require 9–12 months, with a pathway and goal noted to achieve six-month repair cycle in the future.

Global signs of growth. As part of the presentation, Long also discussed growth trends in various locations across the globe. In Greenville, the OEM is working toward increasing capacity, and in Singapore, they're expanding their shop by about 50%.

Globally, GEV is also ordering and staging additional hardware for HA rotor enhancements and qualifying new rotor forging suppliers for production and refurbishment needs. All of these efforts have helped streamline rotor repair cycles through lean processes.

RCAs

In 2023, GEV received feedback from several of its users looking for more frequent updates on fleet-wide root cause analysis. David Cihlar, GT product service manager, and David Boehmer, principal controls engineer, addressed customers' voiced frustrations over a lack of visibility to RCA status and progress. Over the last year, the team has worked to mitigate some of these frustrations by creating an HA fleet dashboard, increasing visibility and transparency on the user side.

The team presented the HA Fleet RCA Dashboard to the audience, which summarized the status of the top gas turbine issues and tracks containment measures, RCA completion, CAPA implementation timelines, and relevant TILs.

In addition, GEV has created more opportunities to interact with its customers directly through recurring webinars and user conferences. Each format allows customers to ask the team questions, providing more clarity on certain topics while also helping the team address users' needs for future development.

Vibration issues

Jonathan Hollenbeck and Molli Dill of the power train dynamics and diagnostics team addressed vibration challenges related to system resonance in gas turbines and generators (Fig 6).

The team has been tracking various vibration RCAs since 2018 and implemented and communicated corrective actions to customers via TILs. Hollenbeck and Dill highlighted corrective and preventative actions addressing past concerns over 7HA.02 exhaust seismic vibrations. They found that transmissibility improved between 20-26% when ribs were installed to the fleet, further reducing seismic vibration by an average of 32%.

HA first vibratory response. The presentation also dove into the HA first vibratory response. Rounds of testing and customer data has indicated a higher Q factor in the 7HA.02 compared to the 7F.05. Findings point to lower rotor and oil film damping contribution, higher uncoupled stator/rotor eigenfrequency ratios, and gas turbine/foundation interface dynamic stiffness. Data suggests the change in first critical vibration amplitude tends to slow with continued operation, driven by rotor eccentricity. The corrective action for units currently in service is through, among other things, midspan balancing.

Cold start thermal peak vibration. HA cold start thermal peak vibration risk cost analysis was also outlined to conference goers. Hollenbeck and Dill demonstrated the effect of replacing the train load coupling in a 9HA.01 engine. The engineers were able to shift the turbine's resonance mode away from its normal running speed, resulting in a reduction in thermal stress during cold starts.

This improvement, which increased the separation margin from the resonance frequency, had a positive impact on the turbine's thermal response, reducing wear and enhancing overall reliability, especially during start- up conditions. This kind of enhancement helps the turbine run more smoothly, reduces the impact of thermal stresses, and potentially extends the life of the turbine.

S1N distress

Since 2019, customers have expressed ongoing challenges with S1N LE and TE distress in both 7HA.01/2 and 9HA.01/2 engines. The root cause was identified as excessive oxidation, leading to debris accumulation in cooling holes, especially in hot or humid climates. GEV teamed up with Florida Power & Light in 2019 to investigate this issue more closely. Jenn Scharfe, CT fleet team engineering leader for FPL joined GEV's Clayton Greer, a GT product service lead engineer to present their findings and conclusions.

Throughout the course of the study, FPL and GEV tried various measures to prevent oxidation, including a rainbow test to determine effectiveness. The rainbow test concluded after 19k hours of operation in 2024 and led to new maintenance approaches. Corrective measures, including the addition of OD/ID filters, have proven effective and are now standard in all new and repaired hardware. Users were also advised to consider additional casing coatings and early inspections to prevent assembly gaps.

Dual-end drive (DED) collector

Across the W84.6 model generator fleet, some customers have identified collector performance issues, and unchecked units have experienced flashovers. GEV detailed RCA findings and discovered that key components in 7HA.02/3 gas turbines like carbon brushes, shunts, brush holders, and collector rings were contributing factors.

Addressing GEV's initiative to identify and repair the W84.6 dual end drive units was Paul Quail, a generator rotor COE technical leader (Fig 7). The team noted three main findings in their root cause analysis: aerodynamic windage, brush track heating, and collector ring configuration.

Aerodynamic windage. GEV performed

several validation tests and studies and concluded that aerodynamic windage, or lifting of the brushes, can lead to poor ring-to-brush contact. As such, a high ring surface speed can enable a high-pressure boundary layer. The team concluded that installing dual groove rings reduce the windage effects on the brushes; dual groove and slotted brushes provide better brush-to-ring contact, eliminating brush overheating and blue shuts and reducing selectivity to acceptable levels; using dual groove brushes is preferred since it does not require that brushes be re-slotted, thereby reducing maintenance.

Brush bouncing. GEV's team of engineers investigated the root cause of brush bouncing, a phenomenon that occurs when insufficient or deteriorated collector ring film leads to the brushes breaking. A key driver in this is high collector ring temperatures, which can lead to their breakdown. To combat these issues, GEV's technical experts ran through a series of validation tests and studies, and their root cause analysis pointed to brush track heating.

After running through tests, the team has made crucial discoveries and recommendations: A six- wide brush layout is more effective at heat distribution across the ring and brushes; and a lower brush track temperature is expected to retain film for longer based on promising preliminary data.

Brush vibration. Additionally, customers have noted a pattern of brush vibration in in their 7HA.02/03 units. Brush vibration affects stability and can lead to ring surface imperfections. The GEV team conducted test stand validation studies and thermal modeling simulations. They also conducted factory test vibration measurements and are currently analyzing site vibration measurements. Their findings led to the discovery of misaligned axial holes, which distorted collector rings.

GEV concluded that brush vibration and bouncing was caused by collector ring deformation from the axial cooling holes. Over time, the structure of the axial cooling holes can warp or shift from factors like change in temperature or mechanical stress, weakening the collector rings and relaxing the original shrink fit.

To address the cause of brush vibration, GEV reengineered the size and quantity of the cooling holes, moving them closer together to be less than the width of the brush. Doing so resulted in the collector rings becoming more compliant and enabled a reduction in its diameter. This change has shown to positively impact windage and brush track temperature.

Ongoing corrective actions. Quail concluded the presentation by outlining the current status of corrective actions and next steps. So far, some of these measures have been implemented and have yielded positive results, but GEV is continuing to develop and test solutions, including a full-size collector test stand expected to be operational by 2025.

Thrust bearing challenges

Customers have observed higher-than-expected hot gas path thrust loads in some 7HA.02 units. Consulting engineer Will McEntaggart outlined GEV's findings and the steps they're continuing to take to mitigate future problems.

McEntaggart focused heavily on various operational and design factors and how they can impact forces acting on gas turbine thrust bearing and the synchro-self-shifting (SSS) clutch. Built to help manage thermal expansion and accommodate temperature-based shaft growth, some units were experiencing sliding SSS clutches. This change in motion, in conjunction with the forces from the unit's steam turbine load, has added additional forces to the thrust bearing in some cases.

7. Quail unveils the RCA for collector performance issues in W84.6 generators

Additional factors. Other contributing factors affecting a unit's thrust bearing capabilities were component alignment, gas turbine aero thrust load, and the condition of certain components like S1 nozzles and mid-section seals. Each of these parts interact with one another and influence the amount of force that the thrust bearing and SSS clutch experience while in operation.

Achieving temperature regulation. The GEV team is working diligently on corrective measures to alleviate thrust bearing challenges and regulate the unit temperature. All units will now alert users if the temperature rises above 105°F, helping to prevent further wear or damage.

Improved TC cable routing. Improvements have also been made in the fleet's thermocouple cables, per TIL-2485. By adjusting the cable routing for more accurate temperature readings, customers can receive more reliable data. In turn, teams can use their findings to help maintain safer operational limits.

S1B Leading Edge Erosion

Some 7HA.02 units have experienced spallation of the thermal barrier coating (TBC) due to bonding issues. Clayton Greer delivered the presentation, highlighting GEV's root cause analysis and corrective actions to improve the fleet's overall durability.

Improving the bi-layer TBC system. Issues surrounding delamination and erosion of the bi-layer thermal barrier coatings were reported across multiple turbine models, particularly the 7HA.02 engines. Studies indicated that the root cause was from top-down exposure to high velocity gases and erodent materials.

As part of the initiative to improve the units, GEV made changes to the cooling hole clearing process, helping to ensure better airflow and temperature regulation. The new TBC technology is scheduled to be rolled out over time, with the 7HA.02 AGP turbines receiving the improvements first, followed by 7HA.02 non-AGP turbines in August 2024, and a full process cut-in expected by the beginning of 2025 for 7HA.02 AGP turbines.

