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Your ref: Docket No. 52-006
Our ref: DCP_NRC_002876

May 14, 2010

Subject: AP1000 Response to Request for Additional Information (SRP 11)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 11. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following RAI(s):

RAI-SRP11.5-CHPB-05 R1

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

Robert Sisk, Manager
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/Enclosure

1. Response to Request for Additional Information on SRP Section 11

D063
NRO

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ENCLOSURE 1

Response to Request for Additional Information on SRP Section 11

RAI Response Number: RAI-SRP11.5-CHPB-05
Revision: 1

Question:

Staff review of Change Number 45 to DCD Tier 2 (Rev 18) Appendix1A, sections 3.1.4, 3.6.3.3, 5.2.5.3.3, and 11.5.2.3.1, and LCO 3.4.9 sections B.3.4.7 and 3.4.9 indicate that the applicant provided insufficient information in regards to the new containment particulate radiation monitor (PSS-JE-RE027) sensitivity to satisfy the reactor coolant system (RCS) leakage rate technical basis. The technical basis for the RCS leakage detection instruments and RG 1.45 (Rev1) establish radiation monitor sensitivity requirements for leakage detection increase of 1 gpm within 1 hour using a realistic primary coolant concentration. Although Change Number 45 specifies the radiation monitor sensitivity for particulate radioactivity, the change does not provide an analysis to demonstrate that the specified monitor sensitivity is capable of satisfying the technical basis using realistic radioactive concentrations in the RCS.

Please provide an analysis to demonstrate that the particulate radiation monitor sensitivity is capable of satisfying the technical basis for the RCS leakage using a realistic radioactive concentration in the RCS. Include in this analysis all models, modeling assumptions and their basis, parameter values and their basis, and any references.

Additional Question by NRC for Revision 1:

The NRC staff cannot validate and verify the conclusions presented in the March 31, 2010 response to RAI –SRP11.5-CHPB-05 because the applicant did not provide sufficient details in its response. Please provide the following:

- The equations and parameter values used to calculate the containment air concentration for Fluorine -18. NRC also requests that the applicant provide detailed justifications for every important parameter in the equations. Conspicuously missing are the following important information:
  - o reactor coolant concentration of Fluorine-18 and how the applicant derived its value
  - o detailed justification of the 3% fraction of F-18 activity entering the containment atmosphere. This justification should provide summaries of the conversations and findings with each industry expert and reference by name and contact information the experts included in the discussions.
- the beta particle background activity contribution on the moving filter, and how this activity may affect the detection of F-18

A detailed justification why the RCS leak detection at Catawba is relevant to the AP1000. This justification should address differences between Catawba and the AP1000. Please be sure to address differences in reactor coolant activity of F-18, containment free volume, monitor type (beta or gamma) and monitor location. In addition, please address the F-18 contribution to the total count rate on the filter at Catawba.

Westinghouse Response Rev. 0:

Introduction

The AP1000 credits two methods in the technical specification for RCS leak detection inside containment: the containment sump level monitors and radioactivity measurements of the containment atmosphere. This discussion will focus on the containment atmosphere radiation monitor.

Reg Guide 1.45 Revision 0 (May 1973) requires a leakage monitoring system capable of detecting a 1 gpm leak in 1 hour or less. The AP1000 is licensed as a leak-before-break plant and is committed to detecting a leak of 0.5 gpm in 1 hour.

Nitrogen-13 (N-13) and Fluorine-18 (F-18) are two of the more significant radioisotopes in the primary coolant that might be used for RCS leakage detection. The concentrations of these isotopes in the primary coolant vary linearly with power level and are independent of fuel defect percentage. This is the reason that N-13 and F-18 isotopes are the focus for the leakage monitoring system for the AP1000.

Originally, the containment RCS air sampling system included an N-13/F-18 gas monitor and a separate noble gas (Xenon/Krypton) monitor that provides backup information. Only the N-13/F-18 gas monitor was credited in the Tech Specs as the RCS leakage detection Reg Guide 1.45 monitor. A design change was made to replace the N-13/F-18 gas monitor with an F-18 particulate monitor. No changes to the noble gas monitor were made.

Based on review of the design, consultations with RMS vendors, review of industry documents, review of plant operating experience and discussions industry aerosol experts in leakage detection, it was determined that an N-13/F-18 gas monitor could not provide adequate sensitivity to detect a 0.5 gpm leak in 1 hour with a high confidence level for the following reasons:

a. The half-life of N-13 is only 10 minutes, with the consequence that the accumulation of N-13 concentration in the containment atmosphere is rather limited.
b. The half-life of F-18 is 110 minutes; the accumulation of F-18 activity in the containment atmosphere is more significant compared to N-13. However, fluorine will most likely attach to dust particles or be embedded in dried-out boron acid crystals and can be detected as a particulate more readily compared to the gaseous form. In addition, there has been experience in operating plants that F-18 has been observed and measured in particulate form.

Analysis of N-13 Gas

Westinghouse performed an analysis to estimate the concentrations of N-13 gas inside containment assuming ideal mixing. The analysis showed that a conservative estimate of the concentration of N-13 is 2.84E-8 μCi/cc one (1) hour after initiation of a 0.5 gpm leak. Typical gas monitors have a lower measurement limit on the order of 1E-7 to 1E-8 μCi/cc. Therefore, measurement of N-13 in gas form as an indication of an RCS leak is not feasible because the

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estimated concentration for a 0.5 gpm leak in 1 hour is below the minimum detectable concentration for commercially available gas detectors.

A detailed analysis of F-18 concentrations in gaseous form for a 0.5 gpm leak was not performed because it was judged that F-18 will most likely attach to dust particles and take the form of particulates.

Analysis of F-18 Particulate

The isotope F-18 in particulate form was further analyzed for use in RCS leakage detection. A relatively small part of the non-flash leakage is expected to become aerosol (small water droplets suspended in air) while the rest will remain in the liquid phase and be collected in the containment sump or the leakage collection system. The major constituent in the aerosol due to RCS leakage is boric acid (200-2000 ppm in RCS). After evaporation of the water, the liquid aerosol inside containment becomes fine boric acid crystal and F-18 (most likely in the chemical form of LiF) is embedded in boric acid crystal or is attached to dust. Therefore, it is expected that the majority of the F-18 activity in the containment atmosphere will be present in particulate form. Most of the surviving F-18 particulates will be of smaller sizes (less than 3 microns in diameter after dried-out) because the larger sizes will become trapped in the tortuous path from the RCS through the piping insulation or be removed due to impingement on nearby structures.

Based on discussions with industry aerosol experts, it was concluded that a conservative estimate of 3% is the fraction of the F-18 activity from the RCS leakage that will enter the containment atmosphere in particulate form.

Westinghouse performed an evaluation to estimate the concentrations of F-18 particulates inside containment. The evaluation provided a conservative estimate (assuming a 0.5 gpm leak and 3% fraction entering containment atmosphere) of the concentration of F-18 particulates is 2.84E-9 µCi/cc one (1) hour after initiation of the leak at 100% power.

