Advanced tracer technique enhances leak detection

Leakage in cooling water systems is detected by a variety of methods. A new technique makes use of SF_6 as a tracer where leak rates are extremely low and otherwise undetectable

By Sheldon D Strauss, Senior Editor

Traditional methods for pinpointing condenser cooling-water leakage include the use of plastic wrap, foam, flame from a match or candle, sound, vibration, eddy-current inspection, chemical analysis, and even tracing with helium gas. While commonly used to identify relatively large leaks, these have not been suitable for detection of very small leaks—of the order of 1 gal/day. Though relatively insignificant, leaks of this magnitude can introduce impurities (such as sodium) to cycle components in excess of recommended limits.

The use of sulfur hexafluoride (SF_6) as a tracer gas offers an alternative approach with far greater sensitivity than other methods. Investigation of this technique, initiated several years ago by the Electric Power Research Institute (EPRI), resulted in the publication of recommended guidelines.[1] Experience at Commonwealth Edison Co indicates its ability to detect leaks as small as 1 gal/day.[2] Experiments performed by EPRI and Carolina Power & Light Co demonstrate a novel injection method offered to expedite tracing with SF_6.[3]

Tracer techniques involve injection of a suitable gas into the bulk cooling water and monitoring for its presence at a point outside the system (turbine room, condenser offgas system, etc). Detection of the tracer gas is followed by efforts to narrow down the location of the leak as rapidly as possible (preferably with the unit on-line) to minimize the downtime required for its repair—by plugging a condenser tube, for example.

Protecting steam generators

Several gases other than helium have been considered, but SF_6 seems to offer the desired improvement in detection sensitivity with the fewest disadvantages and the least interfering background. The preferred application is in the form of tiny bubbles entrained in the water. As described by Larry Alexander of Commonwealth Edison Co at a recent electric utility workshop,[2] the company has used the technique to replace helium tracing at its Byron, Braidwood, and Zion nuclear stations, and is exploring possibilities for broadening the use of SF_6 to help identify leaks of fluids other than cooling water.

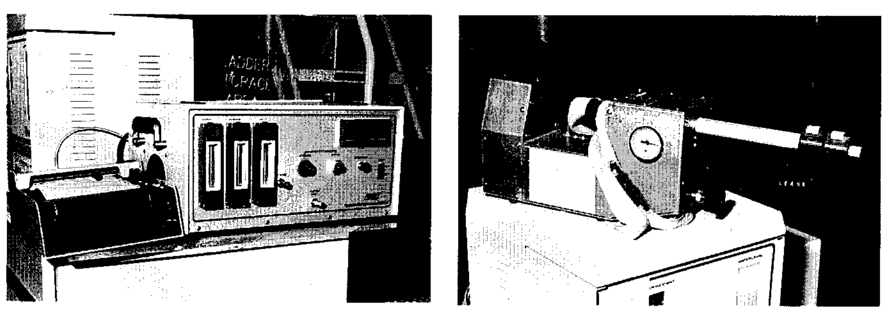
Although detection of almost imperceptible leaks may not be necessary at some stations, it was considered vital at the utility's PWR (pressurized-water reactor) stations. Tubing in the recirculating steam generators (SGs) of these units has been subject to chemical attack, identified as microbiologically influenced corrosion (MIC). If allowed to continue, the integrity of the boundary between radioactive and non-radioactive water could be jeopardized. The major source of the attack was believed to be from condenser cooling-water leakage.

Each PWR unit has its own unique cause of condenser cooling-water leakage. Need for a better detection method was greatest at Braidwood. The station's condenser has a stainless steel tubesheet and tubing; the tubes have been plagued with many very small leaks, causing significant damage. MIC was initiated during construction of the condenser, when the steam side was tested using lake water; the water was allowed to remain in the condenser for several weeks. (Plans are under way for eddy-current testing of the tubes in one section to determine the extent of the damage.)

The condenser at Byron station is the same as at Braidwood, except that the tubes are welded to the tubesheet at both ends. The failure there was caused directly by debris from the cooling tower; ice damage of the cooling-tower fill and concrete damage of the tower were the source of the debris. When wedged into the expanded area of the tubing, debris eventually wore through the tube wall. All leaks in Byron's cooling-water system are located within the first 12 inches of the tubes.

Previous approaches to leak detection at Byron and Braidwood stations involved monitoring samples educted by a condensate side-stream flow from some 20 different points in the high-vacuum condensers. Both batch-type and on-line methods were tried, with cation conductivity monitored to track leakage. Accurate interpretation requires a leak-tight system, which is hampered by the large number of fittings present and the difficulty of sealing a cation-resin column. Dilution of leakage flow by steam condensate in some of the sample lines makes it even harder to identify an elevation in cation conductivity. While an ion chromatograph was installed for on-line measurements, it could not detect a leak as small as 0.01 gal/min (14 gal/day).