GEV aims to create more resistance to erosion and delamination within the units by improving the bi-layer TBC system. For customers, this translates into better performance and a longer shelf life for their units.

What's next for GEV

Diving into several root-cause analyses throughout the HA fleet over the past several years, the OEM has shown their dedication to improving their units for a global customer base. Considering customer feedback, the team has prioritized users' most pressing needs and provides full transparency in their problem-solving solutions. CCJ

AOG 2025 – 8th Annual Conference
July 14-17 | Niagara Falls, NY

Powering forward: AOG 2024 showcases non-OEM technical solutions and global collaboration

The Alstom Owners Group (AOG) serves the global community of Alstom gas and steam turbine power generation equipment owners and operators. This group began in 2018 as a private user organization and has gained widespread support from third-party service providers. Reported below is the 7th annual meeting, held July 29-31, 2024, in Savannah, GA.

Presentations from this and previous AOG conferences are available to end users by registering for the discussion forum at www.aogusers.com, which is a great way to get up-to-speed on the rapid advancements being made by third-party solutions providers in the Alstom GT and ST markets.

The basic 2024 agenda:

- Monday – Presentations by owners/operators and by FM.
- Tuesday – Presentations by service providers.
- Wednesday – Technical training options.
- Thursday – Tour of K-Machine Industrial Services, Savannah.

ROCKSAVAGE, UK

In a follow-up to AOG 2023, Chris Bailey, InterGen UK's plant manager, offered *GT B EV combustor performance update 2024*. This overall project was introduced last year as a "rebuild success" with a "truly pragmatic solution."

The Rocksavage Power Plant is a fully merchant 2 x 1 800 MW CCGT in the northwest of England, operational since 1998, featuring two GT26 A/B version machines. There is no service agreement with the OEM.

Gas turbine B's failure, calling for a complete EV combustor rebuild, occurred on May 21, 2022. To replace the EV combustor structural components with new from the OEM (Alstom/GE) would be a 46-week lead time. Estimated return to service would be

1. GT26 EV combustion chamber in 2022

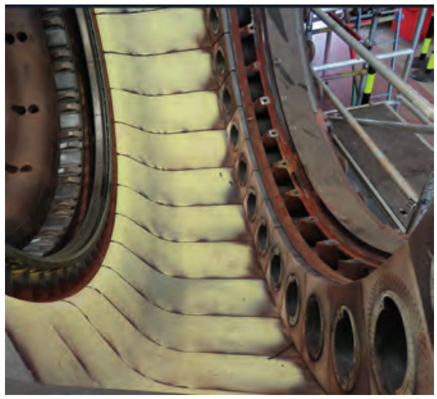
June 2023. That was not acceptable. The plant's pragmatic approach, including a global search, was launched (Fig 1).

One fundamental issue: there are very few GT26 A/B units operating worldwide, and InterGen owns the majority (four).

Bailey outlined the four-pronged project approach:

1. Engage globally with independent power generation owners, GT consultants and service companies.
2. Contact the engineering teams of the other GT26 A/B owners and operators, including Dock Sud in Argentina (Fig 2).
3. Work with the OEM to explore resource options beyond the European teams (e.g. US GT24 team).
4. Use contacts within the OEM team to secure, assess and purchase selected used parts.
5. The EV combustor rebuild began October
6. The gas turbine rebuild was completed in November, units were synchronized, and the plant returned to commercial service on December 6, beating the OEM-assumed schedule by six months.

Bailey then gave us plant performance data up to April 2024, challenging an OEM con-



2. EV combustion chamber parts from Dock Sud, ~28k EOH

straint of 100 starts in that time period. Gas Turbine B has undergone 149 starts, and the overall plant total for two GTs and one ST is 500 starts. "Starting reliability is above 96 percent, and none of the failed starts has been attributed to GT B," Bailey said.

First in and last standing. Beginning with third quarter 2025, it is expected that only Rocksavage will operate GT26 A/B machines. The two at Doc Sud (Argentina) have changed to HE (high-efficiency conversion), as will the Rocksavage sister plant (Croyton) in 2025.

Bailey's key message takeaways:

- Challenge yourself.
- Know that the OEM is not the only service provider.
- Trust in-house experience and third-party experts.
- Gain support from your shareholders and your insurance provider.
- Ask the right questions, and don't take no for an answer.
- Innovate, collaborate, and be pragmatic.

One underlying message is strong support for the AOG Owners Forum, available via

3. Four-acre site at Sand Lake

www.aogusers.com.

Bailey's final statement: "We can help each other out, especially for parts. This avoids us all having to call around."

SAND LAKE, ORLANDO

What existed as Orlando Cogeneration is now Sand Lake Energy Center, a 120 MW facility now owned by Florida Municipal Power Agency. The facility began operations in 1993 with one Alstom GT11 NMC combustion turbine and one Siemens steam turbine, supplying power to Duke Energy Florida.

The facility was acquired by Florida Municipal Power in 2024.

Danny Slade, maintenance manager, was on hand to explain *30 years of operation at Sand Lake*. He called it a "small cogen site that is now running more hours than expected, and is in base-load operation." It runs on a small footprint "with a small staff in a city (Orlando) with limited heavy manufacturing," he explained. Site area is 4 acres including laydown area for parts and parking for craft (Fig 3).

During the pre-sale outage, the GT11 underwent a major C inspection, repair on 36 burners, combustor parts and inner liner, turbine rows 1 through 4, and heat shields (Fig 4). The geared, axial flow (VAX) steam turbine also underwent a major inspection.

A significant discovery was row 16 compressor blade damage, with replacement parts to be supplied by GE (Baden). Other damage was repaired on site. Ignitors also suffered internal failure and were repaired. Major non-OEM suppliers included Hughes Technical Services and K-Machine.

The outage was completed February 2, 2024.

Operation data for the plant as of June 2024 includes 558 starts and 251,522 operating hours.

Slade stressed both the outage and long-term operation as a "good example of local experience and solutions."

Insurance

Involving a plant's insurance provider early in project planning was a recurring topic during discussions at AOG 2023, and a key provider was on hand for 2024.

Tom Hadfield is an engineering specialist at FM, a policy-holder-owned commercial property insurance provider. He came to Savannah to offer *FM – 10-year loss study* focusing on Alstom machines.

4. Sand Lake pre-sale outage

In total, FM holds insurance on 4000 steam turbines and 3500 gas turbines in various uses and industries worldwide.

Looking at Alstom machines in the US and UK, Hadfield offered a review of failure events based on parts of the machines. FM's goal is to "review each event and pinpoint the cause to help provide loss prevention improvement recommendations." He added, "Our goal is to improve availability, reliability and reduce downtime."

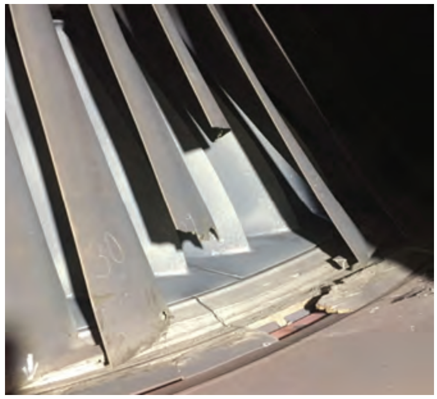
Hadfield offered loss scenarios on GT 24/26 and GT 11/13 machines for more than 100 insured Alstom units, covering 12 losses from 2014-2024, and comparing frequency with severity (Fig 5). For this chart, the loss scenario costs represent the initiating event plus consequential damages.

"Compressor issues," he explained, "lead to the highest costs."

He then shared data on gas turbine operating modes based on demand in both the US and UK, highlighting increases in component stresses as well as heat transients, thermal fatigue and fretting. He added that "two-shifting is done to make more money, but leads to more forced outages."

He then offered selected examples:

- Compressor loss caused by a liberated Row 16 locking piece, causing damage to Rows 17-22. The unit had tripped due to high EV combustion chamber pressure.



6. Blade liberation LPT4

- Turbine trip due to high vibration. The cause was partial liberation of an LPT4 blade causing damage to multiple LPT4 blades and the EGH (Fig 6).
- Foreign object damage. A GT11 suffered increased vibration, then tripped due to turbine inlet temperature. Inspection revealed a liberated M16 cap bolt along with vane/blade damage and other liberations.
- Again for a GT11, an OTCC pipe failure and large release of stored energy led to a plant trip and caused considerable damage to the surrounding area. Some parts were found 30 meters away. Incorrect welding consumables had been used during construction.

