Pressurized Water Reactor
B&W Technology
Crosstraining Course Manual

Chapter 8.1

Non-Nuclear Instrumentation

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8.1 NON-NUCLEAR INSTRUMENTATION

Learning Objectives:

1. Explain how the following signals are developed:

    (a) Loop - T_c, T_h, ΔT, T_{ave}
    (b) Unit - T_c, T_h, ΔT, T_{ave}, ΔT_c

2. Explain how the automatic/manual selector switch determines which input signals will be used for the unit T_{ave} signal.

3. State, as listed in Table 8.1-1, the functions provided in the integrated control system by the non-nuclear instrumentation inputs.

4. Explain why temperature compensation of the RCS flow signal is required.

5. Explain why pressurizer level is density compensated.

6. List the inputs and outputs for the pressurizer level control system.

7. State the interlock provided by the pressurizer level signal and explain the purpose of the interlock.

8. List the inputs and outputs for the pressurizer pressure control system.

8.1.1 Introduction

Non-nuclear instrumentation may be defined as the sensors, instrument strings, and control system inputs that are necessary for normal plant operation.

The non-nuclear instrumentation system interfaces with the integrated control system (provides input signals), plant control systems (provides input signals), the plant computer (provides input signals), the plant annunciation system (provides alarm signals), and the essential controls and instrumentation system (receives optically isolated inputs).

A variety of signals are available from the non-nuclear instruments; they range from makeup tank pressure to reactor coolant system flow. Non-nuclear instrumentation signals are not, however, required for the safe shutdown of the plant or for the protection of the core. The system is non-Class 1E.

This chapter provides information on the more important non-nuclear instrumentation.

8.1.2 Reactor Coolant System Temperatures

The temperatures required for control of the reactor coolant system are the reactor outlet temperature (T_H), the reactor inlet temperature (T_C), the average of these two temperatures (T_{ave}), and the difference between these two temperatures (ΔT).

8.1.2.1 Reactor Outlet Temperature (T_H) Detectors

A total of six (three dual-element) resistance temperature detectors (RTDs) are installed in each reactor outlet (hot leg) (Figure 8.1-1). Two of these detectors provide temperature signals to the reactor protection system (RPS), and two detectors are installed RPS spares. One detector supplies the essential controls and instrumentation (ECI) system, and the remaining detector supplies a non-nuclear instrumentation temperature input. Each ECI RTD is wired into a resistance bridge (loop A supplies ECI-X; loop B supplies ECI-Y), which supplies a temperature input to the non-nuclear instrumentation by means of a fiber optical isolator.

8.1.2.2 T_H Signal Outputs

Either the non-nuclear instrumentation T_h signal or the essential controls and instrumentation system signal may be selected to supply either the plant computer or the non-nuclear instrumentation circuitry with a narrow-range temperature signal (530° to 650°F) (Figure 8.1-2).

The plant computer input is supplied by the non-selected (i.e., not selected for NNI circuitry) T_H input. The plant computer uses the hot-leg temperature for the calculation of plant power output based on core ΔT, for the calculation of plant power based on the enthalpy rise across the core, and for computer-supplied temperature indication.

The non-nuclear instrumentation circuitry supplies indication, ΔT calculation, loop T_{ave} calculation, a signal to the RCS flow circuitry, and an input to the integrated control system (ICS).

T_H is supplied from each loop to the operator for indication. The indication is narrow range with a scale of 530° to 650°F.

T_H supplied for the ΔT calculation has its associated cold-leg temperature (T_C) subtracted from it, and the result is loop ΔT. At steady-state power levels, the loop ΔT is a very accurate indication of plant power. This circuitry provides an indicator with a range of 0° to 80°F.

The T_H and T_C signals are averaged to supply an indication of loop T_{ave}. In addition to indication, loop T_{ave} may be selected as an input to the ICS.

The T_H is also used to temperature compensate reactor coolant flow that is supplied from flow transmitters located in the hot-leg piping.

Each of the loop T_H signals is supplied to an averaging circuit that calculates the average hot-leg temperature for the RCS. This average T_H signal, along with each loop T_H signal, is supplied to a selector switch that, in turn, supplies an input to the ICS. The ICS uses T_H in the calculation of once-through steam generator BTU limits (see Chapter 9.0). Besides the ICS input, the selected T_H signal is used for the computation of unit T_{ave} and ΔT, for the high T_H alarm set at 635°F, and for a recorder input.

8.1.2.3 Reactor Inlet Temperature (T_c) Detectors

A total of 8 RTDs are used to sense the reactor inlet temperature (T_C) in each loop (Figure 8.1-1). Two dual-element RTDs are inserted into wells in the discharge of each reactor coolant pump. Four RTDs in each coolant loop supply signals to the NNI and ECI systems. The NNI RTDs supply narrow-range circuitry (530° to 650°F) and wide-range circuitry (50° to 650°F). The ECI RTD in each loop supplies wide-range circuitry.

8.1.2.4 Wide-Range T_C Signal Outputs

The non-nuclear instrumentation wide-range T_C (50° to 650°F) RTD supplies a temperature signal to a selector switch, and the essential controls and instrumentation system T_C detector supplies the second signal to the same selector switch (Figure 8.1-3). The selector switch (one for each loop) supplies the non-nuclear instrumentation signal to an indicator located in the main control room, to an indicator located in the auxiliary control room, and to the start circuitry for the reactor coolant pumps. Wide-range indication is necessary to allow the operator to cool down or heat up the RCS when temperature is less than that in the normal operating range (530° to 650°F). The starting of a fourth reactor coolant pump if temperature is less than 500°F is prevented by circuitry from the associated loop wide-range T_C. The non-selected wide-range temperature signal is sent to the computer for indication.

8.1.2.5 Narrow-Range T_C Signal Outputs

The narrow-range T_C signals are supplied to the plant computer, to indication circuits, and to the ICS (Figure 8.1-4). The plant computer inputs are supplied from each NNI narrow-range T_c RTD. These inputs are used in the calculation of the departure from nucleate boiling ratio (DNBR), the calculation of plant power based on the enthalpy rise across the core, and the calculation of plant power based on core ΔT.

The loop indication circuitry receives inputs from both T_C narrow-range signals in that loop and the average of these two inputs. A selector switch position decides which signal will be used to provide indication of T_C. A selector switch is provided for each loop.

The selected signal provides the operator with narrow-range temperature indication (530° to 650°F), provides an input to loop ΔT and loop T_{ave}, and provides inputs to the unit T_C circuitry and to a difference unit that provides a unit ΔT_C signal to the ICS.

The T_C input to the loop ΔT circuitry is subtracted from loop T_H and provides the operator with ΔT indication with a range of 0° to 80°F.

The T_C input to the loop T_{ave} computation is averaged with loop T_H to provide loop T_{ave}. Loop T_{ave} has a range of 530° to 650°F and may be used as an input to the ICS.

The unit T_C signal is derived from the average of the selected T_C signals of both loops. Unit T_C is averaged with unit T_H to yield unit T_{ave}. Unit T_{ave} may be used as an input to the ICS.

A unit ΔT_C input is supplied to the feedwater demand subassembly for proportioning of feedwater flows if a difference in loop T_C exists (see chapter 9.0).

8.1.2.6 Differential Temperature (ΔT) Signals

Reactor coolant differential temperature (ΔT) is calculated from the T_H and T_C outputs and is used only for indication. Three different ΔT signals, with a range of 0 to 80°F, are displayed; that is, one from each loop and unit ΔT (Figure 8.l-5).

The unit ΔT is calculated by subtracting unit T_C from unit T_H. Unit ΔT is displayed in the main control room.

8.1.2.7 Average Reactor Coolant System Temperature (T_{ave})

The calculated average reactor coolant system (RCS) temperature (T_{ave}) is used for indication and control (Figure 8.1-5).

Three T_{ave} signals are computed: loop A T_{ave}, loop B T_{ave}, and unit T_{ave}. The loop T_{ave} signal is the average of the selected loop T_H and loop T_C signals, and the unit T_{ave} is the average of unit T_H and unit T_C.

The three T_{ave} signals are supplied to an automatic/manual selector switch, which also receives inputs from loop A and loop B RCS flow. As long as all four reactor coolant pumps are running, the operator may select any of the three signals for use in the reactor demand subassembly of the ICS. The Tave signal is supplied to the reactor demand subassembly for regulating rod movement. During asymmetric loop flow conditions, the automatic/manual selector switch automatically supplies the ICS with the loop T_{ave} signal from the loop with the highest RCS flow. This selection is performed through interlock circuitry from RCS flow, and the operator cannot override this selection. The output of the automatic/manual selector switch is digitally displayed in the control room.

8.1.3 Reactor Coolant System Flow

8.1.3.1 Reactor Coolant System Flow Detection

Reactor coolant flow is sensed by a flow element located in each reactor coolant hot leg (Figure 8.1-6). The flow element is a flow tube designed to provide minimum restriction to RCS flow. The flow tube, pictured in Figure 8.1-7, is an integral portion of the hot-leg piping. The tube contains penetrations that provide a method of sensing differential pressure; that is, a high-pressure tap that senses the velocity head of the RCS fluid, and a low-pressure tap that senses the static head of the RCS. The flow tube taps are piped to six flow transmitters for each loop. Four of these flow transmitters supply flow signals to the reactor protection system (RPS), and two of these transmitters supply the non-nuclear instrumentation system.

8.1.3.2 Reactor Coolant Flow Signal Outputs

The outputs of each loop's non-nuclear instrumentation flow transmitters are supplied to a selector switch that decides which flow transmitter supplies the indication and control signal (Figure 8.1-8). The non-selected signal is supplied to the plant computer.

The selected flow signal is routed to a square root extractor that converts the differential pressure signal to a flow signal (flow is proportional to the square root of the ΔP). From the square root extractor, the flow signal is supplied to a function generator. In the function generator, the flow signal is density compensated by the associated loop T_H signal. With density compensation of the RCS flow, a mass flow rate signal is sent to the ICS rather than a volumetric flow rate. The output of the function generator is supplied to an indicator, a bistable, the ICS, and a summing amplifier (Σ). An indication of loop flow with a range of 0 to 120×10^6 lb mass per hour is provided for each loop.

The bistable performs two functions: it supplies a low flow alarm, and it supplies an input to the T_{ave} automatic/manual selector switch. The low flow alarm is set at approximately 90% of rated flow and alerts the operator to a degraded flow condition. The input to the T_{ave} automatic/ manual selector switch causes the selection of the opposite loop T_{ave} when loop flow drops to approximately 90%.

Individual loop flow signals are supplied to the feedwater demand subassembly of the ICS and are used for the control of feedwater to the once-through steam generators (OTSGs). The ratio of feedwater supplied to the steam generators depends on the RCS loop flows through the primary (tube) sides of the OTSGs. The ICS also uses RCS loop flows in the calculation of OTSG BTU limits (see Chapter 9.0).

The summing amplifier sums the flow signals from the individual loops and provides inputs to a recorder and to the ICS. The recorder provides the operator with an indication of total core flow, which has a range of 0 - 240×10^6 lbm/hr. The unit load demand of the

ICS receives an input of total RCS flow and, on the basis of this input, will run back unit electrical load to maintain power production consistent with RCS flow.

As previously mentioned, the plant computer receives inputs from the non-selected flow transmitters. The RCS flow inputs are used in the calculation of DNBR and core thermal power and in the primary heat balance program.

8.1.4 Pressurizer Level

The pressurizer is equipped with two level transmitters with a 0 to 400-in. range. These transmitters supply the essential controls and instrumentation system with redundant inputs. The ECI level transmitter signals are fed to the non-nuclear instrumentation system by means of fiber optical isolators. From the optical isolators, the level transmitter signals are routed to a selector switch. The selector switch is used to select the signal that is to be used for pressurizer level control. The non-selected pressurizer level signal is supplied to the plant computer for indication and annunciation.

