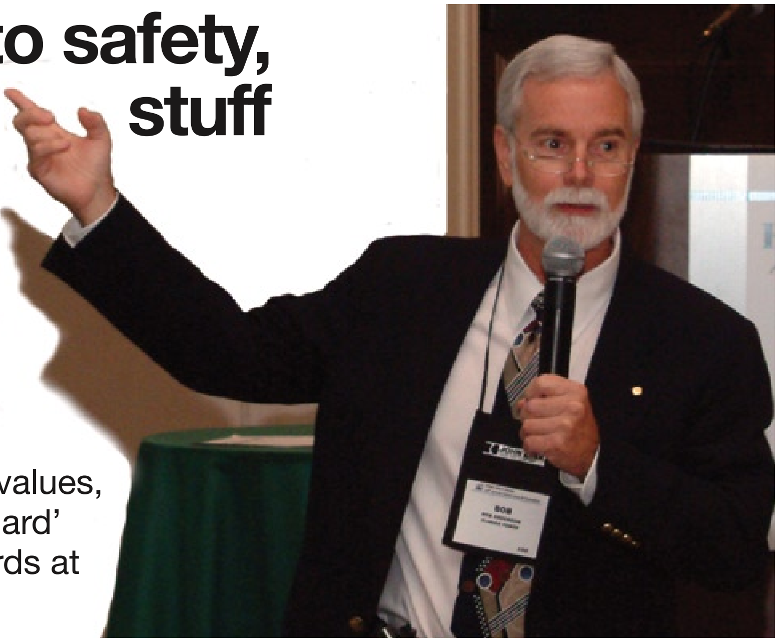
By **Robert W Anderson,** Progress Energy Inc

When it comes to safety, sweat the small stuff



As managers responsible for combined-cycle facilities, we rightfully devote much of our time to the safety culture that exists in our respective organizations. But while we cultivate the big-picture, 'soft' concerns like attitudes and values, we must also communicate the 'hard' info—details on the specific hazards at each of our plants

A recurring theme in our trade journals, conference papers, and corporate training programs is the need for powerplant leaders to build and maintain a safety culture in their facilities. This can be defined as a constant commitment to safety that permeates the entire organization, or an accident-free mindset that drives all decision-making.

Building and nurturing a safety culture is a prerequisite for operating and maintaining a safe powerplant. However, it's only one of the essential steps.

Along with establishing a safety culture—correctly focusing management priorities, winning buy-in from employees, rewarding and reinforcing safe behaviors, etc—plant leaders need to identify the specific, real-world hazards that exist in their facilities, and implement practical procedures to avoid them (Fig 1). These tangible specifics are best managed at the plant level, not by safety professionals back in a corporate office.

Corporate staff can help with such things as administering training, setting company policy, and, yes, building that safety culture. But the details in, for instance, each plant's ammonia-handling procedure must be championed by a leader at the plant level. The ultra-lean staffing at combined-cycle facilities imposes a unique challenge in this regard: Our onsite safety leader also is likely to be responsible for maintenance, operator shift schedules, environmental compliance, accounting, human resources, and/or even ordering the office stationery.

Another challenge unique to gas-turbine-based combined-cycle and cogeneration facilities is the makeup of our plant staffs. With the construction boom of the 1990s, we hired

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1. Combined-cycle plants face many of the same safety hazards found at any industrial site. But they also have specific hazards that must be identified and communicated to plant staffs, contractor workers, and site visitors many new workers from other industries who, while possessing expertise in their technical discipline, often have little experience in powerplant operations. For example, gas-turbine (GT) specialists from the US Navy, rightfully prized for their engine know-how and can-do attitudes, often have no experience with steam. Both the propulsion plant and the electric generators on most navy surface ships today are powered by GTs. Even "hotel services" like laundry and galley cooking no longer use steam, having been converted to electricity to reduce maintenance.

