Isolation Condenser Reliability Study

1 IC SYSTEM OPERATION AND DESCRIPTION

This analysis focused on the ability of the IC system to start and provide design-rated core cooling for its required mission time. The system description and boundaries, data collection, failure categorization, and limitations of the study are briefly described in this section.

The data used in this report are limited to the set of plants listed in Table 1. This analysis focused only on the isolation condenser's emergency core cooling system (ECCS) function to reduce reactor pressure and remove fission product decay heat. The containment isolation function of the system was not evaluated in this study.

The IC system is a standby high-pressure system that removes residual and decay heat from the reactor vessel in the event of a scram in which the reactor becomes isolated from the main condenser, or if any other high pressure condition exists. Also, at most plants, the IC system aids in reactor vessel depressurization in the event that either (depending on plant design) the feedwater coolant injection or high-pressure coolant injection system fails. Because of its role in emergency core cooling, the IC system is designated as an emergency core cooling system (ECCS). The IC system is a single-train system in three plants and dual-train system in the other two plants. Figure 1 provides a simplified single train IC system diagram. This configuration is typical of the single train plants and is effectively doubled for the dual-train plants. Four plants have a single dual-pass isolation condenser per train, while one plant (Nine Mile Pt. 1) has two single-pass isolation condensers per train.

Table 1. BWR plants with a dedicated IC system.

Plant name	Docket	Trains	Total number of IC condensers	Number of condensers per train	Condenser design	Time before make-up is required (min)
Dresden 2	237	1	1	1	Dual-pass	20
Dresden 3	249	1	1	1	Dual-pass	20
Millstone 1	245	1	1	1	Dual-pass	30
Nine Mile Pt. 1	220	2	4	2	Single-pass	90
Oyster Creek	219	2	2	1	Dual-pass	45

