Responses to Questions Regarding Low Level Primary-to-Secondary Leakage

1) If a leak has occurred in the steam generator tubes. What are the key parameters and their monitoring locations used for leak detection and judgment? Is N16 the most representative indicator?

Response: Most plants have radiation monitoring systems that monitor condenser off-gas, SG blowdown, and the main steam lines. The condenser off gas is monitored to identify the presence of radioactive gases removed from steam condensate. The SG blowdown is monitored to identify non-volatile radioactive species in the SG bulk water (excluding once-through SGs). The main steam lines are monitored to detect volatile gases, and in some cases Nitrogen 16 (N-16), carried from the SGs via the main steam lines. Grab samples are also commonly used, such as reactor coolant samples (to quantify the source term), SG blowdown samples (to detect non-volatile radioactive species in liquid), and condenser off-gas samples (to detect noble gas and other volatile species removed from steam condensate). Other common grab samples include condensed main steam (to detect noble gas and other volatile species carried over with main steam) and condensate (to detect soluble species such as tritium and iodine). In addition, blowdown filters and ion exchanger columns are used to detect particulates and ionic species from liquid streams. Although no single monitor should be expected to fulfill all monitoring roles, some monitoring methods have demonstrated value in certain situations. Continuous control room display of key radiation monitor trends (e.g., SG blowdown, condenser exhaust, N-16 monitor of leak rate and change in leak rate over time) gives operators real-time information that can be used to respond safely 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 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, limitations of N-16 monitors, influenced by the short half-life for N-16, present 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 within the SG) will affect the N-16 concentration reaching the detector thus the apparent leak rate. Therefore, leak rates from N-16 monitors need to be calibrated against other monitor types (e.g. condenser off-gas grab samples) to be most accurate. Once well-calibrated, they will respond quickly to changes in leakage and thus be very useful.

2) In the event of a small leak, e.g., 0.3 L/h, what is the typical operational response? Should operation continue with monitoring, or shall a shutdown for inspection be considered? Is the decision-making approach related to the analysis of probable

failure modes, such as stress corrosion cracking (SCC), foreign object wear, or other mechanisms?

Response: Continual monitoring is all that is necessary for small leakage. Under 0.8 L/h, no changes to operation are required by those Guidelines. Any leakage should continue to be monitored and trended for changes. Ideally, an online radiation monitor system is in place to detect significant changes in leakage and react in a timely manner. Grab samples should also be taken to supplement online monitors with the frequency dependent on the stability of leakage (i.e. if the leak rate is very steady, lower frequencies like once per day should be sufficient, but if the leak rate is increasing every few hours may be appropriate).

If leakage increases to greater than or equal to 0.8 L/h, the condition of “Increased Monitoring” is reached. At this stage, still no operational changes are required, but an increased monitoring frequency is now required over just the recommended situation above. If leakage reaches 4.7 L/h with a leak rate of change of <9.4 L/H per day, the plant reaches Action Level 1 with additional monitoring requirements

However, plants always can react more strongly and shut down at any leakage rate to determine the cause of leakage and repair those tubes. This operational decision analysis will require the plant to consider several different factors.

Items for review include but are not limited to:

Evaluate secondary contamination potential and contain as required. It should be noted that plants which were operated for lengthy periods of time with primary-to-secondary leakage in Action Level 1 range found activities were highly impacted. Thus, shutdown even before Action Level 1 should be considered to reduce the possibility of significant secondary side contamination.

Initiate review of applicable procedures to be utilized by Operations, Chemistry, Radiation Controls, etc. in case leak rate conditions change.

Transition criteria from steam generator leak to steam generator tube rupture, Plant shutdown /cooldown with a steam generator leak, and Requirements for posting radiological hazard signs (e.g., radiation areas, contaminated areas, etc.) where not normally required (e.g., turbine building).

Once stable, reset off gas alert / alarm setpoint to 4.7 L/h above existing baseline reading to permit detection of rapidly increasing leak rate. Other radiation monitor setpoints (e.g., blowdown, N-16) should also be reset if these are used by the station for leak rate trending.

