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GUIDANCE ON MONITORING AND RESPONDING TO REACTOR COOLANT SYSTEM LEAKAGE

A. INTRODUCTION

This revision to Regulatory Guide 1.45 (Ref. 1) describes methods that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for use in implementing the regulatory requirements specified below with regard to selecting reactor coolant leakage detection systems, monitoring for leakage, and responding to leakage. This guide applies to light-water-cooled reactors.

General Design Criterion (GDC) 14, "Reactor Coolant Pressure Boundary," as set forth in Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the *Code of Federal Regulations* (10 CFR Part 50), (Ref. 2), requires that licensees or applicants design, fabricate, erect, and test the reactor coolant pressure boundary (RCPB) so as to ensure an extremely low probability of abnormal leakage, rapidly propagating failure, and gross rupture. As a result, the design of these nuclear components normally follows the criteria established in Section III of the Boiler and Pressure Vessel Code (Ref. 3) promulgated by the American Society of Mechanical Engineers (ASME).

During the design phase, degradation-resistant materials are normally specified for reactor coolant system (RCS) components. However, materials can degrade as a result of the complex interaction of the materials, the stresses they encounter, and the normal and upset operating environments they experience. Such material degradation could lead to leakage of the reactor coolant. Consequently, GDC 30, "Quality of Reactor Coolant Pressure Boundary" (Ref. 2), requires that plants provide the means for detecting and, to the extent practical, identifying the location of the source of reactor coolant leakage.

Additionally, 10 CFR 50.55a, "Codes and Standards" (Ref. 2), requires the performance of inservice inspection and testing of nuclear power plant components. Thus, the concept of defense in depth is applied to provide assurance that the structural integrity of the RCPB is maintained.

B. DISCUSSION

Background

Reactor design and construction should include every effort to use materials and environments that limit the potential for degradation. During the operational life of a plant, reactor components could degrade through normal operational wear, mechanical deterioration, corrosion, and/or fatigue. This degradation can lead to coolant leakage. A limited amount of leakage inside containment may occur from RCSs that plants cannot practically render 100-percent leaktight.

The safety significance of leakage from the RCS can vary widely, depending on the source of the leakage as well as the leakage rate and duration. Operating experience and research have indicated that very low levels of leakage could cause (or indicate) material degradation arising, for example, as a result of boric acid corrosion, primary water stress-corrosion cracking, and intergranular stress-corrosion cracking. Such forms of degradation could potentially compromise the integrity of a system, leading to a loss-of-coolant accident. To minimize the probability of rapidly propagating failure attributable to material degradation and gross rupture of the RCPB, plants should keep the leakage to a level that is as low as practical and take prompt action in responding to leakage to limit the safety consequences.

Prompt corrective action requires continuous online monitoring for leakage. Continuous leakage monitoring is important to ensuring the safe operation of a facility because it provides an indicator during reactor operation that a potentially adverse condition may exist. In addition to monitoring for leakage, it is important to quantify the reactor coolant leakage and locate its source to assess its safety significance. Detecting and effectively responding to leakage as early as possible provides defense in depth for the integrity of the RCPB.

Types of Leakage

RCS leakage falls under two main categories—identified leakage and unidentified leakage. The definition of identified leakage is as follows:

- leakage (such as pump seal or valve packing leakage) that is captured, flow-metered, and conducted to a sump, collecting tank, or collection system and

- leakage into the containment atmosphere from a known source, which does not interfere with the operation of unidentified leakage monitoring systems and is not attributable to leakage in the RCPB (as defined below).

Unidentified leakage encompasses all other leakage. Until the source of any unidentified leakage is known, such leakage may be RCPB leakage (as defined below); therefore, plants should identify the source as quickly as practicable.

RCPB leakage is leakage from a nonisolable fault in the material of an RCS component, pipe wall (including welds), or vessel wall. Leakage from seals, gaskets, and mechanical connections (e.g., bolts, valve seals) is not considered RCPB leakage although these components are part of the RCPB, as defined in 10 CFR 50.2, "Definitions" (Ref. 2). Thus, RCPB leakage is indicative of degradation of pressure-retaining components that could ultimately result in a loss of component structural integrity.

