REACTOR COOLANT SYSTEM

REACTOR COOLANT SYSTEM LEAKAGE

OPERATIONAL LEAKAGE

SURVEILLANCE REQUIREMENTS

4.4.3.2.1 The RCS leakage shall be demonstrated to be within each of the above limits by:

a. Monitoring the primary containment airborne particulate radioactivity at least once per 12 hours*,

b. Monitoring the primary containment drywell floor drain tank and equipment drain tank fill rate at least once per 12 hours,

c. Monitoring the primary containment airborne gaseous radioactivity at least once per 12 hours*, and

d. Monitoring the reactor vessel head flange leak detection system at least once per 24 hours.*

4.4.3.2.2 Each RCS pressure isolation valve specified in Table 3.4.3.2-1 shall be demonstrated OPERABLE by leak testing pursuant to Specification 4.0.5 as outlined in the ASME Code Section XI, paragraph IWV-3427(b) and verifying the leakage of each valve to be within the specified limit:

a. At least once per 18 months, and
b. Before returning the valve to service following maintenance, repair, or replacement work on the valve.

The provisions of Specification 4.0.4 are not applicable for entry into OPERATIONAL CONDITION 3.

4.4.3.2.3 The high/low-pressure interface valve leakage pressure monitors shall be demonstrated OPERABLE with setpoints per Table 3.4.3.2-2 by performance of a:

a. CHANNEL FUNCTIONAL TEST at least once per 31 days, and
b. CHANNEL CALIBRATION at least once per 18 months.

4.4.3.2.4 The high/low-pressure interface interlock for the steam condensing mode bypass valve shall be demonstrated OPERABLE with trips setpoints per Table 3.4.3.2-3 by performance of:

a. CHANNEL FUNCTIONAL TEST at least once per 92 days, and
b. CHANNEL CALIBRATION at least once per 18 months.

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* - Not a Means of Quantifying Leakage

ATTACHMENT 3

FSAR REVISION

TABLE 1.8-1 (Cont)

Regulatory Guide 1.45 (May 1973)

Reactor Coolant Pressure Boundary
Leakage Detection Systems

FSAR Sections 5.2.5.1, 5.2.5.9, and 11.5

Position

The Unit 2 project complies with the intent of the Regulatory Position (Paragraph C) of this guide through the alternate approaches described below and Section 5.2.5.9.

The interpretation given to Regulatory Position c.5 for the sensitivity and response time of each leakage detection system is consistent with equipment capabilities available in the industry.

(See Section 3.9.6A for the program for pumps and valves.) Subsequent inservice inspections will be performed in accordance with the requirements of 10CFR50.55a(g) as described in the Inservice Inspection Program.

5.2.5 Reactor Coolant Pressure Boundary and ECCS Leakage Detection System

5.2.5.1 Leakage Detection Methods

The nuclear boiler leak detection system (LDS) consists of temperature, pressure, level, flow, airborne gaseous and particulate fission product sensors, and process radiation sensors with associated instrumentation used to indicate and alarm leakage from the RCPB. The LDS in certain cases is used to initiate signals used for automatic closure of isolation valves to shut off leakage external to the containment. The system meets the intent of Regulatory Guide 1.45 and appropriate portions of the system are designed to IEEE-279-1971.

Abnormal leakage from the following systems within the containment and within the selected areas of the plant outside the primary containment is detected, indicated, alarmed, and in certain cases, isolated.

1. Main steam lines.
2. RWCU system.
3. RHR system.
4. RCIC system.
5. Feedwater system.
6. HPCS.
7. Coolant systems within the containment.
8. LPCS.
9. RPV.
10. Miscellaneous systems.

Leak detection methods used to obtain conformance with Regulatory Guide 1.45 for plant areas inside the primary containment differ from those for areas located outside the

primary containment. These areas are considered separately in the following sections.

5.2.5.1.1 Detection of Leakage Within the Primary Containment

The primary detection method for small unidentified leaks within the primary containment is continuous monitoring of drywell floor drain tank fill rate. (The sensitivity of this primary detection method for unidentified leakage within the drywell is adequate to detect a leakage rate of 1 gpm within 1 hr.) This variable is continuously recorded in the control room. If the unidentified leakage increases to a total of 5 gpm, the detecting instrumentation channel(s) will trip and activate an alarm in the main control room. This does not result in a containment isolation signal.

The secondary detection methods for small unidentified leaks within the primary containment include continuous qualitative monitoring of airborne gaseous and particulate radioactivity levels. The sensitivities of the airborne particulate and airborne gaseous radiation monitoring are dependent upon a number of factors as discussed in Section 5.2.5.2.1. Radioactivity levels significantly above normal readings will trip and activate an alarm in the main control room. This does not result in a containment isolation signal.

The tertiary detection methods (i.e., the monitoring of pressure and temperature of the primary containment atmosphere) are used to indirectly detect gross unidentified leakage. High primary containment pressure will alarm and trip the isolation logic which results in closure of the containment isolation valves.

The detection of small identified leakage within the primary containment is accomplished by continuous drywell equipment drain tank fill rate monitoring. An alarm will be activated in the main control room when the identified leakage rate reaches 25 gpm over 24 hours.

The determination of the source of identified leakage within the primary containment is accomplished by monitoring the drain lines to the drywell equipment drain tank from various potential leakage sources. These include reactor recirculation pump seal drain flow and reactor vessel head seal drain line pressure. Additionally, temperature is monitored in the SRV discharge lines to the suppression pool to detect leakage through each of the SRVs. All of these monitors, except the reactor recirculation pump seal drain flow monitor, continuously indicate and/or record in the control room. All of these monitors trip and activate an alarm in the control room on detection of leakage from monitored components.

