Chapter 2

Emergency Core Cooling System

Several events may cause a departure from operation conditions. Two distinct types of event may have an impact on imbalance of heat produced and heat removed in the core, which lead to a potential risk of high fuel temperature. First, transients result from either the heat production is above, or the heat removal is below the nominal value. Second, a loss of coolant induces by leaking of coolant from the break in PHT. In the context of safety analysis, a loss of coolant is considered of more important than transients[5].

A loss of coolant can cause by a major rupture within PHT. Immediately following a large break, coolant is expelled through the break into the containment, causing the system pressure to drop very rapidly. As the same time, the reactor power will rise up due to positive void reactivity in the system until SDS1 and SDS2 are initiated to trip the reactor by high neutron log rate signal[1]. Although the reactor is tripped, decay heat is produced and accumulated in the core, causing fuel temperature to increase. Emergency Core Cooling System (ECCS) is designed to cope with that problem.

The basic function of the ECC system is to provide a means of cooling the reactor fuel in the unlikely event of an accident which depletes the normal coolant inventory in the Heat Transport system (HTS) to the extent that fuel cooling is not assured. The ECC system is designed to detect a Loss Of Coolant Accident (LOCA), refill the fuel channel if voiding has occurred, and remove residual heat from the reactor fuel[6]. This chapter describes system description of ECCS, operation of reactor during normal and after LOCA condition. Control description dealing with control and monitoring loops for component and parameters like pressure, temperature and level will be explained.

2.1 System Description[6]

The ECC system is divided into four major operations :

a: LOCA Detection and ECC Initiation

b: Steam generator crash cooldown

c: Injection phase

d: Recovery phase

LOCA Detection and ECC Initiation

The ECC system is poised during normal reactor operation. The LOCA signal is generated when the HTS system pressure are ROH2 falls below set-point and one of three conditioning signals is received. The conditioning signals are sustained low pressure ROH1, high reactor building (RB) pressure and high moderator level. The sustained low ROH1 pressure will enable the ECC system to detect both large and small LOCAs, while the high RB pressure will generate a LOCA signal more quickly for large LOCAs. The high moderator level signal will help detect in-core LOCAs much sooner than the sustained low header pressure signal.

Steam Generator Crash Cooldown

Once a LOCA signal has been generated, the ECC system will open all of the main steam safety valves (MSSVs) to provide a rapid cooldown and subsequent depressurization of the HTS. The crash cooldown enhances the effectiveness at the ECC system by the temperature differential between the primary and secondary side during the initial period following a LOCA. This serves two purpose;

- During a small LOCA, the crash cooldown helps to depressurize the HTS.

- During a large LOCA, the crash cooldown reduces the heat transfer from the secondary side to the primary side.

There are sixteen MSSVs, four on each main steam line. Each MSSVs is fitted with a pneumatic actuator, which is designed to overcome the spring force that keeps it normally closed.

<u>Injection Phase</u>

The injection portion of the ECC system consists of two gas tanks with four pressurized water tanks. As well, vent valve will be enclosed it they were open for venting. During normal reactor operation, the gas tanks are kept pressurized at 6.7 MPa(g) by compressors.

Once a LOCA signal has been generated, the gas isolation valves will open to allow the gas tanks to pressurize the water tanks. Only one of the three parallel paths is required to open to provide adequate pressurization of the water tanks.

The water tanks are normally isolated from the HTS by more of six one way rupture disks . These disks are designed to withstand heat transport back pressure during normal reactor operation, but burst in the forward direction (ECC TO HTS) with a relatively small differential pressure (≈300-500 kPa) compared with the differential pressure required to rupture disks in the reverse direction (>20 MPa). Accidental pressurization of the water tanks is prevented by means of pressure control valves. Should the gas isolation valve leak, pressure control valve will be open to provide venting to the RB atmosphere and prevent pressurization of the water tanks which would rupture the disks when the HTS is depressurized. Similarly, the valves will be open to vent air from the ECC tanks when fill valve is open. Once a LOCA signal has been received, all vent valves will be automatically closed to prevent leakage of the air during injection. These valves are located in small lines so that the impact to the injection phase will not be significant if the valve is not automatically closed.