At Zion station, where the condenser has stainless steel tubing with Muntz metal tubesheets, tube-to-tubesheet leakage has been identified. Many of the tubes have been rolled twice—and some three times—to stop the leakage. As explained by Alexander, the plant takes relatively clean water from Lake Michigan for makeup. When a leak occurs, inability to detect the low impurity concentrations makes it



1. Sulfur hexafluoride analyzer (left) detects steam-side SF_6 injected into condenser tubes with spray gun (right), senses cooling-water leakage as low as 1 gal/day difficult to identify the location of the leak. The problem is compounded by the fact that the pumps used to draw samples from the high-vacuum condenser have not been reliable. As a result, days of sampling and testing can be spent trying to locate the troublesome condenser region.

The use of SF_6, by comparison, is not dependent on either the cleanliness of the cooling-water source or reliability of the sampling-system. Leaks can be readily located by monitoring the condenser offgas with the Fluorotracer Analyzer, an extremely sensitive SF_6 detector developed by Science Applications International Corp, Gaithersburg, MD. It makes use of an electron-capture cell as the basis of a technique for detecting only 0.1 ppb of SF_6 in air, allowing identification of leakages down to 1 gal/day.

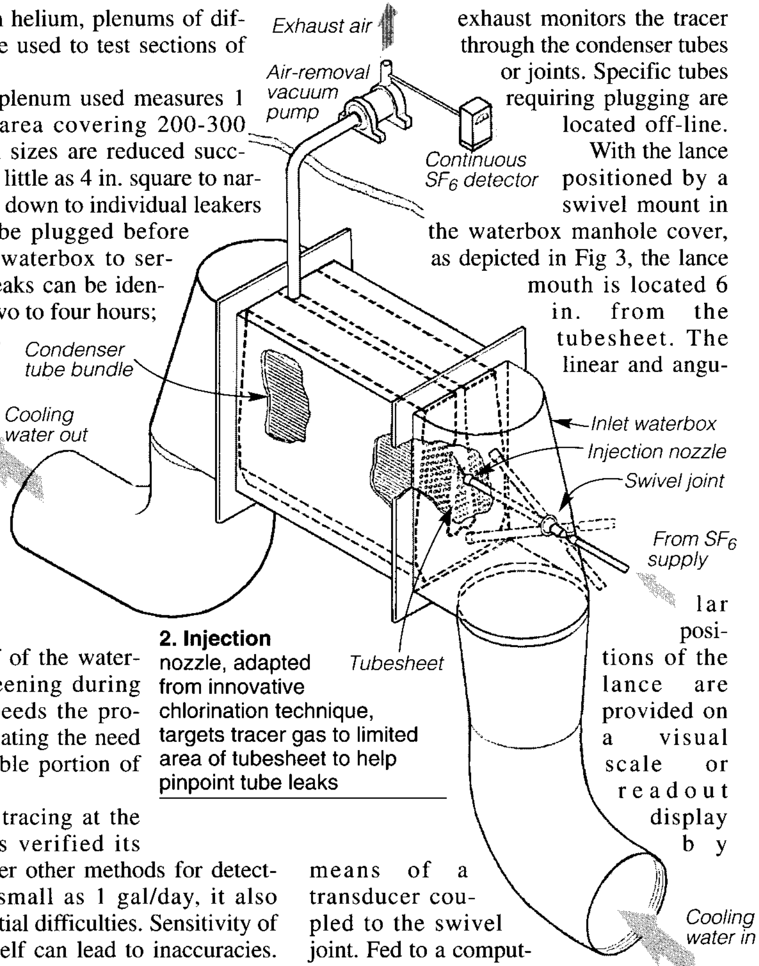
To minimize false indications from escaping gas while scanning the tubesheet, the gas is diluted 1000:1 with air before injection with portable spray gun (Fig 1, right)—which also eliminates possible health risks from ingestion. (Hydrogen, produced by unit beneath spray gun in photo, is introduced into gas stream to neutralize oxygen and prevent competition with SF_6 for electrons.) Its low solubility makes SF_6 easily removable by the off-gas system, preventing it from contaminating the condensate. With the high sensitivity of the detection system and absence of a natural background, only small quantities of the tracer are needed, leading to inexpensive operation and the use of portable detection systems.