Another challenge is that combined-cycle plants tend to rely more on outsourced contractors, compared to fossil-fired steam stations of the regulated era, increasing the odds that an onsite worker will be unfamiliar with his surroundings. To illustrate: A top-notch electrical contractor could be onsite to inspect a failed condensate-pump motor, but he may not know about the steam-flash hazards of the condensate in that system.

Keep in mind that the two workers killed at a US combined-cycle plant in 2003, as well as the five workers killed at a Japanese nuclear plant in mid 2004, were all contractors, not plant staff. Although the Japanese plant is nuclear, its lessons are particularly applicable to the steam systems in a combined-cycle or cogeneration facility: The Japanese fatalities occurred when a condensate pipe burst, caused by wall thinning from undetected flow-accelerated corrosion (FAC). How to minimize the rate of FAC and monitor wall thickness in our steam plants has been a leading topic at HRSG User's Group conferences for a dozen years (see sidebar).

To discuss the specific hazards found in combined-cycle plants in an organized manner, let's think of them in five categories:

1. Hazards created by merely "moving around."
2. Uncontrolled release of fluids.
3. Controlled release of fluids.
4. Hazards during normal plant configurations.
5. Hazards during abnormal plant configurations.

1 Merely moving around

Every day, regardless of plant operating status, employees, contractors, and visitors move around our facilities, and in doing so, are susceptible to a long list of potential dangers: trip hazards from uneven surfaces; fall hazards as they climb ladders; burn hazards from hot HRSG (heat recovery steam generator) casings, pipes, or valves; inhalation hazards from ammonia and water-treatment chemicals; eye hazards from rust particles, and so on. The hazards associated with "merely moving around" are the easiest to avoid, through conscientious use of hard hats, eye protection, ear protection, respiratory gear, proper footwear, gloves, sure handrails, good lighting, etc. Unfortunately, these are the hazards that also are the easiest to overlook because we walk by them daily and become complacent about the dangers they pose.

2. Every confined space in the plant must be clearly marked, and written procedures for entering them must be established and meticulously followed. Confined spaces of concern include HRSG casings, steam drums, blowdown vessels, and both the steam- and water-side of condensers

Perhaps the most lethal hazard in this category occurs when workers move around—and into—a confined space. Routine maintenance activities on combined-cycle systems often require personnel to enter such spaces—HRSG casings, steam drums, blowdown vessels, both the steam- and water-side of condensers, etc—where they can be seriously injured or killed by hazards conducive to asphyxiation, fire, and explosion.

Be aware that danger remains long after the confined-space atmosphere has been properly tested and cleared for work. Recently, at a powerplant in the Southeast, a long maintenance outage was nearing completion when one worker decided to reenter a boiler without formally signing the entry log. He intended to quickly inspect a repair job, and leave. But before he could do so, the log was checked showing nobody left inside, the entry door closed, and unit startup initiated. The worker spent 45 fearful minutes inside the boiler, banging his hard hat against the tubes, yelling, screaming, and praying that somebody would miss him before he became "toast." Fortunately, someone did, and he was let out before any injury occurred.

The steps needed to avoid confined-space hazards such as this are well documented in federal, state, and local regulations, such as the Code of Federal Regulations (CFR) 1910. Plant managers refer to these rules periodically to ensure that their confined-space entry procedures remain in compliance (Fig 2). While there's no need to recite every detail here, a review of highlights specific to combined-cycle facilities is beneficial.

It's not "tagout/lockout." Central to an effective confined-space entry procedure is compliance with the US Occupational and Safety Health Administration's (OSHA) lockout/tagout program. As mentioned earlier, many of our combined-cycle personnel received formal training in the navy. There they learned the importance of hanging red "Danger" tags on equipment and valves and not to remove those tags without proper authorization.

But it's for more than a semantic reason that the OSHA regulation includes the word "lockout" and even places it first, before the word "tagout." A red tag hanging on a valve simply is not enough to ensure safety in a shore-side powerplant where untrained visitors have direct access to valves, switches, etc. That's why a lock is preferred to a tag—every time. Manufacturers now offer a wide selection of devices that enable you to lock out virtually any kind of circuit breaker, valve, damper, or motor starter in the plant.