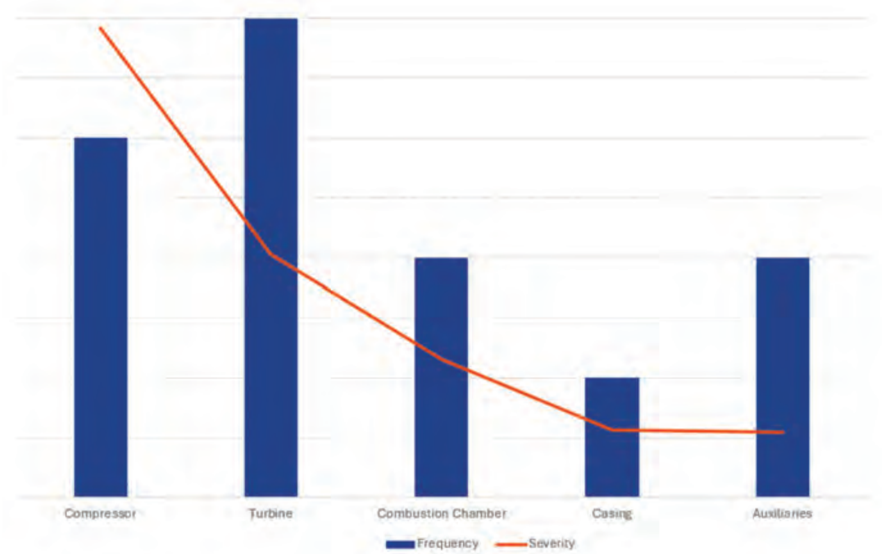
Other examples were discussed.

His conclusions included QA/QC and FME program thoroughness, emergency training, prompt service bulletin compliance, and continually updating inspection criteria based on findings.

His final statement: "Shared knowledge is critical for an available, reliable and efficient fleet of Alstom gas turbines."

COMMISSIONING

Hughes Technical Services (HTS) is a division of AP4 Group and provides field engi-



5. Loss scenarios GT24/26 and GT 11/13, 2014-2024 neering support in all turbine control and excitation systems plus comprehensive field mechanical services on GE/Alstom heavy-duty gas turbines. HTS was formed in 2014 by former ABB/Alstom engineers. Gary Hughes presented *Commissioning and mechanical solutions to optimize reliability and performance*.

He began with commissioning, featuring full gas and steam turbine HTS crews including all tooling, held in-house. Commissioning includes instrumentation and controls, and HTS is an authorized ABB distributor.

He next covered consulting and engineering, including training in operations and controls.

Hughes offered an update on activities since the last AOG meeting, including turnkey projects completed on or ahead of schedule. Examples:

- 8 C inspections: 5 turnkey, 5 countries.
- Multiple A/B inspections.
- 3 steam turbine overhauls.
- 650 individual customer support transactions.
- Zero lost-time accidents.
- 30-day schedule, rotor bearing to mechanical complete.

He offered a full list of C inspection parts, both new and refurbished (working with TRS Houston in an exclusive agreement for Alstom parts).

Parts refurbishment examples (with TRS) included hot gas casings, vanes, blades, heat shields and others.

One helpful note was a list of "What we are seeing."

- Blade tip wear.
- Honeycomb seal wear on vanes.
- Heavy wear in HGC inlet and exit rings, and distortion throughout the HGC.
- Major distortion and out-of-roundness on LCCI and TVC.

He then showed a finished product (Fig 7). He followed with Voith overhaul (authorized distributor), valve servo upgrades, and AVR and SFC control upgrades.

HTS would be part of the Wednesday Training Day for a much deeper dive.

CATALYSTS

Groome Industrial specializes in HRSG tube cleaning, SCR catalyst cleaning, CO catalyst washing, AIG tuning and testing, and acquired the ExPro companies (explosive industrial cleaning) in 2021.

Matt Cohen discussed *Servicing and maintaining GT emissions systems and HRSGs* focusing first on common factors that lead to non-ideal performance:

- Non-uniform gas flow.
- Non-uniform NH3/NOx.
- Non-uniform temperature.
- Catalyst deterioration (poisoning, fouling, thermal phase change).
- Operations (insulation blockage, moisture, damaged seals, poor ammonia control, bypass, load changes).

He then turned to catalyst cleaning for CO (Fig 8) and SCR as well as AIG tuning.

He offered an interesting summary for catalyst testing scheduling (Fig 9).

Regarding catalyst testing specifics, he suggested multiple samples: "Don't base decisions on what might be one bad sample."

EXCITERS/STARTERS

"The primary role of the excitation system," ABB's Chad Mourad explained, is to "maintain the generator terminal voltage" and operate the synchronous machine within its operating limits. "The excitation system guarantees the quality of the generator voltage and reactive power, and therefore the quality of the delivered energy from the powerplant."

Other key technical points:

- Provides variable DC current to the rotor field.
- Controls the terminal voltage.
- Ensures stable operation with network and/or other machines.
- Keeps machine within permissible operating range.
- Contributes to transient stability after a fault.
- Communicates with the powerplant control system.

He then covered the major components of a static starter and its connection to the following items: circuit breaker supplying the medium voltage, medium voltage input transformer, and output isolating switch.

He ended with ABB's capabilities to supply, service and maintain all components.

ABB's excitation systems Americas is located in Montreal, Canada.

GENERATORS

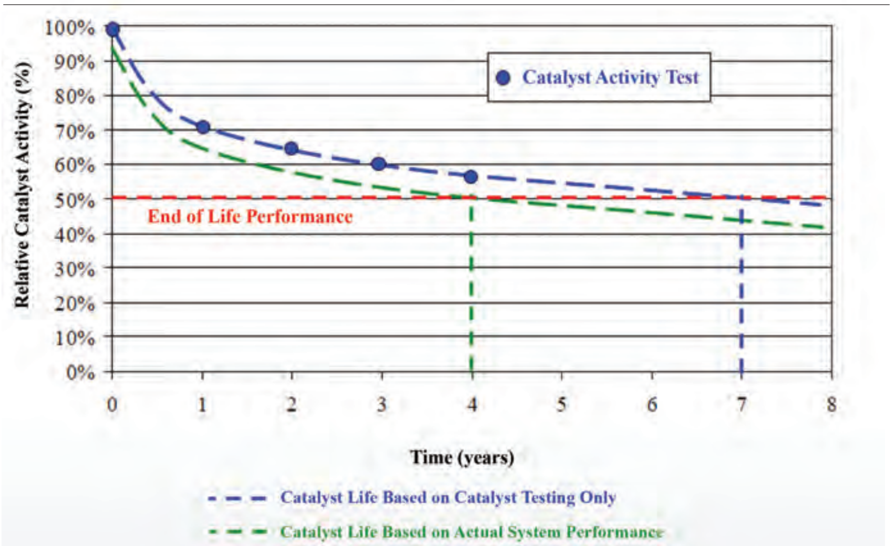
Jamie Clark, AGT Services, presented *Generator outage planning - and contingencies*.

He began with some interesting statistics:

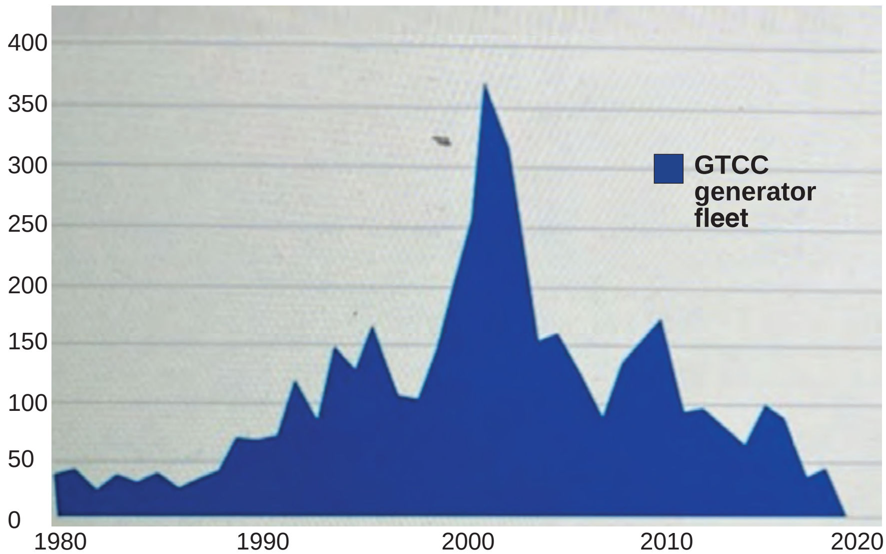
- More than 5000 generators (3000 GE) have been built since 1995, peaking around 2002 (Fig 10).
- Average generator age is 25 years.
- Stator design life is 25-30 years.
- Field design life is 10-15 years.
- All design life numbers assume base load

8. CO catalyst wash

7. Hot gas casing by refurbished by TRS in partnership with HTS



9. Catalyst testing and relative activity



10. GE OEM generator COD

(limited start/stops).