Excessive leakage inside the primary containment (e.g., process line break or LOCA within primary containment) is detected by high primary containment pressure, low reactor water level or high steam line flow (for breaks downstream

of the flow elements). The instrumentation channels for these variables trip when the monitored variable exceeds a predetermined limit to activate an alarm and trip the isolation logic which closes appropriate isolation valves (Table 5.2-9). The alarms and indication and isolation trip functions initiated by the LDSs are summarized in Tables 5.2-9 and 5.2-10.

5.2.5.1.2 Detection of Leakage External to the Primary Containment (Within Reactor Building)

The detection of leakage within the reactor building (outside the primary containment) is accomplished by detection of increases in reactor building floor drain sump and reactor building equipment drain tank fillup time and pumpout time (Section 5.2.5.2.2). The reactor building floor drain sump monitors will detect unidentified leakage increases and activate an alarm in the main control room. The reactor building equipment drain tank monitors will detect identified leakage increases and activate an alarm in the main control room when leakage increases above normal operating levels. See Section 5.2.5.2.2 for a discussion of the fuel pool liner leakage detection method.

5.2.5.1.3 Detection of Leakage External to the Primary Containment

Areas outside the primary containment that are monitored for primary coolant leakage are: equipment areas in the auxiliary bays, the main steam tunnel, and the turbine building. The process piping for each system to be monitored for leakage is located in compartments or rooms separate from other systems where feasible so that leakage may be detected by area temperature indications.

These areas are monitored by dual element thermocouples for sensing high ambient temperature in all these areas and high differential temperature between the inlet and outlet ventilation ducts in the main steam tunnel. The temperature elements are located or shielded so that they are sensitive to air temperatures only and not to radiated heat from hot piping or equipment. Increases in ambient and/or differential temperature indicate leakage of reactor coolant

23 into the area. The monitors located in the main steam tunnel and turbine building have sensitivities suitable for detection of increases in ambient air temperature which are equivalent to reactor coolant leakage into the monitored areas of 25 gpm or less. The temperature trip set points are a function of room size and the type of ventilation provided. These monitors provide alarm, indication, and recording in the main control room, and trip the isolation logic to close selected isolation valves (e.g., the main steam tunnel monitors close the MSIV, and main steam line drain isolation valves and other valves [Table 5.2-9]).

23 The turbine building temperature monitors alarm and indicate in the main control room and trip the isolation logic to close the main steam isolation and main steam line drain isolation valves when leakage exceeds 25 gpm. These sensors monitor ambient temperature in the enclosed space between the steam tunnel outlet and the inlet to the high pressure turbine.

Excess leakage external to the containment (e.g., process line break outside containment) is detected by low reactor
23 water level, high process line flow, high ambient temperature in the piping or equipment areas, high differential flow, and low main condenser vacuum. These monitors provide alarm and indication in the main control room and trip the isolation logic to cause closure of appropriate system isolation valves on indication of excess leakage (Table 5.2-9). Set points for the high ambient temperature monitors in the piping and equipment areas of
23 the reactor building and auxiliary bays are based on limiting the maximum environmental conditions of these areas to within the environmental qualification capabilities of the applicable equipment.

5.2.5.1.4 Intersystem Leakage Monitoring

Leakage from the HPCS, LPCS, RCIC, and RHR systems outside containment is detected by a combination of methods, including high area temperature, high area radiation, high sump level, and reactor pressure vessel condition (see Section 5.2.5.1.3).

Radiation monitors are used to detect reactor coolant leakage into cooling water systems supplying the RHR heat exchangers and the RWCU nonregenerative heat exchanger. These monitoring channels are part of the process radiation monitoring system. Process radiation monitoring channels monitor for leakage into each common cooling water header downstream of the RHR heat exchangers and the RWCU

nonregenerative heat exchanger. Channels will alarm on high radiation conditions indicating process leakage into the cooling water. No isolation trip functions are performed by these monitors.

Radiation monitors are also used to detect reactor coolant leakage into that portion of the RBCLCW system which supplies cooling water for the RHR and RWCU pump seal coolers. The return water from these coolers is combined with the return from the spent fuel heat exchangers and is monitored with a radiation monitor (see Figure 9.2-3e).

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5.2.5.2 Leak Detection Instrumentation and Monitoring

5.2.5.2.1 Leak Detection Instrumentation and Monitoring Inside Primary Containment

<u>Drywell Floor Drain Tank Measurement</u>

The normal design drywell leakage collected in the floor drain tank includes unidentified leakage from the CRDs, valve flange leakage, component cooling water, service water, air cooler drains, and any leakage not connected to the equipment drain tank. Abnormal leakage rates are detected and alarmed in the main control room. Collection in excess of background leakage indicates an increase in reactor coolant leakage from an unidentified source. Leakage into the drywell floor drain system flows through a piping header that penetrates the containment wall and is then directed to the drywell floor drain tank located in the reactor building. Containment isolation is provided by a motor-operated valve (MOV) in the drain line inside containment and an MOV in the drain line outside containment.

As shown on Figure 9.3-13, a level differentiator is used to determine the unidentified leakage rate to the drywell floor drain tank by processing measurements of tank level and pump outflow rate. The leakage rate is determined by the differentiator by the use of the following equation:

$$L_i = (\Delta t)\sum_{i=1}^{n} r_i + \left(l_i - l_o\right)$$

Where:

L_i = Total leakage at time i (gal)

r_i = Flow rate at time i through the sump pumps (gpm)

l_i = Level in tank at time i (gal)

l_o = Initial level in tank at the beginning of the time cycle - i = o (gal)

Δt = Sampling interval over which flow through the pump is assumed constant (min)

n = Number of sampling intervals (where $\Delta t \times n$ = 6 min)

The leakage rate is determined and updated on a chart recorder every 6 min. In addition, the average leakage rate for the previous 24 hrs. is also determined every 6 min.

The instrumentation and equipment associated with the fill rate monitoring of the floor drain tanks were procured with sufficient accuracy, sensitivity, and response time to ensure that a sensitivity of at least 1 gpm in 1 hr. can be attained.

