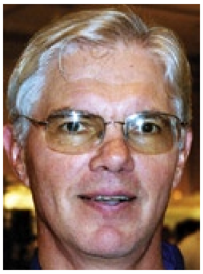
7EA Users focus on repairs, upgrades to improve performance, reduce emissions

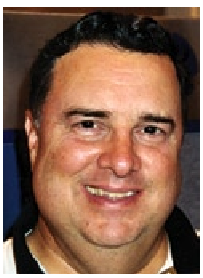
The 7EA Users Group, led by Chairman Paul Bruning who manages Calpine Corp's Sumas plant in Washington state, is a gritty bunch. The nearly 80 plant personnel attending the annual meeting in New Orleans, October 19-22, absorbed material from 11 prepared presentations over two days of intense seminar activities, peppering speakers with well over a hundred comments and questions.

Interspersed between the presentations were 11 "Hot Topic Discussions" each lasting about half an hour. Bruning (pbruning@calpine.com) was the equivalent of a rapid-fire game-show host pushing the users in attendance for answers to lists of questions that he organized by subject matter—a self-help clinic for sure. Everybody contributed, everybody learned. Nobody nodded in such a high-energy environment.


Bruning

Throw in a vendor fair, plant tour (Air Liquide's facility in Geismar, La), and networking meals and you have a busy three days. As for the temptations of Bourbon St, who had the time or any fuel left in the tank?

Three of the 11 formal presentations reflected work done under studies sponsored by the Combustion Turbine and Combined Cycle (CTC²) Users' Group, managed by Doug Vandergriff (dvandergriff@lg.com, 704-553-3162) of Lockwood Greene, Charlotte, NC and chaired by Mike Hoy of TVA. Melrose Berry (mberry@lg.com, 770-829-6514), who works with Vandergriff at Lockwood Greene, manages the 7EA meeting for Bruning.


Vandergriff

Two of the CTC² studies were conducted by Lisa Beeson, president, and Rodney Shook, PE, senior consulting engineer, Quietly Making Noise LLC (QMN), Oviedo, Fla, a diversified consulting firm with a specialty in powerplant noise control. They are the first two of the presentations summarized below. Details of the third CTC² study, "Maintenance Monitor for GE Mark V and Mark VI Gas Turbine Control Systems," conducted by Bruce R Fick Consulting Inc, Jasper, Ga, was described in detail in the COMBINED CYCLE Journal, Summer 2004, p 80, available at http://www.psimedia.info/ccj.htm. The complete reports on these and other studies conducted by CTC² are available for sale; contact Vandergriff for details.


Beeson

A point to keep in mind as you read through the presentation summaries: The information provided is merely the "tip of the iceberg" in terms of content delivered. The editors have focused on the highlights to manage the overall length of the 7EA conference report. To extract maximum value from any user conference, you must attend in person. No audio or video tapes are available and they too would fall short because the invaluable discussion sessions could not be included.

Reliability of dual-fuel systems

Hallway buzz at the 7EA Users meeting included interest on the part of some owners with GTs equipped for natural gas firing only in modifying their units for dual-fuel operation. This thinking assumes that gas prices will remain high in the years ahead and that oil and gas prices, which historically have moved pretty much in synch with each other, will decouple, giving oil-capable units an advantage in competitive electricity markets.

Interestingly, one of the research projects commissioned by the CTC² Users and contracted to QMN was a study to investigate the reliability of dual-fuel systems equipped with low-NO_x combustion technology. While converting to dual-fuel operation might look wise to a financial analyst working in an office tower and having access to forward prices for gas, oil, and electricity, the CTC² investigation suggests that such equipment decisions should not be made in a vacuum. Senior plant management has much to contribute in the fuel-conversion decision-making process.

The presentation of survey results by Beeson to supervisory personnel at generating plants equipped with 7EA machines was sobering for all those contemplating conversion to enable oil firing. First and foremost, most plants returning the questionnaire—all dual-fuel capable—were not burning oil because of reliability issues. A problem typically encountered is coking of distillate in the fuel piping upstream of the nozzle. Other, more general problems associated with dual-fuel systems, included unreliable operation of actuators and valves (sticking, etc) for fuel, purge air, etc.

Another cause of problems associated with oil firing is rooted in the oil itself. Nearly all plants surveyed are not proactive in monitoring and conditioning oil in storage to maintain its quality. According to Shook, Beeson's co-investigator, oil has been sitting in the storage tank at one plant for seven years without "maintenance." Storage times of a year or more were common.

Why is this important? Shook said that distillate oil from some refineries might begin to degrade within a few weeks after delivery, depending on the distillation process, source of crude, etc. The deterioration mechanism causes distillate to revert back to crude in at least some cases.

There are methods for maintaining oil quality in storage, but these require proactive management in the way of oil recirculation within the tank, use of chemical additives, control of temperature and air ingress, etc.

Primer on TBC coatings

Thermal barrier coatings (TBCs) are important for maximizing the lives of hot-gas-path components. Work has been ongoing by specialized coatings manufacturers to develop products offering better and better protection.