Once the rupture disks have burst, the water from the water tanks will flow into the HTS via connections to each of the six headers. Each of these water tanks is filled with a floating ball seal. When the tanks are full, the balls will be held at the top of the tanks by the buoyant force of the water. Once the water from the tanks has depleted, the ball seals will seal in at the exit of the tanks to prevent air from being injected into the HTS. Control logic acting on level indication will close the gas isolation valves when the water level has reached a pre-set value.

The pressure of the gas will hold the balls in their seat during the recovery phase to prevent water from refilling the tanks. Should the vent valve on the water tanks leak during the recovery phase, the operator can go to the motor control center and close the water tank isolation valve to prevent the tanks from refilling. These valves are power operated but are normally locked open at the motor control center.

Recovery Phase

During the injection phase, the ECC inventory in the reserve water tank (RWT) will be drained to the reactor building (RB) floor via the RWT dump line. This water serves to temper the sump water and ensure that there is an adequate inventory and net positive suction head (NPSH) available to the ECC recovery pumps. The RWT dump line is normally isolated by RWT isolation valves which are opened on a LOCA signal.

The recovery pumps are started on LOCA signal and once there is an adequate water level on the RB floor, the sump isolation valve for the operating pumps will be open as required. The RB water level is used as a conditioning signal for the system to open the sump isolation valves. The pumps will operate in a recirculation mode until the injection phase is completed. Once the level in the water tanks has reached a sufficient low level, a permissive will be generated to open the low pressure isolation valve to initiate the recovery phase.

The recovery portion of the ECC system is separated into two trains, each is designed to provide 100% of the flow required for a large LOCA. Each train contains two recovery pumps and two plate type heat exchangers. The ECC recovery phase can operate with any two of the four pumps. Each pump is provided with a separate suction line so that each pair of pumps can independently draw from one of the recovery pumps. Each of the ECC sumps is provided with sufficient screens and trash racks to ensure that post LOCA debris will not enter the ECC system. Vortex breakers are provided in each sump to ensure that air is not drawn into the pumps. There is a connection between the two recovery sumps to allow the pumps to draw from either sumps in case of the unlikely event of debris blockage to one of the screens.

2.2 Operations[6]

2.2.1 Normal Reactor Operation

- The gas tanks are pressurized with dry air.

- The gas lines between the gas isolation valves and the water tanks are filled with nitrogen at a low positive pressure.

- The water tanks and the injection piping upstream of the rupture disks are filled with demineralized light water at a low positive pressure.

- The injection piping downstream at the sump isolation valves are filled with light water at low temperature.

- The pump suction piping upstream of the sump isolation valves including the recovery sumps are kept dry.

2.2.2 Operation following a LOCA

<u>Blowdown</u>

In the event of a LOCA, the pressure of the HTS falls and the pressure in the RB rises at a rate depending on the break size. The reactor is tripped by SDS1 and SDS2. The period of time between the beginning of the LOCA and the time when the HTS pressure reaches the ECC injection pressure is called the blowdown period.

A LOCA signal is initiated by a low ROH2 pressure signal conditioned by a high reactor building pressure, sustained low ROH1 pressure signal or high moderator level signal. The ROH1 conditioning signal is used for conditioning since it is closest to the pressurizer and will not see the same pressure transients as ROH2. This conditioning time delay on the ROH1 signal is needed to allow for normal reactor transients.

The LOCA signal initiates the following actions:

a). close gas vent valves.

b). close gas isolation vent valves.

c). open gas isolation valves to pressurize the water tanks.

d). open all main steam safety valves to depressurize the steam generators

e). open RWT isolation valves. This action will initiate the dump of the RWT Water.

f). start the two AUTO ECC pumps one on each train. If either pump fails to start, as indicated by a low differential pressure across that pump, a STANDBY pump is automatically started.

g). open the service water isolation valve to allow service water into the heat exchangers in the operating train. If one pump is operating in each train, service water is supplied to all of the exchangers.

h). close ECC test valves if either was open for pump testing.

i). lock out the gas compressors and dryers.