The selected pressurizer level input is temperature compensated by the pressurizer water space temperature. Temperature compensation is necessary to provide accurate level indication for temperatures ranging from cold shutdown pressurizer temperatures to normal operating pressurizer temperatures. The temperature input to the pressurizer level circuitry also supplies an indicator with a 0 - 700°F range. The output of the temperature compensation circuitry is selected compensated pressurizer level.

The pressurizer level circuitry supplies low, low-low, high, and high-high alarm bistables. The low- and high-level alarm setpoints are based on the pressurizer level change associated with a 5°F change in T_{ave}. The high-high alarm alerts the operator that the pressurizer is approaching solid water conditions. The alarm associated with the low-low bistable informs the operator of an extremely low-level condition. The low-low alarm is also used to de-energize the pressurizer heaters. This interlock prevents any heater damage that might occur if the heaters were to become uncovered while in operation.

In addition to providing alarms, the selected compensated pressurizer level is used for pressurizer level control. The control scheme consists of comparing the actual pressurizer level with an operator-supplied setpoint. The setpoint is manually varied as a function of T_{ave}. As shown in Figure 8.1-10, the no-load pressurizer level, corresponding to a T_{ave} of 550°F, is 180 in. As power is escalated, T_{ave} increases, and the operator changes the pressurizer level setpoint. The change in setpoint allows part of the volume increase associated with the change in T_{ave} to be accommodated by the increase in pressurizer level. The remaining volume change is accommodated by diverting letdown flow to the reactor coolant bleed tanks. The above actions are continued until T_{ave} reaches 601°F (15% power value); T_{ave} is then held constant, and the pressurizer level setpoint is maintained at 220 in.

Regardless of the value of the level setpoint, it is compared with actual pressurizer level in a difference (Δ) amplifier. The output of this amplifier, pressurizer level error, is supplied to a proportional-plus-integral controller that modifies the error signal on the basis of the amount and duration of the deviation from setpoint. From the proportional-integral controller, the signal is routed through a manual/automatic station and is then supplied to an electrical-to-pneumatic (E/P) converter that changes the error signal to an air signal. The air signal is used to modulate the makeup control valve (V-46). The modulation of makeup rate, along with a constant letdown rate, allows the control of pressurizer level. The manual/automatic station allows the operator to control the position of the makeup control valve when manual is selected.

8.1.5 Pressurizer Pressure

8.1.5.1 Wide-Range Pressurizer Pressure

Two wide-range (0 - 2500-psig) pressurizer pressure inputs are supplied from the essential controls and instrumentation system to the non-nuclear instrumentation system (Figure 8.1-11). The signals are routed through optical isolators to a selector switch that selects the wide-range pressure that is to be used by the non-nuclear instrumentation system. The non-selected signal is supplied to the plant computer. Wide-range pressure is used to monitor RCS pressure/temperature limits during plant heatups and cooldowns.

8.1.5.2 Narrow-Range Pressurizer Pressure

Two narrow-range pressurizer pressure transmitters send signals to the non-nuclear instrumentation system (Figure 8.1-12). A selector switch provides a method of selecting the signal that is to be used for pressurizer pressure control. As is typical in the non-nuclear instrumentation system, the non-selected signal is supplied to the plant computer and is used for indication and DNBR calculations.

The selected pressurizer pressure transmitter is used to provide alarms; to control the power-operated relief valve, the spray valve, the on/off pressurizer heaters, and the proportional pressurizer heaters; and to provide a recorder with an indication range of 1500 - 2500 psig.

The high- and low-pressure alarms are driven by bistables that receive an input directly from the selected pressure transmitter. These alarms are used to alert the operator that RCS pressure has deviated from the normal control band.

The power-operated relief valve (PORV) is also controlled by a bistable that receives an input directly from the selected pressure transmitter. The bistable opens the PORV at 2400 psig and closes the PORV when pressure drops to 2375 psig. The bistable control of the PORV is independent of the controller/setpoint comparison that is used for heater and spray valve control.

The remaining pressurizer pressure control devices are controlled by the output of a summing amplifier (Σ). The summing amplifier has two inputs: actual pressurizer pressure and the setpoint. The setpoint is supplied by a setpoint module in the non-nuclear instrumentation cabinets and is normally adjusted to a value of 2195 psig. However, provisions are installed to allow a different value to be used. The resultant error from the comparison of actual pressurizer pressure to the setpoint is used to control the spray valve and the pressurizer heaters.

Automatic control of the spray valve is accomplished by a bistable that opens the valve when pressure increases to 2245 psig and closes the valve when pressure decreases to 2195 psig. A maximum output limiter prevents the spray valve from opening more than 40% when the valve's manual/automatic (M/A) controller is in automatic. The valve can be fully opened using manual control. The M/A controller "Open Limit Exceeded" light alerts the operator that the spray valve has opened more than 40%.

There are 10 Groups of pressurizer heaters which are arranged in 4 heater Banks: Bank 1 contains Group 10; Bank 2 contains Groups 7, 8 and 9; Bank 3 contains Groups 4, 5 and 6; and Bank 4 contains Groups 1, 2 and 3. Heater Groups 8 and 9 are powered from separate vital AC buses. The control of heater Banks 2, 3 and 4 (sometimes called On/Off heaters) is accomplished by bistables. As pressurizer pressure decreases below the pressure setpoint, the bistables sequentially change state at discrete setpoints (see Figure 8.1-12), and the associated heater banks sequentially energize. As pressure increases, the heaters sequentially de-energized. Heater banks 2, 3 and 4 are interlocked with pressurizer level. Should pressurizer level drop to the low-low level setpoint (120 inches), automatic heater energization is prevented until the level returns to a value above the low-low setpoint.

The control of the proportional heaters (Bank 1) is accomplished by a proportional-integral controller. As pressure decreases below the setpoint, the controller signal causes a silicon controlled rectifier (SCR) to increase the power output to the proportional heaters. The proportional heaters are in a maximum power condition when pressure drops to 2175 psig and a minimum power condition at a pressure of 2195 psig. An M/A station is installed to allow operator control of the proportional heaters. Pressurizer level is also used as an interlock in the proportional heater control circuitry. If pressurizer level drops to the low-low level setpoint, the output of the SCR control is driven to its minimum value.

8.1.6 Feedwater System Instrumentation

The sensing of feedwater flow, feedwater valve differential pressure, and feedwater temperature is performed to provide the ICS with the required inputs. Two feedwater flow signals (Figure 8.1-13) are processed by the non-nuclear instrumentation system: (1) a low-range flow signal, called startup feedwater flow, with a range of 0 - 2×10^6 lbm/hr, and (2) a full-range signal, called main feedwater flow, with a range of 0 - 9×10^6 lbm/hr. Startup feedwater flow is sensed from a venturi located in series with the startup feedwater regulating valve, and main feedwater flow is sensed by a venturi located in series with both the main and startup feedwater regulating valves. Both flow signals are density compensated by feedwater temperature and are used as inputs to the ICS.

The pressure differential between the inlet and the outlet of each feedwater regulating valve is measured by differential pressure transmitters. The output of the differential pressure transmitters is supplied to the ICS, which regulates feedwater pump turbine speed on the basis of the transmitter signal.

Feedwater temperature is used to density compensate the feedwater flow signals and as an input to the ICS. Feedwater temperature is measured by dual-element resistance temperature detectors located downstream of the main feedwater isolation valves (MFIVs).

8.1.6.1 Feedwater Flow

Figure 8.1-14 shows the feedwater instrumentation for feedwater loop A. The instrumentation for loop B is identical; therefore, the following description is applicable to both loops.

A single flow transmitter is used to sense startup feedwater flow. The output of this transmitter is sent to a square root extractor (for conversion into a flow signal) and to the plant computer, where an internal conversion is used to calculate startup feedwater flow.

From the output of the square root extractor, the flow signal is sent to a variable gain unit (χ). The variable gain unit increases or decreases the flow signal as a function of feedwater temperature. The feedwater temperature signal is supplied through a function generator (f(T)) from the selected feedwater temperature, and the variable gain unit is used to provide the necessary temperature compensation of feedwater flow.

The temperature-compensated, startup feedwater flow signal supplies an indicator with a range of $0 - 2 \times 10^6$ lbm/hr and an input to the ICS. Startup feedwater flow is used by the ICS when the main feedwater block valve is closed. The main feedwater block valve automatically opens when the startup regulating valve reaches an 80% open position. When the main block valve is fully open, the ICS uses main feedwater flow as an input.

Main feedwater flow is sensed by two flow transmitters that supply inputs to square root extractors and a selector switch. The square root extractors convert the ΔP signals into flow signals, and the selector switch chooses the plant computer input from one of the two transmitters. The conversion of the raw ΔP signal into flow is performed by the computer software.

The outputs of the square root extractors are supplied to variable gain units that also receive inputs from feedwater temperature function generators. These function generators density compensate the main feedwater flow signals by changing the gains of the variable gain units.

From the variable gain units, the density- compensated main feedwater flow signals are routed to a selector switch. The signal that is selected by the selector switch supplies indication and the ICS; the non-selected signal is supplied to the plant computer for indication and secondary power calculations. The selected signal provides an indicator (with a range of 0 - 9 × 10^6 lbm/hr) and an ICS input that is used for comparison with feedwater demand. The selected loop feedwater flow signals are summed by the ICS and compared to feedwater demand for the generation of cross limits (see Chapter 9.0).

8.1.6.2 Feedwater Valve Differential Pressure

Feedwater valve differential pressure (ΔP) is measured by two differential pressure transmitters for each feedwater loop (Figure 8.1-14). The outputs of the transmitters are supplied to a selector switch. The selected transmitter supplies an indicator (with a range of 0 - 100 psid) and the ICS. The ICS uses feedwater valve ΔP to control main feedwater pump speed. The non-selected transmitter output is supplied to the plant computer for indication purposes.

8.1.6.3 Feedwater Temperature

A dual-element resistance temperature detector is installed in a temperature well downstream of the main feedwater isolation valves (MFIVs) in each feedwater loop (Figure 8.1-14). Each element supplies a bridge circuit that converts the resistance to a temperature signal. Each bridge circuit, in turn, feeds a function generator (f(T)), which is used to density compensate one of the two main feedwater flow signals, and a selector switch.

The selected feedwater temperature supplies density compensation for startup feedwater flow and an indicator with a range of 0 - 600°F. The selected feedwater temperature also provides the low temperature MFP trip signal and is used by the ICS to calculate OTSG BTU limits. Additionally, the selected loop temperatures from both loops are averaged by the ICS. The average feedwater temperature is used by the ICS to limit feedwater demand. The non-selected signal is supplied to the plant computer for indication and for the calculation of secondary plant power.

8.1.7 Steam System Instrumentation

The sensing of startup-range OTSG level, turbine header (steam) pressure, and OTSG pressure provides the ICS with the parameters required to control the plant.

8.1.7.1 Once-Through Steam Generator Level Instrumentation

Two different ranges of OTSG level transmitters are installed on the integral economizer OTSGs: (1) startup-range transmitters that provide indication and control signals and (2) full-range transmitters that are used for indication (Figure 8.1-15).

The startup-range circuitry consists of two redundant ECI level transmitters for each OTSG, which supply outputs through optical isolators to a selector switch. The selected startup-range level, in turn, is supplied to an alarm bistable that alerts the operator to high- and low-level conditions in the OTSG and to the ICS, which uses the level information for low-level limit control of the OTSGs. The non-selected signal is supplied to the plant computer for indication functions. Each of the startup-range detectors supplies an indicator with a range of 0 - 80 in.

