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NUCLEAR ENERGY DIVISION

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APPLICATION CORE COOLING AND CONT.

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1. SCOPE

1.1 This specification defines and describes the basic requirements of the leak detection of a nuclear boiling water reactor plant.

1.2 This design specification is based upon no specific division of work assignment or responsibility between the General Electric Company and its customers or contractors. The division of work is specified elsewhere.

1.3 The instrumentation to be supplied by Others shall satisfy the functional design requirements contained herein while complying with all applicable regulations. Implicit equipment requirements specified are intended only as a guide and should not in any way restrict the design of instrumentation supplied by Others.

2. APPLICABLE DOCUMENTS

2.1 General

2.1.1 The latest issue of the following references form a part of this specification to the extent specified herein. General Electric Company documents are shown by title, Master Parts List (MPL) number, and/or document number.

2.2 General Electric Company Documents

2.2.1 Supporting Drawings

a. Leak Detection IED MPL# E31-1010
b. Nuclear Boiler P&ID MPL# B21/22-1010
c. Reactor Recirculation System P&ID MPL# B33/35-1010
d. Reactor Water Cleanup System P&ID MPL# G33-1010
e. Residual Heat Removal System P&ID MPL# E12-1010
f. Reactor Core Isolation Cooling System P&ID MPL# E51-1010
g. High Pressure Core Spray System P&ID MPL# E22-1010

2.2.2 Supporting Specifications

a. Electrical Equipment Separation for Safeguard System - MPL# A61/62-4340

3. DESCRIPTION

3.1 The nuclear boiler leak detection system consists of temperature, pressure, radiation level, and flow sensors with associated instrumentation and alarms. This system detects, annunciates, and isolates (in certain cases) leakages in the following systems:

a. Coolant System within the primary containment
b. Main Steam Lines
c. The Reactor Water Cleanup System (RWCU)
d. Residual Heat Removal System (RHR)
e. Reactor Core Isolation Cooling System (RCIC)
f. Feedwater

Isolation and/or alarm of affected systems and the methods used are summarized in Table 1.

3.2 Leaks are detected by utilizing the following techniques:

a. Sensing excess flow in the process piping systems
b. Sensing pressure and temperature changes in the primary containment
c. Monitoring temperatures in areas containing equipment and piping systems
d. Monitoring level in the drain sumps
e. Radiation monitoring in the drywell

3.2.1 Small leaks (5 gpm and less) are detected by temperature and pressure changes and drain pump activities.

3.2.2 In addition to methods described in Paragraph 3.2.1, large leaks are detected by changes in reactor water level and by the changes in the amount of flow in the process line.

4. REQUIREMENTS

4.1 General Criteria

4.1.1 The temperature detectors shall be located or shielded so that they are sensitive to air temperature and not to the radiated heat from the equipment. Divisionally separated detectors should be located so that, basically the same enviornmental conditions are monitored by a detector of each division.

4.1.2 The ventilation inlet/outlet temperature and ambient temperature of the equipment rooms for the systems listed in Paragraph 3.1 shall be used to initiate alarm and/or isolation logic. The temperature alarm setpoint can be established by calculating a heat balance for the normal room enviornment, and then introducing the heat release caused by an alarm limit leak. A controlled volume room is necessary for optimum operation of the temperature detection method.

4.1.2.1 Equipment room cooling capacity should be sufficient to cool only the normal heat release from the system piping and equipment. If normal or additional capacity is used, it must be controlled to prevent negating the leak detection capacity at alarm and isolation limits.

4.1.2.2 When equipment room coolers are used, the following additional leak detection equipment should be used:

a. Cooler condensate drain monitoring

b. Ambient temperature at cooler inlet air.

4.1.3 Leak detection instrumentation shall meet the design criteria listed in the BWR Equipment Environmental Interface Data - MPL# A62-4270.

4.1.4 The nuclear boiler leak detection system shall be designed to detect leaks of steam inside the primary containment at 1 gpm within a 1 hour period. An alarm shall be actuated at an unidentifiable leakage of no more than 5 gpm and at an identifiable leakage of no more than 25 gpm.