OSHA frequently revises CFR 1910, so be sure to review your confined-space entry procedures periodically. A good time is one month before each major maintenance outage. This not only ensures that your specific procedures are up-to-date when you most likely will be needing to enter a confined space, but also allows time to train workers on any revisions before the space is opened.

One more note specific to combined-cycle plants: Under the CFR 1910 definition, the GT enclosures at US plants are *not* considered confined spaces. However, the British Health & Safety Executive takes a different view. The UK regulatory agency enacted its GT procedures after a 1996 explosion at the Teesside power station, caused by ignition of leaking backup fuel. One operator inside the enclosure at the time of the explosion was critically injured. British regulations now require all GT enclosures to be locked and off-limits when the turbine is operating, and controlled by confined-space permits when the turbine is shut down. This regulation may surprise some US operators, who routinely enter enclosures to take readings, inspect components, or merely wipe up dripping lube oil while the gas turbine is running (Fig 3).

3. A gas-turbine enclosure is specifically defined as a confined space for plants in the UK. Operators in the US, though not required by CFR 1910, should consider following that lead in view of the explosive hazards that exist

2 Uncontrolled release of fluids

A combined-cycle or cogeneration process requires the movement of large quantities of combustion air, steam, exhaust gas, fuel gas, oil, and water through a variety of components. These fluids can contain high levels of energy because of their mass flow rates, pressures, and/or temperatures. Thus their uncontrolled release presents a significant safety hazard to personnel. An uncontrolled release of fluids typically is sudden, violent, and accompanied by significant noise and substantial movement of equipment and structures.

Those in the immediate area of an uncontrolled release can be injured or killed by asphyxiation, burning, scalding, falling, or being struck by flying debris. Injuries also have occurred while the startled worker is franticly trying to escape the area.

Although we cannot precisely predict *when* an uncontrolled energy release might occur, we can precisely predict *where*. As plant leaders we need to identify the specific locations in our facilities that are vulnerable and take steps to minimize personnel risk. All employees and contractors should be made aware of these areas, so they can avoid them when possible and be mindful of a safe means of egress whenever they need to work there.

Steam. Industry experience tells us that the single most common source of uncontrolled fluid release is pressure-boundary breach caused by material failure. In a combined-cycle plant, this can mean uncontrolled releases of steam from failures of:

- Threaded or compression fittings.
- Drum or drip-pot level gages.
- Valve packing.
- Bolted pressure boundaries (valve bonnets, flanges).
- Drain piping.
- Blowdown pumps, tank, and pit.
- HRSG headers, tubes, and interconnecting piping.
- High-energy piping, particularly at joints where dissimilar metals or P91 materials are welded. These include high-pressure, cold-reheat, hot reheat, high-pressure bypass, and hot-reheat bypass systems.
- Steam-drum manway gaskets. At its 2004 Annual Conference, the HRSG User's Group devoted substantial time to this issue. It was clear from the discussion that many plants continue to suffer gasket failures, and continue to experiment with different solutions. But this serious safety problem is no place for a trial-and-error approach. The manway door and the gasket, together, comprise an engineered system that must be properly designed, operated, and maintained according to the HRSG manufacturer's specifications (Fig 4).

Hot gases. Steam is not the only dangerous fluid. Uncontrolled releases of hot gases also can injure or kill in a combined-cycle plant. Specific locations that our employees and contractors need to be attentive to include:

- GT exhaust duct/HRSG expansion joints, which can emit 1200F gas.
- Duct penetration seals, also subject to releases of 1200F gas.
- Flanges, valves, fittings, and heat exchangers (don't forget fuel gas which may be heated up to 350F).
- GT flanges, expansion joints, valves, and fittings (compressor bleed air, for instance, may be as hot as 700F).

- Drains on the exhaust stack (GT exhaust may still be 300F at this point in the cycle).