Leakage from the RCS to the secondary system at pressurized-water reactors (PWRs) is termed primary to secondary leakage. This leakage is not considered RCPB leakage and is treated as a special form of identified leakage in plant technical specifications. Primary-to-secondary leakage in PWRs is considered a form of identified leakage because it can be monitored separately from other forms of leakage and it does not affect the operation of unidentified leakage detection systems.

Reactor coolant pump seal injection and leakoff at PWRs is not considered leakage for plant technical specification purposes, although such leakoff typically satisfies the definition of identified leakage. Reactor coolant pump seals are commonly designed to permit controlled leakage for cooling and lubrication purposes. This leakage is not indicative of degradation in the RCPB and does not affect the operation of the unidentified leakage detection systems because the leakage is collected.

Leakage Separation

Procedures for separating the sources of leakage (i.e., leakage from an identified source versus leakage from an unidentified source) are necessary for prompt identification of potentially adverse conditions, assessment of the safety significance of the leakage, and quick corrective action.

The reactor vessel closure seals and safety and relief valves should not have significant leakage; however, if leakage occurs through these paths or through pump and valve seals, it should be detectable and collectable, and the system should isolate it from the containment atmosphere to the extent practical so as not to mask any potentially serious leakage that may occur. This leakage is "identified leakage," and it should discharge to tanks or sumps so that the plant operator can measure or calculate, monitor, and analyze the flow rate and trend in flow rate during plant operation.

Leakage to the containment atmosphere, which is not collected (such as from valve stem packing glands and other sources), increases the humidity of the containment. The moisture removed from the atmosphere by air coolers, together with any associated liquid leakage to the containment, is "unidentified leakage," and the system should collect it in tanks or sumps separate from the identified leakage so that the plant operator can establish, monitor, and analyze the flow rate and the trend in flow rate of the unidentified leakage during plant operation.

It is important to note that there may be leakage into the containment from systems other than the RCS (e.g., secondary-side steam leakage in a PWR). This non-RCS leakage may increase the unidentified leakage rate. Chemical analysis of samples of the unidentified leakage may provide an indication of whether the unidentified leakage is from the RCS or from other sources.

Methods for Monitoring Leakage and Identifying Its Source

Effective methods for monitoring (including detecting) any leakage and locating its source are important because leakage may have the following implications:

- It may indicate that a component no longer has adequate structural integrity.
- It may cause degradation or corrosion of a component (other than the leaking component) as a result of the interaction between the leaking coolant and the other component.

- It may indicate that there is an accumulation of chemical compounds (e.g., boric acid) that could invalidate various design assumptions.
- It may contaminate work surfaces.
- It may affect the capability of other instruments (including leakage monitoring instruments) or components.

Various instruments and methods are available for monitoring RCS leakage. The capabilities of these instruments and methods differ in terms of their response time, sensitivity, and accuracy. In addition, some instruments and methods continuously monitor for leakage, while others are for periodic use only. An effective leakage monitoring strategy will include a combination of leakage monitoring instruments and methods. Monitoring changes in the following parameters can be useful for detecting a leak, as well as quantifying the flow rate:

- level or flow rate to tanks and sumps,
- airborne particulate radioactivity,
- airborne gaseous radioactivity,
- containment atmosphere humidity,
- containment atmosphere pressure and temperature, and
- condensate flow rate from air coolers.

Because of the need to identify the source of leakage to assess its safety significance, plants should install monitoring systems to assist in locating the source of leakage during reactor operation. Plants can accomplish this, in part, by installing a number of instruments throughout containment and monitoring the response of each of these instruments to leakage. An instrument that is closer to a leak is likely to respond sooner than an instrument that is further away, assuming that the two instruments have similar capabilities (e.g., sensitivity). The following examples illustrate some other methods for identifying the source of leakage:

- humidity sensors mounted on specific component surfaces,
- acoustic emission monitoring systems mounted on specific component surfaces, and
- online surveillance via radiation-resistant video cameras throughout the containment.