Evaluate the potential sources of leakage, and what the past inspection results indicate about the condition of their SGs. Sometimes plants experience very low levels of leakage with no clear cause identified. Small changes in low levels of leakage can be due to changes in monitoring equipment, either putting new equipment in service or recent calibrations of the existing equipment. In the past, small changes of observed leakage have been directly correlated to putting new detection equipment in service. This led to a step increase in the very small amount of leakage observed. This could also be observed after calibrating equipment, or any other major change that would reset the baseline readings. Although reliable identification of the leakage source is not possible while the plant is operating, insights can be obtained by reviewing past SG tube examination findings from the eddy current testing during the last outage and knowledge of loose parts in the SGs. Tube wear from anti-vibration bars (AVB) can have a significant through-wall extent, even in replaced SGs that have not been in service many years. Some plants also have known loose parts in the affected SG that they have not been able to retrieve, which they have identified through techniques such as FOSAR (foreign object search and retrieval). In some cases, the licensees will plug tubes around a loose part that they are unable to retrieve, to reduce the chance of tube rupture from the loose part during the next cycle. It should also be noted that it is not practical for licensees to shut down plants at low levels of leakage. In fact, sustained leakage below about 37 liters per day in some older plants with 600MA tubing is not unusual. Some plants that shut down with low leakage levels found it very difficult to determine the source of the leakage.

Since most US plants have replaced SGs with improved materials, the only cause of leakage has been from foreign objects except for San Onofre which was a design issue.

3) For small leaks, what are the commonly used leak detection methods (including but not limited to helium testing, hydrostatic testing, and eddy current testing)? What is the recommended priority sequence for implementing these leak detection methods?

Response: Secondary-side leak tests performed early during outages to identify leaking tubes is the most common. To conduct these tests, nitrogen pressure is applied to the water inventory in the secondary side of the SGs and maintained for a period of time. If the visual inspections reveal any observed dampness or drops of water from the tubesheet face, tubes in that area need to be evaluated carefully with appropriate inspection methods

Even at small levels of leakage (4.7 L/h), a secondary side hydro test is most often able to help identify the leaking tube. Helium leak testing is not used in the US to identify leaking tubes.

4) When small leaks occur in steam generator tubes, are there generic empirical calculation or analysis methods for leak rate propagation corresponding to different failure modes?

Response: The exact source of leakage is usually not determinable while online due to complex relationships between flaw size, shape, and leakage. The variability in all the factors of leakage make rate propagation very difficult to correlate exactly with failure mode.

5) If a leak develops at the seal weld of steam generator tubes, are there effective leak detection methods other than helium testing? For small leaks, is hydrostatic testing a valid detection method?

Response: Even at small levels of leakage (113 liters per day), a secondary side hydro test is most often able to help identify the leaking tube. Helium leak testing is not used in the US to identify leaking tubes.

6) Since steam generator tubes were upgraded to Alloy 690 material, has SCC problem been eliminated? What other major failure modes can cause tube leakage? Are there many cases of leakage caused by foreign object wear? Is the propagation rate of leakage due to foreign object wear predictable? Are there instances where operation continued under monitoring with small leaks caused by foreign object wear?

Response: There have been no documented instances of SCC in Alloy 690 tube material in the US to date. The only instances of SG tube leaks have been attributed to mechanical wear or foreign objects. Foreign object wear has been the cause of leaks in Alloy 690 tube material. Continued monitoring of low-level leak rates, that remain within acceptable operational limits, until a safe shutdown can be planned has proven to be an acceptable approach.

7) In the event of a steam generator leak where a large amount of primary coolant enters the secondary circuit, are there dedicated decontamination methods for the secondary circuit?

Response: There aren’t standard methods. It would all depend on plant configuration, leakage amounts, etc. And since there haven’t been large leaks in around 20 years, plants don’t have recent experience. A clean-up plan should be developed but there are no standard methods.