Injection

Once the ECC injection pressure has exceeded the HTS pressure by the burst pressure of the one way rupture disks, the disks will open and the injection phase will begin. The duration of the injection phase will vary depending upon the size of the break.

Recovery

During the injection phase, the recovery pumps will operate in a recirculation mode. Flow recirculates back to pump suction via the testing/bypass lines and the individual pump bypass lines. As well, the RWT continues to dump water onto the RB floor until it has exhausted the inventory dedicated to the ECC. Once the ECC sump has reached a predetermined level, the sump isolation valves are opened for the operating pumps.

Once the water in the water tanks is depleted, the ball seals at the discharge of the tank to ensure that gas does not enter the HTS. A low level measurement in the water tanks signals the gas isolation valves to close. As well, the low level measurement signals the low pressure isolation valves to open and begin the recovery phase.

The operating recovery pumps draw water from the sumps and return it to the HTS via the ECC heat exchangers. If both operating pumps are on the same train of equipments, each heat exchanger on that train provides 50% of the cooling. In the event that one pump is operating on each train, each of the heat exchangers provides 25% of the cooling.

For large breaks, decay heat is removed from the core via the heat exchanger. For very small breaks, the majority of the decay heat is removed by heat transfer to feedwater in the stream generators. ECC then provides inventory makeup to the HTS, with the heat exchangers only providing a minimal amount of cooling.

The recovery mode continues until the decay heat has reduced to low level, or the break path has been isolated. For design purpose this is assumed to be three months.

2.3 Control Description[6]

ECC is initiated when two of the three loops measuring the pressure at ROH2 indicate a value below the initiation setpoint and one of the three conditioning signals is received. Reactor header ROH2 is the outlet header farthest away from the pressurizer. The three conditioning signals are as follows

2.3.1 Sustained Low HTS Pressure

This signal is generated when two of the three loops measuring the pressure at ROH1 (closest to the pressurizer) indicate that the pressure has remained below the initiation setpoint for a period of time known as the sustaining time. This sustaining time is tentatively set at 10 minutes. The ECC initiation setpoint is tentatively set at 6.0 MPa(g). The primary function of this signal is to help detect the presence of small out of core LOCA situations.

2.3.2 High Reactor Building Pressure

This signal is generated when at least two of three ECC RB pressure loops indicate that the pressure is above the ECC RB pressure setpoint. This conditioning signal is required for large out of core LOCA events. This signal is also useful for small LOCA events.

2.3.3 High Moderator Level

This signal is generated when two of three ECC moderater level loops indicate a level higher than the ECC moderator level setpoint. High moderator level is required for detection of in-core LOCAs.

A LOCA signal is provided for each of the three ECC channels. The majority of all end devices required for the injection and recovery phase of ECC operation are controlled by channel K and channel M circuits. The operation of K devices is very similar to the operation of channel M devices. The channel L circuits operate two gas isolation valves, two pneumatic valves and 6 of the 16 MSSVs.

2.4 Control and Monitoring Loops[6]

All analog signals use for checking and monitoring for flowrate, level, pressure and temperature in the system for irrational signals. An alarm is issued when an irrational signal is detected.

2.4.1 Flow Loops

2.4.1.1 ECC Injection Flow Loops.

Each loop monitors the flow entering a specific header. The signals from these loops are not used to control any end devices. The signals are used for display and monitoring purposes. The flow for each loop is measured by an orifice and a differential pressure drop transmitter.

2.4.1.2 ECC Pump Discharge Flow Loops

Flow in these loops is measured by checking differential pressure between inlet and outlet pressure of the pumps. This signals are used for display and monitoring purposes only.