Intersystem leakage from the RCPB to other systems across passive barriers or valves may be possible. Monitoring intersystem leakage is important because it provides information on the following:

- loss of coolant inventory,
- potential release outside containment, and
- potential location of contamination.

Intersystem leakage may not be detectable through the above-mentioned systems; therefore, plants should employ other alarm and leakage monitoring methods. Methods should include monitoring the activity of water flowing through the containment boundary into the connected systems, as well as measuring airborne radioactivity where such systems vent outside the containment boundary. Another method of obtaining indications of uncontrolled or undesirable intersystem flow is to perform a water inventory balance, which is designed to provide appropriate information (such as abnormal water levels in tanks and abnormal flow rates). Plants should monitor the primary-to-secondary leakage in PWRs through various continuous (e.g., steam line nitrogen-16 monitors, condenser offgas monitors) and periodic (e.g., water chemistry grab samples) monitoring techniques.

Potential discharges from closed safety and relief valves usually flow to tanks or water pools and are considered part of identified leakage within the containment. Temperature sensors in the discharge path of safety and relief valves or flow meters in the leakoff lines would provide an acceptable method of signaling leakage from these valves.

While the above-mentioned leakage monitoring methods reflect the present state of technology, the NRC recognizes that the industry may develop and use more advanced monitoring methods. Among such methods are boric acid detection systems using a Fourier transform infrared spectrometer and crack growth monitoring systems, such as acoustic emission or electrochemical potential measurement systems. Because early leak detection can be important to preventing accidents, plants should continue to seek and employ improvements in leakage monitoring and locating techniques.

An individual nuclear power plant does not need to employ all of the above-mentioned leakage monitoring methods or systems. However, because the methods differ in sensitivity and response time, monitoring methods should include sufficient diversity to ensure effective monitoring during periods when some systems may become less effective or entirely ineffective. Less effective systems may, however, still serve as early indicators of a potential problem that would prompt closer examination of other leakage detection systems to determine the extent of any corrective action that may be necessary.

Monitoring System Performance

<u>Capability</u>

Leakage monitoring systems must be able to detect the degradation of the RCPB to limit the potential for a gross failure of the pressure boundary. Some flaws might develop and penetrate the RCPB wall, exhibit very slow growth, and afford sufficient time for a safe and orderly plant shutdown after detection of a leak. Nonetheless, quickly growing flaws leading to a larger leakage rate may require more rapid detection, more frequent monitoring, and more urgent corrective action based on safety significance.

For critical components and critical areas, monitoring methods with the capability to locate the source of the leakage as soon as practical after it begins will limit the potential safety significance of the leak.

An increase in humidity of the containment atmosphere would indicate release of water vapor to the containment. Plants can use dewpoint temperature measurements to monitor humidity levels of the containment atmosphere. An increase of 1 °F (0.56 °C) in dewpoint is well within the sensitivity range of available instruments. Since several factors influence the humidity level, a quantitative evaluation of an indicated leakage rate may be questionable, and there should be a comparison with observed increases in liquid flow from sumps and condensate flow from air coolers. Humidity-level monitoring is most useful as an alarm or indirect indicating device to alert the operator to a potential problem.

Plants may also use methods that monitor air temperature and pressure to infer that large coolant leaks to the containment are occurring. Containment temperature and pressure fluctuate slightly during plant operation, but a rise above the normally indicated range of values may indicate leakage of the reactor coolant into the containment. The accuracy and relevance of temperature and pressure measurements depend on containment free volume and detector location. Alarm signals from these instruments can provide a valuable warning of a rapid and sizable coolant leak into the containment.

Reactor coolant normally contains sources of radiation that the monitoring systems can detect when these sources release to the containment. However, reactor coolant activity should be low during initial reactor startup and for a few weeks thereafter until activated corrosion products have formed and fission products have potentially been released from fuel elements. During this period, radioactivity monitoring instruments may be of limited value in providing an early warning of very small leaks in the RCS. However, every plant should include radioactivity monitoring systems (especially particulate activity monitoring) because of their sensitivity and rapid response to coolant leakage.