An RMS vendor was contacted to determine if detecting F-18 concentrations of 2.84E-9 µCi/cc was feasible. The conclusion is that a beta scintillation detector in conjunction with a moving filter provides sufficient sensitivity to detect the 0.5 gpm leak in one hour. At a sample flow rate of 2 ft^3/minute, the filter collects approximately 3.4E+6 cc of activity in 1 hour. The moving filter is sensitive to about 80% of the deposited activity in this case. The activity viewed by the detector at 1 hour is approximately 80% x 3.4E+6 cc x (1/2[1] x 2.84E-9 µCi/cc) = 0.004 µCi. At the detector sensitivity of about 7 x 10^4 cpm/µCi, the calculated raw signal from F-18 at 1 hour is about 280 cpm. The background is approximately 100 cpm for the detector in a lead shield, and the calculated minimum detectable signal at 95% confidence level is about 5 cpm, for a response time of 9 minutes. Since the calculated raw signal above background is 280 cpm, the smoothed signal that is delayed by the response time remains significantly greater than the 5 cpm minimum detectable signal. At 20% power, the count rate is 56 cpm (0.20 x 280 cpm = 56 cpm) which is approximately 10 times greater than 5 cpm and can also be detected with high confidence. Therefore, this moving filter detector provides for detection of the 0.5 gpm leak in 1 hour with high confidence (much greater than 95% confidence level) and is considered acceptable for the AP1000 design.

A deposition analysis for the sample lines will be performed at a later date during the detailed design. The deposition analysis will be used to quantify the deposition losses for the specific sample line configuration and to determine if correction factors are required to account deposition losses. Since only small particles (less than 3 microns) are expected to be the prevalent particle sizes inside containment, the small particles can be transported longer distances with less deposition losses compared to larger particles.

Note 1: The time dependence of the buildup in F-18 concentration in containment is conservatively approximated as a linear ramp. The activity deposited on the filter is proportional to the average value of the F-18 concentration in the 1 hour time interval. Based on this approximation, the average value is equal to one-half the value at the end of the time interval.

Industry Experience

Argonne national Laboratory Report NUREG/CR-6861, "Barrier Integrity Research Program" performed a study of the various methods for RCS leak detection. The report concluded airborne gaseous radioactivity monitoring is inherently less sensitive compared to particulate monitoring. The value of monitoring gaseous radioactivity for leakage detection is diminished because the primary systems have less contamination resulting from improvements in fuel cladding and RCS chemistry controls.

The NRC has recognized the limitations of gaseous radioactivity monitors in Regulatory Issue Summary 2009-02, Revision 1 for operating plants. Operating plant gaseous radioactivity monitors were designed and licensed many years ago when there were more occurrences of fuel cladding defects. Today, with lower fuel cladding defects, the effectiveness of these gaseous radioactivity monitors has diminished and may not provide accurate measurements and may require longer response times. This NRC RIS has no impact on the AP1000 design because the noble gas monitor is not being credited in the AP1000 technical specifications for meeting Reg Guide 1.45.

Recently, Westinghouse was made aware of an RCS leak at Catawba. The plant was using a fixed-filter particulate monitor and a gaseous monitor for RCS leak detection. The plant observed the counts per minute on the particulate monitor increased and triggered an alarm. The filter paper was removed, analyzed and the presence of F-18 was observed and was indicative of an RCS leak. The leak was not detected by the noble gas monitor. The leak was also confirmed by the containment sump levels. The containment sumps were estimated to be filling at a rate of approximately 1 gallon per hour or 0.02 gallon per minute. This data demonstrates in practice that a particulate monitor has adequate sensitivity to detect a leak that is approximately ten times lower than AP1000 requirement of 0.5 gpm.

Therefore, based on industry experience and the evaluation above, it is concluded that the RCS leak detection radiation particulate monitor is capable of detecting a 0.5 gpm leak in 1 hour using conservative estimates for the expected F-18 concentrations inside containment.

Westinghouse Response Rev. 1:

To address the NRC staff's concerns the response is provided in separate parts.

NRC Comment:

- The equations and parameter values used to calculate the containment air concentration for Fluorine -18. NRC also requests that the applicant provide detailed justifications for every important parameter in the equations. Conspicuously missing are the following important information:
  - reactor coolant concentration of Fluorine-18 and how the applicant derived its value

Westinghouse Response: *See Attachment A.*

NRC Comment:

- detailed justification of the 3% fraction of F-18 activity entering the containment atmosphere. This justification should provide summaries of the conversations and findings with each industry expert and reference by name and contact information the experts included in the discussions.

Westinghouse Response: The information in this section was provided to Westinghouse by Shaw Stone & Webster (Shaw) to assist in answering this question. The analysis report is Reference 1, and will be made available for NRC review upon request.

This information summarizes Reference 1, which is a proprietary QA Category I analysis performed by Shaw for an operating Westinghouse pressurized water reactor. This analysis estimates the likely percentage of non-volatile activity in the reactor coolant leakage that would become airborne inside the containment in the initial stages of a reactor coolant leak.

The analysis evaluated the effects of a one gpm leak from a medium size reactor coolant pipe. The pipe was enclosed in reflective metallic insulation (RMI), with an axial offset of approximately 1" from the pipe. This offset was determined by plant operations during refueling. Similar insulation, with a similar annular gap, is specified for AP1000.

The initial flowpath through the pipe wall followed the grain boundaries to determine the flow resistance, and was assumed to remain in the liquid phase until entering the piping/insulation gap. This assumption is conservative as two-phase flow within the pipe wall would generate a smaller particle size distribution due to hydraulic forces.

An impaction parameter was calculated in order to estimate a removal efficiency versus droplet size due to impingement on the insulation surfaces. The calculation of this parameter was based on the exiting velocity for the leak and the droplet size distribution / concentration generated by the flash and liquid spray.

Based on the rate of steam generation from both the steam flash and rate of boiling, it was concluded that in the short term there would be insufficient pressure differential to cause failure of the insulation clasps holding the insulation around the pipe. Thus, the steam generated by the leak and the entrained aerosols would flow parallel to the piping surface. This mixture would then escape into containment at joints and gaps in the insulation. Some entrained particulates would be lost from the stream in the annular regions and at bends prior to escape into containment.

The analysis estimated the percentage of the RCS leakage mass (after flash) that would become aerosolized, and the particle size distribution. The amount of aerosol is reduced by impingement on the pipe insulation, deposition in the annular space between pipe and insulation, and loss in the flow bend and the insulation gap. The overall fraction of non-volatile activity entering containment is estimated to be 5% of that which exited the pipe wall.

The analysis performed for a one gpm leak envelopes smaller leaks, since a lower velocity field reduces losses at bends and in the annular region between the coolant pipe and the insulation.