Loop K monitors the testing/bypass line flow from pumps P1 and P2 while loop M monitors the testing/bypass line flow from pumps P3 and P4. Measurements from the loops are used during pump testing and during the recovery phase to indicate potential problems with pump flow.

2.4.2 LEVEL LOOPS

2.4.2.1 Moderator Level Loops

Moderator level is used as a conditioning signal for ECC initiation. The moderator level is monitored by triplicated level loops.

Each loop consists of a level transmitter providing for increasing moderator level and a dual alarm unit. Each alarm unit has two independent alarms. The first low alarm is used by the control circuits that operate the injection and recovery phases. The second alarm is used by the crash cooldown logic circuits. A window alarm is provided for each loop on the ECC panels.

2.4.2.2 ECC Water Tank Level Loops

Measurements from these loops are used for display and monitoring purposes and to indicate to the control logic that the end of the injection phase has been completed. Since all four tanks are located at the same level; all four loops will indicate at the same level under normal operating conditions. The measurements are used in a two out of four logic circuits to close the gas isolation valve at the end of the injection phase, and to open the low pressure isolation valve before the end of the injection phase.

Each loop consists of a level transmitter providing for increasing water tank level, a dual alarm unit #1 and a dual alarm unit #2.

The contacts from the first alarm are used to open the low pressure isolation valve. The alarm level is approximately one third of the normal tank operating level. The contacts from this current alarm unit open on low water tank level or loss of power to the unit. The open contacts are used to generate the permissive for opening the valves. One contact from the alarm is used by the channel K control logic.

Similarly the second alarm is used to open the other low pressure isolation valve. The alarm setpoint is the same as the first alarm. One contact from the alarm is used by the channel M control logic.

Dual alarm unit #2 has two independent alarms. The contacts from the first alarm are used to close the gas isolation valve at the end of the injection phase. The high alarm setpoint is approximately 1 m from the bottom of the tank. The contacts from this current alarm unit are open when the water levels are above the setpoint, or when there is a loss of power to the unit. When the water level has fallen below the setpoint, the contact is close which then enables the two out of four voting permissives to close the gas isolation valves.

The contacts from the second alarm are used to provide logic for the "WATER TANKS LEVEL VERY LOW" window alarm. The high alarm setpoint is approximately 0.8 m below the normal operating level. The contacts from this current alarm unit are open when the water level is above the setpoint or when there is a loss of power to the unit. When the water level falls below the setpoint, the closed contacts are used to generate the window alarm. A window alarm is provided on the ECC panel to indicate low water level in the tanks.

2.4.2.3 Reserve Water Tank Level Loops

These duplicated level loops monitor the water level in the Reserve Water Tank (RWT). This parameter is used for display and monitoring purposes only and is required to determine if the ECC system is poised or not. A low level in the RWT would indicate an inadequate supply of water for the long term recovery phase, and then ECC was unavailable.

Each loop consists of a level transmitter and a dual alarm unit. A window alarm is provided on the ECC panels to indicate low RWT level.

2.4.2.4 Reactor Building Water Level Loops

This parameter is used as a conditioning signal in conjunction with a LOCA signal to generate a permissive required to open the sump isolation valves.

Each loop consists of a bubbler type level measurement transmitter backing up with air supply for each bubbler system providing an air supply for eight hours after the main air supply is lost (perhaps due to seismic event), one flow controller surrounding with an isolated flow indicator that can be valved in locally to check the flowrate, a differential pressure transmitter which is located outside of containment and dual current alarm unit.

The first alarm is used to generate the permissive for opening the channel K sump isolation valves. The contacts from the alarm output relay are open when the reactor building water level is below the setpoint, the input signal is lost, or when there is a loss of power to the unit. When the reactor building water raises above the setpoint, the closed contacts are used to generate the permissive which is then sealed in. Similarly the second alarm is used to generate the permissive for opening the channel M sump isolation valves.

A window alarm is provided on the ECC panel to indicate high water level in the reactor building.

