... basis, app D, plant status to require resident inspectors to specifically monitor primary-to-secondary leakage in SGs and check on licensee actions

② This guidance could be a memo from DE [illegible] to Regions.

DRAFT

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Guidance to Inspectors on Overseeing Facilities with Known Steam Generator Tube Leakage

What are we trying to accomplish with leakage monitoring (technical bases)?

Leak before break cannot be totally relied upon for steam generator tubes to prevent a tube rupture. However, leakage monitoring with adequate shutdown limits can afford early detection and response to rapidly increasing leakage and, thereby, serve as an effective means for minimizing the incidence of steam generator tube rupture and burst. This can be achieved by having near real-time leakage information available to control room operators. Use of such monitoring capability, along with appropriate alarm set points and corresponding action levels, can help operators respond appropriately to a developing situation in a timely manner.

The monitoring program should account for plant design, steam generator tube degradation, and previous leakage experience. Degradation and leakage experience should not be limited to a specific plant. A primary measure of program effectiveness is the ability of operators to appropriately deal with the full range of primary-to-secondary tube leakage.

Action levels defined by leak rate limits and the rate of change of the leak rate are recommended in the EPRI guidelines. The action levels provide a framework that licensees can use to formulate preplanned operator actions based on specified leakage indications. The objective for the normal operating leak rate limit is to establish a reasonable likelihood that the plant is shut down before the tube could rupture under either normal or faulted conditions (i.e., "leak before break"). The objective for a shutdown limit on the rate of change in the leak rate is to provide a high confidence that the plant can be shutdown before a fatigue driven circumferential crack can result in a severed tube. The operating leakage experience together with the analytically based burst pressure versus normal operating leak rate trends provide the bases for a recommended leakage limit.

What are the sources of primary-to-secondary leakage?

Typically, leakage is due to degraded tubes, leaking plugs, and/or leaking or leak-limiting sleeves.

How can the licensee detect leakage during operation?

Most plant have radiation monitoring systems that monitors condenser off gas, steam generator blowdown, and/or the main steam. The condenser off gas is monitored to identify the presence of radioactive gases removed from steam condensate. The steam generator blowdown is monitored to identify non-volatile radioactive species in the steam generator bulk water (excluding OTSGs). The main steam is monitored to detect volatile gases, and in some cases N-16, carried from the steam generator via the main steam.

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Grab samples are also commonly used. Grab samples from the reactor coolant are used to quantify the source term. Grab samples from the steam generator blowdown are used to detect non-volatile radioactive species in liquid. Grab samples from the condenser off gas is used to detect noble gas and other volatile species removed from steam condensate. Grab samples from the condensed main steam are used to detect noble gas and other volatile species carried over with main steam. Grab samples of the condensate are used to detect tritium, iodine and other soluble species. Grab samples from the blowdown filters and ion exchanger columns are used to detect particulates and ionic species from liquid streams.

What are the pros and cons of the detection methods?

What are the recommended limits and where are they found?

From DG-1074: The technical specifications should include an LCO limit with respect to the allowable primary-to-secondary leakage rate through any one SG, beyond which prompt and controlled shutdown must be initiated. An acceptable LCO limit is 150 gallons per day. Alternatively, this limit should be established so that an axial crack which is leaking at a rate equal to the limit under normal operating conditions would be expected to satisfy the performance criteria for structural integrity. Likewise, procedural limits should be established for allowable leak rate and the allowable rate of increase in leak rate.

What actions are appropriate for the various levels of leakage?

In the EPRI guidelines, six operating conditions including three Action Levels have been defined for initiation of station actions based on primary-to-secondary leak rates and action thresholds. The six operating conditions are:

Normal operation: The plant condition in which no primary-to-secondary leakage is detected in routine surveillance. Due to the lack of analytical certainty at very low radiochemical concentrations, it is assumed that the total leak rate is <5 gpd. It is recommended that station radiation monitoring equipment be such that a 30 gpd leak total can be detected, and that station procedures contain a prescribed grab sample program which is designed to quantify leakage at the 5 gpd total level.

No Operable Continuous Radiation Monitor: This describes the condition where there is no continuous radiation monitor providing continuous automatic monitoring of primary-to-secondary leakage. A radiation monitor can be considered operable if it is directly correlated to gpd leakage, can be monitored and will produce an alarm in the main control room, and can detect leak rates greater than 30 gpd at existing RCS activity levels. This condition requires increased use of grab samples or other monitoring systems to ensure that a primary-to-secondary leakage event does not occur without rapid detection and response.

Increased Monitoring: This describes the condition in which leakage has been detected and quantified but is not in a range that can be accurately monitored by most radiation monitors.

Action Level 1: Action Level 1 defines a plant condition in which leakage has increased to a condition that should be frequently monitored by the RMS with periodic benchmarking by laboratory analyses.

