General Electric Advanced Technology Manual

Chapter 6.3

Reactor Isolation Pressure and Inventory Control

TABLE OF CONTENTS

LIST OF FIGURES

6.3 REACTOR ISOLATION PRESSURE and INVENTORY CONTROL

Learning Objectives:

1. Explain the purpose of the isolation condenser.

2. Explain the operations of an isolation condenser.

3. Describe how the various BWR product lines dissipate decay heat.

4. List the high pressure makeup water systems capable of providing makeup water to the reactor vessel when compensating for inventory loss via the pressure control method during vessel isolation.

6.3.1 Introduction

The discussion in this section deals with the various ways BWR product lines provide pressure and inventory control when isolated from their heat sink. In the event the reactor becomes isolated from its heat sink, some component or system must control reactor vessel pressure and inventory. All BWR product lines have Safety Relief Valves (SRVs) to provide over pressure protection, and hence control reactor pressure. In addition to SRVs, BWRs can control pressure with systems like the isolation condenser, reactor core isolation cooling system, and the high pressure coolant injection system. All BWR facilities have a means of providing high pressure makeup water to the reactor vessel to compensate for inventory loss via the pressure control method.

In the case of the BWR/2 product line and certain plants of the BWR/3 product line, both of the isolation functions are carried out by a single system called the isolation condenser system. The isolation condenser system draws off reactor steam, condenses the steam in a condenser, and returns the resultant condensate to a recirculation system suction line. By conserving inventory, this system eliminates the need for additional sources of high pressure makeup.

All BWRs of other product lines (3,4,5, and 6) use SRVs for pressure control and the reactor core isolation cooling system to provide high pressure makeup water to the reactor vessel. All BWR 3 and 4 plants are equipped with a high pressure coolant injection (HPCI) System that can also be used to control pressure by aligning the system in the test mode to the condensate storage tank (HPCI operation is discussed in chapter 6.4). All BWR 5 and 6 plants have a high pressure core spray (HPCS) system in place of the HPCI system installed in BWR 3 and 4's. HPCS is further discussed in chapter 6.4.

6.3.2 BWR/2 Product Line

The BWR/2 product line incorporates both pressure and inventory control into one system, isolation condenser system. The isolation condenser system is a standby, high pressure system that can remove fission product decay heat following a reactor isolation and scram when the main turbine condenser is not available as a heat sink. During reactor isolation, the isolation condenser will control the pressure rise and limit the loss of reactor water, thus avoiding overheating the fuel which could occur through opening of the safety relief valves with no water makeup capability.

The isolation condenser is not intended to be activated fast enough to have any effect upon the initial pressure spikes resulting from the various operational transients (turbine trip, main steam line isolation, etc). The system can be activated manually or automatically upon sustained high pressure. The isolation condenser has the capacity to remove reactor decay heat generated within 5 minutes following a reactor scram from rated power.

6.3.2.1 Isolation Condenser

The isolation condenser, figure 6.3-1, operates by natural circulation. During system operation, steam flows from the reactor, condenses in the tubes of the isolation condenser, and returns to the reactor. The water head, created by condensate flow to the reactor, serves as the driving force for the system.

The isolation condenser is approximately 55 feet long, 12 feet in diameter, and holds approximately 29,000 gallons of water at normal level. Two tube bundles are immersed in water, one bundle at each end of the condenser. The shell side of the condenser vents to atmosphere. Baffles are installed in the shell above the tube bundles to prevent the boiling action from driving shell water out through the shell vents.

The steam inlet valves are normally open so that the tube bundles are at reactor pressure even when in standby. The tube side of the isolation condenser is vented to the main steam line during normal reactor operation. A sustained high reactor pressure automatically puts the isolation condenser system in operation. An automatic initiation will signal the dc motor operated valve on the condensate return line to open and vent valves to the main steam line to close. Steam then flows, under reactor pressure, to the isolation condenser. The steam is routed to both condenser tube bundles where it is condensed by the cooler water in the shell side of the condenser. To obtain the desired flow of condensate from the isolation condenser to the reactor vessel, the normally closed condensate return valve can be throttled by the operator in the control room.