Oils. The uncontrolled release of lube oil cost several operators their lives at a Northeast cogeneration plant in the early 1990s. Lube oil from the steam turbine sprayed onto nearby hot surfaces and ignited, creating a rapidly moving, extremely hot fire that trapped the operators inside their break room. Most steam turbines use mineral oil with a flash point ranging between 375F and 500F.

Fuel oil also has proved lethal in our industry. During the commissioning of a Kentucky plant, a young engineer suffered third-degree burns over 98% of his body and died several hours later when a GT was being switched from natural gas to fuel oil. The engineer had climbed on a metal catwalk with the turbine running, apparently to inspect for fuel-oil leaks. He found one. A compression fitting began spewing atomized fuel and saturated his clothing, which heat from the combustor quickly ignited.

Air and water. Don't forget, too, that our co-workers and friends also can be injured by uncontrolled releases of seemingly harmless fluids like compressed air or water. A compressed air hose can burst or be pressurized while unsecured, injuring personnel with flying debris, the high-pressure jet, or the whipping action of the hose end. And though it may be in its liquid phase within its pressure boundary, water in the feedwater, condensate, or circulating-water system can produce such hazards as flashing steam, scalding water, high-pressure jet, and flying debris, if that pressure boundary is breached.

3 Controlled release of fluids

Even when the release of fluids is not caused by material failure and is, instead, part of a controlled process, it can still present an extreme hazard. A controlled release of fluids may be sudden and unanticipated, as with the lifting of safety-relief valves. Or it may be planned, such as the opening of vents and drains.

Either way, it can pose a safety hazard because the actual point of fluid release typically is far from the actual valve or vent. A contractor may be standing near the safety-relief discharge, unaware that a steam-pressure excursion is about to cause an automatic lifting of that valve. Or a plant operator manually opening vent valves may not know that a mechanic happens to be tackling an unrelated maintenance job, right near that vent's discharge point. Note, too, that drain valves in combined-cycle plants increasingly are being fitted with motor operators and remote controls, escalating the potential for personnel injury from this controlled release of fluid.

Safety-relief valves pose a concern beyond their potential for unexpected fluid release. These valves often are surrounded by a large cloud of steam, hot water, and debris due to the inherent gaps in the valve upper body, discharge nozzle, and vent-stack connection. It is not uncommon for this cloud to envelop nearby walkways and in some cases to block normal egress routes.

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4. HRSG users report recurring failures of manway gaskets, creating serious hazards of hot steam and flying debris. The manway door and the gasket, together, comprise an engineered system that must be properly designed, operated, and maintained according to the HRSG manufacturer's specifications

As with an uncontrolled release of fluids, we can reduce the risk of a controlled release by identifying the specific locations in each plant that are most vulnerable. Personnel should be trained not to plan their next maintenance job or swap stories about their weekend while standing in these locations. Furthermore, we can continually emphasize these hazards to the operators who monitor the plant and open these valves, so that they can warn others if they know a release is about to occur. A plant-wide loudspeaker system is a great tool. Use it.

4 Normal plant configurations

After the chaos of new construction and commissioning, a powerplant staff settles into a routine of ongoing operations and maintenance. Most time, plant systems are in one of a handful of normal, well-understood configurations, in which the staff starts and stops machinery, warms up and cools down equipment, pressurizes and depressurizes piping, and so on. Even for a plant that cycles daily, the systems are taken through a familiar series of valve and equipment line-ups for GT ignition and loading, steam-system warm-up and loading, plant shutdown, and overnight layup.

As the O&M team gains experience, it naturally becomes competent and comfortable with these normal plant configurations. But as leaders, we need to ensure that *comfort* does not stray into *complacency,* because many hazards are still present in a normal plant configuration.

One example occurred during a normal plant startup some years ago when a cogen plant on a college campus suffered a loss of boiler feedwater flow. The veteran operating crew, which had performed startups so frequently they were "second nature," failed to observe the loss of flow, and continued the normal startup procedure—including the full firing of duct burners. Unfortunately, improper maintenance by the instrumentation technician had left the control-system interlocks jumpered out, so the duct burners continued to fire within the dry HRSG. The complacent operators realized something was wrong only when the campus fire department rushed into the plant, in response to neighbors' calls about the 20-foot flames shooting out the stack.