2.4.2.5 Water Level in ECC Recovery Phase Piping Loops

Loop K monitors the water level in the piping near heat exchangers HX1 and HX2. Loop L monitors the water level in the piping near heat exchangers HX3 and HX4.

Each loop consists of a level transmitter. There are no automatic control function associated with any of these measurements. Alarms are also provided for each loop.

2.4.3 Pressure Loops

2.4.3.1 Injection Gas Line Pressure Loops

This loop monitors the pressure in the line downstream of the gas isolation valves. The measurement is used to indicate small leaks in these valves. The measurement is also used to control a pressure control valve.

The loop consists of a pressure transmitter calibrated at the range from 0 to 200 kPa(g) and a dual alarm unit.

The pressure exerted on the one-way rupture disks due to the water in the tanks is approximately 140 kPa(g). The nitrogen upstream of the tanks is normally maintained around 20 kPa(g). The rupture disks burst with a forward differential pressure of approximately 350 kPa to 500 kPa. There is a margin of

190 kPa(g) between the normal pressure upstream of the rupture disks and the pressure at which they burst.

Each unit of dual alarm unit has two independent alarms. A contact from the first alarm closes when the pressure rises above a predetermined setpoint (tentatively set at 40 kPa(g)) which is used to generate an alarm. The contact is opened when the pressure falls below this setpoint or on a loss of power to the unit. The alarm is conditioned out during a LOCA situation.

A contact from the second alarm closes when the pressure rises above a predetermined setpoint (tentatively set at 60 kPa(g)) which is used to open pressure control valve. The setpoint must be high enough to permit an alarm to be issued before the valve is opened. The contact is opened when the pressure falls below this setpoint or on a loss of power to the unit (the valve fails closed). The valve is closed when a LOCA signal has been detected. A window alarm is provided to indicate high pressure upstream of the ECC water tanks.

2.4.3.2 ROH-1 Pressure Loops

ROH-1 is the output header closest to the pressurizer. Pressure measurements from this header are used to generate one of three conditioning signals used to indicate the presence of a LOCA. This particular conditioning signal is generated if two of these three pressure measurements remain below the initiation setpoint for a period of time knows as the sustaining time. The sustaining time is tentatively set at 10 minutes. The initiation setpoint for this conditioning signal is the same one as used for the low HTS pressure signal. This set point is tentatively set at 6 MPa.

Each loop consists of a pressure transmitter and a dual alarm unit. The first alarm of dual alarm unit is used by the control circuits that operate the injection and recovery phases. The second alarm is used by the crash cooldown logic circuits.

The contacts from each current alarm unit are wired to the control logic for that channel and open on low header pressure or loss of power. The open contacts are used to activate the parameter in the logic circuits. A window alarm is also provided.

2.4.3.3 ROH-2 Pressure Loops

ROH-2 is the output header farthest away from the pressurizer. Two of these three pressure measurements below the low HTS setpoint combined with one of the three conditioning signals will initiate ECC.

Each loop consists of a pressure transmitter and a dual alarm unit. The first alarm of dual alarm unit is used by the control circuits that operate the injection and recovery phases. The second alarm is used by the crash cooldown logic circuits. The contact from each current alarm unit are wired to the control logic for that channel and open on low header pressure or loss of power. The open contacts are used to activate the parameter in the logic circuits. A window alarm is also provided.

2.4.3.4 Reactor Building Pressure Loops

The reactor building pressure is monitored by triplicated pressure loops. This parameter is one of the three conditioning signals used to indicate the presence of a LOCA. This conditioning signal is generated when two of these three loops indicate values above the high RB pressure setpoint.

Each loop consists of a differential pressure transmitter and a dual alarm unit. The high pressure leg of the transmitter is connected to the reactor building atmosphere. The low pressure (or reference) leg of the transmitter is connected to the atmosphere outside of containment. Normally, the differential pressure across the transmitter is slightly negative. The output of the differential pressure transmitter provides for increasing RB pressure.

The first alarm of the dual alarm unit is used by the control circuits that operate the injection and recovery phases. The second alarm is used by the crash cooldown logic circuits.