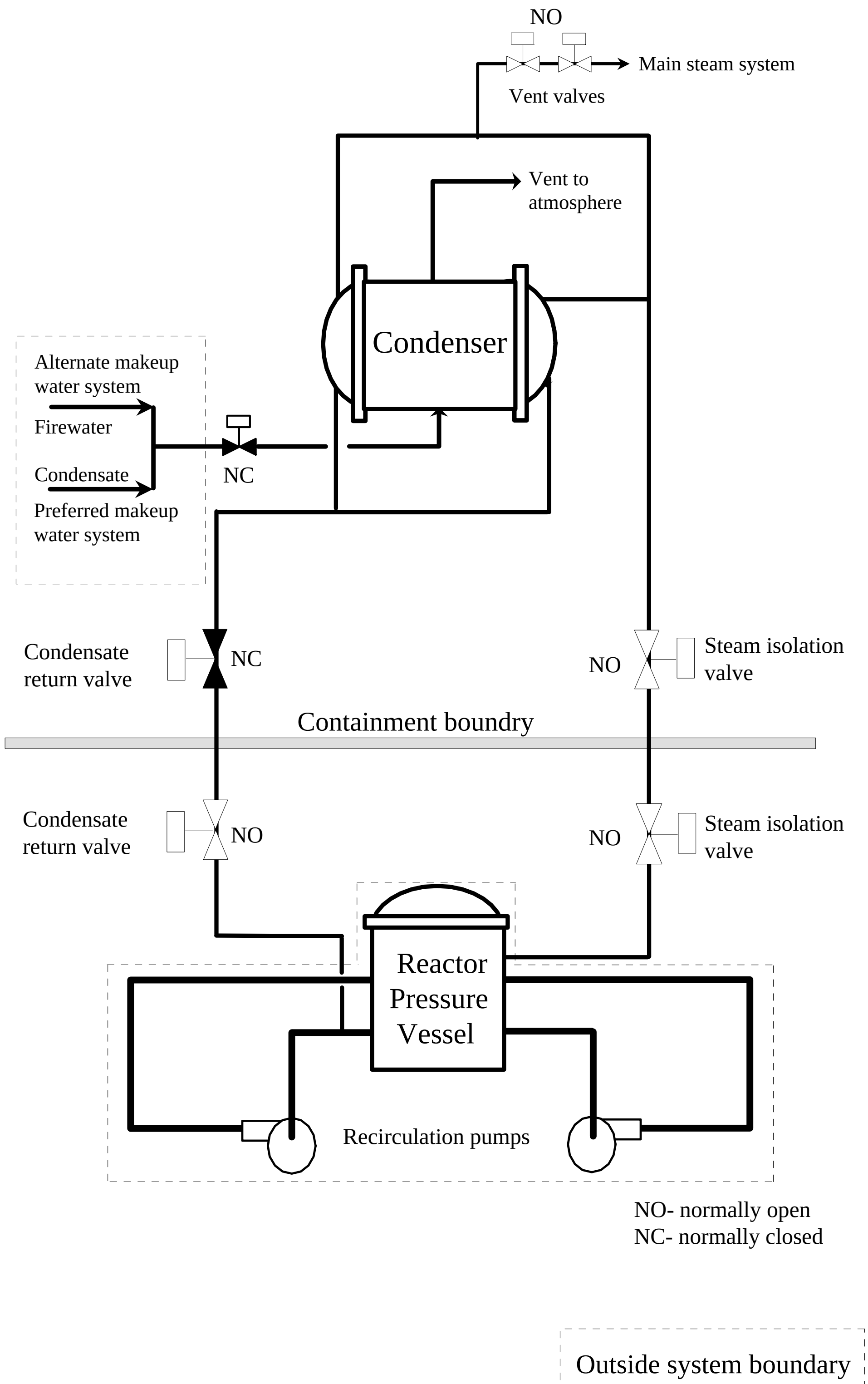

Figure 1. Simplified single train isolation condenser system schematic.

1.1 System Operation

The IC system transfers residual and decay heat from the reactor coolant to the water in the shell side of the heat exchanger resulting in steam generation. The steam generated in the shell side of the heat exchanger is then vented to the outside atmosphere. The system employs natural circulation as the driving head from the reactor steam side, through the isolation condenser tubes, and back to the reactor.

A typical IC system is designed to handle three percent reactor power, which means that five minutes after a scram and initiation of the IC system, the heat removal capacity of the system equals the decay heat production rate of the shutdown reactor. Therefore, reactor water inventory will only be lost through the relief valves for five minutes following a scram and isolation. This represents a minor loss relative to the vessel inventory.

The IC system is typically required to be operable when there is fuel in the reactor vessel and steam is being produced. During normal operation the isolation condensers are in standby, and are placed in service automatically when needed to provide heat transfer to the environment. In the stand-by condition, the steam isolation valves are open so that the condenser tube bundles are at reactor pressure. Condensate builds up in the condenser and condensate return piping; the condensate is prevented from returning to the reactor by having one of the condensate return valves for that train closed. The steam lines contain vent valves, which are open to vent air and noncondensibles to the main steam system. Collection of air or noncondensible gases in the IC system could prevent natural circulation flow. The initiation signal places the IC system into operation by opening the condensate return isolation valve. This valve can also be remotely operated from the control room.

The IC system operates in a closed loop mode. Steam rises from the reactor vessel to the condenser where it is condensed by boiling the water in the condenser shell. As the reactor steam condenses, it returns by gravity flow through the condensate return valve to the suction of a reactor recirculation pump and thus to the reactor vessel. The water inventory on the shell side of the condenser will provide heat removal for between 20 and 90 minutes depending on the plant design, at which time makeup water must be provided to prevent uncovering the condenser tubes. The sources of makeup water are a combination of condensate water, demineralized water, or the fire water system depending on individual plant design. One plant (Nine Mile Pt. 1) has gravity fed makeup water tanks, which can supply enough water for eight hours of operation before additional makeup is required.

The IC system instrumentation and control consists of initiation and containment isolation circuitry. These circuits provide different functions, both of which are important to system reliability. The initiation circuitry provides for automatic and manual start of the system. The purpose of the containment isolation circuitry is to initiate closure of appropriate primary containment isolation valves to limit fission product release should a steam line rupture occur.

The IC system is automatically initiated if a high reactor pressure condition is sustained for 15 seconds. The time delay prevents unnecessary system initiation during turbine trips. Also at most plants, the IC system automatically initiates on a low vessel water level to aid in reducing reactor pressure for small line breaks. The isolation condenser system can be operated manually by opening the condensate return valve. The IC system is designed to provide core cooling regardless of whether electrical power is available.

The IC system is automatically isolated if high IC steam flow or condensate return flow is sensed indicating a line break (Group V isolation). This isolation shuts all the steam and condensate isolation valves and the steam line vent valves, rendering the IC system inoperable. The steam line vent valves will also automatically shut on a low vessel water level condition (Group I isolation). Isolation of the vent valves for a prolonged period could render the heat exchanger inoperable due to the buildup of noncondensible gases. However, failure of this circuit to close the vent valves would not preclude operation of the system.

1.2 System Boundaries

For this study, the IC system includes all steam piping from the reactor vessel penetration to the condenser, the isolation condenser, and condensate piping back to the reactor, and all valves and valve operators. Additional components that are considered part of the IC system are the circuit breakers at the motor control centers (MCCs), but not the MCCs themselves, the dedicated DC power system that supplies IC system power, and the initiation and isolation logic circuits with their associated detectors.

The ability to provide makeup water to the isolation condenser was included in this study. The makeup capability was limited to the IC system makeup water supply valve. This valve must be operable in order to supply water to the IC tank level control valve for long term cooling.