Certainly, not all startup hazards are serious enough to burn an HRSG to the ground, but all of them warrant our attention. Remember that many components in today's combined-cycle plant are energized automatically by a robust control system or remotely by a control-room operator who is challenged by time constraints and revenue goals. Even though the operator's action is intentional, the sudden actuation of valves, pumps, turbine shafts, and compressors can injure personnel near the equipment who are caught unaware. Specific components that present actuation hazards include:

- Motor-operated valves.
- Air-operated isolation valves.
- Control valves.
- Boiler feedwater pumps.
- Condensate pumps.
- Circulating-water pumps.
- Sump pumps.
- Air compressors.
- Air dryers (jets of compressed air).
- Entrance gate (movement of shafts, chains, and the gate itself).

Components may actuate unintentionally, as well, because of equipment malfunction or operator error. These problems can initiate sudden movement of entire piping legs, support structures, walkways, stairways, etc. Note that both intentional and unintentional events often produce startlingly loud noise, which can cause permanent hearing loss to an unprotected worker or plant visitor. Hazards attributed to equipment failure or operator error include:

- Water hammer—pipe or structure movement, sudden noise, flying or falling debris, possible steam or water release.
- Gas-path explosions (caused by inadequate GT purge)—sudden noise, escape of GT exhaust gas, movement or distortion of ducts and structure, expansion joint and penetration seal failures, flying debris.
- Metal clad switchgear failure—sudden noise, arc burn, flying molten metal, flying debris. While rare, explosive failure of the high-voltage (5 kV, for example) switchgear controlling our large auxiliaries—such as boiler feedwater pumps and GT starting motors—has occurred, usually when the breaker is actuated to close. Fatalities have occurred during these events when personnel were near the breaker and the metal enclosure failed to contain the blast. Personnel should minimize the time they spend near this equipment and never attempt to close the switchgear on a load using the local controls on the front of the breaker enclosure.

5. Perhaps the most hazardous time in a powerplant's service life occurs when the plant systems are in an abnormal configuration, with unfamiliar valve and equipment line-ups. This leg of cold reheat pipe became a projectile that, luckily, missed onsite personnel

5 Abnormal plant configurations

Perhaps the most hazardous time in a powerplant's service life occurs when the plant systems are in an abnormal configuration. During these times, the valve and equipment line-ups are unfamiliar to the crew and often extremely complicated, creating conditions ripe for mishap (Fig 5). For example, one unit at a 2 × 1 combined cycle may be operating, while the second unit is in a major maintenance outage with personnel working inside that second HRSG. In this case, improper valve line-up, allowing interconnection between the two steam systems, could prove lethal.

A possible fatality was narrowly avoided during a scheduled outage a few years ago when auxiliary steam was admitted to the main condenser while a plant engineer was inside performing an inspection. Fortunately, the engineer was close enough to the manway to make his escape without injury. Note that the operator who opened the steam valve also escaped injury, by running faster than the plant engineer intent on "enlightening" the young man.

Another hazard of abnormal plant configurations is the need to sometimes connect piping and equipment rated only for low pressures to piping and equipment rated for higher pressures. Equipment failure or inappropriate operation of these interconnections can quickly cause over-pressurization and catastrophic failure of the lower-pressure system. Examples here include auxiliary steam ties between units; ties among high-, intermediate-, and low-pressure boiler drains; and HRSG layup systems such as nitrogen-blanket or recirculation systems.

During the HRSG User's Group's Fall Maintenance Workshop last year, chemistry specialists emphasized the need for periodic recirculation of an HRSG in cold wet layup, to prevent stratification of water-treatment chemicals. This is excellent corrosion-prevention advice. Note though that such an arrangement requires the temporary connection of small, low-pressure recirculation pumps. Prior to the subsequent plant startup, it is essential that these pumps be isolated from the steam system, to prevent their over-pressurization. Two tips from the HRSG User's Group: (1) Install spectacle flanges for these connections, so that operators can visually see that the pumps are isolated; and (2) Use a written checklist to ensure that the flanges are properly positioned prior to steam-system pressurization.