However, information required by plant managers to specify the optimum coatings for their equipment has become increasingly difficult to obtain.

To help users better understand issues surrounding selection of coating materials and their application, CTC² engaged QMN to gather or develop pertinent information on actual temperature distributions in first-stage nozzles and buckets when the components are subjected to different firing and cooling temperatures. Very broad research, primarily in Europe and Japan, addressed the various TBC materials, methods of application, and future trends in thermal protection. But little has been done to translate this research into practical and useful information for the GT user.

Anderson

The first of two projects on this subject was initiated to study the performance of a 7EA first-stage nozzle under various firing temperatures and for different TBC materials and thicknesses. Primary objective of the project was to identify an optimized TBC thickness (possibly variable) and generate design guidelines for various TBC parameters. The complexity of the various variables influencing temperature distribution across the nozzle dictated selection of only the most critical temperature regimes and two representative TBC materials.

First step was to establish a correlation among firing and cooling temperatures, TBC thickness, and TBC material in relation to temperature distribution on the nozzle substrate surface. Next step was to derive guidelines on how to control nozzle surface temperature with simple tools. A graph format was identified as the best method for predicting temperature. State-of-the-art computational methods were used to derive the graphical data.

Results of the nozzle study prompted a second investigation, now underway, to evaluate TBC and operational impacts on the first-stage buckets for the 7EA and other common frame sizes. This study will examine performance degradation or improvement for the buckets using a thermal finite-element analysis method. The results will be used to develop a tool that allows owners to select coating materials and operating conditions that best suit their business requirements. The analytical effort will determine the effectiveness of various thicknesses and types of TBCs with a range of thermal properties. For each case, TBC coating thickness will be constant across the bucket surface; thickness will be changed from case to case.

Compressor blade issues

Rodger Anderson's presentation on Frame 7EA compressor blade issues is a perfect example of why all GT owners should have their senior plant personnel attend and actively participate in user group activities: They will return with proven solutions to fleet-wide O&M problems that can be implemented in your facility.

Anderson (randerson@drs-pt.com, 518-347-0272), manager of GT technology for DRS-Power Technology Inc (PTI), Schenectady, NY, has spent virtually his entire professional career in the design of GTs, investigation of their failure mechanisms, and in the redesign of specific components to correct deficiencies.

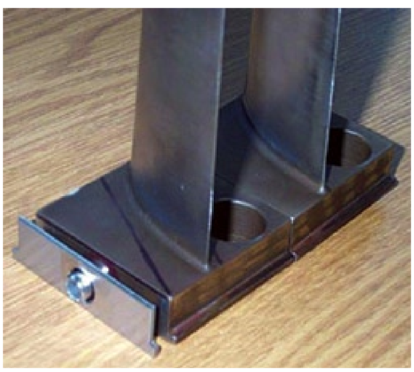
He began his presentation with this question: "Are your square-base compressor blades loose, shims missing, and rotor blades damaged?" Anderson, of course, knew that the answer for many in attendance was "yes." He then proceeded to dissect the 7EA compressor, explain why these problems exist, and propose a modification to both minimize blade movement and eliminate shim loss—with the aid of about two dozen pictures and sketches.

Anderson specifically addressed the 7EA's loose-blade problem commonly associated with the fifth compressor stage. These stator vanes, as well as those in other stages, often loosen in the casing groove over time (Fig 1). Here's how Anderson explained the reason for this condition:

- During operation, individual vanes are loaded by pressure forces and react against the case.
- Loading is dynamic, as pressure fluctuates about the mean.
- When the machine is shut down, the load is removed.
- Loading/unloading/fluctuation result in relative motion.
- The sliding and hammering that result from motion wear the vane base and casing groove.

Wear and blade motion allow shims installed between adjacent

1. Gaps between adjacent blades occur when shims wear and fall into the flow stream, causing foreign object damage



2. Addition of pin retains both shim and blade. Note that shim retaining ears are in mint condition because blade movement is stopped

3. Pinned blades still "rock solid" after 700 starts and 8000 hours in service, despite heavy foreign object damage vanes to work their way into the flow path, even in the lower half of the compressor. Compressor performance suffers as the shims protrude into the flow path. However, shims have been observed to migrate 1/8 in. or more into the flow stream, which can initiate a flow disturbance that produces a strong once-per-revolution stimulus at the tips of downstream rotor blades.

In the extreme, when sufficient wear occurs at shim tabs—often referred to as "ears"—because of blade movement and the sharp corners in the casing groove, shims can release into the flow stream. Result is downstream foreign-object damage.

Anderson suggested that a good way to gauge blade movement with minimum effort is through the fifth-stage air extraction port. Simply insert a 0.875-in.-diam bar into the extraction hole drilled into the square base of the vane and see how much it moves.

PTI's solution (patent pending) for the loose-blade problem is to machine holes partway into the base of each vane (on the two sides of the base perpendicular to the direction of air flow) such that PTI's engineered spring dowel pin can be inserted into adjacent blades preventing movement. Of course, any shims would be drilled so that they would be retained by the dowel (Fig 2).

