4.3 LEAK DETECTION SYSTEM

4.3.1 DESIGN BASIS

Three methods are provided to alert the operator of the presence of leakage from the RCS in a timely manner. The timed response allows detection and isolation of the leak to ensure the radiation emitted as result of the leak does not exceed acceptable limits. The systems which comprise the leakage detection system are, the containment sump level alarm system, a containment atmosphere particulate radioactivity monitoring system, and a containment atmosphere gaseous radioactivity monitoring system. In determining the acceptability of this leakage detection system, the system was compared to the guidance given in Regulatory Guide 1.45 (May 1973). The system, as described below, meets the intent of the guidance provided by Regulatory Guide 1.45. However, it must be noted that the three systems which comprise the leakage detection system are not equally sensitive to RCS leakage. The Regulatory Guide addresses the fact that when there is little radioactivity in the RCS, the radiation monitors are less effective in determining leaks. The design basis for the gaseous and particulate monitors is based on an assumption of 1% failed fuel and the resultant activity level in the RCS. As shown below, the time to detect a small leak varies with the RCS radioactivity concentration. Given the low concentration of radionuclides in the RCS during a normal operating cycle, it is unlikely that the radiation monitors would detect small leaks. Under normal operating conditions, there are two other diverse systems that can detect leaks in the RCS: the containment sump level alarm system and the performance of a water inventory balance.

During normal operations, a reactor coolant inventory analysis (commonly called a water balance inventory) is performed at least every 72 hours as required by Technical Specifications. This analysis uses changes in pressurizer level, changes in volume control tank level, changes in RCS average temperature and RCS makeup as inputs.

There is no practical analytical method available by which a leak rate can be correlated to crack size. In addition, due to the magnitude of more probable RCS leakage sources (i.e., packing and seals), RCS leakage is not relied upon for assurance of RCS integrity. Assurance of RCS integrity is warranted by the conservatism of the design and the operating restrictions that limit loadings on the RCS components. Periodic in-service inspections will, in addition, verify the integrity of the RCS boundary and ensure that degradation of the boundary has not occurred.

4.3.2 SYSTEM DESCRIPTION

The leakage detection system consists of three diverse systems, the containment sump level alarm system, a containment atmosphere particulate radioactivity monitoring system, and a containment atmosphere gaseous radioactivity monitoring system.

The containment normal sump level detection and alarm system consists of instrumentation that senses and indicates sump level, and provides an alarm. A sensor in the sump sends a signal to the level indicator/alarm in the Control Room. Should sump level exceed a predetermined value, the indicator/alarm provides an alarm to alert operators of the condition. The water collected in the sump is then processed by the Miscellaneous Waste Processing System.

The Containment Atmosphere Particulate and Gaseous Radioactivity Monitors consist of off-line detectors, sample pumps, pump controls and signal conditioning, recording, indication and alarm functions. The off-line sample pumps take suction from the containment ventilation system - this provides a representative sample of the containment atmosphere - and deliver the sample to the monitors. The particulate monitor is a fixed filter, scintillation type detector. The filter is removed periodically and analyzed for identification of any radioactive isotopes captured by the filter. The detector continuously

monitors the radiation level of the filter and provides a signal which is conditioned so it can be read by the indicating and recording electronics in the Control Room. The signal is sent to the recorders for trending purposes. Should the samples collected by the filter exceed predetermined limits, the radiation monitoring electronics also provide an alarm to alert operators of the condition. After the particulates are collected by the filters, the cleaned atmosphere sample is sent to the scintillation detector gaseous monitor where the radiation level is continuously monitored. The signal from the gaseous monitor is processed in a manner similar to the particulate monitor described above.

During plant operation, Technical Specification periodic surveillance of the leakage detection system are performed.

4.3.3 DESIGN ANALYSIS

The response of the containment sump level alarm is highly variable depending upon the location of the leak, how much vapor condenses and where it condenses. If the leaking vapor condenses on the containment air coolers, the water will drain by gravity to the containment normal sump. If leaking water condenses in other locations and drains to the normal sump, a total amount of approximately 49 gallons will cause a sump level alarm.