During operation, the water on the shell side of the condenser will boil off and vent steam to the atmosphere. Two radiation monitors are provided on the shell side vent so that in the event of excessive radiation levels, the control room operator will be alerted and can take necessary corrective actions.

Following a reactor isolation and scram, the energy added to the coolant will cause reactor pressure to increase and may initiate the isolation condenser. The capacity of this system is equivalent to the decay heat rate generation 5 minutes following the scram and isolation. With no makeup water, the volume of water stored in the isolation condenser will be depleted in 1 hour and 30 minutes. This allows sufficient time to initiate makeup water flow to the shell side of the condenser.

Makeup water is normally added from the demineralized water makeup system but can be supplied from the condensate storage tank or the fire protection system. Since the shell side of the isolation condenser is vented to atmosphere the potential exists for a radioactive release if a tube leak occurs or if condensate storage tank water is added to the shell side. The potentially contaminated water from the CST could concentrate and result in a release due to the boil off that occurs when the system is in standby.

6.3.3 BWR/3 Product Lines

The BWR/3 product line plants utilize either the isolation condenser or the reactor core isolation cooling system. The previous isolation condenser discussion also applies to the BWR/3 product lines that have isolation condensers.

6.3.3.1 Reactor Core Isolation Cooling

The Reactor Core Isolation Cooling (RCIC) system, figure 6.3-2, consists of a steam turbine driven pump capable of delivering water to the reactor vessel at operating conditions. Operation of the RCIC system is fully automatic, or manual by operator selection. The system will start automatically upon receipt of an initiation signal from the reactor vessel low water level sensors(L2). The system will shutdown automatically upon recovery of reactor water level to the high water level set point(L8) or upon indication of certain RCIC malfunctions which will trip the turbine. A shutdown on RPV level 8 will allow an automatic restart at level 2 but a turbine trip due to a malfunction will not.

Water supply to the system is normally from the condensate storage tank through a motor operated suction valve and check valve. This RCIC suction line is maintained flooded in the standby condition to keep the RCIC pump continuously primed. An alternate source of water for the RCIC system is provided by the suppression pool. This source of water would be used if the water level in the storage tank were low or the water level in the suppression pool is too high.

The turbine is driven by steam produced in the reactor vessel and exhausts to the suppression pool, under water. The turbine driven pump supplies water to the reactor vessel via the feedwater piping. Additional discharge flow paths are provided to allow recirculation to the condensate storage tank for system testing and to provide pump minimum flow to the suppression pool for pump protection. Sufficient capacity is provided to prevent reactor vessel level from decreasing below the top of active fuel (TAF). The system flow rate is approximately equal to the reactor water boil off rate 15 minutes following a reactor scram and isolation.

6.3.4 BWR/4 Product Lines

The BWR/4 product lines all have a RCIC system to provide core cooling makeup water to the reactor vessel under isolation conditions. High Pressure makeup water can be provided by the High Pressure Coolant Injection (HPCI) system which is discussed in section 6.4.

6.3.5 BWR/5 and BWR/6 Product Lines

The BWR/5 and BWR/6 product lines provide reactor vessel pressure and water level control during isolated conditions with the RCIC system (figure 6.3-3). The basic RCIC system remains unchanged except for changes in turbine gland sealing and pump discharge. Some BWR/6s were designed to have the RCIC system discharge into the reactor vessel head for better pressure control. However, plant Perry is the only remaining BWR 6 that injects RCIC into the RHR head spray line. High pressure makeup can be provided by a high pressure core spray (HPCS) system that is discussed in chapter 6.4.

6.3.6 Sources of High Pressure Makeup Water

All BWR product lines have several systems with varying capacities that can be utilized for high pressure makeup under isolated conditions. These systems are identified in the table below.