Drywell Equipment Drain Tank Measurement

The equipment drain tank collects only identified leakage. This tank receives piped drainage from pump seal leakoff and reactor vessel head flange vent drain. The equipment drain tank instrumentation is identical to the floor drain tank instrumentation. Collection in excess of background leakage indicates an increase in reactor coolant from an identified source.

Leakage into the drywell equipment drain system flows through a piping header, separate from the floor drain header, which penetrates the primary containment wall, and is then directed to the drywell equipment drain cooler and drain tank in the reactor building. An MOV in the drain line on each side of the containment wall provides isolation.

Temperature Measurement

The ambient temperature within the primary containment is monitored by four dual-element thermocouples located equally spaced in the vertical direction. An abnormal increase in primary containment temperature could indicate a leak within the primary containment. Ambient temperatures within the primary containment are recorded and alarmed on the leakage detection and isolation system panel in the control room.

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Gaseous and Particulate Monitoring

The primary containment monitoring system is used along with the temperature and pressure monitors described above to detect leaks in the nuclear system process barrier. The system continuously monitors the primary containment atmosphere for airborne radioactivity (noble gases and particulates, which includes iodine). The sample is drawn from the primary containment. A sudden increase of activity, which may be attributed to steam or reactor water leakage, is annunciated in the main control room (Section 7.6). The radiation monitors sample primary containment for the activity levels on the assumption that flashing coolant leakage will result in radioactivity in the atmosphere.

The reliability, sensitivity and response times of radiation monitors to detect 1 gpm of Reactor Coolant Pressure Boundary leakage in 1 hour will depend on many complex factors. The major factors are discussed below:

A. Source of Leakage

1) Origin of Leakage

The amount of activity which would become airborne following a 1 gpm leak from the RCPB will vary depending upon the leak origin and the coolant temperature and pressure. For example, a feedwater pipe leak will have concentration factors of 100 to 1000 lower than a recirculation line leak. A steam line leak will be a factor of 2 to 100 lower in iodine and particulate concentrations than the recirculation line leak, but the noble gas concentrations may be comparable. Differing coolant temperatures and pressures will affect the flashing fraction and partition factor for iodines and particulates. Thus, an airborne concentration cannot be correlated to a quantity of leakage without knowing the origin of the leakage.

2) Coolant Concentrations

Variations in coolant concentrations during operation can be as much as several orders of magnitude within a time frame of several hours. These effects are mainly due to spiking during power transients or changes in the use of the RWCU system. Examples of these transients for I-131 can be found in NEDO-10585 (8/72), Behavior of Iodine in Reactor Water During Plant Shutdown and Startup. Thus, an increase in the coolant concentrations could give increased containment concentrations when no increase in unidentified leakage occurs.

3) Other Sources of Leakage

Since the unidentified leakage is not the sole source of activity in the containment, changes in other sources will result in changes in the containment airborne concentrations. For example, identified leakage is piped to the equipment drain tank in the secondary containment, but the tank is vented to the

drywell atmosphere allowing the release of noble gases and some small quantities of iodines and particulates from the drain tank.

B. Drywell Conditions Affecting Monitor Performance

1) Equilibrium Activity Levels -- During normal operation, the activity release from acceptable quantities of identified and unidentified leakage will build up to significant amounts in the drywell air. Due to these high equilibrium activity levels, the activity increase due to a small increase in leakage may be difficult to detect within a short period of time.

2) Purge and Pressure Release Effects -- Changes in the detected activity levels have been known to occur during containment venting operations. These changes are of the same order of magnitude as approximately a 1 gpm leak and are sufficient to invalidate the results from iodine and particulate monitors.

3) Plateout, Mixing, Condensation, Fan Coolant Depletion -- Plateout effects on measured iodine and particulate levels will vary with the distance from the coolant release point to the detector. Larger travel distances would result in more plateout. In addition, the pathway of the leakage will influence the plateout effects. For example, a leak from a pipe with insulation will have greater plateout than a leak from an uninsulated pipe. Although the drywell air will be mixed by the fan coolers, it may be possible for a leak to develop in the vicinity of the radiation detector sample lines. In addition, condensation in the coolers and sample lines will remove iodines and particulates from the air. Variations in flow, temperature, and number of coolers will affect the plateout fractions. Plateout within the detector sample chamber will also add to the reduction of the iodine and particulate activity levels. The uncertainties in any estimate of plateout effects could be as much as one or two orders of magnitude.

C. Physical Properties and Capabilities of the Detectors

1) Detector Ranges

The detectors were chosen to ensure that the operating ranges covered the concentrations expected in the drywell. The operating ranges are approximately:

Noble Gases	1×10^{-7} to 1×10^{-1} μCi/cc
Particulates	1×10^{-11} to 1×10^{-5} μCi/cc

2) Counting Statistics and Monitor Uncertainties

In theory, this radioactivity monitor is statistically able to detect increases in concentration as small as 2 or 3 times the square root of the count rate, i.e., at 100 cpm an increase of 20, or 20% is detectable. At high count rates, the monitors

have dead-time uncertainties and a potential for saturation of the monitor or the electronics. Uncertainties in calibration (plus or minus 5%), sample flow (plus or minus 10%), and other instrument design parameters tend to make the uncertainty in a count rate closer to 20 to 40% of the equilibrium drywell activity.

3) Monitor Setpoints -- Due to the uncertainty and extreme variability of the radioactivity concentrations to be measured in the containment, the use of tight alarm setpoints on the radioactivity monitor would not be practical or useful. The setpoint, which would be required to alarm at 1 gpm, would be well within the bounds of uncertainty of the measurements. The use of such setpoints would result in many unnecessary alarms and the frequent resetting of setpoints. The alarm setpoints for the radiation monitors are set significantly above normal readings to prevent nuisance alarms.

4) Operator Action -- There is no direct correlation or known relationship between the detector count rate and the leakage rate because the coolant activity levels, source of leakage, and background radiation levels (from leakage alone) are not known and cannot be effectively determined in existing reactors. There are also several other sources of containment airborne activity (e.g., drywell equipment and floor drain tank vents) that further complicate the correlation.