Given chemistry of very dilute solutions of fluorides and cations such as lithium, F-18 will predominately reside in the liquid phase of the leakage. The liquid component will evaporate from the leakage stream, resulting in airborne particulates. These particulates include boric acid crystals and other solids such as lithium fluoride. The reactor coolant leak event at Catawba was detected by a particulate radiation monitor, and showed the presence of F-18 on the filter paper. F-18 was also found in containment sump liquids, providing supporting evidence of its particulate nature.

Westinghouse concludes that this Shaw analysis is applicable to AP1000, which has similar primary chemistry and specifies a similar reflective metal insulation system as current plants. The Shaw analysis concluded that approximately 5% of the F-18 in the coolant will reach the containment atmosphere in particulate form during a leak of one gpm or less, and Westinghouse has conservatively used 3% in our design.

NRC Comment:

- This justification should provide summaries of the conversations and findings with each industry expert and reference by name and contact information the experts included in the discussions.

Westinghouse Response: The industry experts referred to in the response to Revision 0 are the same experts from Shaw Stone & Webster (Shaw) who performed the analysis referenced in this response.

NRC Comment:

- the beta particle background activity contribution on the moving filter, and how this activity may affect the detection of F-18

Westinghouse Response: The detector being used for AP1000 is a beta scintillation detector. Beta particle background levels will be minimal in the absence of RCS leakage to the containment atmosphere; leakage such as that from the reactor vessel O-ring is piped to the reactor coolant drain tank and will not enter the atmosphere. However, low level counts are expected during normal operation. The discussion below demonstrates that anticipated background does not compromise the F-18 leak detection approach.

Since the submittal of the Revision 0 response to the RAI, Westinghouse had continued to contact several other operating plants to further confirm the assumption of the 100 cpm assumed background level. Phone contact was made with Oconee and McGuire. These plants were able to provide a timely response and informed Westinghouse that the background counts on their particulate radiation monitors using fixed filter beta scintillation detectors was approximately 200 cpm and 300-400 cpm, respectively. Given this new information, the RMS vendor re-evaluated detection using 400 cpm. The conclusion is that a beta scintillation detector in conjunction with a moving filter provides sufficient sensitivity to detect the 0.5 gpm leak in one hour.

The response to Revision 0 of the RAI established that the for a moving filter with a sample flow rate 2 ft^3/minute and a detector time constant of 9 minutes, the estimated F-18 contribution for a 0.5 gpm leak at 1 hour is 238 cpm.

Assuming a background of 400 cpm for the detector in a lead shield, the minimum detectable signal is given per ANSI N42.18 found as follows:

$$n_S = 2\sqrt{\frac{B}{2T}}$$

B=400 cpm
T=9 minutes

The minimum detectable signal is:

$$n_S = 2\sqrt{\frac{400}{2 \times 9}}$$

$$n_S = 9.4\ cpm$$

Thus, at 100% core power the 238 cpm contributed by the F-18 is approximately 25 times the minimum detectable signal at the 95% confidence level, as defined in ANSI N42.18.

As discussed in the Revision 0 response, at 20% core power the count rate contribution from the F-18 was estimated to be 56 cpm. This is approximately six times the minimum detectable signal. This provides high confidence of detection of the leak at reduced core power operation as well.

NRC Comment: A detailed justification why the RCS leak detection at Catawba is relevant to the AP1000. This justification should address differences between Catawba and the AP1000. Please be sure to address differences in reactor coolant activity of F-18, containment free volume, monitor type (beta or gamma) and monitor location. In addition, please address the F-18 contribution to the total count rate on the filter at Catawba.

Westinghouse Response: Unfortunately, to the best of our knowledge detailed information on the Catawba leak has not been published and so is not available for general reference.

The intention of referencing the Catawba leak was not to claim it was exactly applicable to AP1000, but rather to increase overall confidence in the F-18 particulate approach.

Nevertheless, Catawba and AP1000 are generally comparable, as shown in this table:

Parameter	Catawba (from FSAR R14)	AP1000	Comment
Core Power	3411 MWth	3400 MWth	Effectively the same
RCS Volume	12,429 ft^3	9,600 ft^3	Smaller volume of AP1000 increases concentration of F-18 in coolant
Containment Free Volume	1,196,000 ft^3	2,060,000 ft^3	Larger volume of AP1000 decreases concentration of F-18 in atmosphere
Primary water chemistry	Boric acid / ^{7}Lithium hydroxide	Boric acid / ^{7}Lithium hydroxide	Identical
Insulation type	Reflective metal insulation with stand-off posts	Reflective metal insulation with stand-off posts	Identical
Detector Intake Location	Lower Containment and Incore Room.[1]	Operating Deck General Area	

[1] The typical alignment of the Catawba system is shown. The system has the capability to sample any or all of the following locations:
- Upper Containment
- Lower Containment
- Incore Room

The reactor coolant concentration of F-18 at Catawba at the time of the leak is not known; core power and RCS volume are provided as indicators of anticipated F-18 concentration.

While there are differences between the plants, the similarities in the two designs give confidence that the fundamental science of the F-18 approach is equally applicable to both.

Detection of RCS leakage by detection of F-18 is logical because F-18 is an activation product of oxygen (found in water), and will be a predominant isotope in the absence of fuel defects. This evaluation has established the expected airborne concentration of F-18 for a 0.5 gpm leak in the AP1000 plant, and demonstrated that such a leak can be reliably detected.

References:

1. Shaw Stone & Webster Proprietary QA Category I analysis for an operating Westinghouse PWR, estimating the likely percentage of non-volatile activity in the reactor coolant leakage that would become airborne inside the containment in the initial stages of a reactor coolant leak. (Available for NRC review upon request)

ATTACHMENT A

This attachment presents the analysis performed to determine the expected concentration of F-18 for a 0.5 gpm leak.

Background

The purpose of the AP1000 containment atmosphere radioactivity monitor is to monitor leakage from the reactor coolant pressure boundary based on the detection of F-18. These radioisotopes are created by knock-on protons that arise from neutron-hydrogen collisions:

F-18 production reaction:

$$p + {}^{18}O \rightarrow {}^{18}F + n$$

Cross sections for these reactions are not conveniently available: Reference A-1 includes a one neutron energy group cross section developed in 1965 that lacks accuracy. An alternative approach is to evaluate the performance of the monitoring system based on measured values of F-18 activities in the coolant as opposed to calculated values. The following calculations then estimate what is the volumetric activity in containment of these radioisotopes one hour after a coolant leak.

Operating Experience

Plant measurements and previous estimates of F-18 specific activities are available in References A-4 and A-5, and as calculated for AP1000:

Description	Fluorine-18(1)	Reference
Estimated equilibrium content of activity in the coolant of a 3000 MWth PWR	2.1 MBq/kg = 2.1 MBq/l (5.68E-2 μCi/cc)	A-4
Concentration measurements in coolant at SONGS (3411 MWth)	0.12 μCi/ml = 4.44 MBq/l (1.20E-1 μCi/cc)	A-5

Note 1: Production rate of F-18 is directly proportional to reactor power, but coolant volume is also roughly proportional to reactor power, therefore the specific activities do not need to be adjusted to the AP1000 reactor power level of 3400 MWt.