The sensitivity of the containment gaseous monitor is at least 3×10^{-6} μCi/cc for Xe-133. The response time of this monitor will vary greatly with radiation level in the RCS, the location of the leak, and whether the leakage occurs from a line coming from the RCS or one returning to the RCS from the CVCS. As discussed before, when there is little radioactivity in the RCS, the radiation monitors are much less effective is detecting leaks. The values given in the table below represent the time required to detect a leak with the gaseous radiation monitor. The time provided in this table represents the time needed to leak a sufficient amount of reactor coolant at 0.1 gpm, the time required to obtain sufficient mixing of the Xe-133 in the containment atmosphere, and the time required to obtain 3×10^{-6} μCi/cc of Xe-133 in the portion of the containment volume directly affected by the containment ventilation system.

Time in Minutes	Percent Failed Fuel
61.1	1.0
75.1	0.1
208.6	0.01
1743.0	0.001

The minimum setting for the level of radioactivity the Containment Atmosphere Particulate Monitor can detect is based on background radiation and operating experience. Operating experience is a factor because there are many assumptions (e.g., particulate size, distribution, transport, and deposition) that must be made in order to quantify a setpoint. Since the setpoint is a variable factor, the monitor is only able to provide operators with the ability to observe and trend leaks of radioactivity inside containment. With no fuel leakage present, the alarm for the Containment Atmosphere Particulate Monitor is set as low as possible and still avoid nuisance alarms caused by varying background levels.

4.3.4 IDENTIFIED VERSUS UNIDENTIFIED LEAKAGE

In accordance with Regulatory Guide 1.45, it is important to differentiate between identified and unidentified leakage from the RCS. This permits the development and acceptance of leakage detection systems that can detect leakage for these different conditions. The discussion below addresses the basis for identified and unidentified leakage as it impacts the Technical Specification limits and the capabilities of the leakage detection systems within the confines of Regulatory Guide 1.45.

The maximum allowable leak rate for the RCS is defined in Technical Specifications as 1 gpm for unidentified leakage and 10 gpm for identified leakage. The basis for the 1 gpm leak rate is that this rate can be readily detected and that appropriate action can be taken well prior to the time it constitutes a public hazard. The basis for the 10 gpm leak rate is that it is well within the 44 gpm capacity of one charging pump. Therefore, the leakage rate is based on the ability of one charging pump to replace reactor coolant leakage and still maintain a reasonable margin to the 10 gpm allowed limit such that repairs may be made without the necessity for shutdown.

The consensus of opinion by operating plants is that there would normally be some minimum quantity of unidentifiable RCS leakage. Significantly greater leakage than this reported minimum would be considered abnormal and would require an immediate search for its source. After a source of leakage is identified, it would be eliminated as soon as repairs could be made. The normal total unidentified leakage for each Calvert Cliffs unit is approximately 0.4 gpm. The typical sources of leakage are valve stem packing, valve bonnet gaskets and other gasketed mechanical joints.

Instrumentation is provided in the Control Room to provide means to identify the general location of the leak. These objectives are accomplished by either or both of the following:

a. Leakage from the RCS to the containment may be indicated by: increased pressure and temperature in containment, increased airborne radioactivity, increased level in the containment sump, decreasing pressure and level in the pressurizer, increased make-up flow from the CVCS, increased level in the reactor coolant drain tank, or increased humidity in the containment.
b. Leakage from components in the RCS can also be identified for the following components: relief and safety valves, reactor vessel head closure seal, reactor coolant pump seals, steam generator tubes or tubesheet and miscellaneous RCS valve stem leakage.

4.3.5 OTHER CONSIDERATIONS

Other methods and instrumentation that may be used, but are not credited, as part of the leakage detection system are contained in this section.