Anderson said that PTI has applied its solution on 12 engines. The fleet leader had 700 starts and 8000 hours of operating time with the fix by mid 2004. Despite heavy foreign object damage (Fig 3), the pinned blades are still "rock solid."

Before-and-after measurements on one engine revealed an average axial tip movement for the blades of 0.063 in. (maximum of 0.140 in.). Such movement was thought capable of interfering with rotor blades and the fix described above was implemented. After addition of the PTI spring dowel solution, movement was less than 0.002 in.

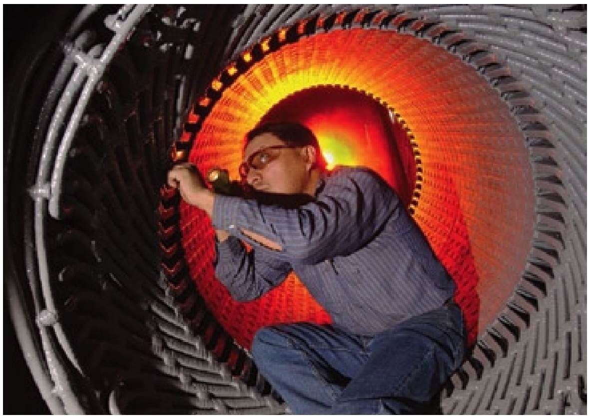
Among the benefits of the PTI solution, continued Anderson, are these:

- No new blades are required. The existing ones are removed, modified, and reinstalled. This means the user retains a set of blades that has the correct tip clearance and works well.
- No casing patch rings are required—even when severe casing groove wear exists—because pinning transforms the individual square bases into ring segments that cannot move in the casing groove.
- The pinning modification can be added to any planned outage without schedule impact. The job can be completed in as few as 12 hours from casing removal and not impact scheduled work by other subcontractors.

Don't take generators for granted

"The generator normally receives very little maintenance attention except during the major inspection outage scheduled for gas turbines," said David Branton, VP of operations for Wood Group Generator Services Inc, Farmington, NM (david.branton@woodgroup.com, 505-327-6363). "But the repercussions of a festering problem usually cause significant outage impacts," he warned.

The premise of Branton's presentation was that for every GT inspection (borescope, combustor, hot gas path, or major) an inspection of commensurate scope should be performed on the generator to assess its condition. He said that only by developing a routine and systematic inspection plan for the generator can you expect its availability to remain high and minimize the potential for a forced outage.



4. Winding looseness in stator slot must be identified early and corrected to prevent serious operating problems

According to Branton, the most common problem identified with older units and peakers—especially those units that were not designed for peaking operation—is armature winding looseness either in the stator slot or in the end winding (Fig 4). If the looseness is not identified early and corrected, serious issues may result—including corona discharge and winding faults.

During outage inspections, evidence of looseness can be seen using a borescope. Corona is detected by exciting the winding and using a camera sensitive to corona discharge frequencies to isolate the affected area. Looseness of the winding can be corrected by tightening the fit of the windings in the stator slots and consolidating the end winding so that resonances are avoided.

The second most common problem with generators driven by 7EAs, especially peakers, said Branton, is rotor-winding shorts, which manifest as vibration issues. Too many peaking cycles on generators that do not have modern insulation systems cause uneven expansion of the copper and distort the windings. Distortion can cause the shorts and uneven heating. Generally, there is plenty of time to manage winding problems without affecting availability if they are detected early and corrected during planned GT outages.

Although Branton strongly recommended that specific inspections and tests be made at every outage, he added that there are several in-service monitoring devices that can be used to detect vibration in end and slot windings. These include the products offered by VibroSystM, Longueuil (Montreal), Que, Canada, which were discussed in detail.

Optical sensors for critical GT applications

When you see the Goodrich name attached to a presentation at a GT users group meeting your mind may conjure up an image of a gas turbine on wheels. However, nothing could be further from the truth. The BFGoodrich company, long ago adopting the current Goodrich name, sold off its tire division in 1986. Since then the company has made more than 40 acquisitions—including businesses such as TRW Aeronautical Systems, Coltec Industries, Rosemount Aerospace—and divested of a few non-core divisions.

Today, Goodrich is a high-tech company that may be best known in land-based GT circles for having taken advanced aerospace sensor and controls know-how developed for commercial, military, and space applications and created leading-edge products for power generation systems.

Warren Lacina (warren.lacina@goodrich.com, 651-681-5823), a senior applications engineer for Goodrich Sensor Systems, Burnsville, Minn, had these messages for the 7EA Users:

- Fiberoptic flame detection is an example of a successful migration of advanced military sensing technology to the industrial GT market.
- Fiberoptic technology has many applications beyond flame detection for industrial gas turbines—including TBC (thermal barrier coating) monitoring, flame pattern analysis, and emissions monitoring.
- Ultimately, optical sensing is a key component to what Goodrich calls "sensor fusion," a way of managing highly dynamic processes—such as combustion—by use of multivariate controls and high-speed data processing.