To alert the operator to increasing leakage, the drywell floor drain tank level monitor alarms in the Control Room when leakage increases to 5 gpm. When the alarm is actuated, the operator will review other parameters (e.g., noble gas, particulates, containment temperature and pressure, etc.) to attempt to determine if the leakage is from the primary coolant pressure boundary and not from the cooling water system, etc.

Appropriate actions will then be taken in accordance with Technical Specifications. The review of other monitors will consist of comparisons of the increases and rates of increase in the values previously recorded. Increases in all parameters except tank level will not be correlated to a RCPB leakage rate. Instead, the increases will be compared to normal operating limits and limitations , and abnormal increases will be investigated.

The radiation monitor alarms will not be set to levels that correspond to RCPB leakage levels since the correlations cannot be made. Also, since the containment airborne activity levels vary by orders of magnitude during operation due to power transients, spiking, steam leaks, and outgassing from drain tanks, etc., an appropriate alarm setpoint, if one is used, should be determined based on plant operating experience. A setpoint level of 5 to 10 times the background level during full power steady state operation may be useful for alarming large

leaks and pipe breaks, but it would not always alarm for 1 gpm in 1 hour, and therefore could not be considered as any more than a qualitative indication of the presence of abnormal leakage.

Due to the sum total of the uncertainties identified in the previous paragraphs, gaseous and particulate monitors are not relied upon for immediate leak detection purposes. The monitors are used to give supporting information to that supplied by the tank discharge monitoring, and would be able to give an early warning of a major leak, especially if equilibrium containment activity levels are low. Grab sampling and laboratory analyses of airborne particulates and noble gas may be used to characterize leakage detected by other means.

Containment Pressure Measurement

The primary containment is at a slightly positive pressure during reactor operation and is monitored by pressure sensors. The pressure fluctuates slightly as a result of barometric pressure changes and leakage from containment. A pressure rise above the normally indicated values indicates a possible leak within the primary containment. Pressure exceeding the preset values is annunciated in the main control room and safety action is automatically initiated.

Reactor Vessel Head Seal

The reactor vessel head closure is provided with double seals with a leakoff connection between seals that is piped through a normally closed manual valve to the equipment drain sump. A branch line penetrates the primary containment and terminates at a pressure transmitter. Leakage through the first seal is detected by the pressure transmitter and annunciated in the main control room.

Due to the lack of a correlation between flange leakage rate and resultant pressure in the leakoff line, the annunciator in the Control Room is not associated with a specific leakage value. The system, in conjunction with the other LDS systems, is used to locate the source of leakage. An increase in pressure combined with an indication of coolant leakage from the tank level or airborne radiation monitors would be indicative of failure of the inner reactor vessel head seal.

Reactor Water Recirculation Pump Seal

Reactor water recirculation pump seal leaks are detected by monitoring flow in the seal drain line. Leakage, indicated by high flow rate, alarms in the main control room. The leakage is piped to the equipment drain tank.

Safety/Relief Valves

Temperature sensors connected to a multipoint recorder are provided to detect SRV leakage during reactor operation. SRV temperature elements are mounted, using a thermowell, in the SRV discharge piping several feet downstream from the valve body. Temperature rise above the alarm set point is annunciated in the main control room. See the nuclear

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boiler system piping and instrumentation diagram (Figure 5.1-2). Refer to Section 1.10, Item II.D.3, for discussion of acoustic monitors.

High Flow in Main Steam Lines (for Leaks Downstream of Flow Elements)

High flow in each main steam line is monitored by differential pressure sensors that sense the pressure difference across a flow element in each line. Steam flow exceeding preset values for any of the four main steam lines results in annunciation and isolation closure of all the main steam and steam drain lines.

Reactor Water Low Level

The loss of water in the reactor vessel (in excess of makeup) as the result of a major leak from the RCPB is detected by using the same nuclear boiler system low reactor water level signals that alarm and isolate selected primary system isolation valves (Chapter 7).

RCIC/RHR Steam Line Flow (for Leaks Downstream of Flow Elements)

The steam supply line for the steam condensing function of the RHR and for motive power for operation of the RCIC turbine is monitored for abnormal flows. Steam flows exceeding preset values initiate annunciation and isolation of the RCIC/RHR steam lines.

High Differential Pressure Between ECCS Injection Lines (for Leakage Internal to Reactor Vessel Only)

A break between the ECCS injection nozzles and vessel shroud is detected by monitoring the differential pressure between the RHR (LPCS mode) "A" and LPCS, RHR (LPCS mode) "B" and "C", and the HPCS and reactor vessel plenum. Indicator and alarm are located in the main control room. 10

Tables 5.2-9 and 5.2-10 summarize the actions taken by each leakage detection function. The tables show that those

systems which detect gross leakage initiate immediate automatic isolation. The systems that are capable of detecting small leaks initiate an alarm in the control room. The operator may manually isolate the leakage source or take other appropriate action.

5.2.5.2.2 Leak Detection Instrumentation and Monitoring External to Primary Containment

Reactor Building Drain Flow Measurement

Instrumentation monitors and indicates the amount of unidentified leakage into the reactor building floor drainage system outside the primary containment. Background
26 | leakage is identified during startup tests. Abnormal leakage is alarmed in the main control room. Identified leakage within the reactor building outside the primary containment includes spent fuel pool, reactor cavity and internal storage pool liner leakage, refueling canal and cask storage area canal gate leakage, and inner and outer refueling seal leakage. Leakage from the liners is piped to sight gauge glasses to provide visual indication. Leakage from the gate drains and inner and outer refueling seals is collected in stand pipes with level switches which provide alarms in the main control room. High water level in a leak detection line generates an alarm in the main control room. An alarm will also be generated if, after the high water level is reached, the pump operates for longer than a predetermined time span.