The effectiveness of airborne gaseous radioactivity monitors depends primarily on the activity of the reactor coolant and also, in part, on the containment volume and the background activity level. A survey of online PWR primary coolant leak detection technologies found that by monitoring the activity of noble gases, a plant could detect a leakage rate of approximately 1 gallon per minute (gal/min) (3.8 liters per minute (L/min)) in approximately 80 minutes (Ref. 4). However, because of the improvement in fuel integrity, many operating plants have reported experiencing much longer response times by using realistic activities (Ref. 5). Therefore, it may no longer be appropriate to reference gaseous radioactivity monitors in the plant technical specifications. Gaseous radioactivity monitoring, such as humidity, pressure, and temperature monitoring, which are not referenced in plant technical specifications, may still be desirable for providing a diverse and independent method and giving qualitative warning signals to operators.

Since the 1970s, improvements have occurred in the available instruments and methods for monitoring leakage, as well as in the overall understanding of the capabilities of those instruments and methods. Plants have used leakage monitoring methods that can detect flow rates lower than 0.05 gal/min (0.19 L/min). Industry practice has shown that several monitoring methods are capable of detecting a leakage rate of 1 gal/min (3.8 L/min) within 1 hour (i.e., instrument sensitivity is 1 gal/min (3.8 L/min) in 1 hour). According to current estimates, airborne particulate radioactivity monitors can detect a leakage rate of 1 gal/min (3.8 L/min) in approximately 10 minutes when there is leakage of fission products from fuel elements. Similarly, containment air cooler condensate flow meters are reportedly capable of detecting a leakage rate of 1 gal/min (3.8 L/min) within 1 hour, although this capability varies depending on plant conditions.

Some plants are currently using or have previously used advanced local humidity monitoring (e.g., FLUS™) and acoustic emission systems. In general, these methods have better detection sensitivity than those discussed above. For example, humidity sensors reportedly have a specified sensitivity of 0.005–0.5 gal/min (0.02–1.89 L/min), and acoustic emission sensors have a specified sensitivity of 0.003–0.25 gal/min (0.01–0.95 L/min) (Ref. 6). (The operational sensitivities of these devices may be different from the vendors' specifications as a result of plant-specific containment conditions.) These methods also permit identification of the general (if not exact) location of a leak and, therefore, are able to monitor critical components. In addition, acoustic emission systems may permit monitoring the progression of material degradation (i.e., growth of a crack), which could provide the operator an early indication of an impending leak. Such sensors have been in use under plant conditions to monitor the propagation of cracks.

The operational (as compared with vendor-specified) sensitivity of an instrument at various leakage rates is an important factor in determining the instrument's usefulness and functionality. At very low leakage rates, an instrument should have adequate sensitivity to reliably determine the leakage rate. The sensitivity at the high end of the range of leakage rates is equally important because the instrument should provide reliable leakage rate information during an accident involving a loss of coolant. In determining the upper limit of an instrument's sensitivity range, it is important not to exceed the saturation limits of the detector. These concerns pertain to all types of leakage monitoring techniques, whether direct (such as flow rate measurements) or indirect (such as detection of radioactivity in the containment atmosphere).

Detector Response Time

Evaluating an alarm or indication of leakage is important, and the ability to compare indications of leakage to those of other monitoring methods is necessary. Therefore, the functional requirements for leakage monitoring systems should include the detector response time. Except for the limitations during the initial few weeks of unit operation (as previously discussed), all monitoring systems referenced in the technical specifications should respond to a leakage increase of 1 gal/min (3.8 L/min) in 1 hour or less. Plants should use multiple instrument locations to ensure that the transport delay time of the leakage effluent from its source to the detector (or instrument location) will yield an acceptable overall system response time. An acceptable overall system response time should ensure that no adverse safety consequences are associated with a leak. A useful technique in identifying the general location of a leak is to provide several sensors within the containment area and evaluate any differences in response from these sensors (as previously discussed). Use of this technique, in combination with the other methods discussed above, satisfies the related requirement of GDC 30 (Ref. 2).