4.1.5 Components that are part of isolation system shall meet the design criteria listed in the electric equipment separation for safeguard system design specification.

4.2 Leak Detection Within the Primary Containment. Leaks within the primary containment shall be detected by:

a. Measuring pressure and temperature in the primary containment

b. Measuring the flow into the equipment drain and the floor drain sumps

c. Measuring the cooling water temperature to and from the primary containment atmosphere coolers

d. Measuring the reactor water level

e. Measuring the condensate flow from the primary containment atmosphere coolers

f. Measuring the fission products in the primary containment atmosphere

4.2.1 Primary Containment

4.2.1.1 Pressure measurement. The primary containment will be pressurized and maintained at a slightly positive pressure during reactor operation. The normal operating pressure is (.75 + 0.1 psig. The pressure may fluctuate as a result of barometric pressure changes and outleakages; however, a pressure rise above the preset valve will indicate leakage in the system.

4.2.1.2 Temperature measurements. A cooling system circulates the primary containment atmosphere through heat exchangers to maintain its design operating temperature of 135°F. An abnormal air temperature rise above 135°F will indicate a coolant and/or steam leakage. A temperature rise in the primary containment should be detected by monitoring; a) the primary containment temperature at various elevations, b) inlet and outlet air to the coolers, and c) the closed cooling water temperature increase between inlet and outlet to the coolers.

4.2.1.3 The condensate collected from the air coolers should be piped to the primary containment floor drain sump. The condensate flowrate shall be measured before the collection tank. High flowrate shall be annunciated in the main control room.

4.2.2 Primary containment drain sumps

4.2.2.1 Equipment and floor drain flow measurements. The floor drain sump instrumentation should be designed to have a sensitivity of detecting leakage of 1 gpm within a 1 hour period while the equipment drain sump should have a sensitivity of detecting steam leakage of 50 percent of anticipated background leakage. The sump outflow rate, in gpm, shall be indicated in the main control room. Leakage just below the license limit shall be annunicated. The alarm set point shall have an adjustable range of 0 to 25 gpm for equipment drain sump and 0 to 5 gpm for floor drain sump. The discharge lines to the radwaste system from both drain sumps shall be provided with sample points outside of the primary containment.

4.2.2.2 The equipment drain sump (EDS). The equipment drain sump collects only identified leakages. This sump shall receive condensate drainage from pump seal leak-off, reactor vessel head flange vent drain, valve packing leak-off, and other equipment. Background leakage will be determined during operational tests. Collection in excess of background leakage would be indicative of the reactor coolant leakage. The sump shall be equipped with a cooling means to prevent liquid flashing and reduce vaporization of its contents. The sump should have a cover which should be either sealed or curbed to prevent inflow drainage. The alarm set point shall have an adjustable range of 0 to 25 gpm.

4.2.2.3 The floor drain sump (FDS). The leak detection signal should be set to actuate an alarm before the unidentified leakage reaches 5 gpm. The alarm set point shall have an adjustable range of 0 to 5 gpm. This sump shall collect leakage from control rod drives, valve flange leakage, floor drains closed cooling water system, the primary containment cooling unit drains, and any other potential sources not already identified. Leakage from the closed cooling water system would be detected by changes in the closed cooling water system surge tank level. Background leakage should be observed during operational test and serve as the basis for set points.

4.2.3 Reactor Vessel Head Closure. The reactor vessel head closure is provided with double seals with a leak-off connection between seals that is piped to the equipment drain sump. Leakage through the first seal shall be detected by a pressure transducer and annunciated in the main control room.

4.2.4 Primary Recirculation Pump Seal. The leakage from the primary recirculation pump seal shall be piped to the equipment drain sump and instrumented as shown in the reference of Paragraph 2.2.1, Item c.

4.2.5 Safety/Relief Valves. Temperature sensors, connected to a multipoint recorder shall be provided to detect safety/relief valve leakage during reactor operation. Safety/Relief Valve temperature elements shall be mounted, using a thermowell, in the valve discharge piping several feet from the valve body. Temperature rise above ambient shall be annunciated in the main control room. Instruments are shown in the reference of Paragraph 2.2.1, Item b.