Visual and Audible Inspection

Accessible areas are inspected periodically and the flow indicators previously discussed are monitored regularly. Any instrument indication of abnormal leakage is investigated.

Differential Flow Measurement (RWCU System Only)

Because of its arrangement, the RWCU system uses the differential flow measurement method to detect leakage. The flow into the cleanup system is compared with the flow from the system. An alarm in the main control room and an RWCU system isolation signal are initiated when high differential flow occurs between flow into the system and flow from the system which indicates that a leak equal to the established leak rate limit may exist. Flow elements are installed on the RWCU system inlet and on the outlets to the feedwater system and the main condenser/liquid radwaste connection.

Main Steam Line Area Temperature Monitors and RCIC Piping Routing Area Temperature Monitors

High temperatures in the main steam line tunnel area and
RCIC pipe routing areas are detected by dual-element thermo-
couples. Some of the dual-element thermocouples are used
for measuring ambient temperatures and are located in the
area of the main steam and RCIC steam lines. The remaining
dual elements are used in pairs to provide measurement of
differential temperature across (inlet to outlet) the tunnel
area. All temperature elements are located or shielded so 23
as to be sensitive to air temperatures and not to the
radiated heat from hot equipment. One thermocouple of each
differential temperature pair is located so as to be
unaffected by pipe routing or tunnel temperature. High
ambient or high differential temperature (main steam tunnel 23
only) causes alarms in the main control room and provides
signals to close the main steam and drain line isolation
valves. High ambient temperature in the RCIC pipe routing 23
areas will alarm in the main control room and provide
signals to close the RCIC steam line isolation valves. A
high main steam tunnel temperature or differential
temperature alarm may also indicate leakage in the reactor
feedwater line which passes through the main steam tunnel.
Twelve monitors in the space between the steam tunnel outlet 23
and the high pressure turbine inlet measure ambient
temperature and trip the MSIVs on a high temperature signal.

Temperature Monitors in Equipment Areas

Dual-element thermocouples are installed in the equipment
areas and near the inlet and outlet ventilation ducts to the
RCIC, RHR, and RWCU system equipment rooms for sensing high
ambient temperature. These elements are located or shielded 23
so they are sensitive to air temperature only and not to
radiated heat from hot equipment. High ambient temperature 23
is alarmed in the main control room and provides trip
signals for closure of isolation valves of the respective
system in the monitored area.

Reactor Building Temperature Monitors

High temperature in the pipe chase areas is detected by
dual-element thermocouples. The thermocouples are used for
measuring ambient temperature in the vicinity of the RCIC,
RWCU, and RHR lines. All temperature elements are located 23
or shielded so as to be sensitive to air temperature and not
to radiated heat. High ambient temperature will alarm in
the main control room and provide signals to isolate the
RCIC steam line, RWCU, and the RHR shutdown cooling path.

23 High temperature in the reactor building general areas is detected by temperature switches located on the building elevations where the RHR shutdown cooling piping is routed. High ambient temperature in the reactor building will alarm in the main control room and provide signals to isolate the RCIC steam line and the RHR shutdown cooling path.

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Intersystem Leakage Monitoring

In addition to the intersystem leakage instrumentation and monitoring discussed in this section and Section 5.2.5.2.1, refer to Section 11.5 for a discussion of the process radiation monitors used to detect leakage into the secondary sides of the RHR heat exchangers and the RWCU nonregenerative heat exchanger.

Monitoring Large Leaks External to the Primary Containment

10 The main steam high flow, RCIC/RHR steam high flow, and reactor vessel low water level monitoring discussed in Section 5.2.5.2.1 can also indicate large leaks from the reactor coolant piping external to the primary containment.

5.2.5.2.3 Summary

Tables 5.2-9 and 5.2-10 summarize the actions taken by each leakage detection function. The tables show that those systems which detect gross leakage initiate immediate automatic isolation. The systems that are capable of detecting small leaks initiate an alarm in the main control room. The operator can manually isolate a leaking system or take other appropriate action. A time delay is provided for the RWCU system differential flow to prevent normal system surges from isolating the system.

The LDS is a multi-dimensional system that is redundantly designed so that failure of any single element does not interfere with a required detection of leakage or isolation. In the four-division portion of the leak detection and isolation system, applied where inadvertent isolation could impair plant performance (e.g., MSIVs), any single channel or divisional component malfunction will not cause a false indication of leakage or false isolation trip because it will only trip one of four channels and two channels are required to trip for closure of MSIVs. It thus combines a very high probability of operating when needed with a very low probability of operating falsely. The system is testable during plant operation.

5.2.5.3 Indication in Main Control Room

Leak detection methods are discussed in Section 5.2.5.1. Instrumentation and controls for the LDS are in Section 7.6.1.3.

5.2.5.4 Limits for Reactor Coolant Leakage

5.2.5.4.1 Total Leakage Rate

The total leakage rate consists of all leakage, identified and unidentified, that flows to the drywell floor drain and equipment drain tanks. The total leakage rate limit, established at 30 gpm, is well within the makeup capability of the RCIC system.

The drywell equipment and the drywell floor drain tanks, that collect all leakage, are each pumped to the radwaste system by two 50-gpm pumps. Each pump normally alternates between lead and backup.

5.2.5.4.2 Identified Leakage Inside the Primary Containment

The recirculation pump seals and other seals (e.g., reactor head) in systems that are part of the RCPB and from which normal design-identified source leakage can be expected are provided with leakoff drains. Recirculation pumps are equipped with double seals. Leakage from the primary recirculation pump seals is monitored for flow in the drain line and piped to the equipment drain tank (Section 5.4.1.3). Leakage from the main steam line SRVs discharging to the suppression pool is monitored by temperature sensors that transmit signals to the main control room. Any temperature increase above the ambient temperature detected by these sensors indicates valve leakage.