The contacts from each current alarm unit are wired to the control logic for that channel and open on low header pressure or loss of power. The open contacts are used to activate the parameter in the logic circuits. A window alarm is also provided.

2.4.3.5 Gas Tank Pressure Loops

Loop K monitors the pressure in the tank and loop M monitors the pressure in the other tank. Since the two tanks are connected, both loops should report the same value. The measurements from these loops are used for display and monitoring purposes. A low reading in both loops would indicate that the ECC system was not poised. The measurement from loop K is used to control one of compressor and the measurement from loop M is used to control the other compressor.

Each loop consists of a pressure transmitter calibrated at the range from 600 kPa(g) to 7000 kPa(g), a dual alarm unit #1 and a dual alarm unit #2.

Dual alarm unit # 1 is used by the control circuits to operate the compressor on the same channel if the corresponding hand switch is placed in the AUTO position. The first alarm is used to start the AUTO compressor. The second alarm is used to stop the AUTO compressor.

Setpoint for starting the AUTO compressor : 6650 kPa(g)

Setpoint for stopping the AUTO compressor : 6750 kPa(g)

Dual alarm unit #2 is used by to control circuits to operate the compressor on the same channel if the corresponding hand switch is placed in the STANDBY position. The first alarm is used to start the STANDBY compressor. The second alarm is used to stop the STANDBY compressor.

Setpoint for starting the STANDBY compressor : 6600 kPa(g)

Setpoint for stopping the STANDBY compressor : 6750 kPa(g)

A low pressure alarm is issued when the pressure drops below 6600 kPa(g). A window alarm is also provided.

2.4.3.6 Gas Injection Line Pressure Loops

This loop is provided for display and monitoring purposes only. A high pressure reading during normal operation would indicate a problem due to leaking gas isolation valves (i.e. at least two valves in series are open or have opened).

The loop consists of a pressure transmitter which is calibrated for the range of approximately 0 to 7000 kPa(g). This loop will permit the operator to monitor the injection gas pressure during a LOCA, whereas loop L will not.

An alarm to indicate high pressure is provided through the main annunciation system.

2.4.3.7 ECC Pumps Differential Pressure Loops

The pressure drop across each pump is monitored by a set of triplicated differential pressure loops. The measurements are used by the logic circuits to control the operation of the pumps during LOCA situations. The measurements are also used for display and monitoring purposes.

Each loop consists of a differential pressure transmitter and a dual alarm unit. The contacts from the first alarm of dual alarm unit are used by the channel K control circuits to operate the ODD pumps (P1 and P3). The contacts from the secondary alarm are used by the channel M control circuits to operate the EVEN pumps (P2 and P4). The contacts close when the differential pressure rises above a predetermined setpoint (tentatively set at 500 kPa(g)). The closed contacts are used by the control circuits to indicate that a pump is operating.

This arrangement provides for fail safe operation overall. A loss of power to the alarm until or a loss of input signal to more than one loop would indicate to the control logic that the pump was not running. In this case a third pump may be started. There are no safety concerns associated with operating more than two pumps.

Comparison of differential pressure signals from all operating pumps, combined with various level and flow measurements, would provide a suitable logic for generating high differential pressure alarms. A window alarm is also provided.

2.4.3.8 ECC Injection Pressure Loops.

Loop K monitors the pressure of the fluid entering header RIH1 , RIH3 and ROH1 and loop M monitors the pressure of the fluid entering header RIH2, RIH4 and ROH2. These loops are provided for display and monitoring purposes only, there is no automatic control logic associated with these loops. The calibrated range for these loops is in the order 0 to 2000 kPa(g). This narrow range permits the loops to be used to detect larger breaks in the one-way rupture disks and also to provide indication that the water tanks are being pressurized from the water side (i.e. during filling of the water tanks, or if ECC water tank fill valve is let open). During the injection phase the loops will report irrational measurements.