Lacina said that optical sensors are an attractive alternative to electrical sensors in GT applications because of their ability to operate reliably at the high temperatures and vibration levels characteristic of these industrial machines. A case in point is the Goodrich FlameHawk™ fiberoptic flame detector.

This product, he said, was designed based on technology developed for an optical pyrometer used in military engine applications. The optical sensor looks at the first-stage turbine blades and provides instantaneous data on blade temperature, blade passing frequency, and other performance parameters. The primary purpose of this measurement is to sense the first-stage turbine blade temperature at maximum power, thereby enabling engine operation close to the ultimate operational limit without artificial constraints. This is said to be especially important in aerial combat situations.

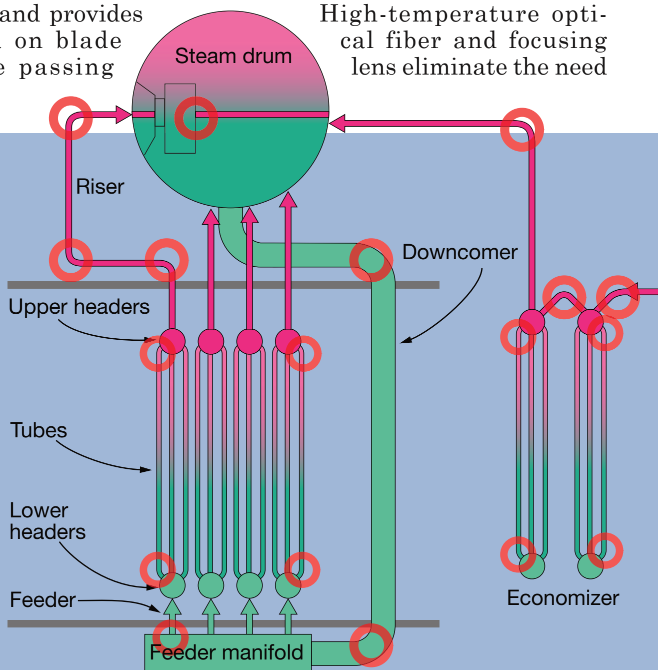
The FlameHawk detector takes the solid-state photo-optics from the military pyrometer and cost effectively applies it to applications like the Frame 7EA. Fiberoptics are used to completely remove the photoelectronics components from the heat and vibration of the package. High-temperature optical fiber and focusing lens eliminate the need

7EA Users have HRSG concerns, too

The only presentation on the program not focused on the gas turbine/generator was by Lester Stanley, PE, HRST Inc, Eden Prairie, Minn (lstanley@hrstinc.com, 952-833-1428). HRST is a consulting firm specializing in heat-recovery steam generator (HRSG) performance analysis, inspection, training, root-cause failure analysis, and field services.

Stanley stressed the need for thorough HRSG inspections to maintain—possibly improve—the reliability and performance of combined-cycle plants. Experience, he said, helps determine where to look for the subtle signs of an impending problem. Stanley addressed two specific areas of concern today: flow-accelerated corrosion (FAC) and casing penetration seals.

The dangers posed by FAC were in evidence again in the deadly pipe rupture this past summer at a nuclear powerplant in Japan (see COMBINED CYCLE Journal, Summer 2004, p 1). FAC is influenced by the combination of water velocity, turbulence, temperature, chemistry, and pressure-part metallurgy. Stanley said that the same



1. FAC high-risk areas are highlighted on simplified sketch of HRSG fluid circuits. Too many to inspect them all in a single outage; prioritization is needed

2. Ultrasonic thickness testing revealed no problems in this low-pressure drum, but does that mean the rest of the boiler is fine?

3. This stainless steel bellows failed because expansion was greater than predicted (above)

4. Drain pipe corrosion remained hidden until fabric seal was removed (right)

5. Optically instrumented fuel nozzle (foreground) is linked to signal processor at left by fiberoptic cable

for auxiliary cooling—for example, forced air or ethylene glycol. Experience includes both aero and frame machines from several engine manufacturers.

Lacina said Goodrich currently is integrating the optical sensing capabilities of the fiberoptic flame detector into the fuel nozzle (Fig 5) and expanding its analysis role. In addition to providing a flame detector integral to the fuel nozzle, the device will (1) permit adaptive NO_x control by helping to regulate the flow of pilot fuel, and (2) act as both a real-time emissions and flame-quality analyzer.

Another effort, he continued, involves the development of a TBC monitor. It, too, would be integral to the fuel nozzle and permit in-situ monitoring of TBC condition on the turbine inlet vanes and the combustor wall. Such a diagnostic tool could prevent premature failure of critical components that today are caused by abnormal firing conditions, changes in fuel quality, etc.

Further down the road, Lacina pointed to the use of the company's space-age technology to solve problems for which there are no existing solutions or sensors. He piqued the attention of the 7EA users with the following analogy: "Just as a Fuzzy Logic network can be used to infer a state or outcome, sensors can be combined and values can be processed in a manner that provides a synthetic measured variable for control."