5.2.5.5 Unidentified Leakage Inside the Primary Containment

5.2.5.5.1 Unidentified Leakage Rate

The unidentified leakage rate is the portion of the total leakage rate received in the primary containment tanks that is not identified as previously described. No significant compromise to the nuclear system process barrier exists if the barrier contains a crack that is less than the critical crack length. Even so, the unidentified leakage rate limit is kept low because of the possibility that most of the unidentified leakage rate might be emitted from a single crack in the nuclear system process barrier.

An allowance for leakage that does not compormise barrier integrity and is not identifiable is made for normal plant operation.

The total unidentified leakage rate limit is established at 5 gpm to allow time for corrective action before the process

barrier could be significantly compromised. This 5 gpm unidentified leakage rate is a small fraction of the calculated flow from a critical crack in a primary system pipe (Figure 5.2-8). Safety limits and safety limit settings are discussed in Chapter 16.

5.2.5.5.2 Sensitivity and Response Time

The sensitivity, including sensitivity tests, and response time of the LDS, is discussed in Section 7.6.1.2.

5.2.5.5.3 Length of Through-Wall Flaw

Experiments conducted by GE and Battelle Memorial Institute (BMI) permit an analysis of critical crack size and crack opening displacement[3]. This analysis relates to axially oriented through-wall cracks.

Critical Crack Length

Satisfactory empirical expressions to predict critical crack length have been developed to fit test results. A simple equation which fits the data in the range of normal design stresses (for carbon steel pipe) is:

$$L_c = \frac{15,000\ D}{\sigma_h} \qquad (5.2\text{-}1)$$

Where:

L_c = Critical crack length, in

D = Mean pipe diameter, in

σ_h = Nominal hoop stress, psi

See data correlation on Figure 5.2-9.

Crack Opening Displacement

The theory of elasticity predicts a crack opening displacement of:

$$\omega = \frac{2L\sigma}{E} \qquad (5.2\text{-}2)$$

Where:

L = Crack length, in

σ = Applied nominal stress, psi

E = Young's modulus

Measurements of crack opening displacement made by BMI show that local yielding greatly increases the crack opening displacement as the applied stress σ approaches the failure stress σ_f. A suitable correction factor for plasticity effects is:

$$C = \sec\left(\frac{\pi}{2}\ \frac{\sigma}{\sigma_f}\right) \tag{5.2-3}$$

The crack opening area is given by:

$$A = C\ \frac{\pi}{4}\ \omega L = \frac{\pi L^2 \sigma}{2E}\ \sec\left(\frac{\pi}{2}\ \frac{\sigma}{\sigma_f}\right) \tag{5.2-4}$$

For a given crack length $L, \sigma_f = 15{,}000\ D/L$.

Leakage Flow Rate

The maximum flow rate for blowdown of saturated water at 1,000 psi is 55 lb/sec-sq in, and for saturated steam the rate is 14.6 lb/sec-sq in[4]. Friction in the flow passage reduces this rate, but for cracks leaking at 5 gpm (0.7 lb/sec) the effect of friction is small. The required leak size for 5 gpm flow is:

A = 0.0126 sq in (saturated water)

A = 0.0475 sq in (saturated steam)

From this mathematical model, the critical crack length and the 5 gpm crack length have been calculated for representative BWR pipe size (Schedule 80) and pressure (1,050 psi).

The lengths of through-wall cracks that would leak at the rate of 5 gpm given as a function of wall thickness and nominal pipe size are:

Nominal Pipe Size (Sch 80) (in)	Average Wall Thickness (in)	Crack Length L (in)	
		Steam Line	Water Line
4	0.337	7.2	4.9
12	0.687	8.5	4.8
24	1.218	8.6	4.6

The ratios of crack length, L, to the critical crack length, L_C as a function of nominal pipe size are:

Nominal Pipe Size (Sch 80) (in)	Ratio L/L_C	
	Steam Line	Water line
4	0.745	0.510
12	0.432	0.243
24	0.247	0.132

It is important to recognize that the failure of ductile piping with a long, through-wall crack is characterized by large crack opening displacements that precede unstable rupture. Judging from observed crack behavior in the GE and BMI experimental programs involving both circumferential and axial cracks, it is estimated that leak rates of hundreds of gpm precede crack instability. Measured crack opening displacements for the BMI experiments were in the range of 0.1 to 0.2 in at the time of incipient rupture, corresponding to leaks of the order of 1 sq inch in size for plain carbon steel piping. For austenitic stainless steel piping, even larger leaks are expected to precede crack instability, although there are insufficient data to permit quantitative prediction.

The results given are for a longitudinally oriented flaw at normal operating hoop stress. A circumferentially oriented flaw could be subjected to stress as high as the 550°F yield stress, assuming high thermal expansion stresses exist. It is assumed that the longitudinal crack, subject to a stress as high as 30,000 psi, constitutes a worst case with regard to leak rate versus critical size relationships. Given the same stress level, differences between the circumferential and longitudinal orientations are not expected to be significant in this comparison.

Figure 5.2-8 shows general relationships between crack length, leak rate, stress, and line size, using the mathematical model described previously. The asterisks denote conditions for which the crack opening displacement

is 0.1 in, at which time instability is imminent as noted previously under Leakage Flow Rate. This provides a realistic estimate of the leak rate to be expected from a crack of critical size. In every case, the leak rate from a crack of critical size is significantly greater than the 5-gpm criterion. If either the total or unidentified leak rate limits are exceeded, an orderly shutdown can be initiated and the reactor can be placed in a cold shutdown condition within 24 hr.

5.2.5.5.4 Margins of Safety

The margins of safety for a detectable flaw to reach critical size are discussed in Section 5.2.5.5.3. Figure 5.2-8 shows general relationships between crack length, leak rate, stress, and line size using the mathematical model.

