7.8 REACTOR VESSEL INSTRUMENTATION

7.8.1 Safety Objective

The safety objective of the reactor vessel instrumentation is to monitor and transmit information concerning key reactor vessel operating parameters during planned operations and abnormal and accident conditions to ensure that sufficient control of these parameters is possible in order to avoid: (1) release of radioactive material to the environs such that the limits of 10 CFR 20 are exceeded, (2) nuclear system stress in excess of that allowed by applicable industry codes, and (3) the existence of any operating conditions not considered by plant safety analyses.

7.8.2 Safety Design Basis

Reactor vessel instrumentation shall be designed to:

a. Provide the operator with sufficient indication of reactor core flow rate during planned operations and abnormal and accident conditions to avoid operating conditions not considered by plant safety analyses.

b. Provide the operator with sufficient indication of reactor vessel water level during planned operations and abnormal and accident conditions to determine that the core is adequately covered by the coolant inventory inside the reactor vessel to avoid the release of radioactive materials to the environs such that the limits of 10 CFR 20 are exceeded, and to avoid operating conditions not considered by plant safety analyses.

c. Provide the operator with sufficient indication of reactor vessel pressure during planned operations and abnormal and accident conditions to avoid nuclear system stresses in excess of those allowed by applicable industry codes.

d. Provide the operator with sufficient indication of nuclear system leakage during planned operations and abnormal and accident conditions to avoid nuclear system stress in excess of that allowed by applicable industry codes and the release of radioactive material to the environs such that the limits of 10 CFR 20 are exceeded.

7.8.3 Power Generation Objective

The power generation objective of the reactor vessel instrumentation is to monitor and transmit reactor vessel parameter information such that the convenient, efficient, and economical operation of the plant is facilitated.

7.8.4 Power Generation Design Basis

Reactor vessel instrumentation shall be designed to monitor and transmit sufficient reactor vessel parameter information to the operator such that he is continually able to operate the plant conveniently, efficiently, and economically.

7.8.5 Description

Figures 7.8-1 sheets 1, 2, 3, 4, 5, and 6 and 4.3-2a sheets 1, 2, and 3 show the numbers and arrangements of the sensors, switches, and sensing equipment used to monitor reactor vessel conditions. Because the reactor vessel sensors used for safety systems and engineered safeguards have been described and evaluated in other portions of the Safety Analysis Report, only those sensors that are not used for safety systems and engineered safeguards are described in this paragraph.

7.8.5.1 Reactor Vessel Surface Temperature

A total of 46 thermocouples are attached to the reactor vessel, the vessel top head, the vessel head studs, and the control rod drive housings to provide the operator with temperature information so that the thermal stresses imposed on the vessel and its attachments can be determined. Figure 7.8-3 shows the locations of the thermocouples. Probe-type thermocouples are used to measure the temperature inside the reactor vessel head studs. Magnetically-attached thermocouples are used to measure the surface temperature of the vessel, top head, and top head flange. Thermocouple and temperature recorder instrumentation are listed in Table 7.8-1.

The collection of thermocouples provides temperature data representative of thick, thin, and transitional sections of the vessel and its attachments. The data obtained from the thermocouples are used as the basis for controlling the rate of heating or cooling of the vessel so that thermal stresses are appropriately limited. Selected temperatures are recorded on a multipoint recorder in the control room. The temperature of the reactor vessel flange and the vessel wall adjacent to the flange is recorded on a temperature recorder.

7.8.5.2 Reactor Vessel Water Level

Reactor vessel water level indication is obtained by comparing the pressure exerted by the actual height of water inside the vessel to the pressure exerted by a constant reference column of water. Pipelines which are connected to widely separated nozzles in the reactor vessel lead from the vessel to locations outside the primary containment where they terminate at instrument racks in the Reactor Building. Level-measuring instruments are attached to the appropriate sensor pipelines so that the proper differential pressure is applied to the level instruments. A condensing chamber is installed in the drywell on each of the pipelines used to provide a reference column of water for level measurements. The reactor vessel instrumentation used for safety systems is described and evaluated in Subsection 7.2, "Reactor Protection System." Each of the instrument pipelines is fitted with one manual isolation valve and one excess flow check valve, both of which are located directly outside the drywell in the Reactor Building. The instrument pipelines slope downward in the direction of the instruments so that no air traps are formed. Pressure and differential pressure measuring instruments also use these same instrument lines.

Reactor vessel water level indication is provided in the main control room on various panels. Redundant indications are provided for the Feedwater Control System, narrow range, wide range, and water level inside the core shroud. Indication is provided for water level all the way to the top of the vessel. A level recorder that receives the controlling level signal from the Feedwater Control System provides a continuous record of narrow range reactor vessel water level. The Feedwater Control System provides high and low water level alarms. Another water level recorder is provided to continuously record the water level above the top of the core. Table 7.8-1 lists the level instrumentation not previously described with other systems.