4.2.6 Valve Packing Leakage. The valve inner packing leakage should be piped to the equipment drain sump. As a minimum requirement, it is recommended that each line be equipped with a method for visual inspection during hydrotests. The valve seal leakoff applies to all power operated valves (larger than 2 inch) located inside the drywell for the following systems: Nuclear boiler, reactor water cleanup, core spray, RCIC, RHR, and feedwater. High temperature at the leak-off line should be annunciated in the main control room.

4.2.7 Leakage of steam or reactor water inside the primary containment should also be detected by using radioisotopic techniques.* A continuous air sampling system should be provided for gross counting of particulates, Iodines and Noble Gases. The counts shall be recorded in the main control room and actuate an alarm on high activities.

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* Through correlation of process fluid radioactivity via the grub sample analysis method, traceable concentrations of isotopes can be established. The airborne traceable concentrations can then be related to a corresponding leakage rate of process fluid within the drywell volume.

4.3 Leak Detection External to Primary Containment

4.3.1 Reactor coolant leakage outside the primary containment shall be detected using a combination of the following:

a. Reactor building sump monitoring, and

b. Equipment areas and steam pipe routing area temperature monitoring.

c. High flow (RHR, RCIC)

d. High Δ flow (RWCU)

4.3.2 A sump system shall be provided in the reactor building to collect drains from the equipment areas. The sump monitoring instrumentation shall be provided to measure leakage. The signal (alarm) setting should indicate a leakage of 5 gpm.

4.3.2.1 Floor Drain Sump. Each equipment area (RHR, HPCS, RCIC, and MSL tunnel), should be equipped with a sump monitoring system capable of detecting coolant leakage in that area. A leakage of 5 gpm shall be annunciated in the main control room.

4.3.2.2 Equipment Drain Sump. Equipment drain sump shall be provided to collect drainage from various equipment. Drain connection shall be instrumented to identify leakage sources.

4.3.3 In addition to the differential temperature measurement in the areas listed below, temperature elements shall be provided to indicate room ambient temperature. These temperature elements are to measure temperature rise due to reactor coolant leakage. High temperature shall be annunciated in the main control room. Areas to be monitored are:

a. Main steam line tunnel,

b. Pipe area between tunnel exit and turbine,

c. RHR,

d. Reactor water cleanup,

e. RCIC equipment area & RCIC steam piping routing.

4.3.3.1 Main steam line. Leaks in the main steam line shall be detected using any one or a combination of the following methods:

a. Low water level in the reactor vessel,

b. High flow rate at the flow limiter, and

c. High temperature and high temperature difference in the main steam line tunnel.

(1) Reactor Water Level. The loss of water in the reactor vessel as the result of a major leak in any major system is monitored at the reactor water level using the same signals that actuate alarms on low reactor water level and close selected primary system isolation valves and initiate: Core Standby Cooling System. A summary of reactor vessel level instrumentation and set points is referenced in Paragraph 2.2.1, Item b.

(2) Steam Line High Flow. Each main steam flow limiter shall contain four differential pressure transducers which give a coincidence signal for main steam line isolation at 140 percent of the effected line rated flow.

(3) Temperature Sensors. The ambient temperature around the main steam lines and the steam tunnel temperature difference shall be measured by locating temperature sensors at the inlet and outlet of the steam tunnel in accessible locations for testing and calibration during normal operation. High ambient and high differential temperatures shall be annunciated in the main control room. The alarm set point shall correspond to 5 gpm steam leakage. The Isolation set point shall correspond to 25 gpm steam leakage.

4.3.3.1.1 The area around the piping from the pipe tunnel exit to the turbine inlet should be monitored for steam leakage. This area may be divided into several ventilating zones and ambient temperature at each zone shall be measured. Temperature rise corresponding to steam leakage of 5 gpm in any zone shall be annunciated in the main control room and automatic isolation actuated at a temperature rise corresponding to 25 gpm steam leakage. A minimum of one temperature switch shall be provided per main steam isolation logic. Design and instrumentation of the leak detection system in the turbine building by the AE unless otherwise shown on the MPL.