5.2.5.5.5 Criteria to Evaluate the Adequacy and Margin of the Leak Detection System

For process lines that are normally open, there are at least two different methods of detecting abnormal leakage from each system within the nuclear system process barrier located in the primary containment and reactor building bays as shown in Tables 5.2-9 and 5.2-10. The instrumentation is designed so it can be set to provide alarms at established leakage rate limits and isolate the affected system, if necessary. The alarm points are determined analytically or based on measurements of appropriate parameters made during startup and preoperational tests.

The unidentified leakage rate limit is based, with an adequate margin for contingencies, on the crack size large enough to propagate rapidly. The established limit is sufficiently low that, even if the entire unidentified leakage rate were coming from a single crack in the nuclear system process barrier, corrective action could be taken before the integrity of the barrier would be threatened. The LDS can satisfactorily detect unidentified leakage of 5 gpm.

5.2.5.6 Differentiation Between Identified and Unidentified Leaks

Section 5.2.5.1 describes the systems that are monitored by the LDS. The ability of the LDS to differentiate between identified and unidentified leakage is discussed in Sections 5.2.5.4, 5.2.5.5, and 7.6.1.3.

5.2.5.7 Safety Interfaces

The balance-of-plant to GE nuclear steam supply system (NSSS) safety interfaces for the LDS are the signals from the monitored balance-of-plant equipment and systems that are part of the nuclear system process barrier, and associated wiring and cable lying outside the NSSS equipment.

5.2.5.8 Testing and Calibration

Provisions for preoperational testing of the LDS are covered in Chapter 14. Calibration is discussed in Chapter 16.

5.2.5.9 Regulatory Guide Compliance

The detection of leakage through the reactor coolant pressure boundary, described in the preceeding sections, meets the intent of Regulatory Guide 1.45. Details of compliance are discussed in the following paragraphs.

Leakage is separated into identified and unidentified categories and each is independently monitored, thus meeting position c.1 of Regulatory Guide 1.45.

Leakage from unidentified sources inside the primary containment is collected into the floor drain tank and monitored with an accuracy better than 1 gpm in 1 hour, thus meeting position c.2.

By monitoring 1) floor and equipment drain tank fillup and pumpout rates, 2) airborne particulates, and 3) airborne gaseous radiation rate, position c.3 is satisfied. The containment atmosphere temperature and pressure monitors are tertiary methods used to detect gross leakage. Isolation and/or alarm of affected systems and the detection methods used are summarized in Tables 5.2-9 and 5.2-10.

Radiation monitoring of cooling water from the RHR heat exchangers and RWCU nonregenerative heat exchangers satisfies position c.4. For system detail see Section 11.5.

The floor drain tank monitoring system is designed to detect leakage rates of 1 gpm within 1 hour, thus meeting the intent of position c.5. However, due to the uncertainties described in Section 5.2.5.2.1, the airborne particulate and airborne gaseous radiation monitoring systems are not designed to detect leakage rates of 1 gpm within 1 hour.

All leakage detection systems are designed to be capable of performing their functions following seismic events that do not require plant shutdown (OBE). Seismic qualification (SSE) is performed only for safety-related portions and for the primary containment radiation monitoring system. Thus, position c.6 is met. It must be noted, however, that administrative procedures can be utilized to verify operability following a seismic event if required.

Leakage detection indicators and alarms for the drain tanks, the airborne particulate and airborne gaseous radiation monitoring systems are provided in the main control room. This satisfies position c.7 of this guide. Procedures for converting the various indications to a common leakage equivalent for the operators, to satisfy the intent of position c.7, are not necessary since the floor drain tank level flow rate indication is expressed as gpm. There is no attempt to correlate radioactivity monitoring indication to leakage flow rate due to the uncertainties involved.

Leak detection complies with IEEE 338. All active components associated with isolation signals can be tested during plant operation. Indication is provided in the main control room that a logic channel is tripped.

The leakage detection systems are equipped with provisions to permit testing for operability and calibration during the plant operation using the following methods:

1. Simulation of signals.

2. Comparing channel A to channel B of the same leak detection method (i.e., area temperature monitoring).

3. Operability checked by comparing one method versus another (i.e., tank fillup versus pumpout).

4. Continuous monitoring of floor drain tank level is provided.

These satisfy position c.8.

Plant Technical specifications comply with position c.9 by specifying limiting conditions for identified and unidentified leakage and by addressing the availability of various types of instruments to assure adequate coverage.

Regulatory Guide 1.22 Assessment

The proper operation of the LDS sensors and logic is verified during the preoperational tests and during plant operation. Each temperature switch (both ambient and differential types) that provides isolation signals is connected to one element of a dual thermocouple. A light illuminates when the temperature exceeds the set point. Verification of the thermocouple input is accomplished by comparing the reading from the trip channel with the recorder channel which is connected to the other element of the dual thermocouple. The trip logics are tested by applying a simulated trip signal from an external source to

the LDS channel. Keylock test switches are used to prevent the isolation signal from performing its isolating function.

TABLE 5.2-8

The information on this page has been deleted.

Process Gaseous Monitors (DRMS)

1. Standby Gas Treatment Discharge Monitor

An offline gaseous monitor is installed on the discharge of the SGTS which isolates the normal containment purge system on a high radiation alarm.

2. Drywell Atmosphere Monitors

Redundant offline gas and particulate monitors are provided to monitor drywell airborne activity levels and detect RCPB leakage as intended by Regulatory Guide 1.45 requirements. The two drywell monitors pull samples through sampling trees located in the drywell and return the samples to the drywell. The sampling trees provide representative samples of drywell air by extracting samples from various elevations.

3. Off-gas Pretreatment Monitors

The off-gas process flow upstream of the charcoal adsorbers is monitored by offline gaseous monitors equipped with iodine and particulate sampling capabilities. The off-gas pretreatment monitors isolate the off-gas effluent upon receipt of a high radiation signal.

4. Turbine Building Ventilation

A connection tap is provided in the system exhaust ductwork for a CAM.

5. Radwaste Building Area Exhaust and Tank Vent Exhaust Monitors

A connection tap for a CAM is provided in the exhaust ductwork of each of the above ventilation subsystems upstream of the filtration units.