For example, he continued, the combination of optical, thermal, pressure, and analytical variables can be processed and weighted to determine the impact of a change in a single variable on the overall system. In the case of active combus-

expertise used to design boilers, combined with a plant's water-chemistry history, are the ingredients for a successful FAC risk assessment. Once the assessment is complete, a plant has a road map for prioritizing where to look for FAC-induced thinning of pressure parts.

Potential areas of the HRSG where FAC is most likely to occur are shown in Fig 1. Inspecting and conducting necessary tests in all of these areas during a single outage is expensive and time consuming. The benefit of a risk-assessment analysis is that it allows you to investigate the most susceptible areas first and then make judgment calls on when to check other areas. This maximizes the value of the inspection effort and will minimize the risk of "missing" an area being damaged by FAC. This, in turn, minimizes the potential for costly repairs, avoids compromising safety, and keeps the inspection process from becoming a critical-path item during any given outage.

FAC is most common in low- and intermediate-pressure evaporators, noted Stanley, so inspectors should always look carefully in their steam drums (Fig 2) for FAC indications. But if no problems are found, does that mean everything is OK? "No," he said. The weak link in the system could be in an economizer jumper pipe or the nozzle from one particular row of evaporator tube panels.

5. Retrofit pipe penetration seal designed by HRST is said to be increasingly popular

To avoid "missing" the problem area, HRST suggests conducting a thorough circuit-by-circuit circulation and flow velocity assessment. This requires accurate HRSG thermal and circulation modeling because as the turbine exhaust passes through each tube row it gets cooler, thereby producing less steam in subsequent rows. The amount of steam produced in each tube row impacts circulation, as does the piping to and from each evaporator tube section. Stanley cautioned that accurate modeling only works with the proper inputs, so the first step in the process is to gather information from a combination of drawings, data sheets, and physical inspection and enter it into their modeling programs.

Water chemistry is both a part of the problem and the solution. Proper analysis depends on knowing the user's history and strategy for minimizing water chemistry conditions that increase the risk of problems. If the strategy requires improvement, or the chemistry targets are not proper, recommendations for corrective action are made as part of the assessment, Stanley said. Water-chemistry history may also influence the urgency to inspect highly susceptible areas identified during the FAC risk assessment study.

Stanley added, "HRST's experience is that the cost of an FAC risk assessment study can be recovered in a single outage from the savings of unnecessary scaffold installation and insulation removal in what would be identified as low-priority FAC areas."

Casing penetration seals. The second part of Stanley's presentation addressed the inspection of casing penetration seals through HRSG liners and the casing. HRSGs that sit idle, and are exposed to rain, can have significant corrosion attack. The cause is improper roof casing seals around hanger rods, access doors, and pipe penetrations. Many floor casing penetration seals under superheaters and reheaters fail from a combination of design- and cycling-related problems (Fig 3). Pressure-part corrosion inside the pipe penetration seals, especially in the floor, can be a hidden problem. The seal or internal liner must be removed to perform a good inspection (Fig 4).

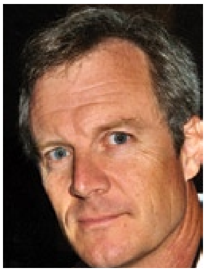
Stanley also showed the HRST retrofit pipe penetration seal that many plants have installed to improve their seal arrangement (Fig 5).

tion control, the benefits of maintaining combustion stability at very low emissions levels are substantial. Additionally, thermal stability and a certain level of flame pattern control may also be achievable with the right combination of devices.

"Ultimately," conceded Lacina, "the limiting factors on implementation may not be the ability to measure, but the ability to find control elements that can respond and survive while operating at the frequencies required to impart sufficient stability."

Very-low-NO_x combustors

Clay Moran, director of Power Systems Mfg LLC's combustion product line, reported on the company's low-emission combustor (LEC)—specifically the LEC III. Moran said that PSM, based in Jupiter, Fla, is the only after-market company with a viable DLN (dry low-NO_x) combustion system for GE Energy's Frame 7 installed base. It offers complete upgrade kits to "easily replace" standard combustors or factory-installed low-NO_x systems to the LEC, currently a gas-only configuration.


Moran

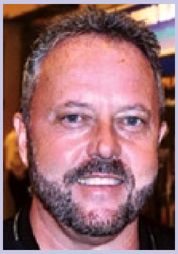
Results of validation-rig tests, high-time operational hardware condition, and instrumented engine data, reported Moran, combine to prove system reliability and performance are equivalent to GE's DLN-1 offering, except that PSM's LEC III is capable of much lower emissions. He added, "There are currently three units configured with the LEC III combustion system that are achieving 2055F base-load emissions of 3 ppm NO_x with CO in the low single digits."