Based on this operating experience, a conservative F-18 specific activity of 2.1 MBq/l is defined for further calculations.

Leak Rate and Release Rate

The Regulatory Guide 1.45 (Reference A-2) indicates that the leak monitoring system must be able to detect a 1 gpm leak within one hour. The AP1000 DCD (Reference A-3) commits to a detection capability of 0.5 gpm to support leak before break. Both requirements assume a 100% power level.

These assumptions give the following release rate result at the leak location:

Description	Leak Rate	Fluorine-18 local release rate
Conservative value	0.5 gal/min = 0.0315 l/s	0.0662 MBq/s

Once the coolant exits the leak point, a fraction becomes vaporized (flashes) while the remaining part stays in the liquid phase and subsequently collects in the containment sumps. According to Reference A-6, most of the fluorine atoms are in a particulate form due to their chemical interactions with other compounds. The Shaw evaluation discussed in the body of this RAI response (Reference 1 of the main RAI response) estimates that 5% of the F-18 particulates escape through the insulation; Westinghouse has conservatively chosen to assume 3% escape. Therefore, the release rate of F-18 in airborne form into containment is 1.99 kBq/s.

Volumetric activity in containment

At equilibrium, the radioisotopes are uniformly distributed throughout containment and the decay rate equals the release rate. The activity A is proportional to the decay rate dA/dt which is equal to the release rate in containment:

$$\frac{dA}{dt} = -\lambda \times A$$

thus

$$A = -\frac{1}{\lambda}\times\frac{dA}{dt} = -\frac{T_{\frac{1}{2}}}{\ln(2)}\times\frac{dA}{dt}$$

Lambda (λ) is the decay constant and $T_{1/2}$ is the half life of the radioisotope of interest.
The volumetric activity is then the activity defined above divided by the containment volume. Based on Reference A-3, the containment free volume is 2×10^6 ft^3 = 5.7×10^{10} cm^3.
The equilibrium volumetric activity (after several hours) in containment is therefore:

Description	Fluorine-18 equilibrium volumetric activity in containment
Half Life	6586 s
Conservative value	0.33 kBq/m^3

The volumetric activity $A_{equilibrium}$ at equilibrium is not reached immediately after the leak because the volumetric activity A of a radioisotope must satisfy the differential equation:

$$\frac{1}{\lambda}\frac{dA}{dt} + A = L$$

Where L is the leak rate. The solution of this first order linear differential equation increases with time following the equation below:

$$A = A_{equilibrium} \times (1 - e^{-\lambda t})$$

The volumetric activity $A_{equilibrium}$ at equilibrium is not reached immediately after the leak. The volumetric activity A of a radioisotope increases with time following the equation below:

$$A = A_{equilibrium} \times (1 - e^{-\lambda t})$$

Therefore the fraction f of volumetric activity at time t over the equilibrium volumetric activity is:

$$f = \frac{A}{A_{equilibrium}} = (1 - e^{-\lambda t})$$

The detection requirements established by Regulatory guide 1.45 are defined after one hour: for F-18, f=31.5%. Based on these fractions, the F-18 volumetric activity in containment one hour after a leak is 0.105 $kBq/m^3 = 2.84 \times 10^{-9}$ $\mu Ci/cm^3$.

Conclusion

The F-18 volumetric activity in containment one hour after a leak is 0.105 kBq/m^3 (2.84 x 10^{-9} $\mu Ci/cm^3$).

References for Attachment A

A-1. Formation of nitrogen-13, fluorine-17 and fluorine-18 in reactor-irradiated H_2O and D_2O: applications to activation analysis and fast neutron flux monitoring, Lennart Hammar and Sture Forsén, J. inorg. nucl. Chem., 1966, Vol. 28.

A-2. Regulatory Guide 1.45, Guidance on monitoring and responding to reactor coolant system leakage, U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research.

A-3. APP-GW-GL-700 Rev. 17, AP1000 Design Control Document, WNPP-L&CI,B. W. Bevilacqua,J. A. Speer,R. Sisk,J. J. DeBlasio,T. L. Morante, November 3rd, 2008.

A-4. Reactor coolant pressure boundary leakage detection system, Erik Dissing and Lennart Svansson, IEEE Transactions on Nuclear Science, Vol. NS-27 No. 1, February 1980.

A-5. Reactor coolant pressure boundary leak detection system using gas radiation monitoring, A.T. Hyde and A.E. Butt, Sorrento Electronics Users' Group, Dan Diego California, February 12, 2002.

A-6. Reference 1 in main RAI response. (Shaw Stone & Webster Proprietary QA Category I analysis for an operating Westinghouse PWR, estimating the likely percentage of non-volatile activity in the reactor coolant leakage that would become airborne inside the containment in the initial stages of a reactor coolant leak.) (Available for NRC review upon request)

Design Control Document (DCD) Revision:

See attached mark-ups. There are two changes in DCD mark-ups from Rev. 0 to Rev. 1 of this RAI response. There were some additional editorial mark-ups made to Table 11.5-1 and Tech Spec Bases for LCO 3.4.9.

Appendix 1A

Reg. Guide 1.45, Rev. 0, 5/73 – Reactor Coolant Pressure Boundary Leakage Detection Systems

C.1	Conforms	
C.2	Conforms	
C.3	Exception	~~The AP1000 reactor coolant pressure boundary leakage detection methods are selected and designed in accordance with the guidelines of this regulatory guide. No credit is taken for airborne particulate radiation measurement in quantifying the leak rate.~~The AP1000 uses two methods for leak detection including sump level and flow monitoring, and airborne particulate radioactivity monitoring.
C.4	Conforms	
C.5	Conforms	
C.6	~~Exception~~Conforms	~~Airborne particulate radioactivity monitoring is not used to determine reactor coolant pressure boundary leakage.~~
C.7	Conforms	
C.8	Conforms	
C.9	Conforms	

3.1.4 Fluid System

Criterion 30 – Quality of Reactor Coolant Pressure Boundary

{Last paragraph has only change}

Leakage from the reactor coolant pressure boundary will result in an increase in the radioactivity levels inside containment. The containment atmosphere is monitored for airborne gaseous radioactivity and ^{18}~~N13/~~F$_{\cancel{18}}$ ~~P~~particulate. From the concentration of ^{18}~~N13/~~F$_{\cancel{18}}$ ~~P~~particulate and the power level, reactor coolant pressure boundary leakage can be estimated.

3.6.3.3 Analysis Methods and Criteria

{Leakage Flaw Section has only change}

Leakage Flaw

Through-wall flaws in candidate leak-before break piping systems are postulated. [*The size of the postulated flaws are large enough so that the leakage is detectable with adequate margin, using 10 times the minimum installed leak detection capability when the pipes are subjected to normal operational loads combining by algebraic sum method.*]* That is, the size of the leakage flaw postulated would be expected to have a leak rate 10 times the size of the rated leak rate detection capability.