BWR 2	BWR 3/4	BWR 5/6
Motor Driven Feed Pumps	HPCI	HPCS
Control Rod Drive	RCIC	RCIC
Standby Liquid Control	Motor Driven Feed Pumps	Motor Driven Feed Pumps
	Control Rod Drive	Control Rod Drive
	Standby Liquid Control	Standby Liquid Control

6.3.7 Summary

All BWRs provide pressure and inventory control for the reactor vessel. All BWRs are equipped with SRVs to provide over pressure protection. In addition to SRVs, Isolation condensers are employed for pressure and inventory control for BWR/2s and some 3s. Reactor core isolation cooling systems are used for BWR/4, 5s, 6s and some 3s for pressure and inventory control when the reactor is isolated. HPCI can also be used for pressure and inventory control for the BWR 3 and 4 product lines. HPCS provides inventory control for BWR 5 and 6 product lines.

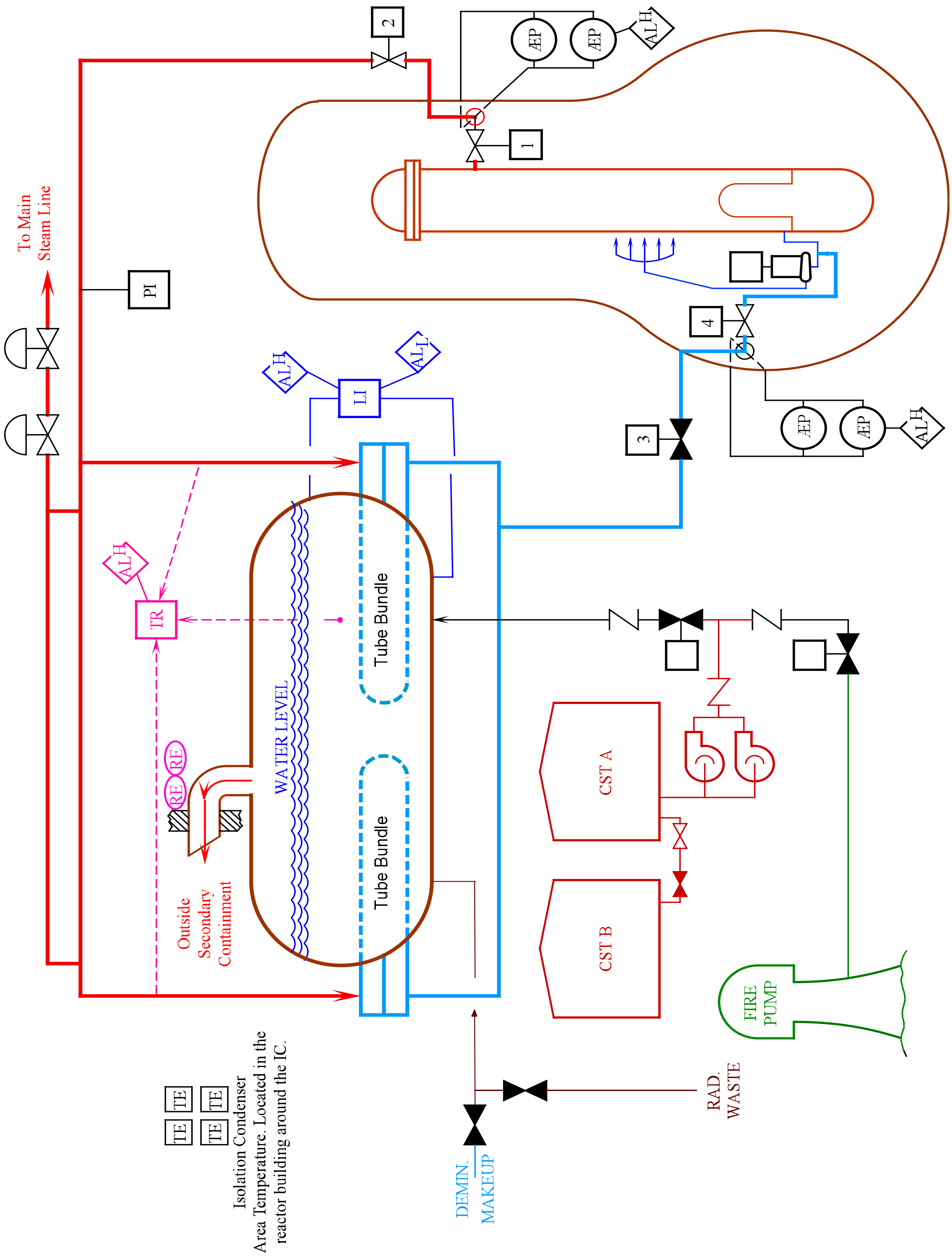

Figure 6.3-1 Isolation Condenser System (BWR 2/3)