Leaks from the RCS to the containment may be indicated by the following instrumentation channels in the Control Room:

Pressurizer pressure indication and alarm
Pressurizer level indication and alarm
Containment pressure indication
Containment temperature
Containment humidity indicators
Reactor coolant drain tank level indication
Reactor coolant make-up water flow integrators

The sensors and indicators discussed above are factory calibrated prior to shipping to the plant. Calibration (sensitivity) was rechecked at the site and was verified during start-up testing. During plant operation, periodic surveillance was conducted as described in the Technical Specifications.

Leakage from components in the RCS can be identified and located utilizing one or more of the following:

a. Relief and Safety Valves
    1. Increased temperature of piping downstream of the valves

2. Increased pressure in the quench tank
3. Increased temperature in the quench tank
4. Increased level in the quench tank
5. Increased level on the acoustic flow monitors

b. Reactor Vessel Head Closure Seal
   1. High pressure in the area between the double O-ring seal

c. Reactor Coolant Pump Seals
   1. Increased seal pressure
   2. Increased seal temperature
   3. Increased level in the containment sump
   4. Increased temperature of the component cooling water from the RCPs
   5. Increased level in component cooling head tanks
   6. Increased radiation monitor reading in component cooling water system
   7. Increased controlled bleed off flow

d. Steam Generator Tubes or Tube Sheet
   1. Increased activity indicated by the condenser off-gas radiation monitor
   2. Increased activity indicated by analysis of steam generator water samples
   3. Increased N-16 activity indicated by the main steam line N-16 radiation

e. Miscellaneous RCS Valve Stem Leakage
   1. Increased level in the reactor coolant drain tank

The response of the containment pressure, temperature, humidity and sump level instruments is highly variable, depending upon the location of the leak, how much water condenses and where it condenses. However, some estimates of sensitivity can be made.

a. If the leaking water all vaporizes and does not condense: A total amount of 106 gallons (1.06 gpm for 100 minutes, 10.6 gpm for 10 minutes, etc.) would have the following effects:
   1. Increase relative humidity by 10% which is noticeable on the humidity indicator.
   2. Result in no significant increase in containment temperature.
   3. Result in no significant increase in containment pressure.

b. If the leaking water condenses in the containment coolers: The water drains by gravity to the normal sump. Upon receipt of the alarm, the operator will open drain valves and the water will drain by gravity to the ECCS room sump.
c. If the leaking water condenses and drains to the normal sump: A total amount of approximately 49 gallons (0.49 gpm for 100 minutes, 4.9 gpm for 10 minutes, etc.) will cause a sump level alarm.
d. If the leaking water drains to the reactor coolant drain tank: the operator in the Control Room is made aware of this by an increasing level indication and eventually a high level alarm which requires the operator to operate the reactor coolant drain tank pump. Since normal and expected leakage, such as valve stem leakage, drains to this tank, an increase in leak rate would be detected as a change in frequency of pumping. A ten gallon per minute leak rate would result in approximately one additional pumping each 75 minutes, which will be noticeable by the operator, within one to two hours.

Pressurizer level sensitivity to leakage depends upon operating conditions. During steady state power operation leaks are indicated as follows:

a. Leak rate less than 11 gpm.

   Leakage in this range is not detectable using pressurizer level, as the level is maintained automatically by the charging pumps within 4.1" of programmed level.

b. Leak Rate 11-55 gpm.

   Leakage in this range is indicated by the first backup charging pump cycling on and off to maintain level between -4.1" and -9.3".
   Time response for a 33 gpm leak:
   5.57 minutes to start the first backup pump.

c. Leak rate 55-99 gpm.

   Leakage in this range is indicated by the second backup charging pump cycling on and off to maintain level between -6.5" and -13.5".
   Time response for a 77 gpm leak:
   2.02 minutes to start the first backup pump.
   4.84 minutes to start the second backup pump.

d. Leak rate greater than 99 gpm.

   Leakage in this range is indicated by all three charging pumps running while level continues to decrease, and a low level alarm.
   Time response for a 121 gpm leak:
   1.23 minutes to start the first backup pump.
   2.17 minutes to start the second backup pump.
   3.18 minutes to low level alarm.

Pressurizer pressure instrumentation will only respond to very large leaks.