As noted in subsection 5.2.5, the rated capability of the leak detection systems for the primary coolant inside containment is 0.5 gpm ~~in one hour~~. The methods used to detect leakage are described in subsection 5.2.5.3. The methods used for primary coolant are the containment sump level, inventory balance, and containment atmosphere radiation. The method used to detect leakage from the main steam line inside containment is the containment sump level. Containment air cooler condensate flow, and containment atmosphere pressure, temperature, and humidity also provide an indication of possible leakage.

5.2.5.3.3 Containment Atmosphere Radioactivity Monitor

Leakage from the reactor coolant pressure boundary will result in an increase in the radioactivity levels inside containment. The containment atmosphere is continuously monitored for airborne ~~gaseous~~ particulate radioactivity. Air flow through the monitor is provided by the suction created by a vacuum pump. ~~Gaseous N_{13}/F_{18} concentration monitors indicate~~An F_{18} particulate concentration monitor indicates radiation concentrations in the containment atmosphere.

~~N_{13} and~~ F_{18} ~~are neutron activation products which are~~particulate is a neutron activated product, which is proportional to power levels. An increase in activity inside containment would therefore indicate a leakage from the reactor coolant pressure boundary. Based on the concentration of ~~N_{13}/~~F_{18} in particulate form and the power level, reactor coolant pressure boundary leakage can be estimated.

The ~~N_{13}/~~F_{18} particulate monitor is seismic Category I. Conformance with the position 6 guidance of Regulatory Guide 1.45 that leak detection should be provided following seismic events that do not require plant shutdown is provided by the seismic Category I classification. Safety-related Class 1E power is not required since loss of power to the radiation monitor is not consistent with continuing operation following an earthquake.

The ~~N_{13}/~~F_{18} particulate monitor is operable when the plant is above 20-percent power, and can detect a 0.5 gpm leak within 1 hour when the plant is at full power.

Radioactivity concentration indication and alarms for loss of sample flow, high radiation, and loss of indication are provided. Sample collection connections permit sample collection for laboratory analysis. The radiation monitor can be calibrated during power operation.

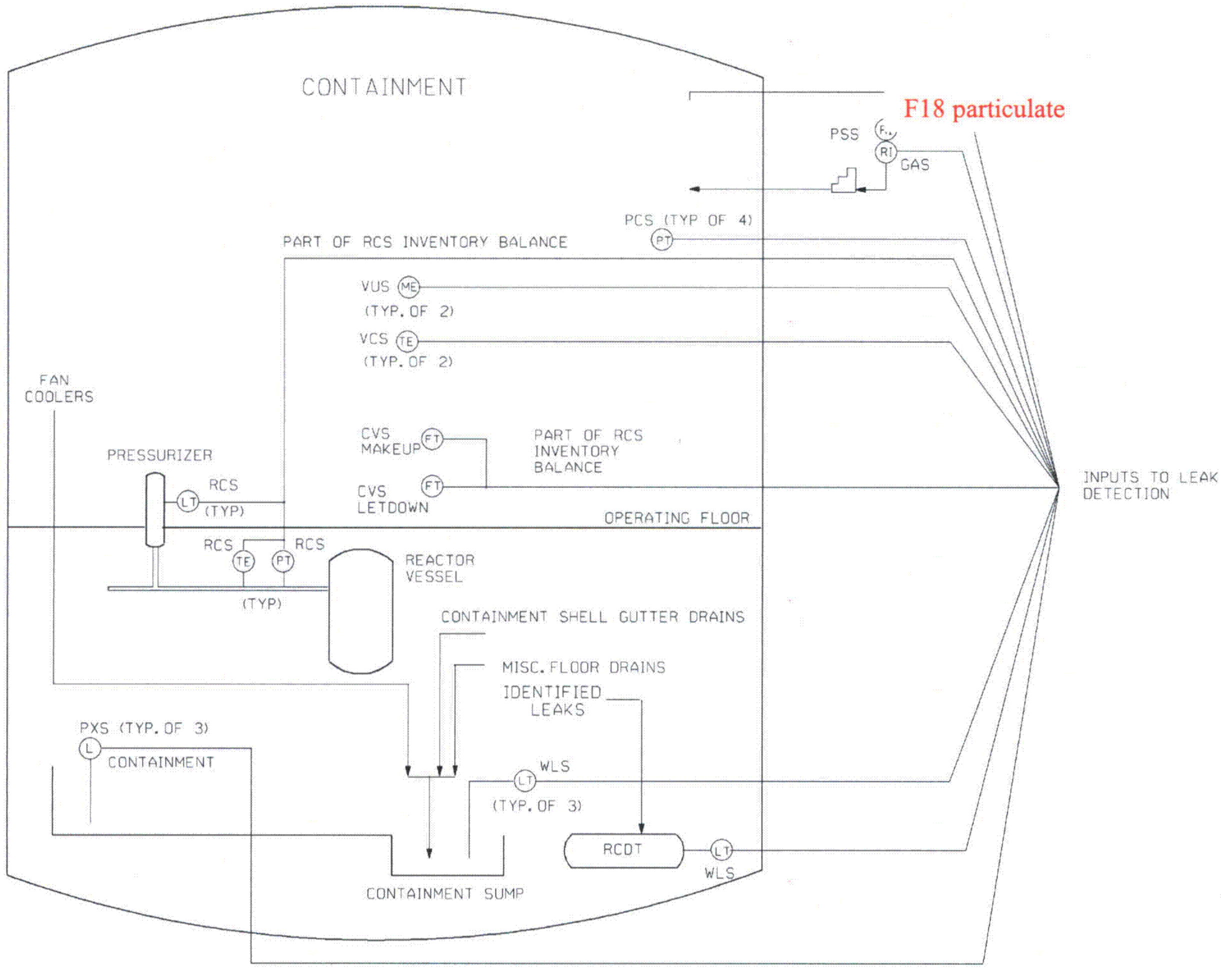

Figure 5.2-1

Leak Detection Approach

11.5.2.3.1 Fluid Process Monitors

{Rest of Section unchanged by this RAI}

Containment Atmosphere Radiation Monitor

The containment atmosphere radiation monitor measures the radioactive gaseous (PSS-JE-RE026) and ~~N^{13}/~~F^{18} particulate (PSS-JE-RE027) concentrations in the containment atmosphere. The containment atmosphere radiation monitor is a part of the reactor coolant pressure boundary leak detection system described in subsection 5.2.5. The presence of gaseous or ~~N^{13}~~-F18 radioactivity in the containment atmosphere is an indication of reactor coolant pressure boundary leakage. Refer to subsection 5.2.5 for further details. Conformance with Regulatory Guide 1.45 is discussed in Appendix 1A.

The containment atmosphere radiation monitor accepts analog signal inputs for sample flow and temperature. These signals are used to calculate concentrations at standard conditions.