- Generator maintenance is normally an afterthought.

At last year's conference, Clark made an interesting point that "around 75 percent of combined cycle starts run less than 24 hours."

At the current time, there are limited resources to test, inspect and repair generators, and there are limited resources to make new windings.

So how do owner/operators predict testing and inspection? More importantly, what are they prepared to do with the inspection findings, and what are their contingency plans?

He covered standard field testing: visual, electrical and mechanical. He then moved on to "improved robotic inspection capability," with cautions:

- Not all generators are the same.
- They have different "entrance gaps" (limitations) for the robotic equipment.

His advice: "Make sure contractors offering robotics provide proof of successful fitment, including EL CID and Wedge Map capability for your particular generator model."

He added: "A borescope-aided visual inspection is also very useful" for (as examples) field end winding condition, main lead condition, stator winding inspection and searches for greasing.

He ended with braze joint inspections and radiography.

His final advice: "Evaluate your fleet mix and determine spares, and long-lead-time component strategies."

BYPASS VALVES

Merijn Reus, Advanced Valve Solutions, discussed *HP bypass valves in cycling power plants*. These valves, he explained, are "critical components undergoing significant changes (challenges) due to the influence of renewable energy."

As explained at HRSG Forum 2024, HP bypass valves in base-load operations traditionally served specific functions:

- Open to 80 to 100 percent during steam turbine trip.
- Bypass HP steam during HRSG startup and shut down, performed a few times per year.

But today these valves face more frequent operation, impacting reliability and system integrity.

This transition is particularly harmful to dump-tube-type valves, due to water impingement (Fig 11) and high-frequency vibration.

Fundamental impacts of cycling in the industry are:

- Failure of dump tube integrated in the valve body.
- Cracking of nozzle at steam line weld (continuous thermal stress regardless of steam flow).
- Thermal stress in downstream piping leading to cracking and deformation (primarily at high steam flows).

He went on to suggest how to prevent dump tube failures (Fig 12):

- Eliminate dump tube, replacing it with heavy-duty perforated plates.
- Introduce a second dynamic pressure stage to prevent overcritical expansion and minimize turbulence (oscillation).
- Support the perforated cage of the second dynamic pressure stage at the bottom.

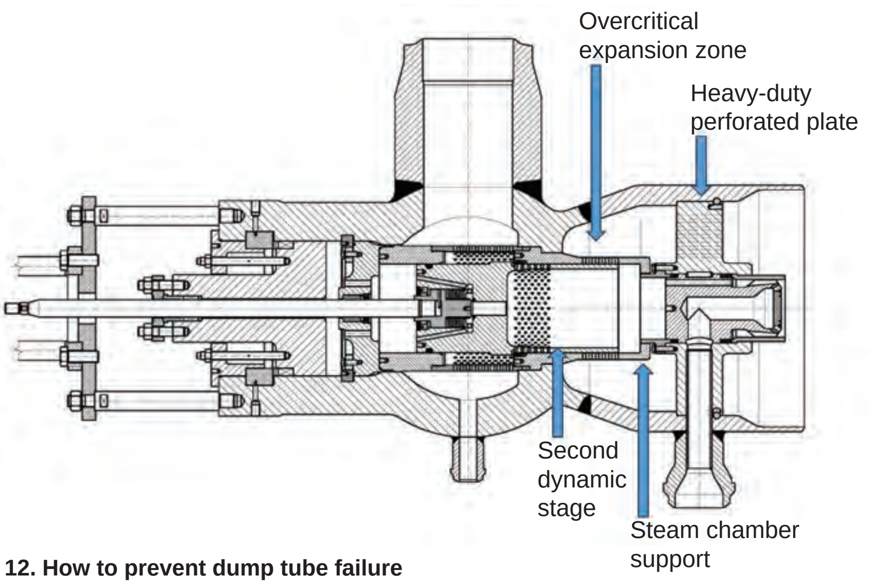
He then suggested how to reduce thermal stress in downstream line and nozzle weld:

- Replace perpendicular spring-loaded nozzles with axial spray injection through steam atomizer.
- Insulate spray water supply line by use of an inner liner.

WARMING SYSTEMS

Pierre Ansmann, Arnold Group, presented *Arnold complete cycle solution*, more specifically the benefits of a turbine warming system, with selected examples. The case studies reviewed optimized cycle time, reduced HP low-cycle fatigue, and improved CT firing time to reduce emissions.

11. HP bypass valve damage due to water impingement



12. How to prevent dump tube failure

For more, see the review of HRSG Forum 2024 in Combined Cycle Journal, Number 82.

He then focused on a D11 case history.

A unique feature shown at AOG 2024 was Arnold's Step Protection system that provides solid ground above the insulation and protects the insulation during inspection and maintenance (Fig 13).

Key steam turbine warming takeaways included:
- Reduced startup time by up to 75 percent.
- Reduced parasitic load.
- Less stress on CT hot-gas-path/exhaust area.

He then mentioned HRSG warming options and a downcomer project involving both Duke Energy and EPRI.

GT HEALTH

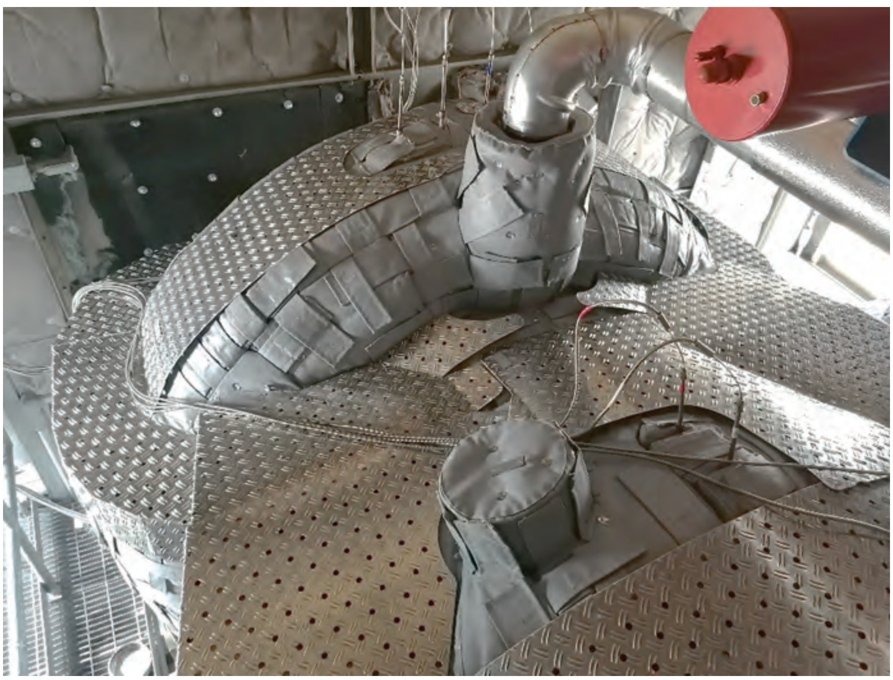
Dan Stankiewicz, Liburdi Turbine Services, discussed *Gas turbine health management* and advanced analysis techniques to both optimize service intervals and detect abnormal conditions.

He introduced the Liburdi gas turbine analysis program (GTAP), a physics-based engine model for full-gas-path aero/thermal analysis and calculations of both power and efficiency loss.

His examples were quite specific covering hot section measurement, compressor map, and stage-by-stage operating conditions.

This leads to FE analysis to calculate metal temperatures and modeling of critical components (e.g. turbine flows at each critical row, among others). Creep strains and deformations during operation can also be calculated.

He went on to discuss oxidation and coat-



13. Arnold's unique step protection system

ing life as a result of stress and temperature.

Finally, a "life model" calculates equivalent operating hours that could perhaps be used to extend an outage interval.

PERFORMANCE ANALYSIS

AIM Power Consulting, presented by Craig Nicholson, dove deep into *Gas turbine performance: behind the data*. Nicholson presented an interesting overview of performance factors and what can and cannot be easily controlled for mechanical characteristics, inlet and exhaust conditions, fuel, and firing temperature.

He then focused on gas turbine performance data, measurement, analysis and monitoring.

Most examples were based on thermodynamic evaluation. The thermodynamic modeling he presented is EPro+. The goal is optimal performance with reduced scope, time and cost.

He then offered highlights from four projects:

1. Evaluate inlet temperatures, then energy-balance HP and LP turbines to improve performance.
2. A controls upgrade to correct years of firing temperature drift leading to a 4 MW increase at full load.
3. Energy balance firing temperature adjustments following installation of non-OEM parts, increasing output.

Nicholson stated that "we have observed numerous occasions where units have been conservatively adjusted, or not adjusted at all."