Analysis of the capabilities of leakage monitoring systems that measure radioactivity should use a realistic primary coolant radioactivity concentration assumption consistent with plant normal operations (as opposed to the maximum concentration permitted by technical specifications or used in accident analysis).

Industry practice has shown that water flow rate changes of from 0.5 to 1.0 gal/min (1.89 to 3.8 L/min) can readily be detected in containment sumps by monitoring changes in sump water level, flow rate, or the operating frequency of pumps. Sumps and tanks used to collect unidentified leakage and air cooler condensate should be instrumented to alarm for increases of from 0.5 to 1.0 gal/min (1.89 to 3.8 L/min).

Signal Correlation and Calibration

The ability to quantify the leakage rate is important. The flow rate or level change measurements from tanks, sumps, or pumps provide information that readily converts to a leakage rate. However, signals from other leakage monitoring systems may not readily convert to a leakage rate. As a result, plants should formulate functional relationships converting signals from these other leakage monitoring systems to a leakage rate and provide them to the operators (or program them into a computer so that the operators have a real-time indication of the leakage rate measured by these monitors). In addition, because operating conditions may influence some of these relationships, the procedures should reflect the various relationships that may exist. To ensure continued reliability of the leakage monitoring systems, the equipment used should comply with the requirements provided in Section 5.7 of the Institute of Electrical and Electronics Engineers (IEEE) Std 603-1991, “Criteria for Safety Systems for Nuclear Power Generating Stations” (Ref. 7), for tests and calibration.

Seismic Qualification

Because nuclear power plants may be operating when an earthquake occurs and may continue to operate after an earthquake ceases, it is prudent to ensure the functionality of the leakage detection systems during and after an earthquake. If a seismic event comparable to a safe-shutdown earthquake occurs, it is important for the operator to quickly assess the condition within the containment. The proper functioning of at least one leakage monitoring system would be necessary to evaluate the magnitude of any leakage that may develop in the containment as a result of a seismic event.

Leakage Management

It may be impractical to eliminate a small amount of unidentified leakage, but the plant should reduce it to a very small flow rate, preferably within the lower ranges of the detection sensitivities of the leakage detection and monitoring systems. The guiding principle should be to keep the unidentified leakage to a level that is as low as practical and to ensure that a small unidentified leakage rate is not masked by a larger, acceptable identified leakage rate.

Leakage Monitoring of Risk-Significant Areas in the Reactor Coolant System

Plants should monitor critical components of the RCPB for leakage. This will ensure prompt identification of a leak that could potentially compromise safety. Critical components are those that are risk significant or potentially susceptible to material degradation. In currently operating reactors, the critical RCPB components include, but may not be limited to, the reactor vessel head, control rod penetration nozzles, pressurizer nozzles, and dissimilar metal weld regions. The critical components may change over time as a result of operating experience, improvements in the understanding of corrosion mechanisms, and mitigative actions (e.g., pipe replacement). Timely identification of the source of leakage is necessary to determine its safety significance.

Capability, Operability, and Availability of Monitoring Instruments

The leakage monitoring system is important to detecting potentially adverse conditions. The system should be capable of detecting leakage in a timely manner and identifying the location of the leak to ensure that the leakage has no adverse safety consequences (i.e., a component or system can continue to function within its required regulatory margins/factors of safety). The capability of the leakage monitoring system includes the overall response time (which includes the transport delay time and detector response time), detector sensitivity and accuracy, ability to identify the location of the leak, and the operator's response to leakage. Plants should periodically evaluate the capability of the leakage monitoring system, which may need to change or improve with time (e.g., as a result of the onset of new forms of degradation) to ensure effective management of leakage (i.e., that there are no adverse safety consequences associated with leakage). In addition, the plant should establish the capabilities of the leakage monitoring systems for the range of environmental parameters, such as temperature, humidity, and radiation level, which are expected during plant operation.

Plants should use multiple, diverse, and redundant detectors at various locations in the containment, as necessary, to ensure that the transport delay time of the leakage from its source to the detector (instrument location) will yield an acceptable overall response time. If leak-before-break (LBB) analysis is approved for the plant, the overall response time of the leakage monitoring system should be sufficient to support the LBB analysis procedures. Under certain circumstances (e.g., to support LBB for smaller diameter pipes), leakage monitoring system specifications may need to exceed the quantitative criteria in this regulatory guide.