The single full-range level signal (0 - 100%) for each OTSG; supplies level information to the operators when full wet layup conditions are established during cold shutdown.

8.1.7.2 Turbine Header and OTSG Pressure Instrumentation

The turbine header pressure is supplied to the non-nuclear instrumentation system by a pressure transmitter located on the steam header from each steam generator (Figure 8.1-15). The pressure transmitter outputs are supplied to a selector switch. The selected pressure transmitter signal supplies a recorder with a range of 500 - 1500 psig, high- and low-pressure alarms, and an input to the ICS that is used for turbine load control and steam dump valve control. The non-selected pressure transmitter signal is supplied to the plant computer for display. OTSG steam pressure (two detectors per OTSG) is supplied to the ICS for the calculation of BTU limits.

8.1.8 Smart Analog Signal Select System

Several significant plant transients have been caused by the failure of the NNI input signals to the ICS. These transients range from uncomplicated reactor trips to severe overcooling events. The causes of input signal failures have ranged from simple transmitter failures to losses of power to the NNI system.

Ideally, one half of the NNI transmitters are powered from one power supply (this is sometimes called NNI-X), and the redundant transmitters are powered from a separate power supply (referred to as NNI-Y). In the event of a loss of power, half of the instrumentation would be available to control the plant in a stable post-trip condition.

The Smart Analog Signal Select (SASS) System is designed to mitigate some of the problems associated with ICS input signal failures. The SASS System has been installed at all operating B&W plants.

SASS is a computer-based signal selection device that is designed to sense degradation of redundant input signals and to automatically transfer to an operable input if a signal failure is detected. The computer receives inputs from redundant signal transmitters (Figure 8.1-16). The signals are compared in magnitude to determine if a 3 percent mismatch exists. If a mismatch of this magnitude is present, the program determines the rate of change of the mismatched signal by comparing the signal with its previous value. If a large rate of change occurs (> 30%/second), the program reiterates to verify failure. If a signal failure is also determined by the second program execution, then SASS will select the operable transmitter for ICS input and control board indication. An alarm will also be generated. If the program determines that only a signal mismatch exists, control room annunciators are actuated, and the system shifts to manual. The operator must manually select the operable transmitter.

8.1.9 Summary

The non-nuclear instrumentation system processes many primary and secondary plant parameter signals for use in the plant control systems. Reactor coolant system temperatures are combined in various ways to develop both loop and unit temperature signals. Figure 8.1-17 shows a simplified one-line diagram of how these signals are developed. The integrated control system uses many of these plant parameters. Table 8.1-1 lists those parameters which input to the ICS and the functions that they provide.

TABLE 8.1-1 NON-NUCLEAR INSTRUMENTATION INPUTS TO INTEGRATED CONTROL SYSTEM

NNI Signal	ICS Subassembly	Function
Unit T_h	Feedwater Demand	Calculation of OTSG BTU Limits.
Unit Delta T_c	Feedwater Demand	Calculation of feedwater flow ratio for OTSGs.
Unit T_{ave}	Reactor Demand	Modify reactor demand signal for regulating rod movement.
Loop A RCS Flow	Feedwater Demand	Calculation of OTSG BTU limits and feedwater flow rationing.
Loop B RCS Flow	Feedwater Demand	Calculation of OTSG BTU limits and feedwater flow rationing.
Total RCS Flow	Unit Load Demand	Initiation of runback signals to maintain correct power-to-flow ratio.
Loop Main Feedwater Flow	Feedwater Demand	Compared to feedwater demand to develop error signal.
Loop Startup Feedwater Flow	Feedwater Demand	Compared to feedwater demand to develop error signal when the main feedwater block valve is not fully open.
Loop Main Feedwater Temperature	Feedwater Demand	Calculation of OTSG BTU limits.
Main Feedwater Valve ΔP	Feedwater Demand	Control main feedwater pump speed.
OTSG Startup Level	Feedwater Demand	Low-level limit control.
Turbine Header Pressure	Integrated Master	Turbine load control and steam dump valve control.
OTSG Pressure	Feedwater Demand	Calculation of OTSG BTU Limits.
Average FW Temperature	Feedwater Demand	Modify feedwater demand signal.

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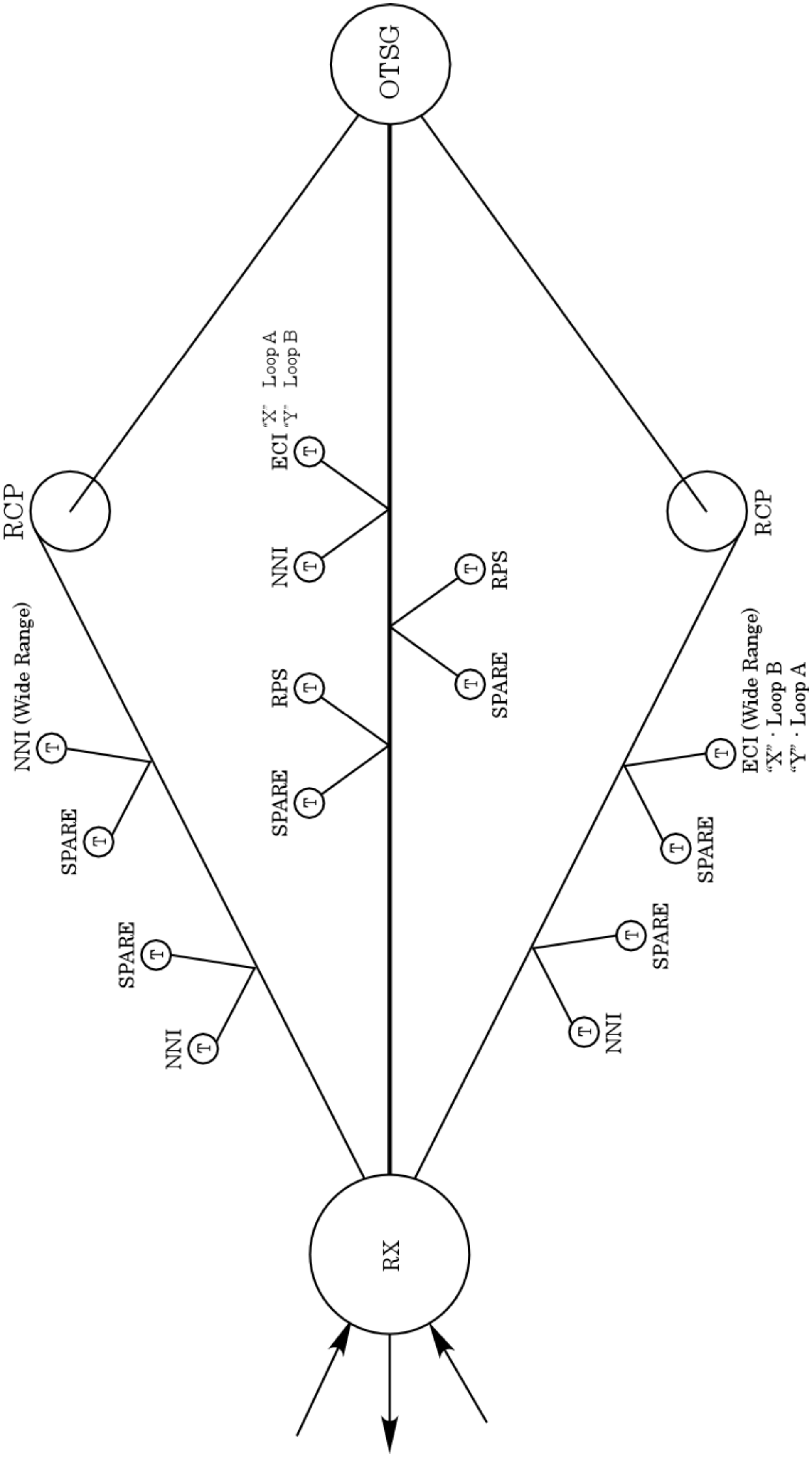