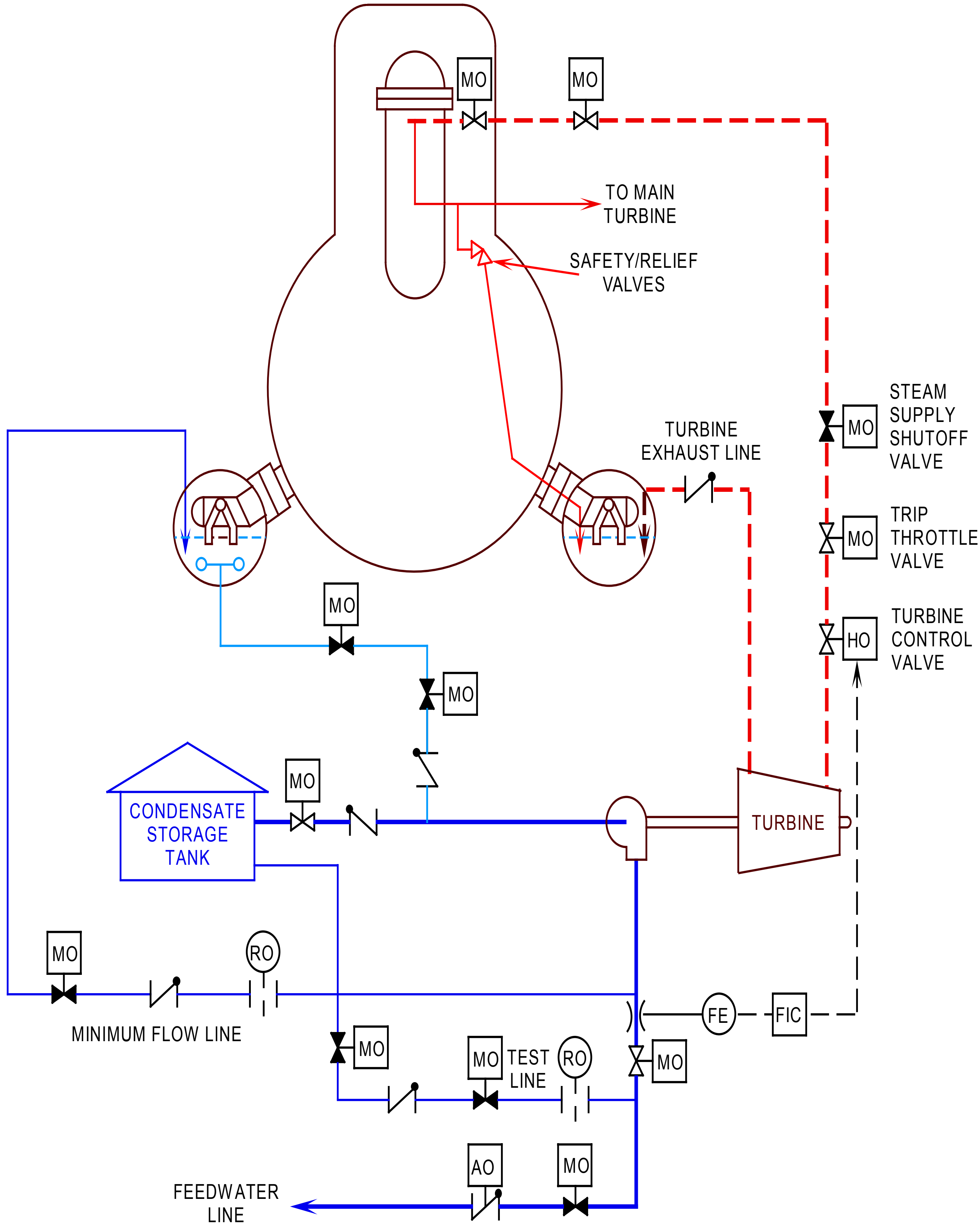

Figure 6.3-2 RCIC System (BWR 3/4/5)

