Pressurized Water Reactor
B&W Technology
Crosstraining Course Manual

Chapter 8.2

Essential Controls and Instrumentation

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8.2 ESSENTIAL CONTROLS AND INSTRUMENTATION

Learning Objectives:

1. State the function of the essential controls and instrumentation system.

2. Explain how the wide-range pressure signal is used in the decay heat removal system.

3. Explain how the once-through steam generator level is used in the auxiliary feedwater flow control circuitry.

8.2.1 Introduction.

The essential controls and instrumentation (ECI) system is a collection of instrumentation that functions to provide the indication, control, and interlock features required to place the plant in a safe shutdown condition. A safe shutdown condition is defined as the condition wherein the reactor is at least 1% ΔK/K shut down, with the reactor coolant system (RCS) in hot or cold shutdown, depending on the initial plant status that exists when the requirement for safe shutdown is initiated. Furthermore, General Design Criterion 19 of Appendix A of 10 CFR 50 requires that instrumentation and controls be installed to place and maintain the plant in hot shutdown in a location(s) outside the main control room, and, by the use of suitable procedures, the instrumentation and controls must have the capability of placing the plant in cold shutdown. To satisfy these requirements, the ECI system supplies instrumentation and controls in both the main and auxiliary control rooms. The auxiliary control room is located outside the main control room. In addition to the requirements listed above, the ECI system instrumentation is designed to remain operable following a loss-of-coolant accident.

To satisfy these requirements, redundancy and separation have been designed into the ECI system. First, the system is separated into redundant channels, ECI X and ECI Y. Each channel is powered from a separate, battery-backed, 120-vac power source. Next, plant process variables are measured by physically independent sensors, and the sensor instrument strings are also physically separated. Finally, the outputs of the instrument displays and controls are isolated from each other by either buffer isolation or fiber optic isolation.

This section describes the various indication, interlocks, and controls supplied by the ECI system.

8.2.2 Primary Plant Essential Controls and Instrumentation

8.2.2.1 Reactor Coolant Temperatures

Dedicated resistance temperature detectors (RTDs) are used to provide an input to the system (Figure 8.2-1). Narrow-range temperature input is supplied from the RCS hot legs, and wide- range temperature input is supplied from the RCS cold legs.

The narrow-range (530 to 650°F) signal for ECI X originates from an RTD located in the A hot leg and the redundant narrow-range signal for ECI Y originates from an RTD located in the B hot leg. Bridge circuits, powered from the ECI cabinets, convert the resistance of the RTD to a temperature signal. Each temperature signal is fed through a buffer module and supplied to a recorder and meter in the main control room and to a meter in the auxiliary control room. The supply to each of these display devices contains a buffer module to prevent a fault in a single display from affecting all indications. The narrow-range temperature signal is used by the operator to maintain hot shutdown conditions and to analyze accident conditions.

The wide-range (50 to 650°F) temperature signal is supplied from an RTD located in one of the reactor coolant pump (RCP) discharges in each loop. ECI X receives an input from loop B, and ECI Y receives an input from loop A. The circuitry for wide-range ECI temperature is identical to the narrow-range temperature circuitry that is described above. Wide-range temperature input is required for placing the plant in cold shutdown.

Both narrow- and wide-range temperature inputs transmit signals to the non-nuclear instrumentation system through optical isolators.

8.2.2.2 Pressurizer Level

Two ECI-powered transmitters, one for ECI X and one for ECI Y, are used to sense pressurizer level. The 4- to 20-ma transmitter output is supplied to a buffer module that converts the current signal to a voltage signal with a range of -10 to 0 to +10 v. This voltage range represents a 0- to 400-in. pressurizer level and is supplied to redundant indicators in the main and auxiliary control rooms. ECI Y also inputs a signal to a main control room recorder. Buffer modules are installed to provide isolation between indicating devices. Each transmitter supplies a pressurizer level signal to the non-nuclear instrumentation system through an optical isolator.

Pressurizer level indication is necessary for the maintenance of RCS inventory during hot or cold shutdown and as an indication during accident situations.

8.2.2.3 Wide-Range Pressurizer Pressure

Wide-range (0 to 2500 psig) pressure is sensed by two ECI pressurizer pressure transmitters (Figure 8.2-3). One transmitter is dedicated to ECI X, and the other transmitter is dedicated to ECI Y. The 4- to 20-ma output of the transmitters is converted to signals with a range of -10 to 0 to +10 v by buffer modules located in the ECI X and ECI Y cabinets. The voltage signal is then transmitted through isolation buffers to pressure indicators located in the main and auxiliary control rooms. The non-nuclear instrumentation system receives wide-range pressurizer pressure inputs from the ECI cabinets through optical isolation. Wide-range pressurizer pressure indication is used by the operator to maintain the plant in hot or cold shutdown and to control the plant during the transition between these two conditions. Pressure indication is also necessary during post-accident conditions.

In addition to pressure indication, wide-range pressure input provides an interlock to the decay heat removal (DHR) system RCS suction valves. This interlock will automatically close the suction valves if RCS pressure exceeds 400 psig to prevent over-pressurization of the DHR piping. The ECI system provides separate interlocking signals; that is, ECI X closes V-25A in the suction supply to DHR pump A, and ECI Y closes V-26B. Redundancy in DHR suction isolation is ensured by closing V-23A and V-24B with signals supplied by the engineered safety features actuation system.