Figure 8.1-1 Reactor Coolant System Temperature Detector Location

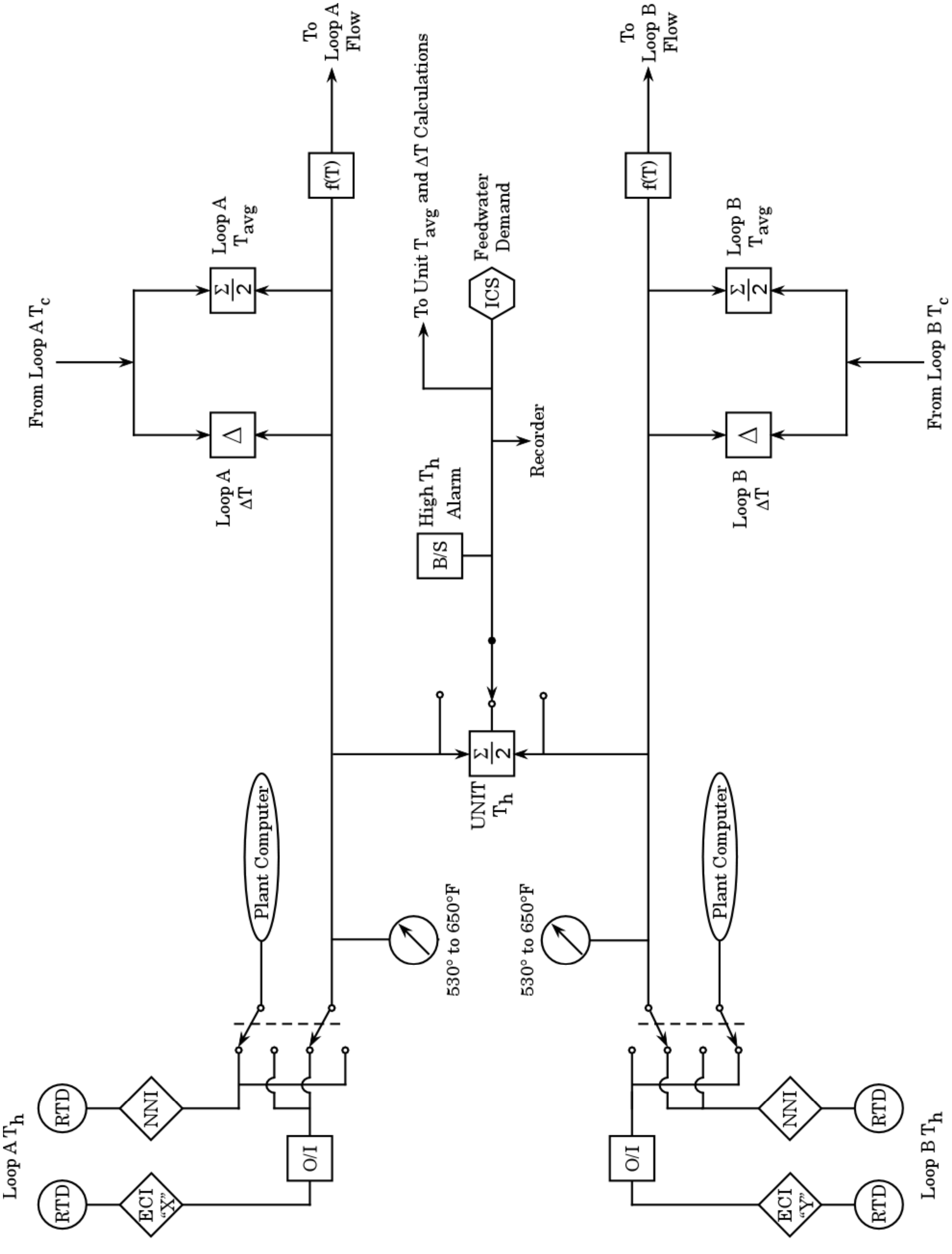

Figure 8.1-2   Reactor Outlet Temperature

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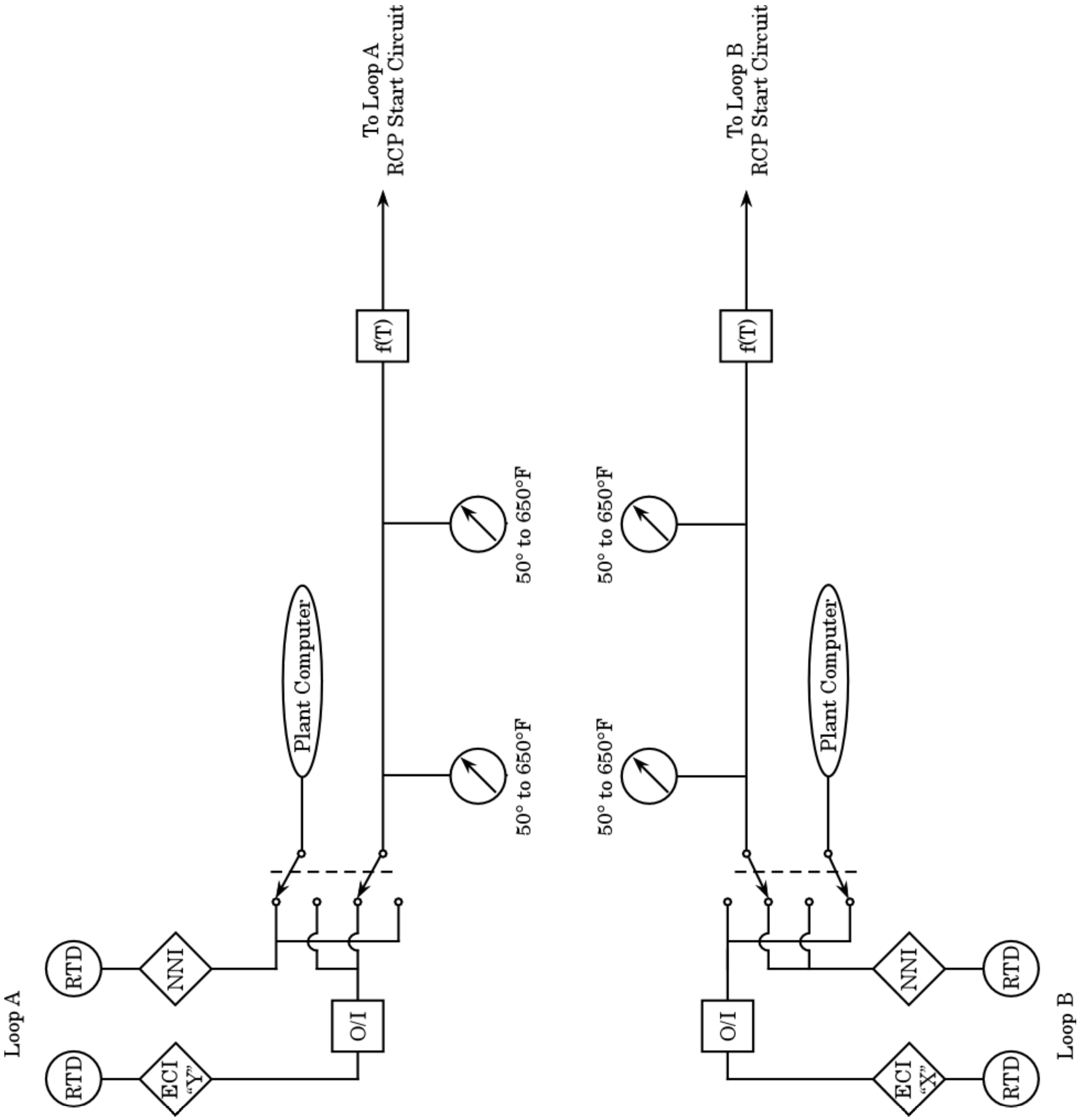

Figure 8.1-3 Wide-Range Reactor Coolant Inlet temperature (T_C)

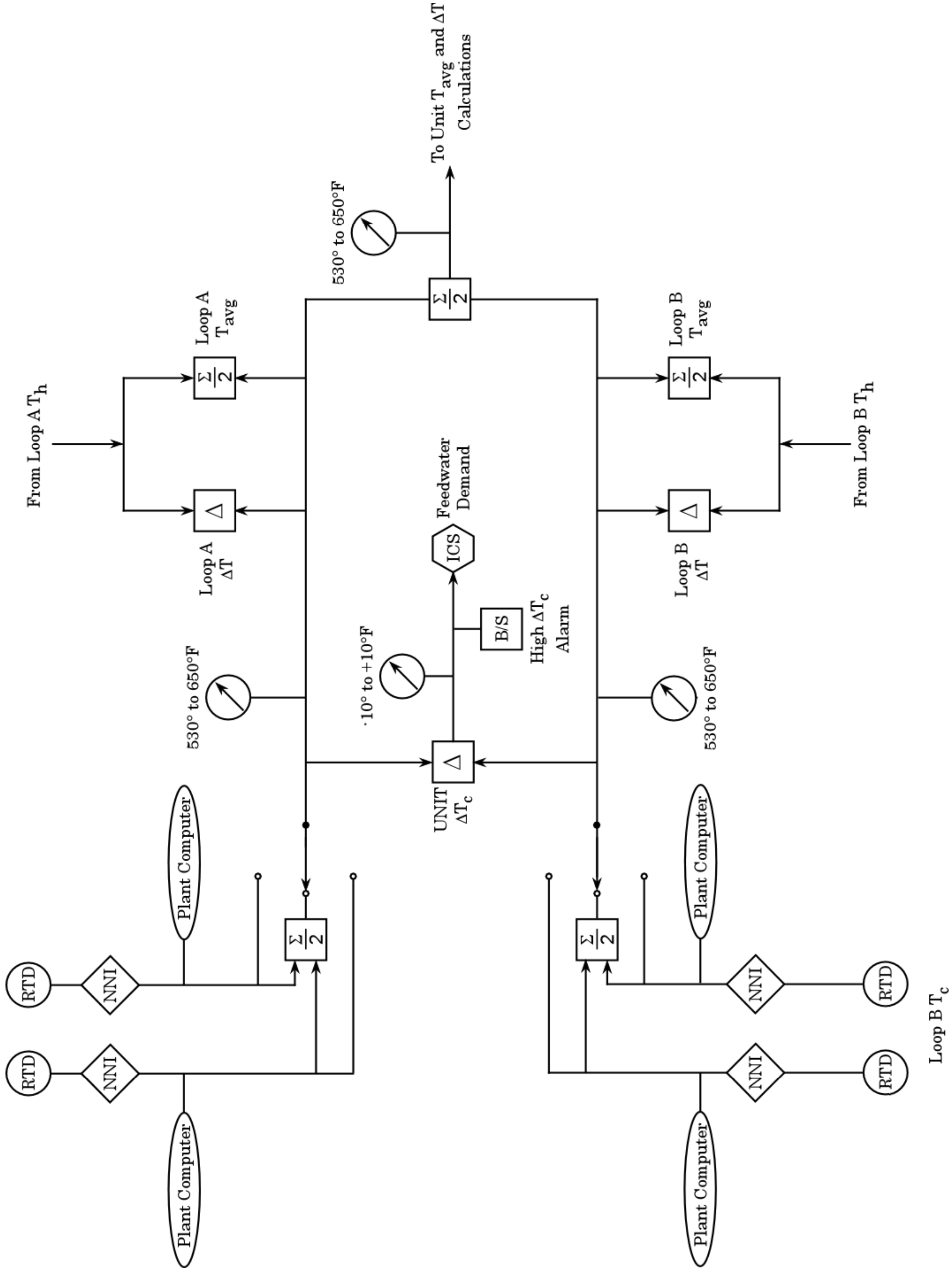

Figure 8.1-4 Narrow-Range Reactor Coolant Inlet temperature (T_C)

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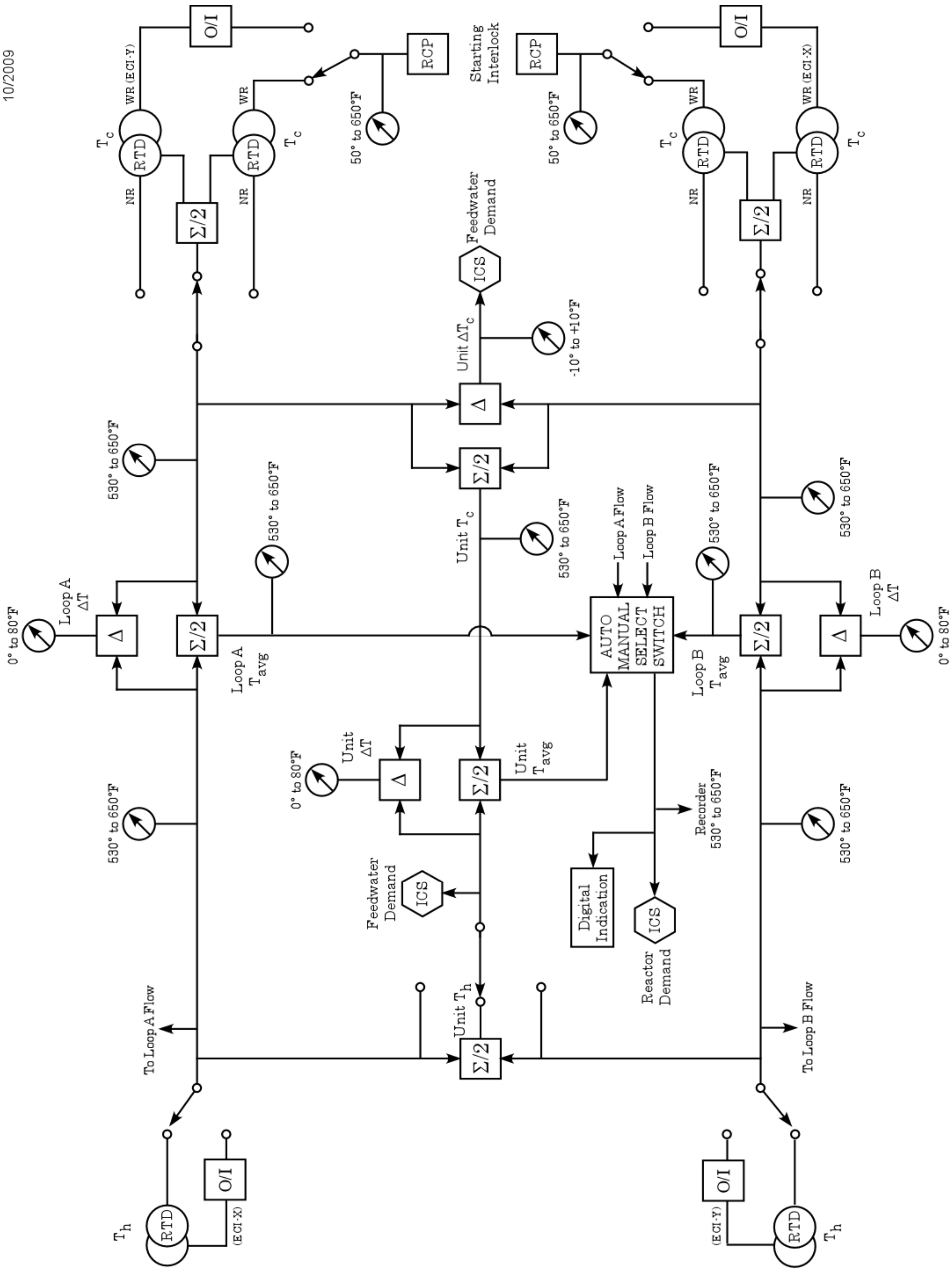

