10.4.2 Main Condenser Evacuation System

The main condenser evacuation system (MCES) removes air and non-condensable gases from the main condenser and connected steam side systems during plant startup, cooldown and normal operation.

10.4.2.1 Design Basis

The MCES performs no safety-related function and therefore has no nuclear safety-related design basis.

The MCES is designed to meet the following functional criteria:

- Air and non-condensable gases are removed from the condenser and connected steam side systems during plant startup, cooldown and normal operation.
- Vacuum is established and maintained in the condenser and connected steam side systems during plant startup and normal operation by using mechanical vacuum pumps.

10.4.2.2 System Description

10.4.2.2.1 General Description

The MCES is non-safety related and is located in the Turbine Building. The MCES is used to evacuate air rapidly from the main condenser and connected steam side systems during plant startup, and to continuously remove non-condensable gases during normal operation to maintain optimum condenser performance.

The MCES and air vent system are shown in Figure 10.4.2-1—Main Condenser Evacuation System and Figure 10.4.2-2—Vent System for Air Removal.

The steam and air mixture extracted from each condenser shell is routed to one of two 100 percent capacity holding vacuum pumps. Discharge from the vacuum pumps is routed by a header to the air vent system, where the radiological activity of the exhausted air is monitored (refer to Section 11.5.4 and Table 11.5-1, Monitor R-3.

Isolation valves serve to stop air removal from the air cooler tube bundle when the circulating water side of the associated condenser shell is shut off.

The connection of the condensers to the vacuum pumps is controlled by air-operated control valves at the inlet of each vacuum pump. These valves are normally open. The vacuum pumps are connected to the air removal header by air intake isolation valves. The vacuum pumps pass the steam and air mixture to the moisture separators–silencers. As a result of compression, the steam component condenses while the exhausted air is vented through the air vent system into the nuclear auxiliary building ventilation system.

Initial filling of the seal water reservoirs of the exhauster and make-up water supply to the units is provided from the sealing and cooling drains system. Excess process water, produced primarily by condensation of the steam extracted during operation, is discharged into the building drain system.

The liquid ring in the vacuum pumps is maintained and cooled by a process water circuit. Process water is extracted from the moisture separators, passed to the vacuum pumps via the heat exchangers and returned to the moisture separators. Heat dissipated by the vacuum pumps and the heat of condensation from the steam component, which is absorbed by the process water circuit, is removed by the heat exchangers. The heat exchangers are supplied with cooling water from the turbine building closed cooling water system (TBCCWS). The TBCCWS is addressed in Section 9.2.10.

Seal water from the sealing and cooling drains system is admitted to the stems of the isolation valves in the air removal lines from each condenser shell, the isolation valves in the air removal header and the air intake isolation valves.

10.4.2.2.2 Component Description

The major components of the MCES are described below. Table 3.2.2-1 provides the seismic design and other design classifications for components in the MCES. Individual codes and standards applicable to each component are also listed below. Section 3.2 describes how the guidance of RG 1.26 is implemented for the U.S. EPR.

Mechanical Vacuum Pumps

The mechanical vacuum pumps remove air and other non-condensable gases from the condensers. The capacity is in accordance with the Heat Exchanger Institute (HEI) Standards for Steam Surface Condensers (Reference 1) and is adequate to maintain condenser backpressure with one holding exhauster in operation, under normal conditions. An additional holding exhauster per condenser and one hogging exhauster for all condensers is installed for the hogging mode. The purpose of these exhausters is to assist in removing air from the turbine, moisture separator reheaters, condensers, feedwater heaters and associated piping, prior to startup of the turbine. The mechanical exhausters are electric motor-driven, two stage, liquid ring seal vacuum pumps. Each is a complete self-contained package consisting of a unit motor, heat exchanger, combination separator and seal water reservoir, exhauster silencer–moisture separator, and control and monitoring instrumentation. Materials are suitable for the specified service and conditions.

Seal Water Heat Exchangers

The vacuum pump heat exchangers will be either shell-and-tube or plate type. Materials will suitable for the specified service and conditions.

Piping and Valves

MCES piping is designed in accordance with the ASME B31.1, Power Piping Code (Reference 2). Materials will be compatible with dry air and water vapor at the expected conditions.

10.4.2.3 System Operation

10.4.2.3.1 Normal Plant Operation

If after startup evacuation, the pressure in the condensers has been reduced to a level where only one holding pump per condenser is required to maintain the setpoint pressure, the second holding pump (standby holding pump) is switched off. The shutoff valves are then repositioned so that each condenser is evacuated separately. In case of condenser air leaks or if a holding pump fails, the standby pump will automatically start without any operator assistance.