PSMs goal is to reach 2 ppm NO_x and compete with SCR (selective catalytic reduction). Field experience with the LEC III operating at less than 5 ppm NO_x is being monitored at three installations on 7EAs, three

Combustor dynamic monitoring goes 'active'

Many conversations in the exhibit hall focused on reducing the formation of nitrogen oxides during the combustion process. As NO_x levels are ratcheted down—combustors capable of 3 ppm are being offered commercially for some frame machines—the more important it is to monitor the combustion process for pressure pulsations that could lead to equipment damage if not corrected.

Michael Thomas, president, Control Center LLC, Orlando (mthomas@controlcenter.net, 407-304-5200), said that his company is a leader in combustor dynamic monitoring systems (CDMS). Control Center supplies a turnkey CDMS that has been installed in more than 60 Siemens Westinghouse Power Corp (SWPC) and GE Energy GTs .


Thomas

There are two types of CDMs, passive and active, Thomas continued. Most of the power industry's experience is with passive systems, which are sold directly to users by Control Center and others offering this diagnostic equipment. Turbine OEMs are involved if a GT is to run on active control. In such cases, a passive system is supplied to the OEM and it takes the lead in enabling the CDMS and turbine to operate in the active mode.

By way of background, characteristics of passive systems include the following:

- Dynamic fluctuation in various frequency ranges initiate alarms on the CDMS computer.
- Operator intervention is required to change GT operating conditions.
- The CDM is not linked to the GT control system.

The good experience with passive systems, Thomas said, has created considerable interest in active CDMSs. The difference between active and passive systems is that in the former, operator intervention is not required to change GT operating conditions. The ACDMS automatically adjusts the turbine fuel/air ratio to minimize or correct a dynamic event.

Thomas stressed that control of the GT is never removed from the operator unless the dynamic event reaches a level known to cause combustor damage. In such rare cases, the turbine is unloaded until the dynamic event is eliminated. He added that the ACDMS is linked to the distributed control system, thereby giving it access to the archiving, trending, and diagnostic functions of the DCS

Benefits of ACDMSs, summarized Thomas, are these:

- Early detection of changes in critical combustor components is accomplished through trending of data and its deviation from baseline conditions.
- Insurance carriers sometimes offer lower deductibles and/or better insurance terms and conditions.
- May allow users to extend the time between outages.

Ben Hunnewell, service marketing manager for SWPC's I&C Div joined the interview and cautioned that while the ACDMS provides a layer of protection for the combustion chamber, it cannot prevent all combustor failures because it cannot control operating variables such as normal wear and tear, fuel quality and consistency, ambient temperature changes, etc. However, he added, it can be a powerful tool for extending combustor life and for warning plant personnel about potential problems before a catastrophic failure occurs.

A secondary application for the ACDMS, Hunnewell said, is "acoustical monitoring." He said that because the data collection computer used in the ACDMS is Windows-based, alarm setpoints can be added and modified by plant personnel. This allows operators to monitor the combustion system for a period of time and then set "fingerprint" alarm points.

Hunnewell continued, noting that the turbine usually will have a constant acoustical signature for specified ambient temperatures and load settings. A shift in this signature can indicate changes in the plant or turbine, but when used in conjunction with plant operating data, the combined information can identify combustor component fatigue or degradation.

He added, "The pilot gas modulation that is implemented to 'enrich' the fuel/air ratio is graphically represented on the operator's screen. When the ACDMS is correcting an anomaly constantly, it too is displayed on the operators' terminal while indicating which burner is associated with the dynamic event. These data alone cannot verify that a problem exists, but a trained operator knows that an increase in pilot-gas biasing without a significant change in load, ambient air temperature, or fuel quality denotes a possible combustor component problem.

on 6Bs, and one on a 9E machine.

Collaboration with powerplant engineers at Dow Chemical Co's huge Freeport facility, he continued, was instrumental in driving down base-load NO_x emissions from the LECs retrofitted on two 7EAs from 4.75 to 3 ppm while holding CO in the range of 0 to 3 ppm.

Moran said that key features of the LEC III include a pilotless secondary fuel nozzle and complete elimination of diffusion combustion. Additionally, the head end is a greatly enhanced premixer because of airflow distribution changes. Less air is used for wall cooling because of the efficiency of effusion cooling, so more air is available for mixing. This arrangement is key to maintaining a near-uniform temperature profile in the reaction zone of about 2700F thereby eliminating the hot spots (temperatures of 3500F) that drive up NO_x production.


Wenger

Improved manufacturing techniques also contribute to a more uniform temperature profile by minimizing the flow variation from liner to liner, he continued. Engine hot streaks are virtually eliminated and exhaust temperature spreads have been improved from a typical 60 deg F to 30-40 deg F.

The company's combustion liner was redesigned so that the venturi is arranged in a forward-flowing cooling-air configuration. This patented technology, Moran said, "has proven to be a tremendous CO reducer." All of the venturi cooling air discharged is collected in an outside plenum surrounding the liner and reinjected into the liner head end. Venturi air is preheated, becomes part of the premixer, and is completely used in the combustion process.