The radiogas detector is a beta-sensitive scintillation detector. The ~~N^{13}/~~F^{18} ~~detector is a gamma-sensitive, thallium-activated, sodium iodide scintillation detector with a window at the N^{13}/F^{18} 0.511 MeV decay energy~~particulate detector is also a beta-sensitive scintillation detector. The ranges and principal isotopes are listed in Table 11.5-1.

The arrangement for the containment atmosphere radiation monitor is shown in Figure 11.5-3.

Table 11.5-1 (Sheet 1 of 2) **RADIATION MONITOR DETECTOR PARAMETERS**				
Detector	**Type**	**Service**	**Isotopes**	**Nominal Range**
BDS-JE-RE010	γ	Steam Generator Blowdown Electrodeionization Effluent	Cs-137	1.0E-7 to 1.0E-2 µCi/cc
BDS-JE-RE011	γ	Steam Generator Blowdown Electrodeionization Brine	Cs-137	1.0E-7 to 1.0E-2 µCi/cc
CCS-JE-RE001	γ	Component Cooling Water System	Cs-137	1.0E-7 to 1.0E-2 µCi/cc
VFS-JE-RE101	β	Plant Vent Particulate	Sr-90 Cs-137	1.0E-12 to 1.0E-7 µCi/cc
VFS-JE-RE102	γ	Plant Vent Iodine	I-131	1.0E-11 to 1.0E-6 µCi/cc
VFS-JE-RE103	β	Plant Vent Gas (Normal Range)	Kr-85 Xe-133	1.0E-7 to 1.0E-2 µCi/cc
VFS-JE-RE104A	β/γ	P.V. Extended Range Gas (Accident Mid Range)	Kr-85 Xe-133	1.0E-4 to 1.0E+2 µCi/cc
VFS-JE-RE104B	β/γ	P.V. Extended Range Gas (Accident High Range)	Kr-85 Xe-133	1.0E-1 to 1.0E+5 µCi/cc
PSS-JE-RE026	β	Containment Atmosphere Gas (Note 2)	Kr-85 Xe-133 Ar-41 N-13	1.0E-7 to 1.0E-2 µCi/cc
PSS-JE-RE027	β~~γ~~	Containment Atmosphere beta-sensitive scintillation detector ~~N^{13}/F^{18} particulate~~(Note 2)	~~N-13~~ F-18	1.0E-~~7~~10 to 1.0E-~~2~~5 µCi/cc
PSS-JE-050	γ	Primary Sampling Liquid	I-131 Cs-137	1.0E-4 to 1.0E+2 µCi/cc
PSS-JE-052	γ	Primary Sampling Gaseous	Kr-85 Xe-133	1.0E-7 to 1.0E-2 µCi/cc
SGS-JE-RE026A	γ	Main Steam Line	Kr, Xe, I	1.0E-1 to 1.0E+3 µCi/cc
SGS-JE-RE026B	γ	Main Steam Line	N-16	30 to 200 gallons per day
SGS-JE-RE027A	γ	Main Steam Line	Kr, Xe, I	1.0E-1 to 1.0E+3 µCi/cc
SGS-JE-RE027B	γ	Main Steam Line	N-16	30 to 200 gallons per day
SWS-JE-RE008	γ	Service Water Blowdown	Cs-137	1.0E-7 to 1.0E-2 µCi/cc

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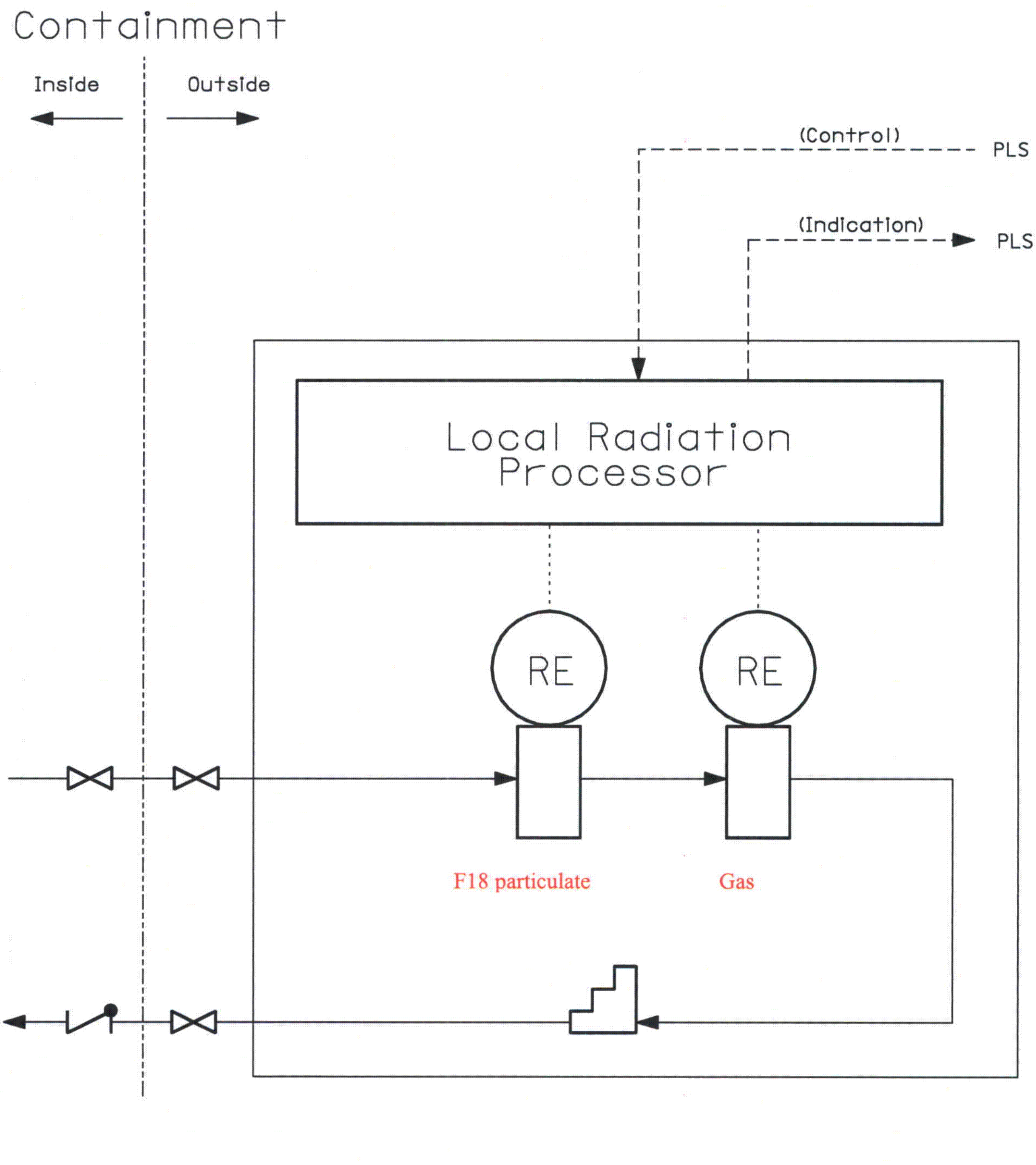

Figure 11.5-3
Containment Atmosphere Radiation Monitor

3.4 REACTOR COOLANT SYSTEM (RCS)

3.4.9 RCS Leakage Detection Instrumentation

LCO 3.4.9 The following RCS leakage detection instrumentation shall be OPERABLE:

a. Two containment sump level channels;

b. One containment atmosphere radioactivity monitor (~~gaseous N13/F18~~F18 particulate).