Trend Analysis of Leakage Data

Plant operating experience has shown that significant increases in the leakage rates below the limits set forth in the technical specifications, but above the baseline values, may indicate a potentially adverse condition. Plants should periodically analyze the trend in the unidentified and identified leakage rates. Evaluating the increase in the leakage rates is important to verifying that the plant will continue to operate within acceptable limits. In addition, the increase in the leakage rate may indicate a potentially adverse condition. As a result, operators should analyze the trend in the unidentified and identified leakage rates to ensure timely response to any adverse trend.

Responding to Leakage

To ensure timely response to leakage, plants should establish a stepwise approach with action levels for responding to leakage. This stepwise approach should include evaluating the data from all leakage monitoring systems to confirm the existence of a leak, identifying possible sources of the leakage (based on operating and maintenance experience), increasing the frequency of verifying/quantifying the leakage rate, performing trend analyses, performing walkdowns outside containment, planning a containment entry, and identifying the source of the leakage (e.g., through containment entry or remote inspections). Plants should monitor and verify the leakage rate more frequently as the leakage rate increases.

Plant procedures should establish time limits for continued plant operation with an unidentified leakage source because it may be impossible to determine the safety significance of the leakage without knowing its source. The purposes of these time limits should be to limit (1) the potential for a loss of structural integrity, (2) the accumulation of chemical species that may adversely affect the assumptions in various design-basis analyses, (3) the contamination of work areas, and (4) the potential for leakage to affect other instruments or components.

During maintenance and refueling outages, plants should attempt to identify the source of any unidentified leakage. In addition, plants should take corrective action to eliminate the condition resulting in the leak. For PWRs, this includes a walkdown of systems and instrumentation lines that contain borated water at the start of outages and during the return to power. This will help ensure that there are no adverse safety consequences associated with the leakage and will permit timely identification of new sources of leakage.

C. REGULATORY POSITION

1. General Positions

1.1. The source and location of reactor coolant leakage should be identifiable to the extent practical, and the plant should measure the leakage rate.

1.2. The plant should collect or otherwise isolate leakage to the primary reactor containment from identified sources so that the following criteria are fulfilled:

(i) Flow rates from identified sources are monitored separately from the flow rates from unidentified sources.

(ii) The plant can establish and monitor the total flow rate.

1.3. The plant should monitor critical components of the RCPB for leaks.

1.4. The plant should monitor intersystem leakage for systems connected to the RCPB.

1.5. The capabilities of the leakage monitoring systems should be known. In addition, the capabilities should ensure effective management of leakage.

2. Leakage-Monitoring-Related Positions

2.1. Plant procedures should include the collection of leakage to the primary reactor containment from unidentified sources so that the total flow rate can be detected, monitored, and quantified for flow rates greater than or equal to 0.05 gal/min (0.19 L/min).

2.2. The plant should use leakage detection systems with a response time (not including the transport delay time) of no greater than 1 hour for a leakage rate of 1 gal/min (3.8 L/min).

2.3. Plant technical specifications should identify at least two independent and diverse instruments and/or methods that have the detection and monitoring capabilities detailed above. The methods to consider for incorporation in the technical specifications include, but are not limited to, the following:

(i) monitoring sump level or flow,
(ii) monitoring airborne particulate radioactivity, and
(iii) monitoring condensate flow rate from air coolers.

In addition to the monitoring systems detailed in the technical specifications, the plant should use other systems to detect and monitor for leakage, even if it does not have the capabilities specified in Regulatory Position 2.2. These supplemental instruments/methods may include, but are not limited to, the following:

(a) monitoring airborne gaseous radioactivity,
(b) monitoring the humidity of the containment,
(c) monitoring the temperature of the containment,
(d) monitoring the pressure of the containment,
(e) monitoring acoustic emission, and
(f) conducting video surveillance.