Moran stated that in the GE venture design, the aft-flowing cooling air is discharged as a cold unmixed stream that surrounds the reacting gases. As a result, a significant amount of CO is "locked in" and prevented from forming CO_2. Liner design also benefits from the latest analysis tools to achieve greater durability. Wear-resistant materials at critical interface locations help minimize loss of fit-up. This also is a key system feature to assure minimum deterioration.

Filters in wet environments

GT inlet air systems usually are supplied by the engine OEM (original equipment manufacturer) as part of a complete turbine package. Competitive pressures often dictate that intake and filtration packages be of a "standard" design, irrespective of where the plant will be located, observed Steve Wenger, managing director, Altair Filter Technology Inc, Louisville, Ky steve.wenger@altairfilter.com, 502-499-2151).

While this approach may be cost effective and viable for some users, he added, for others the specifics of their respective site environments are such that a "standard" solution is not appropriate and may lead to operational problems.

Wenger stressed that before specifying replacement filters it is important to consider how efficiently the alternative offerings work when wet. This calls for a rigorous review of pressure-drop characteristics under wet conditions. The difference in performance between an inlet air system designed to run wet and one that is not, Wenger said, can be significant. In addition to pressure-drop considerations, "standard" filters operating wet often lose their structural integrity. The resulting disfiguration can result in air bypass and loss of filtration protection.

Running wet is not that unusual, Wenger continued, given the high levels of precipitation in many areas and the increased use of inlet air cooling systems—for example, evaporative media and fogging—to boost GT output. The possibility that the air inlet faces prevailing winds, or that a properly designed rain hood or marine vane separator is not installed, only exacerbates the problem.

Testing of various filter types, noted Wenger, has shown considerable variation in performance going from dry to wet conditions. In some instances, the pressure drop through a filter subjected to a relatively small amount of water spray can increase by several hundred percent. "This usually happens to filters with cellulose or fiberglass fibers," Wenger said, "which swell when wet." The high "delta p" may remain for several hours after the water spray has been stopped because the cellulose fibers retain moisture. The solution, proven in the marine and offshore market sectors, is to use synthetic polyester media that is designed specifically to operate wet without increased pressure drop.

Lab results have been confirmed by field experience, he continued. Many users report that early morning fog (a common cause of filters running wet) results both in an increase in pressure drop during the fog's occurrence and also for several hours after the fog has cleared. A high "delta p" has a negative impact on turbine efficiency and power output, both of which put downward pressure on earnings. Finally, Wenger offered this rule-of-thumb: "Every additional inch of inlet pressure loss reduces power output by 0.5%."

Notes from the exhibit hall

The large GT user groups typically host a vendor fair one evening—all except for the Western Turbine Users Inc, which has its exhibit hall open throughout the organization's annual meeting when conference sessions are not scheduled. The 7EA vendor fair, which attracted more than 50 exhibitors, ran four hours the evening of October 21.

Vendor fairs are good places to network. People generally are relaxed and willing to share experiences with their colleagues. The editors of the COMBINED CYCLE Journal found several users thinking about their next outage. A major concern shared by these people is that because most plants schedule two outages annually, typically in the months of April or May and October, labor resources and repair-shop availability often are constrained at those times. They questioned the logic of such scheduling, considering that many plants have very low capacity factors. Perhaps there is something here for asset managers to think about.

The impromptu discussion continued with all agreeing that there is no substitute for detailed, advanced planning for the outage to ensure timely completion, within budget, of all tasks. Failure to plan well almost always leads to wasted man-hours and an extended critical path, the group agreed.

Later contact with Senior VP Mary Jo Yafchak and GT Team Leader Marty Magby of **Gas Turbine Maintenance LLC (GTM),** Cape Coral, Fla, which had a table-top display, revealed that several customers and prospects are indeed concerned about the potential for cost overruns and have either signed long-term service agreements with the company or are considering doing so to mitigate risk.

Yafchak (maryjo@turbinegenerator.com, 800-226-7557) and Magby said that some users have seen cost and schedule overruns in recent outages because they relied on "experienced" people locally who are good qualified mechanics but the bulk of their time is not spent working specifically on powerplant equipment. Yafchak said GTM recently signed a long-term agreement with a major independent power producer that included detailed planning as well as field work.

The goal of this arrangement, as well as others pending, is to provide timely completion of high-quality work at an agreed-to price. Financial penalties are assessed the vendor if contract terms are not met; bonuses are paid when goals are exceeded. All that's needed to break any agreement is dissatisfaction on the part of the customer. GTM says its success hinges on its experienced field teams consisting of a foreman and four or five people, on average, who work well together and consider themselves part of the company served.

Mechanical Dynamics & Analysis LLC (MDA), Latham, NY, also provides integrated outage services extending from pre-outage planning to post-outage review and analysis and virtually everything in between. The company said it is the largest independent turbine repair organization in the US. Leo Molina, general manager of GT operations (lmolina@mdaturbines.com, 518-222-9550) pointed to MD&A's maintenance agreements, specialty tests and inspection capabilities, parts, and repair capabilities as evidence of its ability to provide truly turnkey outage management.