APPLICABILITY: MODES 1, 2, 3, and 4.

- NOTES -

1. The ~~N13/F18~~F18 particulate containment atmosphere radioactivity monitor is only required to be OPERABLE in MODE 1 with RTP > 20%.

2. Containment sump level measurements cannot be used for leak detection if leakage is prevented from draining to the sump such as by redirection to the IRWST by the containment shell gutter drains.

LCO

RCS operation LEAKAGE shall be limited to:

a. Pressure Boundary LEAKAGE

No pressure boundary LEAKAGE is allowed, being indicative of material deterioration. LEAKAGE of this type is unacceptable as the leak itself could cause further deterioration, resulting in higher LEAKAGE. Violation of this LCO could result in continued degradation of the RCPB. LEAKAGE past seals and gaskets are not pressure boundary LEAKAGE.

b. Unidentified LEAKAGE

0.5 gpm of unidentified LEAKAGE is allowed as a reasonable minimum detectable amount that the containment air ~~N13/~~F18 particulate radioactivity monitoring and containment sump level monitoring equipment, can detect within a reasonable time period. This leak rate supports leak before break (LBB) criteria. Violation of this LCO could result in continued degradation of the RCPB, if the LEAKAGE is from the pressure boundary.

SURVEILLANCE REQUIREMENTS (continued)

The RCS water inventory balance must be met with the reactor at steady state operating conditions. The Surveillance is modified by two Notes. Note 1 states that this SR is not required to be performed until 12 hours after establishing steady state operation. The 12 hour allowance provides sufficient time to collect and process all necessary data after stable plant conditions are established.

Steady state operation is required to perform a proper inventory balance since calculations during maneuvering are not useful. For RCS operational LEAKAGE determination by inventory balance, steady state is defined as stable RCS pressure, temperature, power level, pressurizer and makeup tank levels, and with no makeup or letdown.

An early warning of pressure boundary LEAKAGE or unidentified LEAKAGE is provided by the automatic systems that monitor the containment atmosphere ~~N13/~~F18 particulate radioactivity and the containment sump level. It should be noted that LEAKAGE past seals and gaskets is not pressure boundary LEAKAGE. These LEAKAGE detection systems are specified in LCO 3.4.9, "RCS LEAKAGE Detection Instrumentation."

Note 2 states that this SR is not applicable to primary to secondary LEAKAGE because LEAKAGE of 150 gallons per day cannot be measured accurately by an RCS water inventory balance.

The containment atmosphere ~~N13/~~F18 particulate radioactivity LEAKAGE measurement is valid only for plant power > 20% RTP.

The containment atmosphere ~~N13/~~F18 particulate radioactivity LEAKAGE measurement during MODE 1 is not valid while containment purge occurs or within 2 hours after the end of containment purge.

The containment sump level change method of detecting leaks during MODES 1, 2, 3, and 4 is not valid while containment purge occurs or within 2 hours after the end of containment purge.

The containment sump level change method of detecting leaks during MODES 1, 2, 3, and 4 is not valid during extremely cold outside ambient conditions when frost is forming in the interior of the containment vessel.

The 72-hour Frequency is a reasonable interval to trend LEAKAGE and recognizes the importance of early leakage detection in the prevention of accidents.

B 3.4 REACTOR COOLANT SYSTEM (RCS)

B 3.4.9 RCS Leakage Detection Instrumentation

BASES

BACKGROUND

GDC 30 of Appendix A to 10CFR50 (Ref. 1) requires means for detecting, and, to the extent practical, identifying the source of RCS LEAKAGE. Regulatory Guide 1.45 (Ref. 2) describes acceptable methods for selecting LEAKAGE detection systems. LEAKAGE detection systems must have the capability to detect significant reactor coolant pressure boundary (RCPB) degradation as soon after occurrence as practical to minimize the potential for propagation to a gross failure. Thus, an early indication or warning signal is necessary to permit proper evaluation of all unidentified LEAKAGE. Industry practice has shown that water flow changes of 0.5 gpm can be readily detected in contained volumes by monitoring changes in water level, in flow rate, or in the operating frequency of a pump. The containment sump used to collect unidentified LEAKAGE, is instrumented to alarm for increases of 0.5 gpm in the normal flow rates. This sensitivity is acceptable for detecting increases in unidentified LEAKAGE. Note that the containment sump level instruments are also used to identify leakage from the main steam lines inside containment. Since there is not another method to identify steam line leakage in a short time frame, two sump level sensors are required to be operable. The containment water level sensors (LCO 3.3.3) provide a diverse backup method that can detect a 0.5 gpm leak within 3.5 days.

The reactor coolant contains radioactivity that, when released to the containment, can be detected by radiation monitoring instrumentation. Reactor coolant radioactivity used for leak detection is the decay of ~~N13/~~F18. The production of ~~N13~~ and F18 is proportional to the reactor power level. ~~N13 has a short half life and comes to equilibrium quickly. F18 has a longer half life and is the dominant source used for leak detection~~F18 becomes a particulate after leaving the RCS, and is used for leak detection. Instrument sensitivities for ~~gaseous~~ particulate monitoring are practical for these LEAKAGE detection systems. The Radiation Monitoring System includes monitoring ~~N13/F18 gaseous activities~~F18 particulate activity to provide leak detection.

APPLICABLE SAFETY ANALYSES

The need to evaluate the severity of an alarm or an indication is important to the operators, and the ability to compare and verify with indications from other systems is necessary. The system response times and sensitivities are described in Chapter 15 (Ref. 3).

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BASES

APPLICABLE SAFETY ANALYSES (continued)

The safety significance of RCS LEAKAGE varies widely depending on its source, rate, and duration. Therefore, detecting and monitoring RCS LEAKAGE into the containment area is necessary. Quickly separating the identified LEAKAGE from the unidentified LEAKAGE provides quantitative information to the operators, allowing them to take corrective action should a leak occur.

RCS LEAKAGE detection instrumentation satisfies Criterion 1 of 10 CFR 50.36(c)(2)(ii).

LCO

One method of protecting against large RCS LEAKAGE derives from the ability of instruments to rapidly detect extremely small leaks. This LCO requires instruments of diverse monitoring principles to be OPERABLE to provide a high degree of confidence that small leaks are detected in time to allow actions to place the plant in a safe condition, when RCS LEAKAGE indicates possible RCPB degradation.