Another hazard, environmental spills, often occur when a plant is in an abnormal configuration. At one facility, cartridge-type filters in the fuel-oil system were being changed on off-line GTs—a routine task handled by our operators, not a formal maintenance job. As part of the procedure, the operators opened the drain valves to thoroughly bleed the old oil to a waste sump. They inadvertently left the drain valves open after restoring the system, and went home for the evening. The next morning, the operators returned to find the waste sump and surrounding containment area flooded by fuel oil that had flowed by gravity from the fuel-oil head tank into the sump all night long.

Realize that in our lean-staffed plants, many minor maintenance tasks such as this are now performed by a sole operator on watch, without the traditional safeguards of a formal maintenance work order or checklist that must be signed off by a second set of supervisory eyes. We must take appropriate action to mitigate such risk.

Contractors onboard. When the plant is in an abnormal configuration, numerous contractors usually are onsite performing scores of different maintenance jobs. The result often is confusion, as exemplified by this near miss: During commissioning of a plant several years ago, a crew of painting contractors decided to enjoy their coffee break seated high on a big, cool, comfortable pipe. They were unaware that the pipe, which was not yet insulated, was a steam leg that happened to be seconds away from being pressurized. The contractors certainly would have been burned and perhaps killed by their panicked fall, if a plant engineer, aware of the startup status, had not wandered by and shouted for them to move.

Telling contractors how to perform their job can be a thorny issue, though. Plant managers want contractors to adopt the plant's established employee safety program, but each contractor has its own risk-management program. Another concern for plant owners is potential legal action by the US Department of Labor, which can construe overt co-management as direct employment. To avoid such misperception, some plant owners purposely minimize their supervision of contract workers.

But management of contractors is essential if our plants are to maintain high levels of safety. Steps that can improve contractor safety at your site include these:

- Pre-qualify and select only safe contractors. Use both objective and subjective criteria when evaluating qualifications.
- Determine contract requirements. State your safety expectations in the contract the same way that you would state other terms and conditions.
- Communicate your safety expectations to the contractors prior to project award.
- Orientation and training. Prior to the start of work, make sure that the contractor workforce knows the safety requirements.
- Rigorously enforce the requirements.

It all comes down to execution. Training all of our contractors, visitors, and employees on the specific hazards in our plants, and enforcing the use of safety procedures to minimize those hazards, cannot be done once, or even once a year. It's a never-ending battle that must be fought day-in and day-out. The first time we overlook an operator who clears a lockout before the job is done, or we walk past a mechanic who's welding without a fire watch, the safety of our plant is in jeapordy. As in so many other aspects of plant management, success in the safety arena relies, not on corporate programs, catchy slogans, or cute posters hanging in the break room, but on engaged and effective leadership. CCJ

Anderson picks April 11-13 in Tampa for next HRSG User's conference

In addition to his duties as manager of combined-cycle services for Progress Energy Inc, Raleigh, NC, Bob Anderson volunteers as the chairman of the HRSG User's Group. Anderson recently announced the dates and venue for the organization's next Annual Conference and Exhibition: April 11-13, 2005, at the Saddlebrook Resort, Tampa, Fla.

The HRSG User's Group is open to all combined-cycle/cogen professionals—including owners, operators, manufacturers, architect/engineers, and consultants. Over the course of its 12-plus years, the group has grown to become a premier industry association, focusing on the HRSG and all steam-system challenges at both frame and aeroderivative GT plants. For coverage of the group's last conference, see the Spring 2004 issue of COMBINED CYCLE Journal (on-line at www.psimedia.info/ccjarchives.htm).

Register today for the 2005 Annual Meeting at www.HRSGusers.org, by e-mail to info@HRSGusers.org, or by calling 718-317-6737.