He added: "Data validation is the key. We are accurate, impartial, dependable, and available."

When asked "Do you always have to go to the site?" His answer: "No."

PARTS SUPPLY KOREA

Ta-Kwan Woo traveled from South Korea to present Sung-Il Turbine's capabilities for *Casting of gas turbine parts*. He focused on turbine blades, made in-house through reverse engineering.

Based in Busan, South Korea, Sung-Il also produces hot-gas-path parts for Alstom machines, and offers a variety of field services for customers globally.

He gave detailed examples of:

- Vacuum precision casting.
- Thermal barrier coatings.
- Machining/heat treating.
- Testing.
- Inspection and evaluation.

He then outlined the full capabilities of Sung-Il.

PARTS INNOVATIONS

Jeremy Clifton, Allied Power Group (APG), discussed an *Expanded suite of Alstom capabilities*.

Capabilities specific to Alstom machines include:

- Component repair.
- Coatings.
- Rotor repair.
- Casing repair.
- Custom engineering.
- Field services.
- Steam turbine services.
- Parts supply.

Engines served:

- GT8.
- GT11, D-NM.
- GT13 (coming soon).

He then presented various examples including the inspection process, custom-engineered coating robotics, and various field services.

His concluding statement: "There is innovation and growth in the non-OEM world."

OPEN DISCUSSIONS

Open discussions (end-user questions) were held throughout the conference, as time allowed, on:

- Inlet and filtration.
- Compressor.
- Combustor.
- Rotor and casing.
- Hot gas section.

- Borescope/robotics inspections.
- Exhaust systems.
- Generator and electrical, including testing frequency.
- Controls, BOP and auxiliaries.
- Valves and leakage issues.
- Safety, compliance, outages.
- Parts/services lead times.
- Use of OEM service bulletins.
- Questions for GE.

DAY 3 TRAINING

No AOG conference would be complete without training sessions specific to Alstom turbine and generator users. Day 3 was dedicated to participant-selected modules on these options:

- Liburdi Turbine – GT coatings short course.
- AP4 Group/HTS – Canary data historian training course.
- NEC/National Electric Coil – Alstom generator life extension training course.

STEERING COMMITTEE

The steering committee for the 2024 event was:

- Kristi Gledhill, Midland Cogeneration Venture (End user).
- Paul Drake, Tenaska Berkshire Power (End user).
- Ross Goessl, We Energies (End user).
- Chris Hutson, K-Machine (Service provider).
- Jeff Chapin, Liburdi Turbine Services (Service provider).
- Ashley Potts, AOG point of contact (AOGusers.com).

SPONSORS

Arnold Group, Hughes Technical Services (HTS) and Liburdi Turbine Services have supported the group since its beginning. Other sponsors for 2024 were ABB, Advanced Valve Solutions, AGT Services, AIM Power Consulting, APG, Groome Industrial, and Sung-Il Turbine. CCJ

EVERYONE LOVES A SHOP TOUR

On the final day of the AOG 2024 conference, attendees were given an exclusive tour of K-Machine Industrial Services' expansive Savannah facility. Guided by president Andy Dyer, engineering manager David Yager, and gas turbine CSM Chris Hutson, participants explored the 85,000-square-foot repair and manufacturing center.

The facility boasts large CNC and manual machine tools, including vertical lathes with up to 17-foot turning capacity and mills with up to 14-foot x 31-foot travel, as well as an overhead crane capacity of 70 tons. These capabilities enable the growing outfit to handle heavy rotating equipment component manufacturing and repair, along with comprehensive equipment rebuild services.

The tour highlighted K-Machine's specialized services in power generation, particularly their expertise in Alstom gas and steam turbines. Attendees observed the facility's advanced machining capabilities, including reverse engineering with Faro Arm technology and a full-time quality assurance department operating under an ISO 9001:2015 certified program.

The company's welding services, featuring ASME code welding programs and experience with specialty alloys, were also showcased, emphasizing their ability to perform complex repairs and fabrications.

Throughout the visit, the K-Machine team emphasized their commitment to rapid response and customer-focused solutions, buoyed by talk during the earlier user discussion session of many successful projects.

LEGACY TURBINE DOCTOR, NO. 3 IN A SERIES

Excess-fuel trip logic mitigates explosion potential

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

An MS6001B in Florida experienced a significant failure in 1994 when its stop-ratio valve (SRV) servo failed. On startup, the unit cranked and fired successfully; however, the valve continued to open. The failure was caused by the servo sticking at a slightly open position, allowing the SRV to continue opening at a slow rate.

The SRV excess-fuel trip was based on the valve's position, typically 33.3%. The excess-fuel trip was inhibited by L28FDY, flame plus one second.

When flame was established, plus one second, the trip was inhibited but the SRV continued to open. Exhaust temperature increased but not to the over-temperature set point. The fuel/air mixture was high enough to increase the exhaust temperature, but the limited oxygen at crank speed allowed a very rich fuel/air mixture to continue through the turbine until it reached the HRSG inlet duct. The additional oxygen in the HRSG triggered an explosion, damaging the boiler (photo).

The modification suggested to prevent a failure of this type in the future was to add a 60-sec timer to the trip. The failure and modification were described in *Mark V Newsletter,* No. 6, Feb 13, 1995.

The engineering recommendation was detailed in *Mark V Software Note,* No. 98, Mar 3, 1995, thusly:

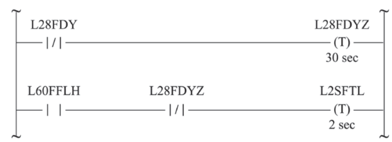
> Two separate events indicate that the setting of the liquid and gas excess-fuel trips are not protecting the unit as intended. The typical setting for the liquid-fuel trip is 15% of rated fuel flow—27 gpm for an MS7001EA. If fuel flow is calculated at fire and 10% speed, it is approximately 1.2% of rated flow, 2.4 gpm. The gas setting is based on the ratio valve opening and is approximately 30%. Typical opening of the ratio valve to establish starting P2 pressure is less than 5%.

The practice for excess liquid fuel has been to depend on the over-temperature trip to protect the turbine, with the excess-fuel trip itself sensing a failure of the bypass valve after startup.

On gas fuel, the excess-fuel trip is based on the ratio-valve position and is intended to avoid the introduction of large amounts of gas if the valve were to fail open on startup.

The following modifications are recommended to use the excess-fuel trip to sense a fuel control-valve failure, closed for liquid and open for gas, and trip the turbine to avoid subjecting the turbine to an over-temperature excursion:

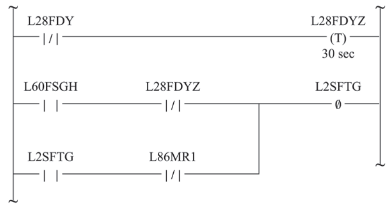
LIQUID FUEL. The excess-liquid-fuel trip constant LK60FFLH should be set to 5% of the 100% FSR (fuel stroke reference) fuel flow, which is the approximate flow at a warmup condition of 16% FSR and 30% speed. The excess-fuel trip rung should be modified to inhibit the trip 30 seconds after flame rather than at the completion of warmup as shown in the diagram below.



Actual operating conditions on liquid fuel, such as startup FSR values and firing speed, may vary from unit to unit. This may necessitate slightly different excess-liquid-fuel trip settings. The unit should be started and the fuel flow monitored to determine the actual flow from firing to the completion of the 30-sec L28FDYZ timer.

The excess-fuel constant should maintain a minimum 1% margin to the observed flow. Fuel flow also should be monitored on a hot start since the unit acceleration and fuel flow will be higher than on a cold start. If the observed flow exceeds the cold-start excess flow, the L28FDYZ timer should be reduced to the point at which the hot-start flow equals the excess-fuel constant minus 1%.

GAS FUEL. The excess-gas-fuel trip constant LK60FFGH should be set to 10%, which is the expected ratio-valve opening with a margin of 5%. The excess-fuel-trip rung should be modified to inhibit the trip 30 seconds after flame rather than at the flame (diagram below).



Actual operating conditions on gas fuel, such as startup FSR values and line pressure, will vary from unit to unit. This may necessitate slightly different excess-gas-fuel trip settings. The unit should be started and the position of the ratio valve monitored to determine the actual movement during firing. This value can then be used as the excess-fuel trip with a 5% margin.

The *Mark V Software Note* added the timer and reduced the SRV position trip from 33% to 10%.

In 2000, GE issued TIL 1275-1R1, *Excessive Gas Fuel Flow at Startup,* which revised the criteria for excessive gas fuel from valve position to SRV inter-valve pressure, P2. GE pointed out that several factors could affect excess fuel flow—such as leaking SRV, inter-valve vent solenoid failure, LVDT failure, and lube-oil condition, among others. The OEM recommended adding logic to detect both high and low P2 pressure. It provided a typical SRV startup position curve and recommended multipliers for low and high setpoints. A time delay for the trip was not included.