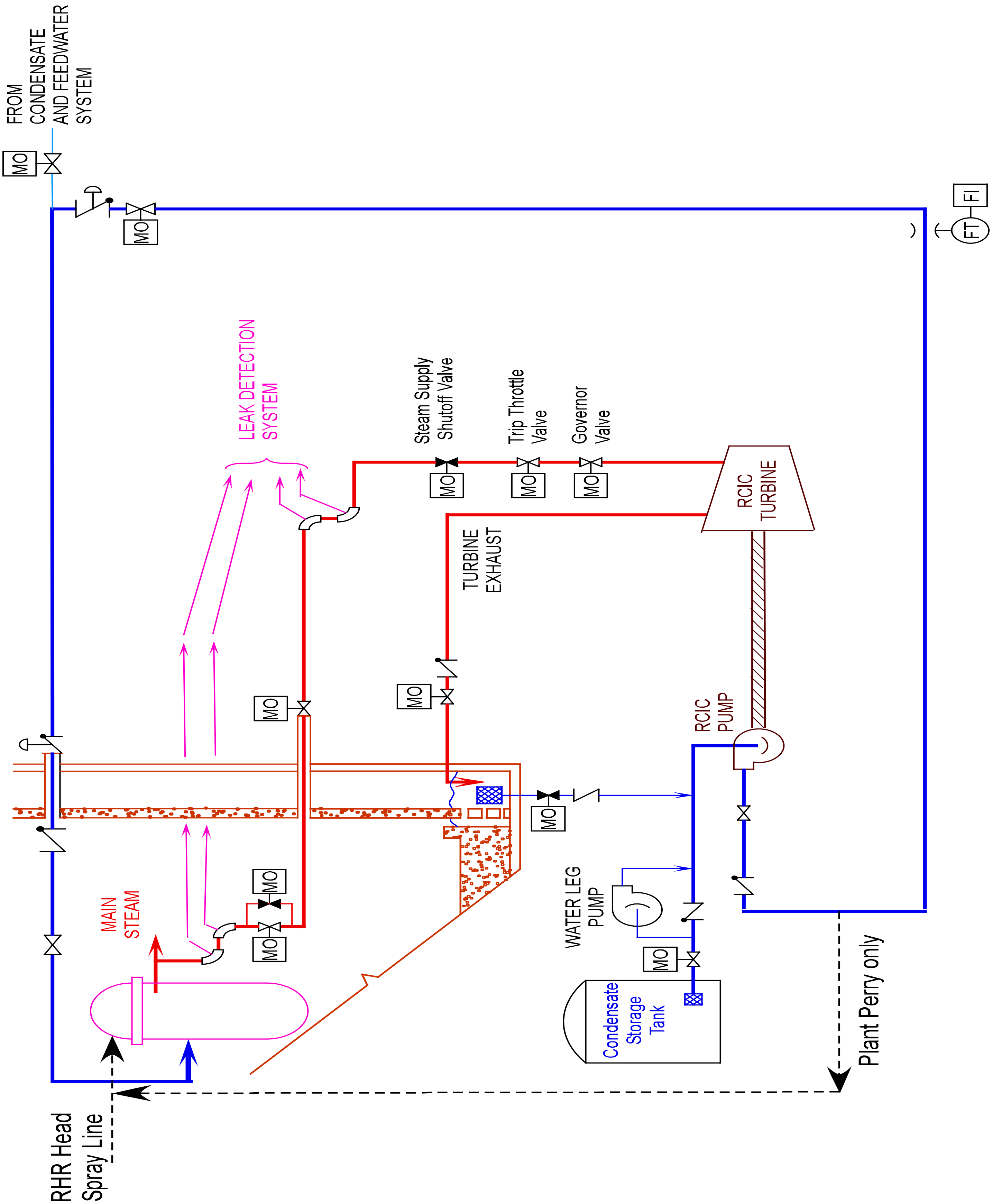

Figure 6.3-3 RCIC System (BWR 6)