Figure 8.1-5 Non-Nuclear Instrumentation Reactor Coolant System Temperature

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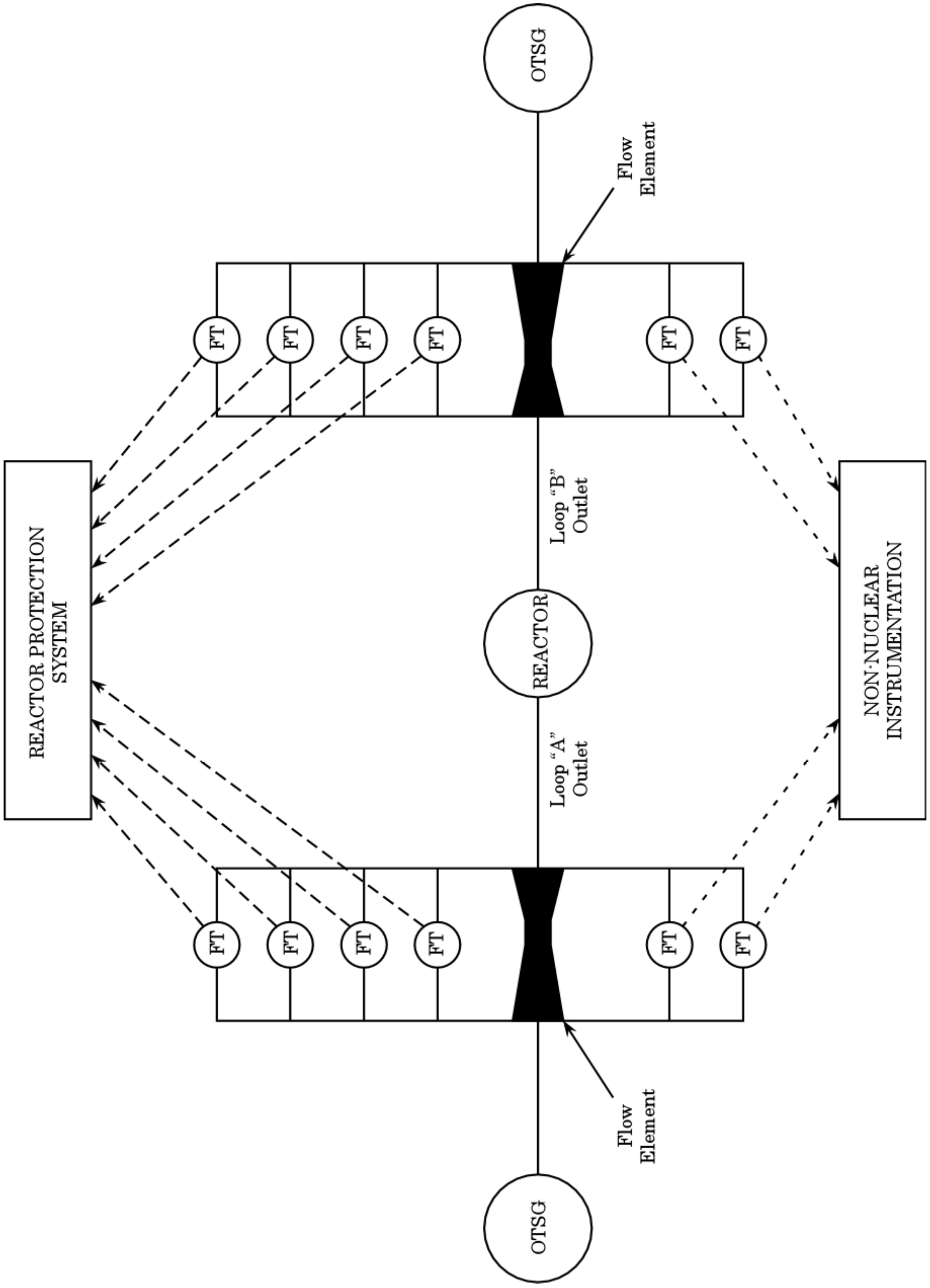

Figure 8.1-6 Reactor Coolant System Flow Detector Locations

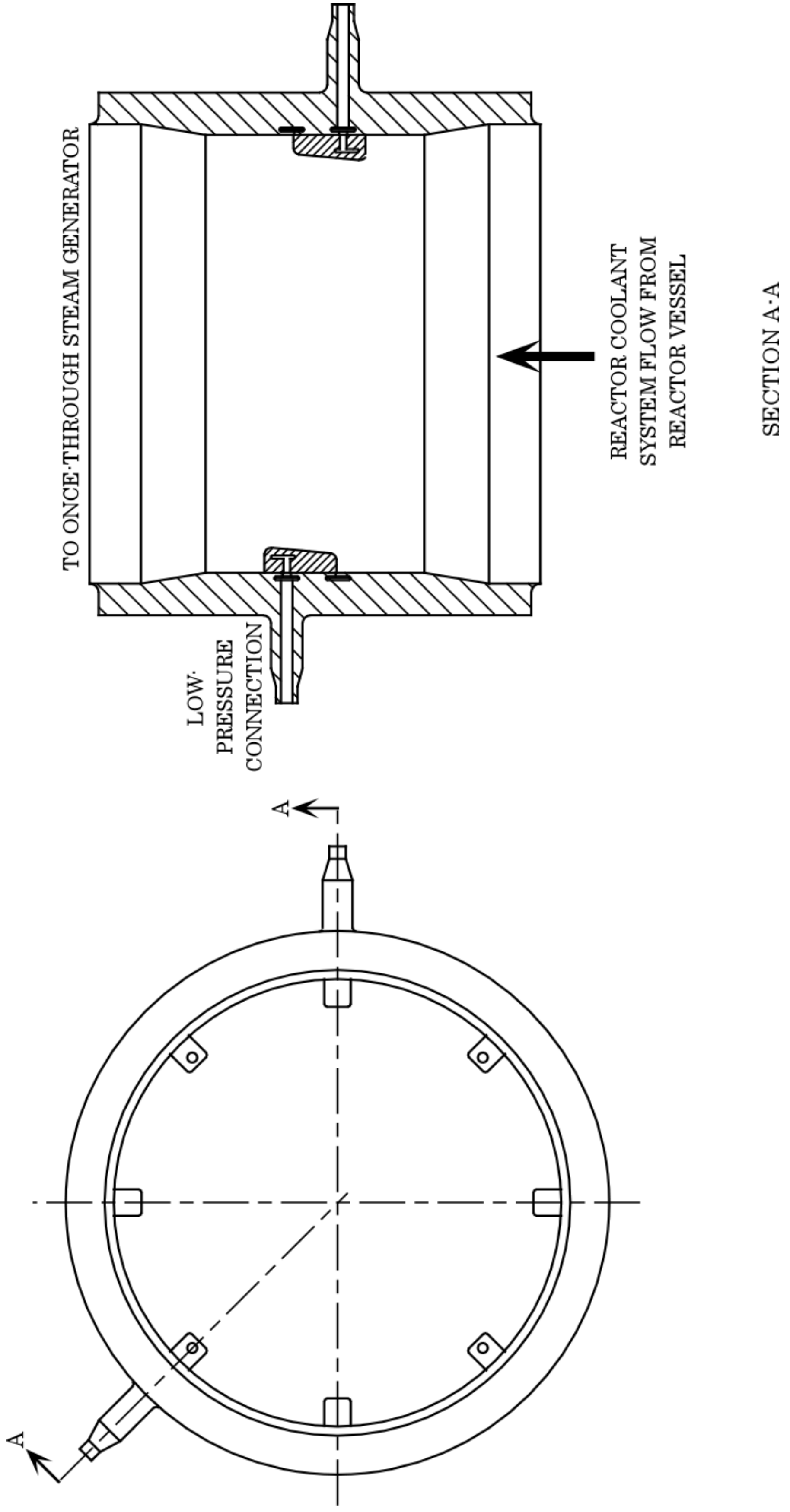

Figure 8.1-7 Reactor Coolant Flow Tube

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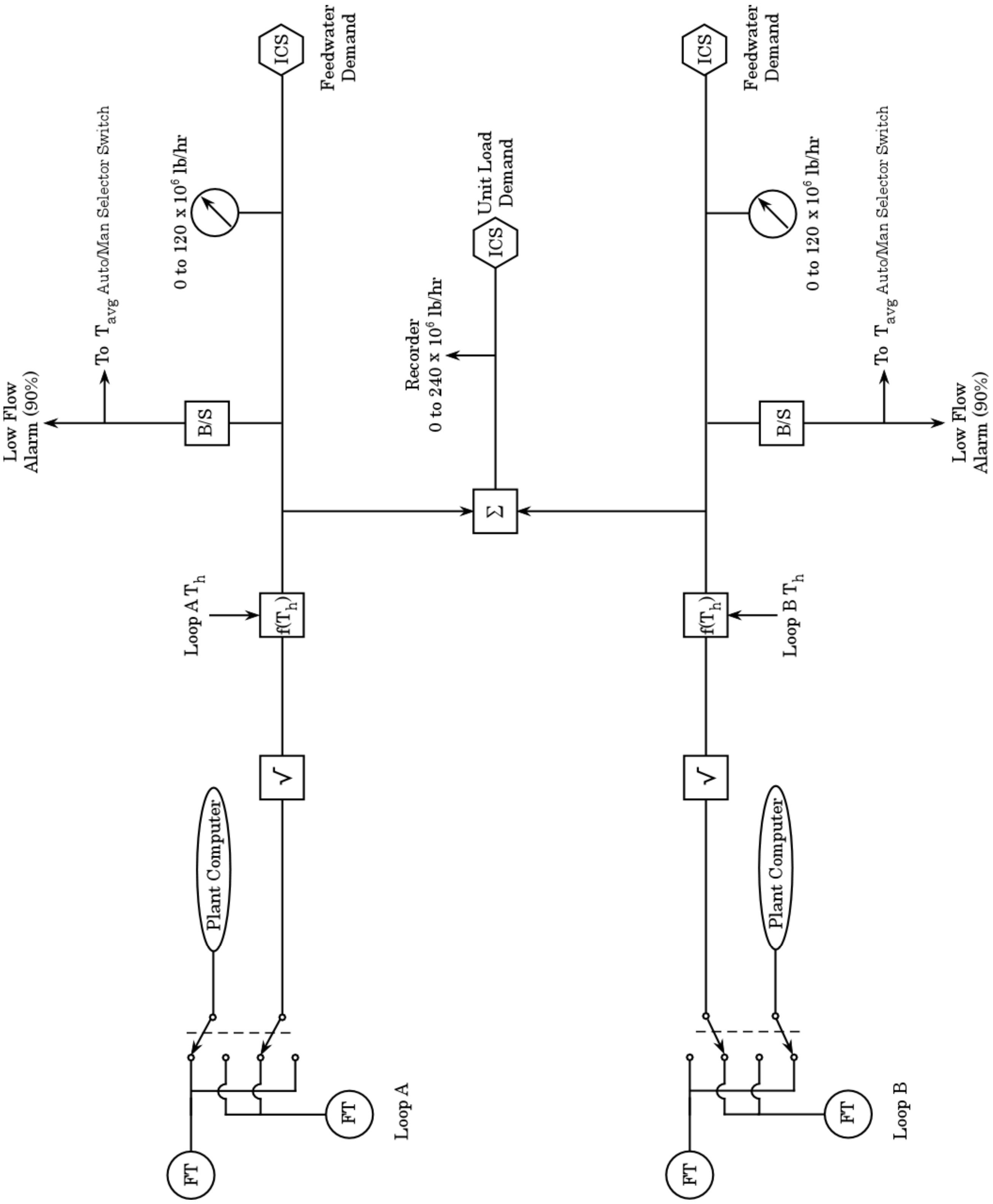