Each of the actions listed is described and evaluated in the subsection of the Safety Analysis Report where the system involved is described. The following list tells where various level-measuring components are discussed.

Level Instrumentation	Subsection in Which Discussed
Level transmitters for initiating scram	Reactor Protection System (7.2)
Level transmitters for initiating containment or reactor isolation	Primary Containment Isolation System (7.3)

Level transmitters used for HPCI, LPCI, core spray, Automatic Depressurization System, recirculation pump trip, or recirculation loop valve closure. Level transmitters used for Emergency Core Cooling System initiation.	Emergency Core Cooling Systems Controls and Instrumentation (7.4)
Level transmitters used to measure water level inside core shroud	Emergency Core Cooling Systems Controls and Instrumentation (7.4)
Level transmitters and recorders used for feedwater control	Feedwater Control System (7.10)
Level transmitters used to trip HPCI turbine.	Emergency Core Cooling Systems Controls and Instrumentation (7.4)
Level transmitters used to initiate the RCIC system. Level Transmitters used to isolate RCIC turbine.	Reactor Core Isolation Cooling System (4.7)

The large number of reactor vessel water level indications is sufficient in providing the operator with information with which the adequacy of the coolant inventory to cool the fuel can be determined. In addition, by verifying that reactor vessel water level is not rising to an abnormally high level, the operator is assured that turbines are not endangered by the possibility of water being carried into the steam lines. The approach of abnormal conditions is brought to the operator's attention by audible and visual alarms. It should be noted that in no case requiring safety system response is operator action required; all essential protection system responses are completely automatic.

7.8.5.3 Reactor Vessel Coolant Flow Rates and Differential Pressures

Figures 7.8-1 sheets 1, 2, 3, 4, 5, and 6 show the flow instruments, differential pressure instruments, and recorders provided so that the core coolant flow rates and the hydraulic performance of reactor vessel internals can be determined.

The differential pressure across each of the jet pumps is measured and indicated in the Main Control Room. Four jet pumps, two associated with each recirculation loop, are specially calibrated. They are provided with special pressure taps in the diffuser sections. The differential pressure measured between the special taps allows precise flow calibration using jet pump prototype test performance data. The flow rates through the remaining jet pumps are derived from the measured pressure differences between the jet pump diffuser near the throat end and the core inlet plenum. The flow rates through the jet pumps associated with each recirculation loop are summed to provide control room indication of the core flow rate associated with each recirculation loop. The total flows for both recirculation loops are again summed to provide a recorded control room indication of the total flow through the core.

A differential pressure transmitter and indicator are provided to measure the pressure difference between the reactor vessel annulus outside the core shroud and the core inlet plenum. This indication can be used to determine the overall hydraulic performance of the jet pump group and to check the total core flow rate. These indications are available in the control room.

A differential pressure transmitter is provided to indicate core pressure drop by measuring the pressure difference between the core inlet plenum and the space just above the core support assembly. The pipeline used to determine the pressure in the core inlet plenum is the same pipeline provided for the Standby Liquid Control System. A separate pipeline is provided for the pressure measurement above the core support assembly. The differential pressure is both indicated and recorded in the Main Control Room.

Instrument pipelines leading from the reactor vessel to locations outside the drywell are provided with one manual isolation valve and one excess flow check valve. All of the flow and differential pressure instruments are located outside the primary containment.

This instrumentation permits the determination of total core flow in two ways. The first method is the readout of the summed flow measurements from all the jet pumps. The second method includes the use of jet pump prototype performance data, the jet pump differential pressures, and the differential pressure between the reactor vessel annulus and the core inlet plenum. A temporary correlation can also be made to define core flow as a function of reactor operating power level and the readout of the pressure difference between the reactor vessel annulus and the core inlet plenum. This correlation is of a temporary nature, because it will change with a fixed core arrangement over a period of time as a result of crud buildup on the fuel. The control room flow rate readouts of the specially calibrated jet pumps can be used to cross-check the flow rate readouts of all the other jet pumps. A discrepancy in the cross-check is reason enough to check local flow indications. Core flow can also be determined by heat balance methods, using the output of sensors in the steam lines, feedwater lines, and the recirculation system.

Flow in each recirculation loop is measured by a flow element, as shown in Figures 7.8-1 sheets 2, 4, and 6. Recirculation water temperature is recorded in the control room. Indicated recirculation loop flow rates can be checked by using recirculation pump performance curves and the differential pressure between the reactor vessel annulus and the core inlet plenum. Extreme accuracy of the flow rate operational readouts in the control room is not necessary, because precise measurements can be obtained during reactor operation if they are desired.