Each loop consists of a pressure transmitter. Alarms are provided for each loop through the main annunciation system.

2.4.4 Temperature Loops

2.4.4.1 ECC Water Tank Temperature Loops.

These temperature loops are provided for display and monitoring purposes only. Measurements are used to alert the operator of either high or low water temperature.

Each loop consists of the following components;

- Thermowell and RTD,

- Temperature transmitter.

Alarms are provided for each loop.

2.4.4.2 Reserve Water Temperature Loops.

These loops monitor the water temperature in the RWT. A too high temperature may lead to inadequate net positive suction head (NPSH) during a LOCA situation. There are no automatic control actions associated with these loops.

Each loop consists of the following components;

- Thermowell and RTD,

- Temperature transmitter.

Alarms are also provided for each loop.

2.4.4.3 Heat Exchanger Inlet Temperature Loops.

Loop M monitors the temperature of the fluid upstream of heat exchangers HX3 and HX4. Loop K monitors the temperature of the fluid upstream of heat exchangers HX1 and HX2. Higher than normal temperature could indicate a problem with the ECC pumps. These loops also provide indication of sump water temperature.

Each loop consists of the following components;

- Thermowell and RTD,

- Temperature transmitter.

Alarms are also provided for each loop.

2.4.4.4 Heat Exchanger Outlet Temperature Loops.

Loop M monitors the temperature of the fluid downstream of heat exchangers HX3 and HX4. Loop K monitors the temperature of the fluid downstream of the heat exchangers HX1 and HX2. Higher than normal temperatures could indicate a problem with the heat exchangers. Alarms are also provided for each loop.

2.4.4.5 ECC Injection Temperature Loops

Loop M monitors the temperature of the fluid entering reactor header RIH2, RIH4 and ROH2. Loop K monitors the temperature of the fluid entering reactor headers RIH1, RIH3 and ROH1.

Each loop consists of the following components;

- Thermowell and RTD,

- Temperature transmitter.

2.4.4.6 Pump/Motor Temperature Loops

For the following pump/motor temperature loops, RTDs are used as the sensing elements.

Each loop consists of the following components;

- RTD and thermowell for the gland seal temperature loops,

- Temperature transmitter.

Alarms are also provided for each loop.

2.4.4.7 ECC Gas Tank Temperature Loops.

These loops are provided to warn the operator that the gas tank temperatures have exceeded the normal operating range (21 to 40°C). Injection when gas tank temperature is too low could lead to brittle fractures of the gas tank piping. This temperature will be determined following material selection of gas tank piping. Temperatures exceeding the higher operating range represent unanalyzed situations.

Each loop consists of the following components;

- Thermowell and RTD,

- Temperature transmitter.

A high or a low temperature alarm is issued when the temperature drops below the lower operating range and an alarm is issued when the temperature rises above the higher operating temperature.

2.5 Component Control and Monitoring[5]

2.5.1 ECC Recovery Pumps

A hand switch (OFF-AUTO-ON) is provided for control of each pump. In this instance, the word AUTO indicates that the logic circuits have control of the pump. An alarm will be issued wherever a hand switch for a pump is not in the AUTO. The OFF hand switch position is provided for maintenance purposes and to shut down the pump if trouble is detected during LOCA operation, (i.e. warning alarm is issued pump motor temperature and/or vibration loops).

Two ECC pumps are started upon receiving of a LOCA signal. Pumps P1 and P3 are controlled by the channel K circuits while pump P2 and P4 are controlled by the channel M circuits. Interlock prevents a pump from starting if any two pumps are operating. A pump is considered to be operating when two of the three differential pressure loops across a pump indicate that the differential pressure is above a certain value (tentatively set at 500 kPa). This arrangement requires that each of the twelve differential pressure loops.

Each pump has time delay incorporated into the control circuit so that preference is given to starting the two auto pumps (P1 and P4). An assumption is made that a pump starts (i.e. differential pressure rises above 500 kPa) within 10 seconds. This time is dependent on the actual pumps used and will have to be verified during commissioning.