Figure 8.1-8 Non-Nuclear Instrumentation Reactor Coolant flow

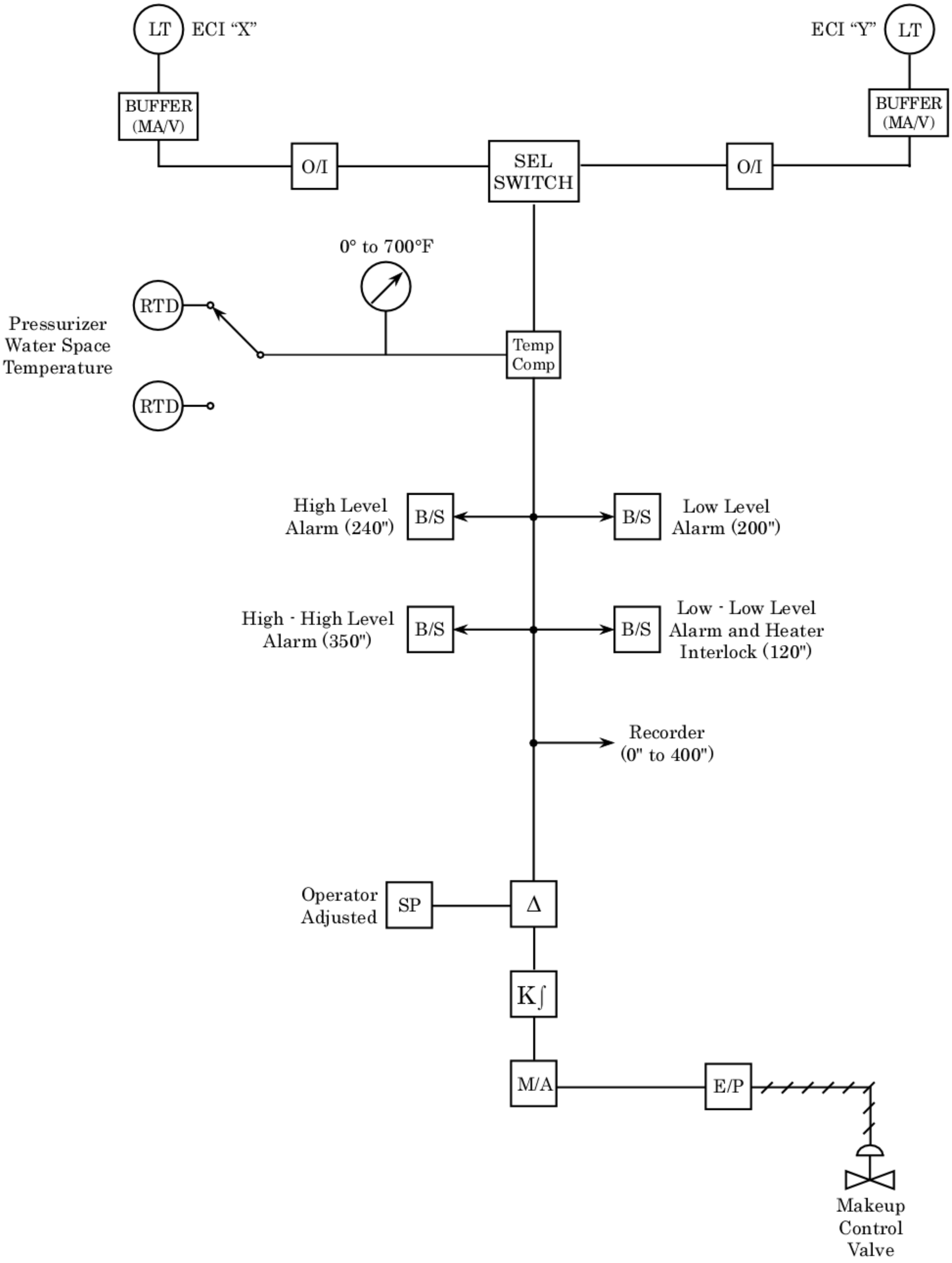

Figure 8.1-9 Pressurizer Level Control

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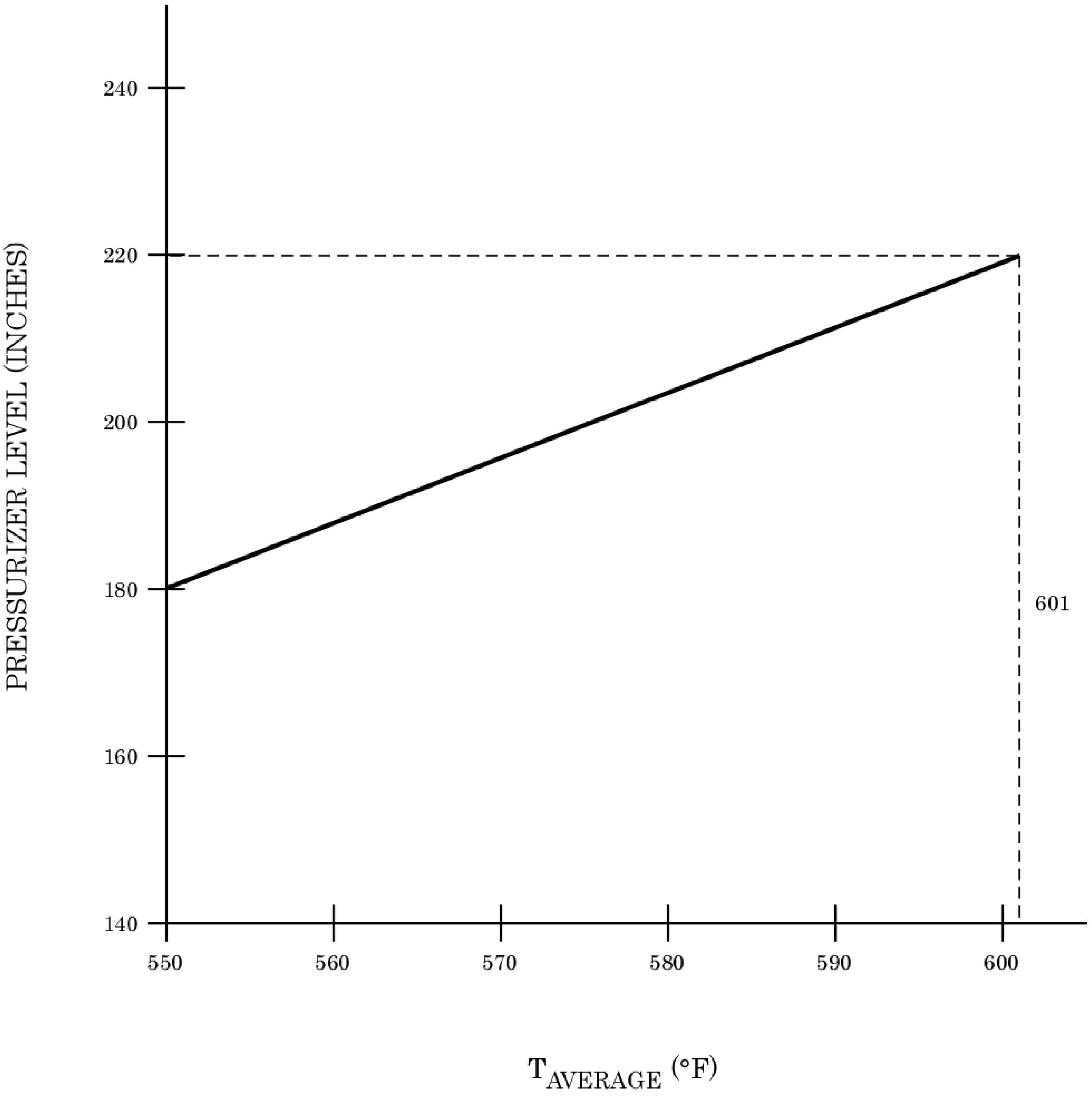