Process Liquid Monitors (DRMS)

The following process streams are monitored by offline liquid monitors for detection of radiation levels:

1. Spent fuel pool cooling and cleanup (SFC) system pumps discharge.

2. Turbine building closed loop cooling water.

3. Reactor building closed loop cooling water.

TABLE 11.5-1

PROCESS AND EFFLUENT RADIATION MONITORING SYSTEMS

Monitor Location	Monitor Type	Range[4]	Isotope	Trip/High Set Point	Function
Monitors Required for Safety					
Reactor building ventilation above and below refueling floor (2HVR*CAB14A,B; 2HVR*CAB32A,B)	Offline gaseous	10^{-7} to 10^{-1} uCi/cc	Xe-133, Kr-85	Tech. Spec.	Monitors radiation levels in the reactor building ventilation system. Isolates reactor building[5]
Main control room intake (2HVC*CAB18A,B,C,D)	Offline gaseous	10^{-7} to 10^{-1} uCi/cc	Xe-133, Kr-85	Tech. Spec.	Monitors incoming control room air; activates Category I HEPA/Charcoal Filters[5]
RHR heat exchanger service water[2] (2SWP*CAB23A,B)	Offline liquid	10^{-7} to 10^{-1} uCi/cc	Cs-137	$\leq 3.0 \times 10^{-4}$ uCi/cc	Monitors service water effluent from heat exchangers for contamination[4]
Main steam line [3] (2MSS*CAB46A,B,C,D)	Online steam	$1\text{-}10^{6}$ mr/hr	N-16	Tech. Spec.	Monitors main steam lines for fuel damage and carry over to turbine building; scrams reactor and isolates steam lines[5]
Monitors Required for Plant Operation					
Drywell and containment atmosphere[1] (2CMS*CAB10A,B)	Offline gaseous Particulate	10^{-7} to 10^{-1} uCi/cc 10^{-11} to 10^{-5} uCi/cc	Xe-133, Kr-85 I-131	5 to 10 times background	Monitors drywell for qualitative indication of abnormal RCPB leakage
Service water system discharge monitors (2SWP*CAB146A,B)	Offline liquid	10^{-7} to 10^{-1} uCi/cc	Cs-137	ODCM	Monitors service water system discharge[5]
Radwaste/reactor building vent[2] (2RMS-CAB180)	Offline isotopic	10^{-6} to 10^{4} uCi/cc 10^{-11} to 10^{2} uCi/cc 10^{-11} to 10^{2} uCi/cc	Xe-133, Kr-85 I-131, particulates	ODCM NA NA	Monitors reactor and radwaste building ventilation effluent releases for RG 1.21 report generation[5]
Main stack exhaust[2] (2RMS-CAB170)	Online isotopic	10^{-6} to 10^{5} uCi/cc 10^{-11} to 10^{2} uCi/cc 10^{-11} to 10^{2} uCi/cc	Xe-133, Kr-85 I-131, particulates	ODCM NA NA	Monitors isotopic content of effluent releases for RG 1.21 report generation[5]

of radioactive releases expected and the location being monitored. The guidance of ANSI N13.1 and Regulatory Guide 1.21 is followed for the airborne radioactivity monitoring system design.

In the case of the drywell radioactivity monitoring system, which is used to detect leakage from the reactor coolant pressure boundary (RCPB), the intent of Regulatory Guide 1.45 is followed.

The primary design criteria for the safety-related inplant airborne radioactivity monitoring systems are to:

1. Withstand the effect of natural phenomena (e.g., earthquakes) without the loss of capability to perform their functions.

2. Perform their intended safety functions under normal, abnormal, and postulated accident conditions (Section 3.11).

3. Meet the reliability, testability, independence, and failure mode requirements of engineered safety features.

4. Provide continuous display on main control room panel.

5. Permit the checking of the operational availability of each channel during reactor operation with provision for calibration function and instrument checks.

6. Assure an extremely high probability of accomplishing their safety functions in the event of anticipated operational occurrences.

Additional criteria are found in Section 11.5.1.2.

The primary design criteria for the nonsafety-related inplant airborne radioactivity monitoring systems are to:

1. Provide continuous data output in the main control room of radiation levels in selected building exhaust systems.

2. Permit checking the operational availability of each channel during reactor operation with provision for calibration function and instrument checks.

3. Perform their intended functions under normal operating conditions for the design life of the plant.

Additional criteria are found in Section 11.5.1.2.

12.3.4.2.2 Criteria for Airborne Radioactivity Monitor Locations

The following criteria for locating airborne radioactivity monitors are dependent upon the point of leakage, the ability to identify the source of radioactivity so that corrective action may be performed, and the possibility for exposing personnel to airborne radioactivity:

1. Airborne radioactivity monitors sample the drywell atmosphere for reactor pressure boundary leak detection.

2. The outside air intake ducts for the main control room area are monitored to measure the possible introduction of radioactive materials into the main control room to ensure habitability of those areas requiring personnel occupancy for safe shutdown.

3. Exhaust ducts servicing an area containing processes which, in the event of a major leakage, could result in concentrations within the plant approaching the limits established by 10CFR20 for plant workers are monitored.

Monitor sensitivity criteria are noted in Section 12.3.4.2.5.

Airborne process and effluent radiation monitor locations and functions are summarized in Table 12.3-2. ANSI N13.1 was used as a guide in locating monitors and sample points. Monitor locations are shown on the shielding arrangement and facilities drawings, Figures 12.3-1 through 12.3-33.

12.3.4.2.3 System Description (Airborne Radioactivity Monitors)

Monitors Required for Safety

Drywell Atmosphere Monitoring The drywell atmosphere radiation monitors are designed for early RCPB leak detection as intended by Regulatory Guide 1.45.

Redundant offline gas and particulate monitors located in the reactor building are dedicated to sampling the drywell