10.4.2.3.2 Startup and Shutdown

For startup, the turbine and condenser are completely evacuated. The holding vacuum pumps and the hogging vacuum pump operate simultaneously to reach the target vacuum.

For shutdown, the turbine is shut down and turbine valves closed.

10.4.2.4 Safety Evaluation

The MCES is not safety-related and is not required to operate during or following an accident.

The design of the MCES satisfies general design criteria GDC 60 and GDC 64, as they relate to the MCES design for the control and monitoring of release of radioactive materials to the environment. The non-condensable gases and vapor mixture discharged from the MCES are not normally radioactive during normal plant operation. However, it is possible for the discharged mixture to become contaminated in the event of primary-to-secondary system leakage.

- For the U.S EPR, no hydrogen buildup is anticipated in the main condenser. Sources of hydrogen during normal operation include: 1) hydrogen generated within the secondary side systems by general corrosion, 2) hydrogen generated by the thermal decomposition of hydrazine within the secondary side systems, and 3) hydrogen from the primary coolant diffusing through the steam generator tubing material. The generation rate of hydrogen from these sources is very small compared to the amount of steam in the vapor space in the main condenser and the amount of water vapor in the MCES.

- Dissolved oxygen is present in the condensate and condenser hotwell inventory but only trace amounts of this oxygen is released into the main condenser, and the amounts are negligible compared to the amount of gas and vapor being evacuated by the system.

- There is no potential for explosive mixtures within the MCES, which would result in excessive releases of radioactivity; therefore, the MCES design satisfies GDC 60 and is not required to be designed to withstand the effects of an explosion. The design capacity of the holding (continuously operating) vacuum pumps in the MCES is such that the water vapor content is above 58% by volume of the total mixture. There is no buildup of non-condensable gas in the main condenser because the MCES operates continuously whenever the main condenser is in operation. The vacuum pumps in the MCES are liquid ring vacuum pumps. Cooling water is used to seal the vacuum pumps. The mixture passing through the MCES is at low temperature and high humidity due to contact with the water ring in the vacuum pumps. As indicated in Table 10.1-1—Design Heat Balance for Steam and Power Conversion System Cycle, the average design backpressure is 2.5 inches HgA. Based upon standard steam tables the corresponding saturation temperature is approximately 109° F. The MCES operates at a lower pressure and temperature than the backpressure in the condenser.

- The exhaust from the MCES is discharged to the air vent system. The exhaust flow is monitored for radioactivity as described in Section 11.5.4 and discharged to the nuclear auxiliary building ventilation system. The radiological aspects of primary-to-secondary leakage, including anticipated releases from the system, are described in Section 11.5.4 (refer to Table 11.5-1, Monitor R-3).

Malfunction of MCES components does not affect the safe operation of the plant or any safety related system.

- MCES operation does not directly affect the reactor coolant system. If the air removal system fails completely, a gradual reduction in condenser vacuum results from the buildup of non-condensable gases. This reduction in vacuum causes a lowering of turbine cycle efficiency, which requires an increase in reactor power to maintain the demanded electrical power generation level. The reactor power increase is limited by the reactor control system, as described in Section 7.7. The reactor protection system, described in Section 7.2, maintains the plant within safe operation limits. If the MCES remains inoperable, condenser vacuum increases to the turbine trip setpoint and a turbine trip is initiated. A loss of condenser vacuum is addressed in Section 15.2.

10.4.2.5 Inspection and Testing Requirements

Inspection and testing of the system is performed prior to plant operation. Refer to Section 14.2 (test abstract #065) for initial plant startup test program.

Components of the system are monitored during operation to confirm proper operation. Periodic inspections of the evacuation system are performed in conjunction with the scheduled maintenance outages. The vacuum pumps are initially tested for proper performance in accordance with HEI Standards for Liquid Ring Vacuum Pumps (Reference 3).

10.4.2.6 Instrumentation Requirements

The process automation system controls the functions of equipment of the MCES from the main control room panel.

A single 100 percent capacity vacuum holding exhauster is in operation for each condenser shell when the plant is operating under normal conditions. On an increasing condenser pressure, as detected by a pressure switch, the standby holding exhauster starts to maintain the set pressure level and prevent a turbine trip.

10.4.2.7 References

1. HEI “Standards for Steam Surface Condensers,” 10th Edition, Heat Exchanger Institute, 2006.

2. ANSI/ASME B31.1-2004, “Power Piping,” The American Society of Mechanical Engineers, 2004.

3. HEI “Standards for Liquid Ring Vacuum Pumps,” 3rd Edition, Heat Exchanger Institute, 2005.

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