Figure 8.1-10 Typical Pressurizer Level Program

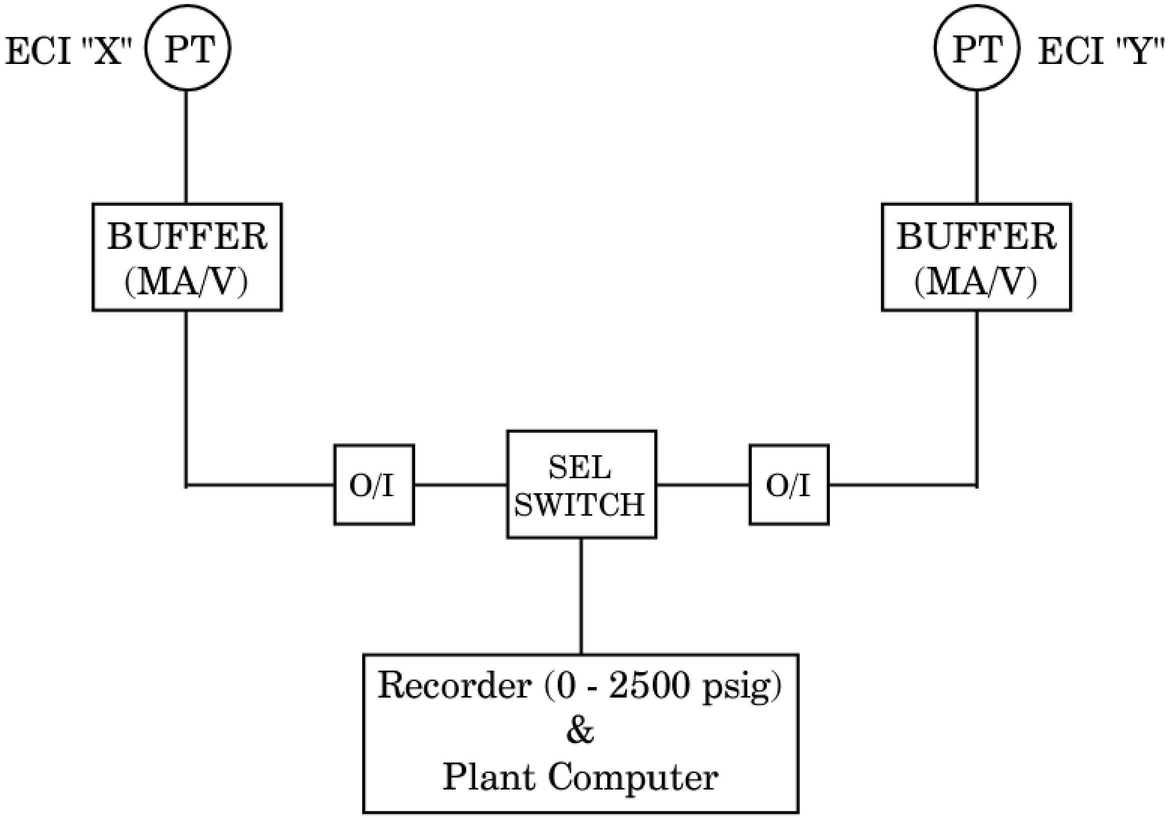

Figure 8.1-11 Wide Range Pressurizer Pressure

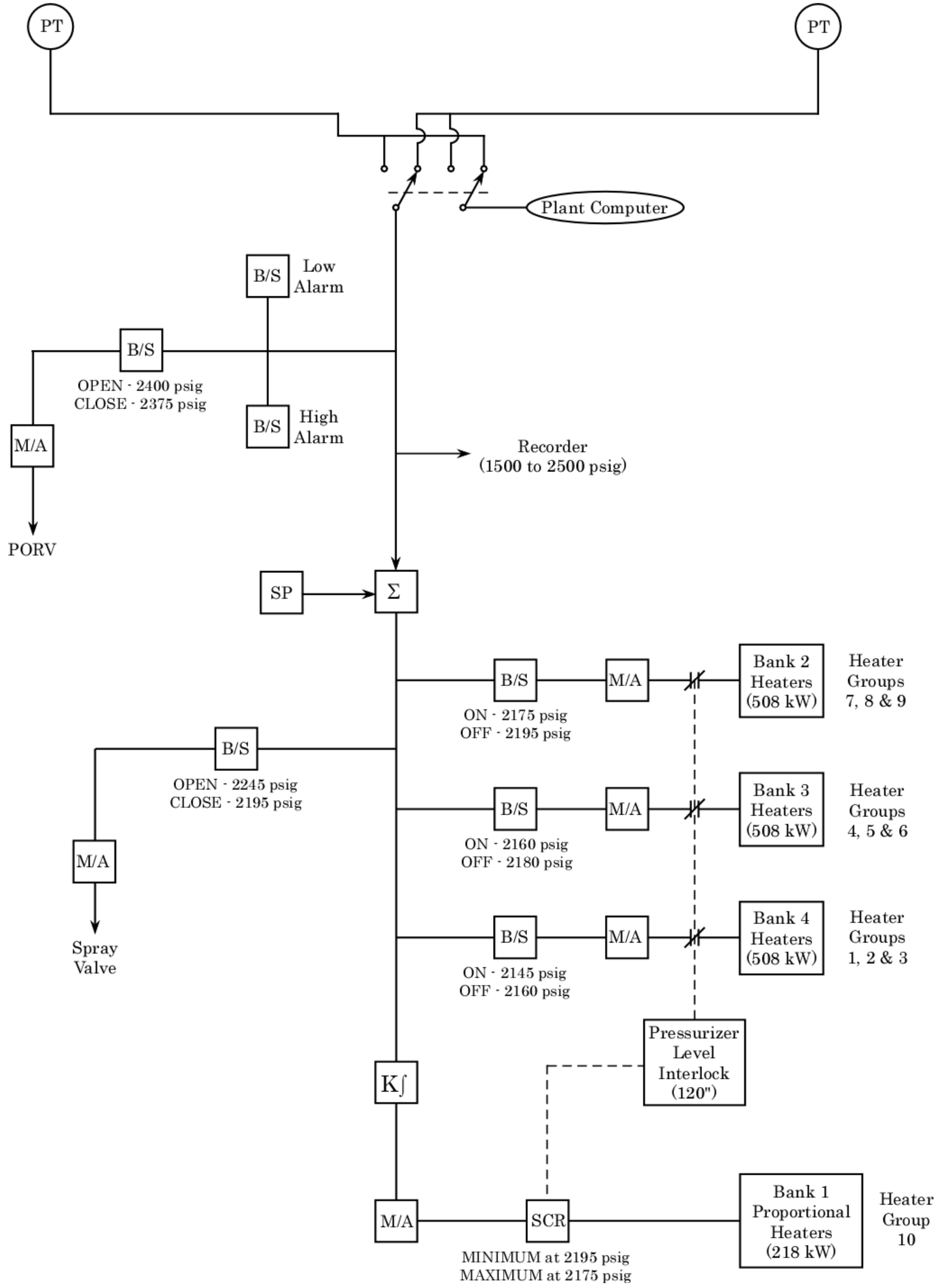

Figure 8.1-12 Narrow Range Pressurizer Pressure

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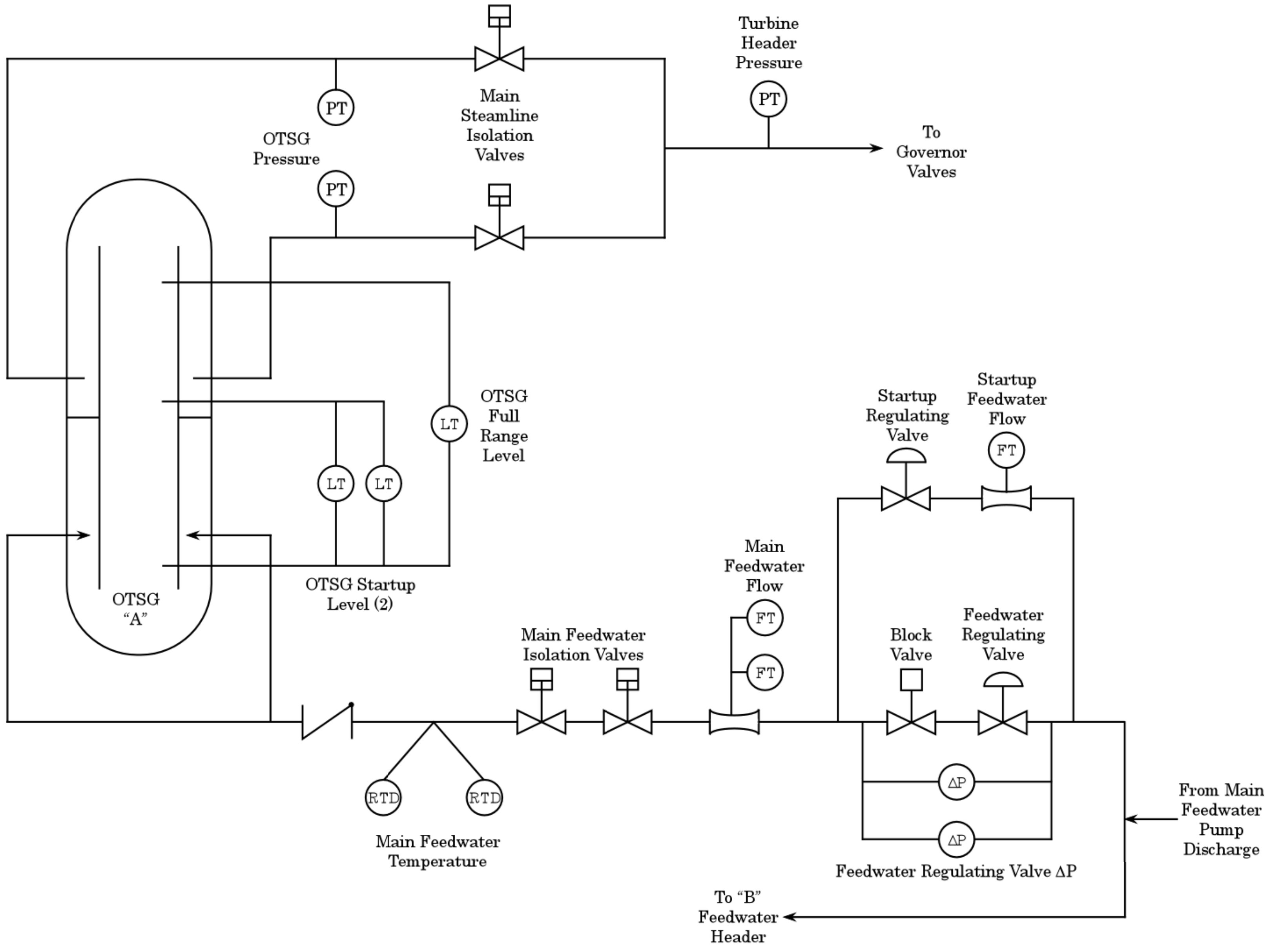

Figure 8.1-13 Feedwater System Instrumentation Locations

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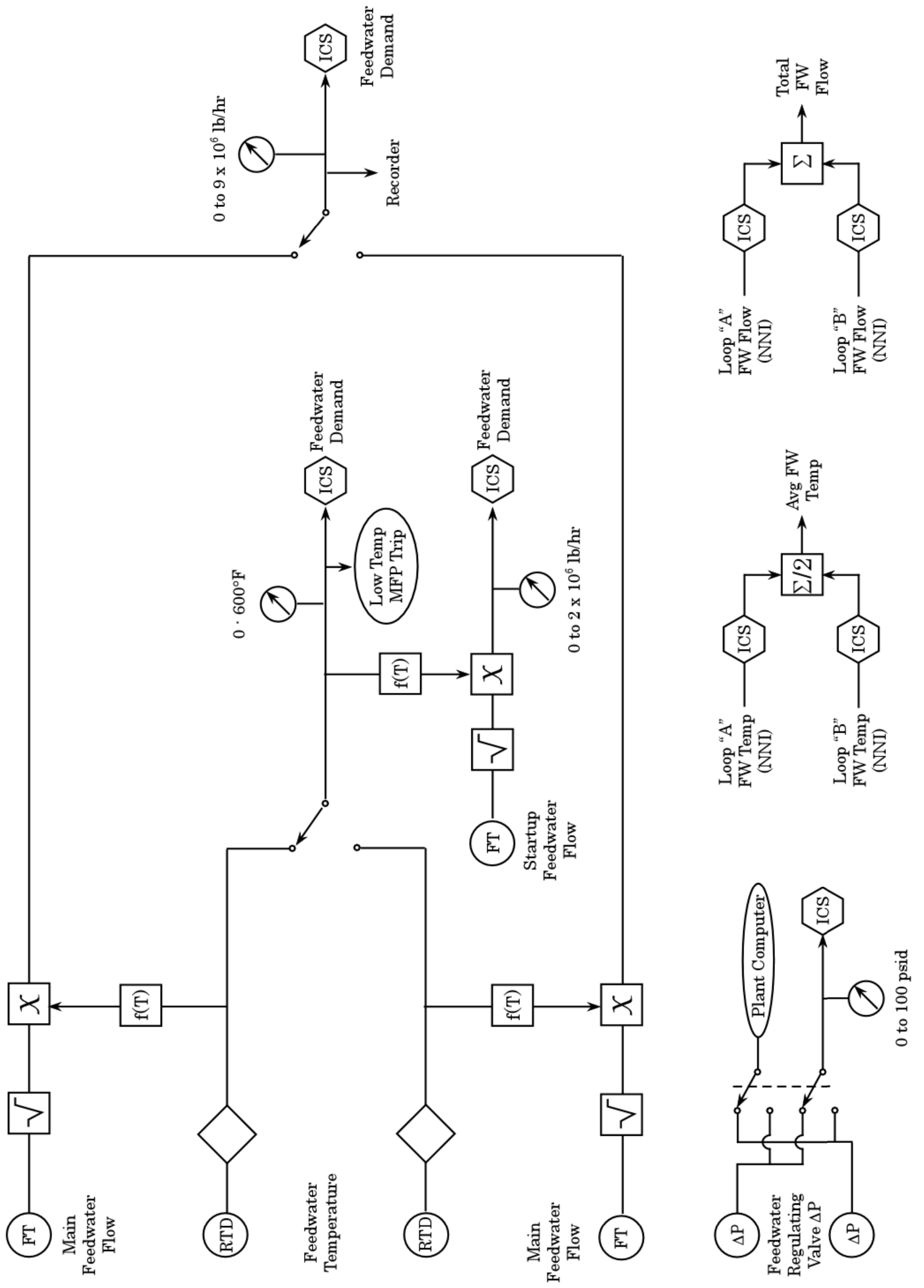