Parts and repair services for frame machines were highlighted at several other booths in the 7EA Users exhibit hall, in addition to MD&A. Representatives of **Power Systems Manufacturing LLC,** including Dave Stevens, general manager of sales (dstephens@powermfg.com, 561-354-1100, x-7173), stressed that PSM "doesn't merely duplicate existing combustion systems and replacement parts. Instead, we analyze them. We model them. We redesign them. And—in the end—we improve them."

In addition to the buckets and blades manufactured by many shops, PSM makes primary fuel nozzles, transition pieces, and complete upgrade kits to convert non-low-NO_x or factory-installed low-NO_x systems to the company's low-emission combustion (LEC) system discussed earlier. LEC is dual-fuel capable. The upgrade kit includes low-emission combustion liners, primary fuel nozzles, igniters and flame detectors, transition pieces, and other key parts.

Sulzer Hickham Inc, LaPorte, Tex, which had a great deal to talk about, was represented in the exhibit hall by Glen Greer, Don Shelton, Will Trbula, and Mike England (mike.england@sulzerhickham.com, 713-567-2700). The company provides complete turnkey field and shop refurbishment of gas and steam turbines. Services include repair of rotating and stationary components, hot section and combustion components, and rotors, plus recoating of critical components and at-speed balancing. Sulzer Hickham's gas turbine division is supported by twin 25,000 ft^2 repair facilities. One handles the repair of large turbine rotor assemblies, having a 50-ton crane and special jigs and fixtures for fixing complex rotors. The second, called the assembly bay, houses large turbine skids and is used to overhaul piping, lube oil systems, wiring, instrumentation, and controls.

Tri-Star Turbine Technologies Inc, Houston, a unit of North American Energy Services Co, Issaquah, Wash, touted its new 35,000-ft^2 repair facility with cranes capable of handling 20 tons per bay, vertical boring mills capable of swings up to 126 in., and horizontal boring mills with 110-in. tables. President Dennis Werner, PE (dwerner@tristarturbine.com, 832-484-9400), also discussed the company's engineering and nondestructive examination capabilities at the new shop. A complete menu of gas and steam turbine components repaired by Tri-Star is easy to find on the company's website at http://www.tristarturbine.com/tristar3.html.

PowerSpares Inc, Boca Raton, Fla, promoted Outage in a Box™, billed as the way to ensure a smooth GT inspection. Kit includes gaskets, washers, nuts, bolts, and the small parts critical to completing a 7EA outage smoothly that often are overlooked at the planning stage, said Mike Elliott (melliott@powerspares.com, 561-447-4393). Sets also are available for Frame 6B, 7B, and 7E models. Users pay only for the parts removed from the box. After the outage, the box is returned to PowerSpares and the plant is billed only for the parts used.

Power Support Inc, Houston, said Carman Sanders (powers-up@texas.net, 832-375-1900), is offering new, engine-run, and refurbished parts for both gas and steam turbines.

Before planning an outage, thorough inspections must be conducted to see if there are issues beyond those addressed by component repairs and replacements recommended by the OEM to maintain equipment warranties.

Siemens Westinghouse Power Corp, Pittsburgh, Pa, represented by Emil Pena (emil.pena@siemens.com, 724-387-7346), a marketing engineer responsible for the company's NDE product line, exhibited several new tools designed to reduce outage duration, minimize outage costs, and increase unit availability.

These included a high-temperature borescope for gas and steam turbine application that is capable of transmitting (or recording) high-quality video images to a remote expert for evaluation, and EddyVision™, a remote eddy current/optically enhanced inspection system designed to help a qualified specialist examine, analyze, and validate the existence of indications detected by visual inspection methods. Note that Siemens Westinghouse is offering inspection services only; the new tools are not for sale to users.

Olympus Corp, Orangeburg, NY, had Carl Juneau (carl.juneau@olympusindustrial.com, 866-642-4725) demonstrating the company's new battery-powered videoscope "that can go anywhere." The IPLEX MX weighs less than 10 lb and features LED technology in a ¼-in.-diam insertion tube coupled to optics that provide bright, high-resolution images. The robust insertion tube is designed to last longer than those on earlier videoscopes. Juneau said you can learn how to use the instrument in five minutes. The laptop-type battery can run for two hours before recharging is necessary. Up to 230 jpg images can be recorded on the 32-MB compact flash card provided. Images then can be downloaded to a PC.

Other components for GT-based plants displayed by exhibitors included inlet air filters and SCR (selective catalytic reduction) catalyst. **Donaldson Co,** Minneapolis, Minn, designs and manufactures air inlet systems—cartridges, panels, and prefilters. Patty Gulsvig pgulsvig@mail.donaldson.com, 952-887-3232) displayed the company's Spider-Web nanofiber media for very-high filtration efficiency. **Argillon LLC,** Alpharetta, Ga, represented by Product Line Manager Brian Stone, PE (brian.stone@argillon.com. 678-256-1703) demonstrated the company's SINOx products that are designed to reliably reduce the NO_x concentration in GT exhaust to below required limits. CCJ