The TIL was revised in 2006 to offer P2 pressure protection software to automatically monitor P2 conditions.

A request for an opinion was recently received via a conversion from Mark V to Emerson about excess-fuel trip. Emerson proposed to add the excess-gas-fuel trip on P2 pressure. Emerson told the user that his original GE software had not been updated and to add the P2 excess-fuel sequence or the time-delay trip.

The original GE experience and solution (valve position) was provided as equivalent protection for the turbine and would be simpler to install.

Fuel Regulator units, MS3002 and MS5001, depended on over-temperature control for excess-fuel protection.

Mark I controls for MS3002, MS5001, MS5002, and MS7001 machines used the

SSVA card, which only monitored differences in the servo currents and could trigger a servo fault alarm. Later, the SFUA card was introduced for liquid fuel. The card had an excess-liquid-flow trip adjustable to 15% of fuel flow.

Gas fuel used the SSVA card which monitored the closed position of the SRV and tripped the turbine if the valve opened before flame. Both trips were disabled by L28FDY, flame plus one second. Excess gas fuel depended on the over-temperature control for protection.

Mark II controls for MS3002, MS5001, MS5002, MS7001, and the LM2500 had an excess-liquid-flow trip on the SFUA card. The fuel-gas control used the SSVD card; it monitored the SRV and tripped the turbine if the valve was opened before flame. Both trips were disabled by L28FDY, flame plus one second. Excess gas fuel depended on over-temperature control for protection.

Mark IV and Mark V control systems used both liquid fuel flow and SRV position to trip on excess fuel. Several MS7001EA and MS6001B Mark IV and Mark V users were asked to verify if their excess-fuel software had been modified to include the time delay or TIL 1275. Their response:

- None of the Mark IV units had the timer modification or the reduction of the SRV position from 33% to 10%.
- Results for Mark V were varied. The *Mark V Software Note* position change to 10% had been applied to units sometime after 1995. However, the timer was not part of the change. Some units had the SRV position trip set to 15%. The Mark V units after 2000 had the TIL 1275 upgrade to P2 pressure which did not include the time-delay trip.

Recommendations. There have been at least four events of excess gas fuel on startup involving both MS6001 and MS7001 units with Mark IV and Mark V controls. It is probable there have been others not reported. The damage resulting from a duct or HRSG explosion can be expensive.

Users of Mark IV and Mark V controls installed prior to 2000 should check to see what protection is installed for excess gas-fuel flow. The trip logic is L2SFTG, *Startup Gas Fuel Flow Excessive*. The control constant for the valve position is LK60FSGH, *Startup Fuel Stroke Reference High Alarm Setpoint.*

The easiest change, if the position constant, LK60FSGH, is higher than 10%, would be to reset it to 10%. This will not avoid all potential failure modes, but it is better than doing nothing.

Addition of the 60-sec time delay as shown in *Software Note 98* would be the second most effective protection.

The GE-recommended P2 pressure protection is effective but more difficult to install.

Since "excessive liquid fuel" is based on the actual liquid fuel flow as measured by the flow divider, it is effective protection. **CCJ**

LEGACY TURBINE DOCTOR, NO. 4 IN A SERIES

Updating calculations of maintenance intervals, factored hours

The first article in Luke Williams' continuing column, *Legacy Turbine Doctor,* published last summer in CCJ No. 78, p 92 ("Are your GE B/E-Class hot parts and rotor really near 'end of life?'"), posited that gas-turbine operation at loads less than base would extend the OEM-recommended service lives of critical parts.

The temperature control system is based on a temperature limit that supports parts lives to meet established maintenance intervals. Some examples are major inspections at 8000 hr, major overhauls at 24k hr, and combustion inspections at 12k hr.

General Electric's GER-3620, *Heavy-Duty Gas Turbine Operating and Maintenance Considerations,* issued in September 1989, provided information on maintenance intervals and the effects on various operating parameters.

Also shared were formulas to calculate "factored hours" and "factored starts" based on operating conditions—such as peak operation, type of fuel, fast starts, and turning-gear hours. Factored hours and starts generally reduced the maintenance interval, Example: Operation on-peak resulted in a maintenance factor of 2.0 which reduced the maintenance interval by half, from 8000 to 4000 hours.

The first column reported GER-3620 as saying operation at reduced load "did not always" result in a reduction in firing temperature. More specifically, the OEM said it recognized operation at reduced firing temperature may improve the maintenance interval but that the effect of part-load operation is not applicable.

Williams took issue with that conclusion, suggesting that part-load operation really does affect maintenance factor. A formula was developed based on the GER maintenance factor of peak operation which increased the maintenance factor if the exhaust temperature—hence the firing temperature—was greater than the baseload temperature control curve. The formula decreased the maintenance factor in the same proportion as the GER increase in exhaust temperature.

Data were collected on an MS6001B DLN-1 starting June 2023. Operational hours at three exhaust temperature ranges below the exhaust temperature control curve were recorded in the Mark V control system. The ranges were the following: greater than zero to 15 deg F; 15 deg F to 30 deg F; and greater than 30 deg F.

In March 2024 the data were analyzed. The result was an increase in maintenance interval of 9.2%. For a rotor life of 200,000 hr, the maintenance interval would be 220,372 hr or an increase of 20,372 hr (about 28 months).

In January 2025, the data were again analyzed. The result was an increase in maintenance interval of 9.0%. For a rotor life of 200,000 hr, the maintenance interval would be 221,030 hr or an increase of 21,030 hours (about 29 months).

Conclusion: Data collected over 19 months confirm that unit part-load operation is consistent and a 9% increase in maintenance interval is a reasonable assumption. The 9% improvement in maintenance interval also can be expected for other intervals—such as combustion inspections, hot-gas-path inspections, and major overhauls.

Water wash limits

The permissive inlet temperature for online water wash typically is 50F. While this limit may seem high compared to water freezing at 32F, it protects the unit from aerodynamic factors such as inlet-velocity depression, site-altitude and barometric-pressure effects, and inlet-bleed-heat (IBH) failure.

One horror story involved a compressor failure that the plant initially blamed on foreign object damage (FOD). Investigation of the operators' log found an online water wash had been initiated just prior to the failure. Data from the local airport found that the temperature at the time of wash initiation was 27F.

In the North, winter ambient temperature is often below 32F for extended periods. To learn more about the effects of winter weather on gas-turbine performance, a MS6001B site had an online calculation of compressor efficiency programmed into its Mark V. The site manager calculated unit performance corrected for ambient weekly to monitor unit output in sub-freezing temperatures.

Over one month's time, output declined by 3%. Compressor efficiency, which was corrected to 59F, declined from 88% to 85%. The unit was located in an industrial area with less-than-ideal atmospheric conditions. In the warmer months, online water wash was initiated when to compressor efficiency declined by 3%.

Standard procedure at GE Schenectady was to clean the compressor just before conducting the performance test used to release the unit for shipment. Data were taken to calculate air flow, compressor efficiency, pressure ratio, exhaust temperature, and heat consumption. The results were compared to the cycle deck and statistical data from previous tests and they had to be within one sigma of the historic data to ship.

GEI 41042 describes two types of cleaning compounds, liquid and solid. The latter was selected because Schenectady is "North." The document goes on to discuss two types of solid cleaning compounds: organic (rice and nutshells) and inert (catalyst supports, spent catalysts, and polishing powders). The advantage of organic media is that they are combusted in the cleaning process, leaving virtually no residue.

Compressor cleaning is simple: Remove pipe cap and slowly pour in rice. Replace pipe cap when cleaning is complete

GEI 41042 blames some compressor failures on solid compounds which are said to have caused shallow impact craters and increased surface roughness. Inside knowledge suggested that foreign objects may have been in the solid material, especially nut shells. The presence of foreign objects in packaged rice is not very likely. There is also a story about the compressor manufacturer's tooling that resulted in a knife-like leading edge which was susceptible to impact damage, leading to cracks.

One observed problem with the liquid compounds selected for online washing: Solids in the compound would condense and form deposits on/in downstream compressor stages. This resulted in failures of blades "frozen" in the wheel slots, unable to accommodate the effects of compressor temperatures.

Other failures were thought to be caused by flow disruptions in the inlet plenum, which led to "scrolls" and baffle plates in the plenum.

Experience indicates that organic cleaning media—rice in particular—works fine in cold environments.

The standard in Schenectady was 9 lb of Uncle Ben's rice poured slowly into the fitting provided in the inlet transition piece (photo). Interestingly, the current transition-piece design still includes this port on the turbine side of the transition. The fitting is a 6-in. capped pipe installed at a 45-deg angle.