Manual control of the pumps is possible at any time through the hand switches. Manual control has precedence over the control circuit logic.

2.5.2 Low Pressure Isolation Valves

Each actuator is provided with one limit switch for the open position indication and control and one torque switch for the closed position indication and control. As well, two limit switches are provided on the valve in each of the fully open and fully closed positions for position indication and control. The contacts from each set of limit (and torque) switches are connected to a set of relays, in a two out of three voting circuit for control of the valve. Most valves described in this section require the detection of a LOCA signal before the valve can be operated manually from hand switches.

During normal operation, these valves are closed and are only opened temporarily for testing purposes. A hand switch (CLOSED-AUTO-OPEN) is provided. An off-normal alarm is issued whenever a hand switch is not in the AUTO position

The low pressure isolation valves are opened automatically following a LOCA when two of the four water tank level measurements indicate a level below the opening setpoint of these valves.

2.5.3 Test/Recirculation Line Valves

During normal operation, these valves are closed. The valves are opened for ECC pump testing. The operation of the valves is done during pump testing and is automatically closed when a LOCA signal is detected. The valves can be manually opened by the operator following a small LOCA but the operator is not required to open these valves until eight hours after a LOCA has occurred.

Valve status display (CLOSE-OPEN) is provided. A hand switch (CLOSE-AUTO-OPEN) is provided. An off-normal alarm is issued whenever a hand switch is not in the AUTO position. The hand switches permit the valves to be operated at any time, and the logic is independent of a LOCA signal for operation.

2.5.4 Gas Isolation Valves

During normal operation, these valves are closed and are only opened temporarily for testing purposes. Control circuits from each channel open two valves upon detection of a LOCA signal and then close the valves when a low water level signal is detected from the water tank level loops.

Valve status display (CLOSE-OPEN) is provided. A hand switch (CLOSE-AUTO-OPEN) is provided for each valve. An off-manual alarm is used whenever a hand switch is not in the AUTO position.

The valves can be opened manually. The CLOSE hand switch positions are provided to reset the sealed in logic allowing the valves to be returned to the normally poised state in the event of a spurious ECC initiation to attempt to minimize the economic impact due to downgrading the HTS inventory. (In this case the valves would be closed in a systematic order after the LOCA signals are cleared).

2.5.5 Sump Isolation Valves

During normal operation, these valves are closed and are only opened temporarily for testing. Valve status display (CLOSE-OPEN) is provided as well as hand switch (CLOSE-AUTO-OPEN).

During a LOCA situation, a valve is opened by the automatic control circuits if the corresponding pump is operating, and the permissive to open the valve has been generated. Generally the permissive is enable when the water level in the reactor building is above the opening setpoint as determined by two of the three RB level loops.

After a LOCA signal has been detected, the valve can be opened via a hand switch if the opening permissive has been enabled. This type of interlocking is provided to prevent addition of water to sump and related piping and draining of ECC recovery piping through inadvertent opening of this valves. Manual control is required after a LOCA in case of a problem developing with an ECC pump. Manual control always overrides control logic from the ECC control circuits.

2.5.6 Motorized Valves for Testing Sump Isolation Valves

These valves are required for testing and maintenance purposes only. There will not be hand switches for control of these valves. Control will be through the control logic circuits. Normally these valves are open and are only closed for maintenance when the sump isolation valves are tested. Valve status display (CLOSE-OPEN) is provided.

There is a special situation, where a LOCA occurs before testing of a sump isolation valve is completed, that the operator must manually open one of these valves from the ECC panel. Normally each valve will be open so that this action is not required.

2.5.7 Water Tank Isolation Valves

These valves are provided with local control. There are no automatic controls provided for any of these valves. The operator will need a key to operate the local controls. As well the breaker will be locked open (with a padlock) during normal plant operation. In this position, power will not be available for the valve motor. The operator will require two different keys to operate each valve. Feedback from the torque and limit switches is provided via the control logic to indicate valve position in the control areas.