In the search for tube leaks by Commonwealth Edison, SF_6 is injected into one inlet cooling-water box at a time as a screening step. At Braidwood, the gas is actually attached to the hypochlorite chemical-feed piping, which is connected to a diffuser inside the box. The diffuser distributes the gas uniformly throughout the tubesheet. SF_6 flow rate and injection time are varied, depending on the size of the suspected leak. Injection is typically at 3 scfm for a period of 15 seconds. If the analyzer gives no indication, either the injection rate or time or both may be increased. If no leak is indicated, the next waterbox is checked.

When an indication occurs on the analyzer, the suspect waterbox is retested twice to verify the indication. (The time required for the SF_6 to reach the analyzer and the size of the indication must be repeatable to ensure accurate monitoring; a stopwatch and chart recorder are helpful aids.) The procedure followed after the faulty waterbox is identified is to ramp down the unit and remove the waterbox from service for further testing and repair. With four condenser waterboxes at Braidwood, 25% derating is required.

After the cooling water is drained, the inlet and outlet waterboxes are opened and air-moving equipment is set up at one end to pull air through the condenser tubes. As in tracing with helium, plenums of different sizes are used to test sections of the tubesheet.

The initial plenum used measures 1 ft × 2 ft, an area covering 200-300 tubes. Plenum sizes are reduced successively to as little as 4 in. square to narrow the search down to individual leakers so they may be plugged before restoring the waterbox to service. Larger leaks can be identified within two to four hours; smallest leaks may require up to two days. Steve Brant, engineer in charge of the procedure, points out that most leaks occur in the lower half of the waterbox, and screening during draindown speeds the process by eliminating the need to scan a sizable portion of the tubesheet.



2. Injection nozzle, adapted from innovative chlorination technique, targets tracer gas to limited area of tubesheet to help pinpoint tube leaks

While SF_6 tracing at the three stations verified its advantages over other methods for detecting leaks as small as 1 gal/day, it also revealed potential difficulties. Sensitivity of the method itself can lead to inaccuracies. For example, if there is a leak in the cooling-water supply or return piping, entrained SF_6 gas will escape into the turbine-building atmosphere, possibly entering the condenser as air inleakage. The result could be a false indication of cooling-water leakage.

Another scenario lending to misinterpretation can occur when diluted SF_6 is pushed through sections of tubing in a waterbox to narrow the search for a leaking tube. If the exhaust leaving at the other end is not properly directed, SF_6 can enter the condenser as air inleakage. Routing the exhaust away from the condenser or out of the turbine building may be necessary. Care must also be taken when using the method to detect inleaking air with the same equipment. (A portable SF_6-gas diluter and sprayer are included with the analyzer for this purpose.) Based on their experience, the Commonwealth Edison investigators conclude that, with proper training, plant technicians should be able to distinguish false indications from true leakage.

Reducing downtime

In a variation on this procedure, EPRI applies a gas-delivery system developed to limit chlorine discharge to waterways. Known as targeted chlorination, it uses a water lance to target a tracer gas to a specific section of the condenser tubesheet (Fig 2). Gas-detection units located at the air-jet exhaust monitors the tracer through the condenser tubes or joints. Specific tubes requiring plugging are located off-line. With the lance positioned by a swivel mount in the waterbox manhole cover, as depicted in Fig 3, the lance mouth is located 6 in. from the tubesheet. The linear and angular positions of the lance are provided on a visual scale or readout display by means of a transducer coupled to the swivel joint. Fed to a computer (using a program called "Nozzles"), this information determines the size and location of the tubesheet impact area, which is displayed on the monitor. The lance is repositioned as needed to cover the entire tubesheet, with the impact area under view at all times.

With injection (and detection) periods of one to two minutes, and five-minute allowance for dissipation of residual SF_6, a 100-ft^2 tubesheet can be tested in three to five hours while the unit runs at full power. Final location of a leaking tube should require about one hour.[4]

The concept was demonstrated at Ashville station, Unit 1, simulating 7.6 gal/day leaks. The tests gave repeatable results in detecting these leaks, indicating capability of the system for detecting leaks as small as 1 gal/day.[3] By comparison, the system was not successful when used with helium tracer at 10 times the concentration of SF_6. ■

References

1. "Condenser Leak-Detection Guidelines using Sulfur Hexafluoride (SF_6) as a Tracer Gas," EPRI Report 6014, September 1988
2. L Alexander and S Brant, "Commonwealth Edison's Experience with Sulfur Hexafluoride for Condenser Leak Detection," *12th Annual Electric Utility Chemistry Workshop*, Urbana, Ill, March 1992
3. J L Tsou and Y G Mussalli, "On-Line Condenser Leak-Detection Demonstration using Targeted SF_6 Tracer Gas," *NOMIS Summer Conference*, July 1992
4. Personal communication, J L Tsou, Electric Power Research Institute