To clean the compressor with the organic compound, the following procedure is recommended:

- Reduce load to about 50%. For DLN units, reduce load to at least Lean-Lean.
- Using the turbine control instrumentation, observe exhaust temperature.
- Remove the cap from the fitting on the transition piece and *slowly* add the rice. The pressure inside the inlet will make sure most of the rice goes into the fitting. Performing the procedure *slowly* is important as it is possible that, if done too quickly, the flame detectors may be affected by smoke from rice combustion.
- The exhaust temperature should start to decrease as the cleaning takes effect and compressor air flow increases.
- Continue adding the rice until the exhaust temperature steadies out.

The organic-compound cleaning process was used on the unit described above and output and compressor efficiency improved by about 2%.

Conclusion: Use of organic-compound compressor cleaning avoids loss of output and compressor efficiency when ambient temperatures are less than 50F. CCJ

PSM powers next-gen turbine transformations

Alex Hoffs, president of PSM, opened the 2025 PSM Asset Manager Conference (AMC) by reinforcing PSM's dedication to innovative clean energy solutions aimed at benefiting future generations. He outlined the mission to meet customer demands through a flexible, reliable, and efficient portfolio that enhances asset lifecycle costs. Emphasizing the company's core values—agility, innovation, and trust—Hoffs highlighted PSM's achievements and strategic direction, including its significant global presence and performance metrics.

Hoffs also discussed PSM's commitment to technological advancement, detailing their continuous product development trajectory. Part of the very attractive GT upgrades offerings are key innovations like the FlameSheet™ introduced in 2015, incremental enhancements to combustion pilot systems between 2018 and 2021, and ongoing advancements aimed at improving startup emissions and fuel robustness by 2025 and beyond. These strategic initiatives are vital in addressing today's energy challenges and optimizing operational efficiencies in the electric generation sector.

Grow, baby, grow!

Perhaps the biggest takeaway from Hoffs was his introduction of the company's latest milestone: the launch of PSM North, a new workshop, customer fulfillment, and logistics center in Stuart, Fla. The facility, set to begin operations in Summer 2025, marks a major expansion of PSM's capabilities, complementing its flagship workshop in Jupiter, just 25 miles away.

The 185,000-square-foot facility will focus primarily on repairs for combustion and stationary product lines, with 80,000 square feet dedicated to advanced workshop operations and 100,000 square feet allocated for warehousing, inventory, kitting, and logistics support. A 16,000-square-foot office space will also house supply chain quality and related functions—bringing fulfillment, logistics, and manufacturing under one roof. Core technical capabilities include:

- Precision machining (manual, 3-, and 4-axis CNC)
- Electro Discharge Machining (EDM): wire, plunge, and hole popping
- Vacuum heat treatment and brazing for both manufacturing and repair
- Industry-leading flow testing and combustion support
- Advanced welding techniques (TIG, MIG, laser) and fabrication services
- High-precision metrology: structured light scanning and engine assembly checks

With this expansion, PSM is significantly increasing its footprint and strengthening its ability to deliver high-quality, reliable service to customers around the globe, especially in the USA.

Powering the transition

Jeff Benoit, VP of clean energy solutions, offered a sweeping overview of global and domestic power market trends, highlighting both progress and challenges for the energy transition.

Globally, countries are accelerating their renewable energy efforts. China remains the dominant force in renewable energy and electric vehicle manufacturing, while Japan and South Korea are investing in ammonia as a decarbonized fuel. Australia is pushing forward with large-scale green hydrogen projects. In the Middle East, the UAE is leveraging its sunny climate for ultra-low-cost solar power, while Saudi Arabia's NEOM initiative focuses on clean ammonia exports and the development of a digital economy powered by renewables.

Europe continues to lead in power market transformation, with Germany announcing 20–30 gigawatts of new gas turbines to support its transition. The EU, where renewables have surpassed fossil generation, is building infrastructure for LNG and ammonia imports and implementing carbon pricing mechanisms to manage emissions. Meanwhile, Mexico, heavily reliant on U.S. natural gas for electricity, is enabling renewable growth through structured climate laws.

Domestically, gas turbines produce over 40% of the U.S. electricity and are expected to remain vital due to their flexibility in supporting intermittent renewable energy. A notable trend is the resurgence in demand for power, largely driven by a surge in data centers fueled by AI. This development is seen as a "Sputnik moment," signaling the start of a new era requiring massive infrastructure investment and innovation.

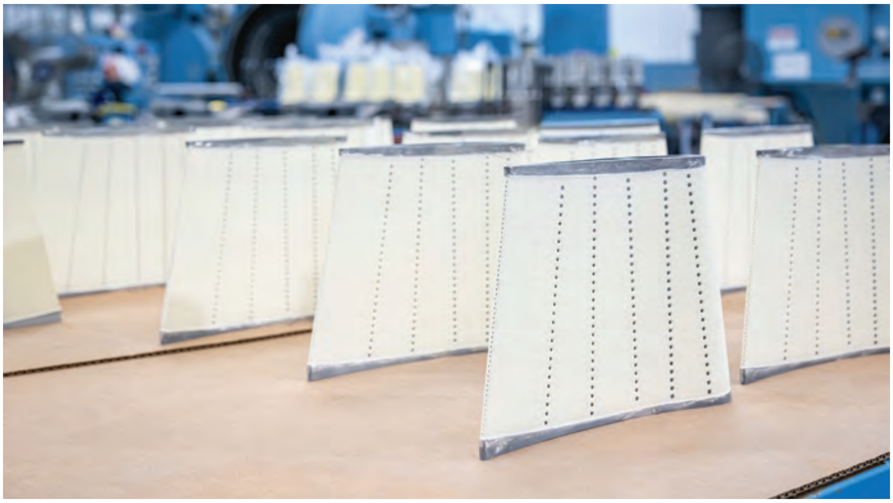
The U.S. gas turbine pipeline shows approximately 75 gigawatts in development, especially in the SERC and ERCOT regions, according to EPRI. These include both large and small-scale installations, as well as complementary internal combustion engines to meet fast-evolving reliability needs.

Benoit also told the Florida story, where solar is rapidly expanding, although natural gas still dominates. Here, gas turbines are not only essential for base and peak load power but are increasingly important to stabilize the grid as solar capacity grows.

The U.S. power grid is being tested by the convergence of electrification, industrial growth, and extreme weather. States like Ohio, Indiana, and Virginia are experiencing rising demand due to data centers and onshoring of manufacturing. Nuclear energy is seeing a potential revival as part of strategies to meet this load sustainably. But, for now, Benoit emphasized that gas turbines remain central to maintaining grid reliability, integrating renewables, and keeping energy costs manageable.

His message was clear: the industry must invest, innovate, and adapt quickly to meet the transformative needs of a decarbonizing and electrifying world.

Hoffs kicked off AMC 2025 by highlighting innovations in clean energy, combustion efficiency, and lifecycle management—reinforcing PSM's commitment to agility, reliability, and sustainability in global energy solutions



PSM North workshop, fully operational in time for Fall outage season, expands its service footprint with state-of-the-art machining, advanced welding, logistics, and fulfillment under one roof

Industry innovation panel

Moderated by Katie Koch and Dan Caggiani of PSM, the panel discussion featuring asset managers and industry experts explored both the innovative strides being taken and the significant challenges in the gas turbine industry.

A key focus was on technological innovations shaping the industry. GTs are increasingly being adapted to support decarbonization strategies across the globe. This includes the integration of low-carbon fuels like hydrogen and green ammonia. The ability of turbines to operate on these diverse fuel types is seen as a critical enabler for future energy systems, particularly in regions such as Asia and the Middle East, where such transitions are accelerating.

Another area of innovation is the retrofitting and upgrading of existing GTs. These upgrades extend the life and improve the efficiency and flexibility of turbine operations, allowing them to better complement intermittent renewable energy sources like solar and wind. The industry is also embracing dispatchable aeroderivative GTs to meet immediate and localized energy needs quickly and efficiently.

As demand surges from sectors like AI and data centers, GTs are being aligned to ensure stable, scalable power supply. These installations, particularly in the U.S., are anticipated to be a major driver of power growth, requiring reliable energy infrastructure. Turbines are increasingly viewed not only as base-load providers but as balancing agents that can quickly ramp up to meet fluctuating demands.

Despite these advancements, the industry faces several pressing challenges. Market volatility—especially from unpredictable, rapid increases in demand—is testing the responsiveness of existing infrastructure. Policy shifts and regulatory uncertainty, especially with new governmental administrations and evolving climate mandates, create a complicated environment for long-term investment planning, even if the immediate future looks bright.

Infrastructure development remains a bottleneck, with grid and pipeline expansion often lagging behind turbine innovation. In some states like Oregon, legislative restrictions prohibit new fossil fuel-based generation, compelling the industry to pursue hybrid solutions or innovations like carbon capture.