Action Level 2: Action Level 2 defines a plant condition in which leakage has increased to a condition that suggests that the underlying flaw has grown to an undesirably large size and that the unit should be shut down in a planned manner.

Action Level 3: Action Level 3 describes a condition that suggests that the leak is increasing rapidly and the unit should be promptly shut down.

What inspection guidance is currently available?

NRC Inspection Manual, Inspection Procedure 50002: — This is a supplemental inspection procedure.

02.09 Primary-to-Secondary Leakage. Evaluate the effectiveness of licensee procedures, equipment, and practices for monitoring and responding to primary-to-secondary leakage. Include the following subjects in the evaluation:

a. Licensee responses to Bulletin 88-02 and Information Notices 88-99, 91-43, and 93-56.

b. Adequacy of procedures and equipment to provide real-time information on leak rate and its rate of change.

c. Appropriate setting of alarm setpoints on those radiation monitors that are used for detecting primary-to-secondary leakage (e.g. condenser air ejector, N-16) to alert operators to any increasing leak rate.

d. Adequacy of emergency operating procedures and operator training for response to steam generator tube ruptures.

What regulatory guidance is available?

- Draft Regulatory Guide DG-1074, "Steam Generator Tube Integrity"

<u>Monitoring Strategy</u>

Each monitoring method has limitations, and therefore, no single means of detecting primary-to-secondary leakage nor single monitored pathway of radionuclide should be relied upon. A monitoring strategy should use an array of methods to detect and measure leakage, and indications should be available to control room operators. Continuous control room display of key radiation monitor trends (e.g., blowdown, condenser exhaust, Nitrogen-16 monitor of leakage rates and change in leak rate over time) gives operators real-time information that can be used to safely respond to the full range of primary-to-secondary leakage.

Use of N-16 monitors installed on or near steam lines has become increasingly common in the industry as a supplemental means of monitoring leakage. These monitors exhibit short time response to changes in leak rate and are very useful to operators, provided their limitations are understood. However, the short half-life for N-16 presents some problems in the ability of the detector to measure leak rate. Changes in power level and characteristics of the leak itself (location and type of leak) will affect the N-16 concentration reaching the detector.

The monitoring program should also include provisions for detection of primary-to-secondary leakage during low power or plant shutdown conditions. Licensees should ensure that means are available to detect tube leakage whenever primary pressure is greater than secondary system pressure. This includes hot shutdown conditions and plant startup situations, when normal means of detecting leakage might be limited or unavailable. For instance, the radionuclide mix is altered following a period of plant shutdown so that condenser offgas monitor indications may be questionable during startup since they are calibrated for a specific radionuclide mix based on power operation. Also, N-16 monitoring is not considered reliable at low power since lower levels of N-16 are available to trigger detector response during a tube leak.

Shutdown or low power monitoring methods do not need to be relied upon to track low levels of leakage over extended periods as might be required for power operation. Plants spend a relatively small fraction of time in low power or hot shutdown. However, it is prudent to have techniques and procedures available to detect a rapidly developing leak under those circumstances. In the event a tube failure develops, operators should have reasonable time to respond to the situation before the plant reaches full power operation, when the consequences of a tube failure would be magnified.

<u>Operational</u>

Clear guidelines should be available to direct operator response to leakage in order to minimize the chance for operator errors during a developing leak event. Licensees should be careful, however, not to return too quickly to a more routine monitoring regime following an increase in leakage. A firm basis, in terms of change in leak rate over time, upon which to determine the stability of the leak is difficult to formulate. Therefore, prudence dictates that operators should use more than a single indication as the basis for concluding that leak rates have stabilized.

As much as is practicable, training scenarios should include various types of leakage progressions based on actual leakage events. The characteristics of specific plant monitoring instrumentation should be considered when providing operator indications for training purposes.

Means should be established for the leakage monitoring program to take advantage of new data. Information from actual leakage events can be used to check the adequacy of the monitoring program or enhance its effectiveness.

Licensees should also have measures in place to allow careful evaluation of leakage monitoring program performance following any primary-to-secondary leakage event at their plant. Suitable adjustments in the monitoring program can then be made, based on the results of such an evaluation.

The technical specifications should include an LCO limit with respect to the allowable primary-to-secondary leakage rate through any one SG, beyond which prompt and controlled shutdown must be initiated. An acceptable LCO limit is 150 gallons per day. Alternatively, this limit should be established so that an axial crack which is leaking at a rate equal to the limit under normal operating conditions would be expected to satisfy the performance criteria for structural integrity. Likewise, procedural limits should be established for allowable leak rate and the allowable rate of increase in leak rate.

- USNRC Information Notice No. 91-43: "Recent Incidents Involving Rapid Increases in Primary-to-Secondary Leak Rate," (July 1991)
- USNRC Information Notice No. 94-43: "Determination of Primary-to-Secondary Steam Generator Leak Rate," (June 1994)
- USNRC Regulatory Guide 1.45, "Reactor Coolant Pressure Boundary Leakage Detection Systems," (May 1973)
- USNRC Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident," (December 1980).