2.4. At least one of the leakage monitoring systems required by the plant technical specifications (as described in Regulatory Position 2.3 above) should be capable of performing its function(s) following any seismic event that does not require plant shutdown.

2.5 The leakage monitoring systems, including those with location detection capability, should have provisions to permit calibration and testing during plant operation to ensure functionality or operability, as appropriate.

3. Operations-Related Positions

3.1. The plant should periodically analyze the trend in the unidentified and identified leakage rates. When the leakage rate increases noticeably from the baseline leakage rate, the plant should evaluate the safety significance of the leak. The plant should determine the rate of increase in the leakage to verify that plant actions can be taken before the plant exceeds technical specification limits.

3.2 The plant should establish procedures for responding to leakage. These procedures should address the following considerations and should ensure that no adverse safety consequences result from the leakage:

(i) Plant procedures should specify operator actions in response to leakage rates less than the limits set forth in the plant technical specifications. The procedures should include actions for confirming the existence of a leak, identifying its source, increasing the frequency of monitoring, verifying the leakage rate (through a water inventory balance), responding to trends in the leakage rate, performing a walkdown outside containment, planning a containment entry, adjusting alarm setpoints, limiting the amount of time that operation is permitted when the sources of the leakage are unknown, and determining the safety significance of the leakage.

(ii) Plant procedures should specify the amount of time the leakage detection and monitoring instruments (other than those required by technical specifications) may be out of service to ensure that the leakage rate is effectively monitored during all phases of plant operation (i.e., hot shutdown, hot standby, startup, transients, and power operation).

3.3 The plant should provide output and alarms from leakage monitoring systems in the main control room. Procedures for converting the instrument output to a leakage rate should be readily available to the operators. (Alternatively, these procedures could be part of a computer program so that the operators have a real-time indication of the leakage rate as determined from the output of these monitors.) Periodic calibration and testing of leakage monitoring systems should take place. The alarm should provide operators an early warning signal so that they can take corrective actions, as discussed in Regulatory Position 3.2 above.

3.4. During maintenance and refueling outages, the plant should take actions to identify the source of any unidentified leakage that was detected during plant operation. In addition, corrective action should take place to eliminate the condition resulting in the leakage.

4. Technical Specification Position

4.1. Plant technical specifications should include the limiting conditions for identified, unidentified, RCPB, and intersystem leakage, and they should address the availability of various types of instruments to ensure adequate coverage during all phases of plant operation (not including cold shutdown and refueling modes of operation).

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC's plans for using this regulatory guide. Regulatory Guide 1.45, Revision 1, is applicable to light-water reactors. It will be referenced in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (Ref. 8), and will be applicable only to new reactors (in accordance with the requirements of 10 CFR 50.34(h)). No imposition or backfit is intended or approved in connection with its issuance.

Except in those cases in which an applicant or licensee proposes or has previously established an acceptable alternative method for complying with specified portions of the NRC's regulations, the methods described in the active guide will be used in evaluating compliance with the regulations, as discussed in this guide for license applications, license amendment applications, and exemption requests.

GLOSSARY

The staff engaged in several indepth discussions to define and clarify the measurement terms used in reactor coolant leakage monitoring requirements. Because earlier definitions are often not clear, the staff researched these terms and attempted to clarify their meanings and applicability to leakage detection. The terminology below appears throughout this document.

accuracy—The degree of conformity between the measured (indicated) leakage rate and the accepted true leakage rate.

background leakage—Very low leakage rates that exist following inspections that are intended to identify the source of any leakage. Normally, the background leakage rate should be zero (or below the threshold of detection for the instrument).

capability—The minimum leakage rate that is measurable within the accuracy and sensitivity requirements in a specified duration.

critical area—The portions of the RCPB that could degrade and leak as a result of the interaction of the material with its environment. A critical area also includes risk-significant components.

critical component—A component within the containment that (1) may degrade as a result of its interaction with the environment, or (2) is risk significant.

detector (instrument) response time—The amount of time that a detection instrument takes to process the input signal and display or otherwise present the measured leakage rate.