Public perception presents another hurdle. Although GTs play a crucial role in grid stability and energy security, they are sometimes viewed as incompatible with clean energy goals. To address this, the industry must continue to engage with stakeholders and demonstrate its alignment with decarbonization pathways.

Additionally, perhaps most pertinent to end users is that the supply chain for turbine components faces strain under rising global demand from both the power generation and aerospace industries, leading to deeply extended lead times and logistical complications.

Despite these obstacles, the outlook remains optimistic. Panelists agreed that GTs are irreplaceable for maintaining power system reliability, particularly as electrification accelerates and renewable energy becomes more prevalent. Continued innovation—from advanced turbine designs to AI-assisted grid integration—will be key to meeting evolving energy needs.

Bulk up your 7F with GTOP

The Gas Turbine Optimization Program (GTOP) delivers measurable performance and operational improvements across 7FA and 501F gas turbine platforms. Through modular upgrade packages, PSM offers asset owners the ability to tailor solutions based on maintenance strategy, desired power output, and heat rate reduction goals—all while leveraging additive manufacturing and aerodynamic innovations to drive efficiency. Focus here will be the 7F.

At the core of GTOP is a progression of upgrade packages—from GTOP Lite to GTOP 4.1—that incorporate new hardware designs, control logic, and thermal management strategies. GTOP Lite offers up to a 2.8% increase in power output with minimal hardware changes, ideal for operators seeking incremental improvements. For more aggressive performance gains, GTOP3.1 and GTOP4.1 deliver up to 17.4% increased output and a 3.5% reduction in heat rate through enhancements in compressor aerodynamics, combustion systems, and turbine cooling technologies.

A significant differentiator in PSM's GTOP approach is its use of modular, additive-manufactured components. PSM's 501F GTOP7 technology underpins the latest upgrades, reducing part count for easier maintenance, improving durability, and incorporating near-wall cooling designs. These advancements are translated into 7F GTOP4 packages, where 3D-aerodynamic airfoils and enhanced materials yield higher efficiency and longer component life. Notably, the FlameSheet™ Gen VI combustor is available as an option for ultra-low emissions (<9 ppm) and deep turndown capability (<26%), even lower when paired with Exhaust Bleed (ExB).

PSM also emphasized its streamlined upgrade pathway. Each GTOP evaluation includes a comprehensive review of site-specific requirements, compatibility with OEM AGP systems, and the opportunity to mix-and-match technologies such as AutoTune logic and FlameSheet™ hardware. These systems enable mode-switching across maintenance, performance, and peak operation strategies, supporting flexible operation without sacrificing efficiency or reliability.

With more than 50 GTOP installations completed across the F-class fleet and decades of performance data—such as fleet leaders surpassing 56,000 hours and 1,127 fired starts—PSM's GTOP program has demonstrated proven value. The 2025 roadmap includes new releases like GTOP4.1 and compressor flow enhancements, reinforcing PSM's commitment to scalable, field-proven turbine optimization.

Announced at the conference and currently underway at a 7F-powered 2x1 CCGT is the first installation of GTOP4.1. Key enhancements to the new package include re-aeroing the entire turbine section, development of second generation single-crystal alloy, S1N advanced cooling via additive manufacturing AM (3D printing) integrated into the modular vane, and a new multi-layer abradable coating system for the S1SB and S1B.

More 7F flexibility. Enhanced low-load operation comes with the integration of PSM's FlameSheet™ combustion system with inlet bleed heat (IBH) and ExB systems—enabling ultra-low emissions, improved heat rate, and safe, reliable turndown below traditional limits.

FlameSheet™, PSM's next-generation combustor, is engineered as a "combustor within a combustor" with two aerodynamic stages and four fuel circuits that support wide operational stability. It features high-velocity premixer exit flows and a trapped vortex design, allowing it to tolerate highly reactive fuels like hydrogen and handle variations in fuel Wobbe index. This architecture not only ensures emissions compliance at low loads but also maintains flame stability across a broad operating range.

To further extend turndown capability and protect the HRSG, PSM couples 501F and 7F FlameSheet™ with IBH and ExB systems. IBH works by extracting compressor discharge air and reinjecting it upstream to raise inlet temperatures, which helps prevent compressor icing at low IGV angles. This allows turbines to operate at lower loads in premixed combustion mode, maintaining NOx and CO emissions below 9 ppm.

The ExB system enhances this functionality by redirecting flow from the compressor shell directly to the exhaust. This bypass flow reduces exhaust temperatures while maintaining the combustor's firing temperature, thus protecting downstream HRSG components from droplet erosion and thermal stress. When used together with FlameSheet™, IBH and ExB enable F-Class turbines to achieve emissions-compliant turndown to as low as 30% load in a 501F and as low as sub-20% load in a 7F —adding roughly 10% more operational flexibility compared to standard configurations.

PSM's approach was validated through performance curves and emissions data demonstrating stable combustion dynamics and emissions compliance across a wide load range. Turbine operators benefit not only from improved reliability during cycling and low-load operation, but also from the ability to handle more renewables into their grids without compromising turbine readiness or HRSG integrity.

7F rotor tsunami

With the majority of 7F units installed between 2000 and 2004 now approaching their expected end-of-life thresholds, end users have supply-chain concerns because of intense competition for raw materials and manufacturing slots. There is a pressing need for strategic planning, inspection, and upgrade solutions tailored to the evolving operational demands of these assets. Addressing the critical challenges faced by 7F operators, much of the focus was on diagnosing prevalent fleet-wide issues and highlighting the operational and maintenance implications driven by changes in operating profiles.

One of the primary issues discussed was the increasing stress on rotor components due to shifting operational profiles, especially the transition toward starts-based cycling. This operational change significantly impacts fatigue and creep characteristics, elevating the importance of early identification of at-risk hardware. PSM outlined several fleet-wide vulnerabilities, including blade attachment cracking on R0 and R1 wheels, lock wire tab cracks, and design limitations of Spacer 1-2 components. For each of these issues, PSM offered actionable solutions ranging from crack-tolerant wheel replacements to improved material selections and enhanced geometries.

The heart of the session centered on PSM's comprehensive rotor lifecycle strategy. This includes options such as spare rotor procurement, rotor exchanges, and most critically, their advanced Lifetime Extension Program. Unlike standard repairs, the LTE approach combines full volumetric inspections—using ultrasonic, eddy current, and metallurgical analysis—with proprietary material models and analytical evaluations to assess component health.

These assessments support precise rework recommendations, enabling turbines to safely continue operation beyond original design limits. The LTE framework also includes 2D/3D fracture mechanics modeling and creep life predictions, ensuring that every extension decision is grounded in rigorous engineering.

PSM's continues investment in new hardware manufacturing, such as upgraded compressor wheels, blades, and spacers, complements its LTE offering. The company currently maintains seed rotors and enhanced back-end compressor stages, which allow operators to avoid long procurement delays while ensuring critical components meet modern reliability standards.

Oh...that old thing?

With many B-E class assets seeing a roadmap to extend beyond their fourth or fifth decade of operation, PSM is noticing a renewed focus on upgrade strategies, emissions control, and lifetime extension.

A broad portfolio of upgrade options tailored to specific operational and market needs are designed to improve emissions, output, fuel flexibility, and overall turbine performance. These included the LEC-III™ and LEC-NextGen combustors, both of which offer ultra-low emissions and enhanced durability. The LEC-III™ features a reverse-flow Venturi system and a robust transition piece to handle increased dynamic loading, while the LEC-NextGen system supports dual-fuel applications and is rated for 32,000 hours and 1,300 starts.

Another key technology featured was the Sequential Fuel Injection (SFI) system, which allows gas turbines to operate efficiently across a wide load range—up to 25% load flexibility—while maintaining NOx and CO emissions below 9 ppm. This system enhances both turndown capability and peaking performance with minimal combustion dynamics, demonstrating a load range from 38% to 112%. Additional upgrades such as the FlameSheet™ combustor, fast start and ramp options (FS1 and FS3), and inlet air systems like IBH and anti-icing (IBHAI) further expand operational flexibility and reliability, particularly in colder climates.

A case study on and 7B-powered CCGT shows a reduction in HRSG inlet temperature and improves turndown performance with the addition of ExB for the first time on this unit. Complementary improvements to exhaust frame cooling, manifold systems, and fuel valve skids were designed to increase durability and streamline maintenance. More detail to come on this project in the coming months as more highlights from the AMC are published. **CCJ**

Panelists discussed relevant industry topics like alternative fuels, supply chain woes, workforce shortages, regulatory hurdles, and AI-driven outage planning. From left, Gilbert Shupe (SRP), Chris Duffy (ExxonMobil), Mike Madia (Argo Infrastructure), Bobby Noble (EPRI)

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