The LCO is satisfied when monitors of diverse measurement means are available. Thus, the containment sump level monitor, in combination with an ~~N13/F18 gaseous activity~~the F18 particulate radioactivity monitor, provides an acceptable minimum. Containment sump level monitoring is performed by three redundant, seismically qualified level instruments. The LCO note clarifies that if LEAKAGE is prevented from draining to the sump, its level change measurements made by OPERABLE sump level instruments will not be valid for quantifying the LEAKAGE.

APPLICABILITY

Because of elevated RCS temperature and pressure in MODES 1, 2, 3, and 4, RCS LEAKAGE detection instrumentation is required to be OPERABLE.

In MODE 5 or 6, the temperature is ≤200°F and pressure is maintained low or at atmospheric pressure. Since the temperatures and pressures are lower than those for MODES 1, 2, 3, and 4, the likelihood of LEAKAGE and crack propagation are much smaller. Therefore, the requirements of this LCO are not applicable in MODES 5 and 6.

Containment sump level monitoring is a valid method for detecting LEAKAGE in MODES 1, 2, 3, and 4. The containment atmosphere ~~N13/~~F18 particulate radioactivity LEAKAGE measurement during MODE 1 is valid only for reactor power > 20% RTP. RCS inventory monitoring via the pressurizer level changes is valid in MODES 1, 2, 3, and 4 only when RCS conditions are stable, i.e., temperature is constant, pressure is constant, no makeup and no letdown.

APPLICABILITY (continued)

The containment sump level change method of detecting leaks during MODES 1, 2, 3, and 4 is not valid while containment purge occurs or within 2 hours after the end of containment purge.

The containment atmosphere ~~N13/~~F18 particulate radioactivity LEAKAGE measurement during MODE 1 is not valid while containment purge occurs or within 2 hours after the end of containment purge.

The containment sump level change method of detecting leaks during MODES 1, 2, 3, and 4 is not valid during extremely cold outside ambient conditions when frost is forming on the interior of the containment vessel.

ACTIONS

The actions are modified by a Note that indicates that the provisions of LCO 3.0.4 are not applicable. As a result, a MODE change is allowed when leakage detection channels are inoperable. This allowance is provided because in each condition other instrumentation is available to monitor for RCS LEAKAGE.

A.1 and A.2

With one of the two required containment sump level channels inoperable, the one remaining operable channel is sufficient for RCS leakage monitoring since the containment radiation provides a method to monitor RCS leakage. However, that is not the case for the steam line leakage monitoring. The remaining operable sump level monitor is adequate as long as it continues to operate properly. Continuing plant operation is expected to result in containment sump level indication increases and in periodic operation of the containment sump pump. Therefore, proper operation of the one remaining sump level sensor is verified by the operators checking the volume input to the sump (as determined by the sump level changes and discharges from the containment) to determine that it does not change significantly. A significant change is considered to be ±10 gallons per day or 33% (whichever is greater) of the volume input for the first 24 hours after this Condition is entered. The containment sump level instruments are capable of detecting a volume change of less than 2 gallons. The containment water level sensors also provide a diverse backup that can detect a 0.5 gpm leak within 3.5 days.

Restoration of two sump channels to OPERABLE status is required to regain the function in a Completion Time of 14 days after the monitor's failure. This time is acceptable, considering the frequency and adequacy of the monitoring of the change in integrated sump discharge required by Action A.1.

ACTIONS (continued)

B.1 and B.2

With two of the two required containment sump level channels inoperable, no other form of sampling can provide the equivalent information; however, the containment atmosphere ~~N13/~~F18 particulate radioactivity monitor will provide indications of changes in LEAKAGE. Together with the atmosphere monitor, the periodic surveillance for RCS inventory balance, SR 3.4.7.1, must be performed at an increased frequency of 24 hours to provide information that is adequate to detect LEAKAGE. A Note is added allowing that SR 3.4.7.1 is not required to be performed until 12 hours after establishing steady state operation (stable temperature, power level, pressurizer and makeup tank levels, makeup and letdown). The 12 hour allowance provides sufficient time to collect and process all necessary data after stable plant conditions are established.

Restoration of one sump channel to OPERABLE status is required to regain the function in a Completion Time of 72 hours after the monitor's failure. This time is acceptable, considering the frequency and adequacy of the RCS inventory balance required by Action A.1.

C.1.1, C.1.2, and C.2

With ~~one gaseous N13/~~F18 particulate containment atmosphere radioactivity-monitoring instrumentation channel inoperable, alternative action is required. Either grab samples of the containment atmosphere must be taken and analyzed or RCS inventory balanced, in accordance with SR 3.4.7.1, to provide alternate periodic information.

With a sample obtained and analyzed or an RCS inventory balance performed every 24 hours, the reactor may be operated for up to 30 days to allow restoration of the radioactivity monitor.

The 24 hours interval for grab samples or RCS inventory balance provides periodic information that is adequate to detect LEAKAGE. A Note is added allowing that SR 3.4.7.1 is not required to be performed until 12 hours after establishing steady state operation (stable temperature, power level, pressurizer and makeup tank levels, and makeup and letdown). The 12 hour allowance provides sufficient time to collect and process all necessary data after stable plant conditions are established. The 30 day Completion Time recognizes at least one other form of leak detection is available.

ACTIONS (continued)

D.1 and D.2

If a Required Action of Condition A, B or C cannot be met within the required Completion Time, the reactor must be brought to a MODE in which the LCO does not apply. To achieve this status, the plant must be brought to at least MODE 3 within 6 hours and to MODE 5 within 36 hours. The allowed Completion Times are reasonable, based on operating experience, to reach the required plant conditions from full power conditions in an orderly manner without challenging plant systems.

E.1

With all required monitors inoperable, no automatic means of monitoring leakage is available and plant shutdown in accordance with LCO 3.0.3 is required.

SURVEILLANCE REQUIREMENTS

SR 3.4.9.1

SR 3.4.9.1 requires the performance of a CHANNEL CHECK of the containment atmosphere ~~N13/~~F18 particulate radioactivity monitor. The check gives reasonable confidence that the channel is operating properly. The Frequency of 12 hours is based on instrument reliability and risk and is reasonable for detecting off normal conditions.

SR 3.4.9.2

SR 3.4.9.2 requires the performance of a CHANNEL OPERATIONAL TEST (COT) on the atmosphere ~~N13/~~F18 particulate radioactivity monitor. The test ensures that the monitor can perform its function in the desired manner. The test verifies the alarm setpoint and relative accuracy of the instrument string. The Frequency of 92 days considers risks and instrument reliability, and operating experience has shown that it is proper for detecting degradation.

SR 3.4.9.3 and SR 3.4.9.4

These SRs require the performance of a CHANNEL CALIBRATION for each of the RCS Leakage detection instrumentation channels. The calibration verifies the accuracy of the instrument string, including the instruments located inside containment. The Frequency of 24 months is a typical refueling cycle and considers channel reliability. Again, operating experience has proven that this Frequency is acceptable.

PRA Revision:
None

Technical Report (TR) Revision:
None