4.3.3.2 Reactor Water Cleanup (RWCU) System and Residual Heat Removal (RHR) System. High temperature process flow of the reactor water cleanup system and RHR system external to the primary containment shall be detected by temperature sensing elements. Temperature sensors shall be located in the inlet and outlet ventilation ducts to measure temperature difference also, local temperature sensors shall be located in all compartments containing equipment and piping for these systems. Alarm in the main control room should be set to annunciate a temperature rise corresponding to a leakage of 5 gpm and the system isolated at 25 gpm.

4.3.3.2.1 Reactor Water Cleanup System Flow. Leakage in the cleanup system, in addition to temperature detection method, shall be detected by means of flow comparison between cleanup system inlet and outlet. If the inlet flow exceeds outlet flow by 20 percent, an alarm shall be actuated and the cleanup system shall be isolated automatically. A bypass timer shall be provided to override the isolation signal during surges. Instrumentation is shown in reference of Paragraph 2.2.1, Item a.

4.3.3.2.2 Leakage in the RHR system (shutdown cooling mode of operation) in addition to temperature detection method, shall be detected by a set of two differential pressure transducers sensing differential pressure across a flow restrictor or elbow. Flow in excess of specified limits shall be alarmed and the system automatically isolated.

4.3.3.3 RCIC Equipment Area. Leakage in this system shall be detected by temperature sensors which shall be located in the equipment area and its inlet and outlet ventilation ducts for measuring ambient and temperature difference rise in the event of steam leakage. High ambient or high temperature difference shall actuate an alarm and isolate the system automatically. Alarm should be actuated by a temperature rise corresponding to steam leakage of 5 gpm and automatically isolate the system on 25 gpm.

4.3.3.4 Leak Detection in the RCIC Steam Pipe Routing Area. Leaks in the RCIC steam pipe routing area shall be detected by means of temperature sensors. High ambient temperature and/or high differential (ΔT) temperature shall actuate an alarm and isolate the system automatically. Alarm should be actuated by a temperature rise corresponding to steam leakage of 5 gpm and automatically isolate on 25 gpm.

4.4 System Test

4.4.1 Periodic inspection, calibration, and testing shall be performed to verify that each component in the system is capable of performing its intended function, both individually and in conjunction with other components.

TABLE I

Summary of Isolation/Alarm of System Monitored and the Leak Detection Methods Used

Source of Leakage (2)	Location	High PC Temperature	PC Sump High Flow Rate	High/PC Air Cooler CCW .T Condensate Flow	Eq. Area High T&ΔT	Low Stm Line Pressure	RB Sump High Flow Rate	PC Pressure (High)	High Flow Rate (1)	RCIC Diaphragm Height Exhaust Line Pressure	RWCU ΔFlow (High)	Reactor Low Water Level	
RESULTING ACTION →		A	A	A	A/I	A/I	A	A	A/I	A/I	A/I	A/I	
Main Steam Line	PC	X	X	X		X		X	X			X	
	RB				X	X[3]	X		X			X	
RHR	PC	X	X	X		X		X				X	
	RB				X		X		X			X	
RCIC Steam	PC	X	X	X		X		X	X				
	RB				X		X		X	X			
RCIC Water (Check Valves)	PC		X										
	RB						X						
Cleanup Water (Check Valves on Inlet)	PC	X	X	X				X[1]			X	X	
	RB hot				X		X				X	X	
	RB cold						X				X	X	
Feedwater (Check Valves)	PC	X	X	X				X					
	RB				5		X						

NOTE:
1. Break downstream of flow element will isolate the system.
2. All systems within the drywell share a common base detection system which is designed to detect leakage at less than established limits.
3. In run mode only.
5. Alarm only (steam tunnel)

PC - Primary Containment
RB - Reactor Building
RWCU - Reactor Water Cleanup
CCW - Closed Cooling Water

A - Alarm
I - Isolation