Figure 8.1-14 Feedwater Instrumentation

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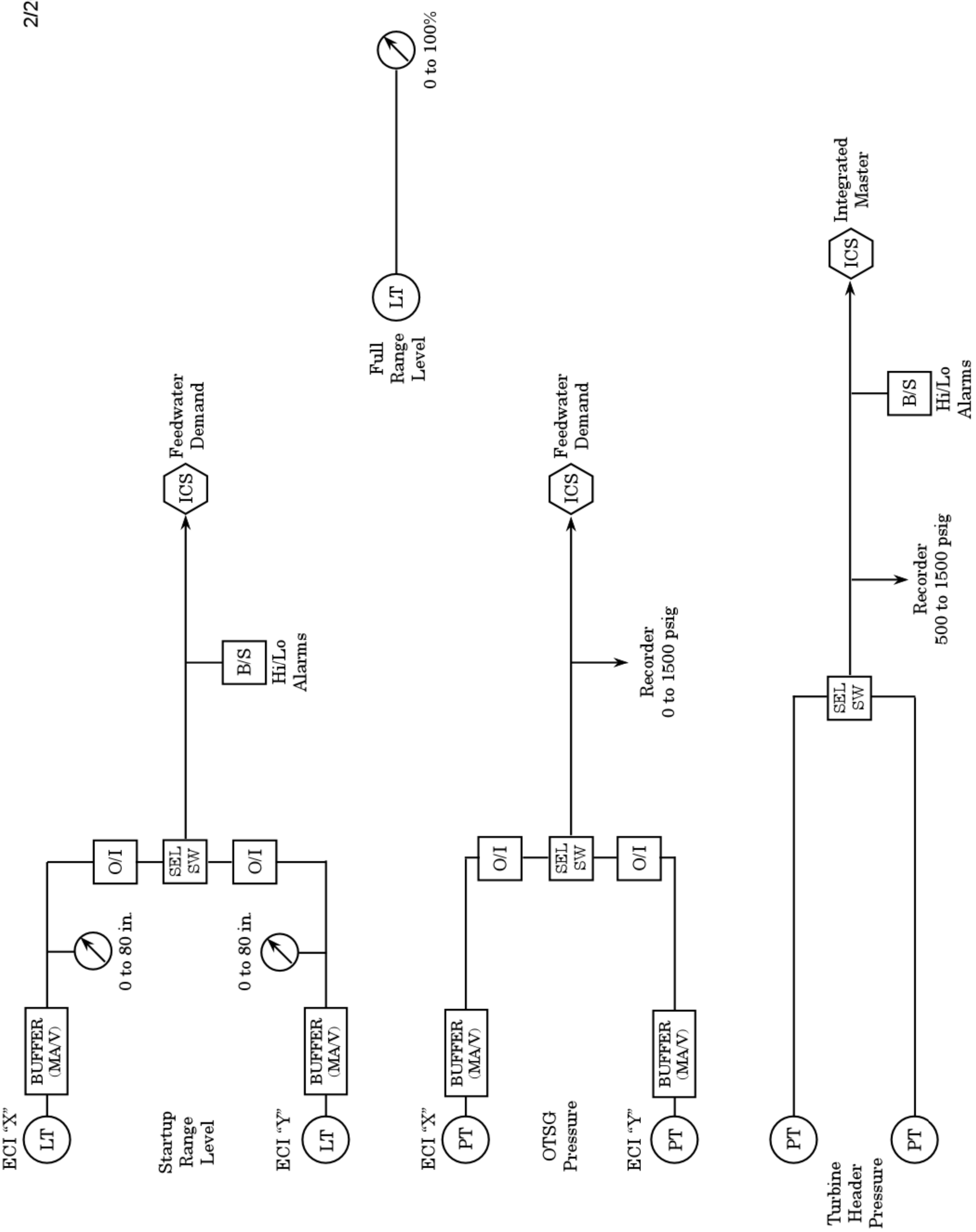

Figure 8.1-15 Steam System Instrumentation

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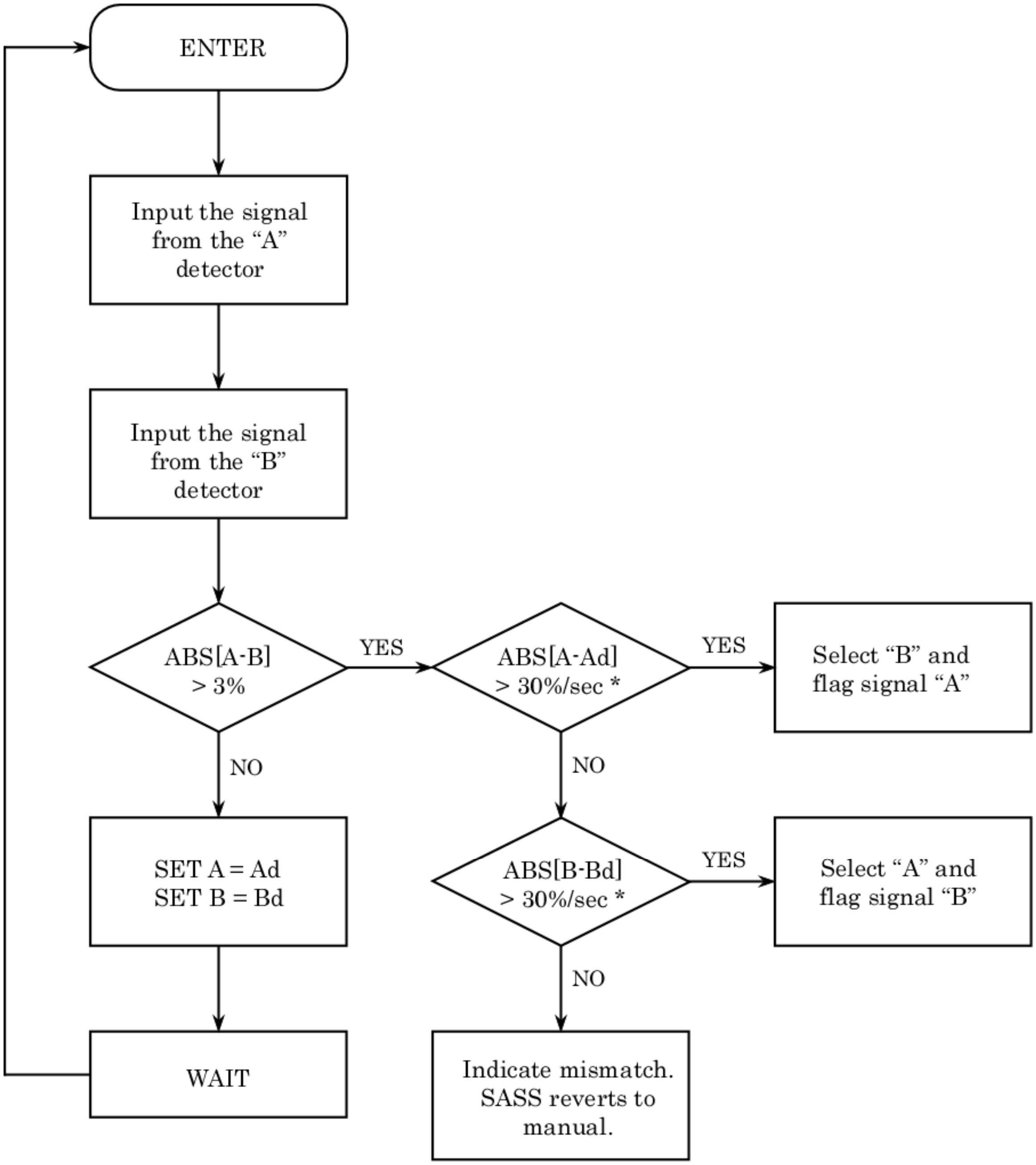

* : If the rate of change is > 30% / sec,
then the program reiterates to verify the failure.

Figure 8.1-16 Smart Analog Signal Select (SASS) System

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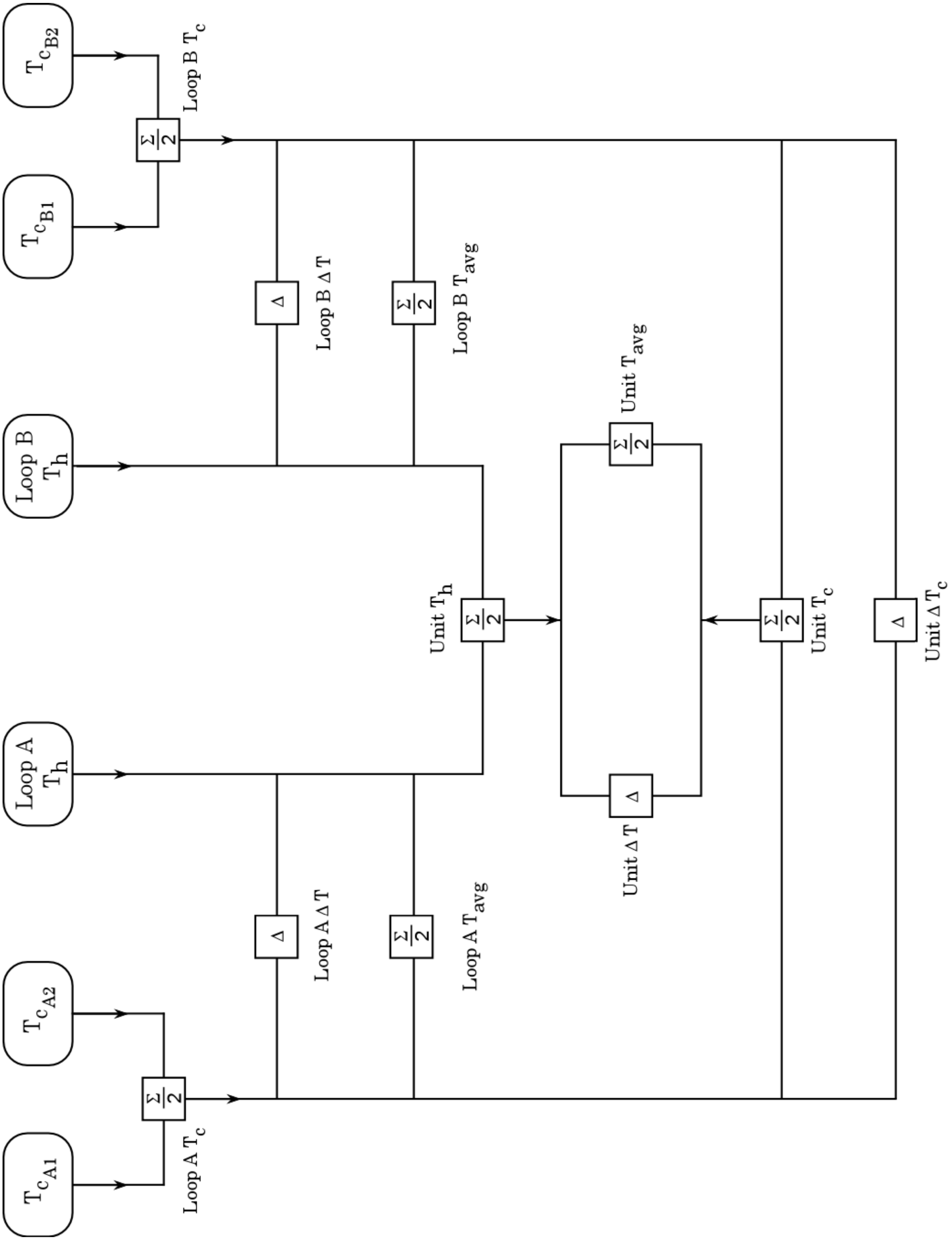

Figure 8.1-17 Non-Nuclear Instrumentation RCS Temperatures Simplified Diagram