identified leakage—Leakage (1) into closed systems, such as pump seal or valve packing leaks that are captured, flow-metered, and conducted to a sump or collecting tank, or (2) into the containment atmosphere from sources that are both specifically located and known either not to interfere with operation of unidentified leakage monitoring systems or not to be from a flaw in the RCPB.

leak before break (LBB)—A component integrity analysis procedure, as described in Section 3.6.3, "Leak-Before-Break Evaluation Procedures," of NUREG-0800 (Ref. 8).

leakage rate—The volume of leakage divided by the duration (time) over which the leakage accumulated. Leakage rate is usually expressed as gal/min or L/min.

overall response time—The maximum amount of time from the start of a leak until the leakage detection instrument/method indicates that the specific leakage rate is occurring. The overall response time includes the transport delay time and instrument response time.

sensitivity—The ability to measure a specific leakage rate (usually a minimum leakage rate) with a required (or specified) accuracy. The sensitivity of a leakage monitoring instrument indicates how well the instrument is capable of measuring small changes in leakage rate and providing a corresponding output with a specific accuracy. The sensitivity may vary, depending upon the type of instrument (e.g., one that measures the change in radioactivity, humidity, acoustic noise, and the like with respect to the background) and factors such as flow rate. Usually, the sensitivity of a leakage detection instrument is low at very low leakage rates and high at relatively high leakage rates.

system response time—The period of time required for the detector system to process detected leakage data from the source and display or otherwise indicate to the plant operator the leakage rate, including alarm. Minimum system response time is preferable in order to detect leakage as early as possible.

transport delay time—The period of time required for the leakage to travel from the source to the detection site of the instrument.

trending—Recording and documenting the observed leakage rate over a period of time.

trend analysis—Any statistical analysis of the leakage rate data over an interval of time to identify the onset and continuation of any trend in leakage rate.

unidentified leakage—Leakage into the containment that is not classified as identified leakage.

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[1] Regulatory Guide 1.45 is available electronically through the Electronic Reading Room of the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/reg-guides and/or ADAMS at http://www.nrc.gov/reading-rm/adams.html. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555-0001; telephone at (301) 415-4737 or (800) 397-4209; fax (301) 415-3548, and email PDR@nrc.gov.

[2] All NRC regulations listed herein are available electronically through the Electronic Reading Room on the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/cfr/. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548; and email PDR@nrc.gov.

[3] Copies of American Society of Mechanical Engineers (ASME) standards may be purchased from ASME, Three Park Avenue, New York, NY 10016-5990; telephone (800) 843-2763. Purchase information is available through the ASME Web-based store at http://www.asme.org/Codes/Publications.

[4] All information notices (INs) listed herein were published by the U.S. Nuclear Regulatory Commission and are available electronically through the Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548; and email PDR@nrc.gov.

[5] All NUREG-series reports listed herein were published by the U.S. Nuclear Regulatory Commission. Most are available electronically through the Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/nuregs/. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548; and email PDR@nrc.gov. In addition, copies are available at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328, telephone (202) 512-1800, or from the National Technical Information Service (NTIS), at 5285 Port Royal Road, Springfield, VA 22161, online at http://www.ntis.gov, by telephone at (800) 553-NTIS (6847) or (703) 605-6000, or by fax at (703) 605-6900.

7. IEEE Std 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations," Institute of Electrical and Electronics Engineers, Piscataway, NJ, 1995.[6]

8. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)," Chapter 3, "Design of Structures, Components, Equipment, and Systems" Section 3.6.3, "Leak-Before-Break Evaluation Procedures," U.S. Nuclear Regulatory Commission, Washington, DC, March 2007.

[6] Copies may be obtained from the Institute of Electrical and Electronics Engineers, Inc., IEEE Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855.

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8 Copies may be obtained from EPRI Customer Fulfillment, 1355 Willow Way, Suite 278, Concord, CA 94520.

9 This standard is available from the ISA Web site at http://www.isa.org/Template.cfm?Section=Shop_ISA &Template=/Ecommerce/ProductDisplay.cfm&Productid=2614.

10 This is available through the IAEA public Web site at http://www.pub.iaea.org/MTCD/publications/PDF/te_1361_web.pdf.

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