What industry guidance is available?

The guidelines developed under NEI 97-06, "PWR Primary-to-Secondary Leak Guidelines - Revision 2", issued April 2000 recommend the following licensee actions in response to Primary-to-Secondary Leakage:

"... each utility should develop plant-specific procedures to manage such leakage to ensure that the likelihood of propagation of flaws to tube rupture is minimized under both normal and faulted conditions."

New action level for leakage, 75 gpd, is incorporated into SG program

New limit on rate of increase of leakage adjusted to 30 gpd/hr sustained for 30 or more minutes

New action level added for the condition of no operable continuous radiation monitor

One radiation monitor capable of detecting leakage >30 gpd is required

Actions and responses should be based on radiation monitor readings rather than on grab sample results

Increased emphasis should be placed on the reliability of these monitors

Periodic grab sample results should be used to provide current correlations between monitor response and leak rate in gpd

Important to recognize that radiation monitors for different systems, or different parts of the system, will not have the same response time from the onset of a leak (for example, a leak would be detected by an N-16 monitor within a few seconds of the event, the condenser offgas radiation monitor may have a time delay of several minutes, and the blowdown sample may have indications delayed as much as 1 hour). This is important to remember in correlating grab sample results to radiation monitor readings, and in many cases the grab sample location and the radiation monitor analysis point are not the same. Time delay differences need to be factored into this correlation when assessing radiation monitor response factors.

"An effective primary-to-secondary leakage monitoring program should designate operational responses for each of the following scenarios:

Low level and/or slowly increasing primary-to-secondary leakage;

Rapidly increasing primary-to-secondary leakage; and

Steam generator tube rupture (no leak before break)."

Categorizing a Primary-to-Secondary Leak

Knowledge of previous steam generator leak history, as well as recent eddy current test results, pulled tube examinations, chemistry history, FOSAR results and physical characteristics (tube material type, AVB material, propensity for tube vibration, etc.) should all be considered with the radiochemistry data when hypothesizing the cause for a primary-to-secondary leakage event.

Characteristics of Primary-to-Secondary Leakage (from EPRI guidelines)

Scenario	Leak Rates	Blowdown Radiation Monitors	Condenser Air Removal Radiation Monitors	Main Steam Line Radiation Monitors	N-16 Monitors	Short-lived Isotopes	Comments
1. Leaking Tube Plug	Low, relatively constant until plug failure	May not be detected immediately - low volatility species may not be seen in the bulk water - as radioiodine and particulate daughter products increase, may detect later		May not be detected due to delays in migration and transit time	May not be detected due to delays in migration and transit time	Probably not be detected or detected in small quantities	Tube plug failure may be accompanied by alarms on SG acoustic monitors as well as rapidly increasing leak rate
2. IGA/SCC at Packed TSP Intersection	Low leak rates expected at initiation - power transients may change leak rate			Due to delays in migrating through the corrosion product deposit, may underestimate or not even detect the leak	Due to delays in migrating through the corrosion product deposit, may underestimate or not even detect the leak		Sudden appearance of short-lived and non-volatile species may indicate that the leakage has opened a clear path through crevice deposits

3. PWSCC at high stress location	low leak rates with plateaus are expected - plant transients may increase or decrease the measured leak rate	should detect if of sufficient magnitude	should detect if of sufficient magnitude	should detect if of sufficient magnitude	should detect if of sufficient magnitude	all isotopes, regardless of volatility and half-life, should be detected	
4. Loose part wear	relatively high leak rates; may be subject to dramatic increase - adjacent tubes may also become involved	should detect	should detect	should detect	should detect	all isotopes, regardless of volatility and half-life, should be detected	leak rates may be accompanied by alarms on SG acoustic monitors
5. SCC at dented TSP Intersection	low leak rates that grow as more pressure is applied on the SG tube	similar to #2	similar to #2	similar to #2	similar to #2	similar to #2	similar to #2

6. Vibration-induced cracking	leakage may or may not start out small, but can rapidly increase to tube rupture	readily detected	readily detected	readily detected	readily detected	all isotopes, regardless of volatility and half-life, should be detected	Fatigue-type cracks due to vibration may increase very rapidly, giving the impression that they were large at the start
7. Sludge pile pitting/cracking	low leak rates are expected at initiation of leakage - leakage due to pitting is not expected to change following a plant transient	similar to #2	similar to #2	similar to #2	similar to #2	similar to #2	

8. Free span ODSCC	most cases: leak rates are low and increase irregularly with occasional spikes and steps; some cases: low rate of leakage followed by rapid increase						In some cases, cracks appear to intermittently plug with deposits - leading to spikes in leak rates