7.8.5.4 Reactor Vessel Internal Pressure

Reactor vessel internal pressure is detected by pressure switches, indicators, and transmitters from the same instrument pipelines used for reactor vessel water level measurements. Two pressure indicators, that sense pressure from different, separated instrument pipelines, provide pressure indications in the Reactor Building. Three (Unit 1) and four (Units 2 and 3) reactor vessel pressure indications are provided in the Main Control Room. These come from the three pressure transmitters used in the Feedwater Control System. Reactor vessel pressure is continuously recorded in the Main Control Room on a recorder. The recorder receives a pressure signal from the Feedwater Control System. There is also a narrow range reactor pressure recorder in the control room. In addition, two pressure transmitters provide reactor pressure to indicators located in the control room. These two pressure indicators are available for postaccident monitoring (PAM) to indicate detection of potential breach in the reactor coolant pressure boundary and long-term surveillance of RPV pressure for one hundred days.

The following list shows where reactor vessel pressure measuring instruments used for the automatic control of equipment or systems are discussed.

Pressure Instrumentation	Subsection in Which Discussed
Pressure switches used to initiate a scram	Reactor Protection System (7.2)
Pressure switches used for Core Spray System and LPCI	Emergency Core Cooling Systems Controls and Instrumentation (7.4)
Pressure transmitters and recorders used for feedwater control	Feedwater Control System (7.10)
Differential pressure switches measuring differential pressure between reactor vessel and	Emergency Core Cooling Systems Controls and Instrumentation (7.4)

jet pump riser pipes	
Differential pressure switches measuring differential pressure between inside of core spray sparger pipes and core inlet above the core support assembly	Emergency Core Cooling Systems Controls and Instrumentation (7.4)
Pressure indicators for 100 days postaccident monitoring	Reactor Vessel Instrumentation (7.8)

7.8.5.5 Reactor Vessel Top Head Flange Leak Detection

A connection on the reactor vessel flange is provided into the annulus between the two metallic seal rings used to seal the reactor vessel and top head flanges. This connection permits detection of leakage from the inside of the reactor vessel past the inner seal ring. The connection is piped to a collection chamber installed between two AC, solenoid- operated valves. The arrangement is shown in Figure 7.8-1 sheets 1, 3, and 5.

The upstream valve is normally open, the downstream valve normally closed. A level switch is provided to detect the accumulation of water in the collection chamber. This level switch actuates an alarm in the control room. A pressure switch is also provided to actuate the alarm in the control room as pressure in the leakage collection piping becomes abnormally high. A pressure indicator is provided to indicate the pressure inside the piping arrangement. The level switch is located inside the primary containment; and the pressure instruments are located outside the drywell, but inside the Reactor Building. The instrument pipeline for the pressure instruments is provided with one manual isolation valve and one excess flow check valve. The two solenoid valves are controlled by a switch in the control room. The positions of the valves are indicated by lights. If leakage past the inner seal ring is indicated, the upstream valve can be closed and the downstream valve can be opened by remote-manual operation from the control room. This action routes the accumulated leakage to the drywell equipment drain sump. After the collection chamber is drained, the solenoid-operated valves can be returned to their normal positions. The leakage rate can be determined by timing the period until the level alarm is reactivated. (See Subsection 4.10, "Nuclear System Leakage Rate Limits.")

A connection is provided on the reactor vessel beyond the outer metallic head seal. This connection is piped to a point in the drywell accessible during reactor shutdown and is capped. (Note: In the event that difficulty is encountered in obtaining a pressure-tight seal on the inner metallic seal, it may be desirable to operate on the outer metallic seal only. It is possible to install a low-pressure seal beyond the outer metallic seal and monitor the space between for outer metallic seal leakage by use of this piped connection.)

7.8.5.6 Primary Containment Monitoring

The instrumentation used for remote monitoring of operational occurrences and post-accident conditions in the primary containment is listed in Table 7.8-2. The range of each instrument and any trip functions are also provided. The configuration of these instruments is depicted in FSAR Figures 5.2-2a sheets 1, 2, and 3, 5.2-2b, 5.2-2c, 5.2-2d, 5.2-2e, 5.2-2f, 5.2-2g, 5.2-6a sheets 1, 3 and 4, and 5.2-6b, 5.2-6c, and 5.2-6d. Post-accident hydrogen and oxygen monitoring is further discussed in paragraph 5.2.6 of the FSAR.

7.8.6 Safety Design Evaluation

The reactor vessel instrumentation is designed to provide sufficient continuous indication of key reactor vessel operating parameters during planned operations and abnormal and accident conditions such that the operator can efficiently monitor these parameters and anticipate any approach to operating conditions which could lead to any of the unacceptable safety results discussed earlier. The redundancy of all indicators provided assures that the possibility that all instrumentation could be lost simultaneously is so remote as to be negligible. In addition, sensors providing safety signals to the Reactor Protection System and Engineered Safeguards Systems for scram and isolation functions are separate from these indicator sensors such that loss of indication does not directly obviate protection against accidents and transients. It is therefore concluded that the safety design bases are satisfied.

7.8.7 Inspection and Testing

A large number of spare thermocouples is provided on the reactor vessel and its attachments to permit cross-checking to verify proper thermocouple response. Pressure, differential pressure, water level, and flow instruments are located in the Reactor Building and are piped so that calibration and test signals can be applied during reactor operation, if desired.