The wide-range pressure transmitters also provide inputs to the core flood tank (CFT) isolation valve interlocks. An alarm is generated if pressurizer pressure is less than 650 psig and the isolation valves are open. This alarm alerts the operator to shut the valves so that the CFTs will not discharge to the RCS during a plant cooldown and depressurization. Also, the isolation valves will receive an open signal when RCS pressure increases to 750 psig during a plant heatup, in order to place the CFT system in its normal at-power configuration. The ECI X pressure transmitter supplies the interlocks for CFT A isolation valve V-31A, and the ECI Y pressure transmitter supplies the interlocks for CFT B isolation valve V-32B.

8.2.2.4 Miscellaneous Primary Plant Controls and Instrumentation

Various pressure, flow, and level indications are supplied by the ECI system to allow the monitoring of emergency core cooling systems and their auxiliaries. These indications include low-pressure injection flow, sodium hydroxide tank level, and core flooding tank pressures and levels. A complete listing of ECI system instrumentation is found in Table 8.2-1.

Besides the indication supplied by the ECI system, hand controllers for decay heat cooler outlet and bypass valves are installed in both the main and auxiliary control rooms. This ECI control is necessary for the second part of plant cooldown.

8.2.3 Secondary Plant Controls and Instrumentation

8.2.3.1 Steam Pressure

The sensing of main steam pressure for each OTSG is identical; therefore, only the pressure sensing and indication for the A OTSG is discussed in this section (Figure 8.2-4).

Two pressure transmitters, one associated with ECI X and one associated with ECI Y, are used to sense main steam pressure. The transmitters detect pressure on the OTSG outlet headers, one transmitter per outlet header.

The ECI Y transmitter supplies indicators in the main control room and in the auxiliary control room. The ECI X transmitter supplies indicators in the main and auxiliary control rooms, a recorder in the control room, and the control scheme for the modulating atmospheric dump valves.

The Class 1E modulating atmospheric dump valves are controlled by a proportional-integral controller that receives an error signal from a difference amplifier (Δ). The inputs to the difference amplifier are actual steam pressure and a setpoint (1205 psig). The differences between these inputs are acted on by the proportional-integral controller to cause actuation of the dump valves. Manual/ automatic (M/A) controllers, located in the main and auxiliary control rooms, provide a method of manually controlling steam pressure. The auxiliary control room M/A overrides the main control room station. From the M/A control station, the control signal travels to an electrical-to-pneumatic (E/P) converter that is used to modulate the air signals supplied to the valves.

The indication and control of steam pressure is required for the mitigation of accidents and for establishing safe shutdown conditions.

8.2.3.2 Once-Through Steam Generator Level

Redundant startup range level transmitters powered from separate ECI cabinets are installed on each OTSG. The circuitry in each ECI cabinet is identical, and only the ECI X circuitry is described below.

The level transmitter signal for each OTSG is supplied to a buffer amplifier that converts its 4- to 20-ma output to a signal with a range of -10 to 0 to +10 v. The voltage signal is then supplied to main and auxiliary control room indicators through isolation buffer units and to the non-nuclear instrumentation system through optical isolators. The voltage output is also supplied to the auxiliary feedwater flow control circuitry.

The control of auxiliary feedwater is accomplished by comparing actual OTSG level with level setpoint (2 or 6 ft) in a difference amplifier (△). The output, an error signal, of the difference amplifier is supplied to a proportional-integral controller that, in turn, supplies the control of the auxiliary feedwater flow control valves. Manual/automatic (M/A) stations located in the main and auxiliary control rooms allow manual operator control of OTSG level. Redundancy of level control signals is shown in Figure 8.2-6, ECI X supplies A OTSG level control through LCV-4025 and B OTSG level control through LCV-4009. ECI Y controls A OTSG level through LCV-4026 and B OTSG level through LCV-4007. With redundant flow control valves and signal sources, level control is ensured even if one complete ECI system is lost.

8.2.4 Summary

ECI provides indication, control, and interlock features required to maintain the plant in a safe shutdown condition. ECI has two redundant channels, and each is battery-backed. Indication and control is provided in the main and auxiliary control rooms.

TABLE 8.2-1
ESSENTIAL CONTROLS AND INSTRUMENTATION

Measured Parameter	Indicator Range
Pressurizer level	0 - 400 in. of water
Pressurizer pressure	0 - 2500 psig
Reactor Coolant outlet temperature, loop A	530 - 650 °F
Reactor Coolant outlet temperature, loop B	530 - 650 °F
Reactor Coolant inlet temperature, loop A	50 - 650 °F
Reactor Coolant inlet temperature, loop B	50 - 650 °F
Steam generator level, loop A	0 - 80 in. of water
Steam generator level, loop B	0 - 80 in. of water
Main steam pressure, loop A	0 - 1500 psig
Main steam pressure, loop B	0 - 1500 psig
High-pressure injection flow, loop A (one per cold leg)	0 - 400 gpm
High-pressure injection flow, loop B (one per cold leg)	0 - 400 gpm
Core flooding tank A level	0 - 21 ft. of water
Core flooding tank B level	0 - 21 ft. of water
Core flooding tank A pressure	0 - 800 psig
Core flooding tank B pressure	0 - 800 psig
Decay heat removal heat exchanger outlet flow A	0 - 7000 gpm
Decay heat removal heat exchanger outlet flow B	0 - 7000 gpm
Reactor building spray flow A	0 - 3000 gpm
Reactor building spray flow B	0 - 3000 gpm
Borated water storage tank level	0 - 55 ft. of water
Reactor building pressure	0 - 60 psia
Reactor building temperature	0 - 450 °F
Sodium hydroxide tank level	0 - 40 ft. of water
Reactor building emergency sump level	0 - 400 in. of water
Reactor building emergency sump temperature	50 - 300 °F

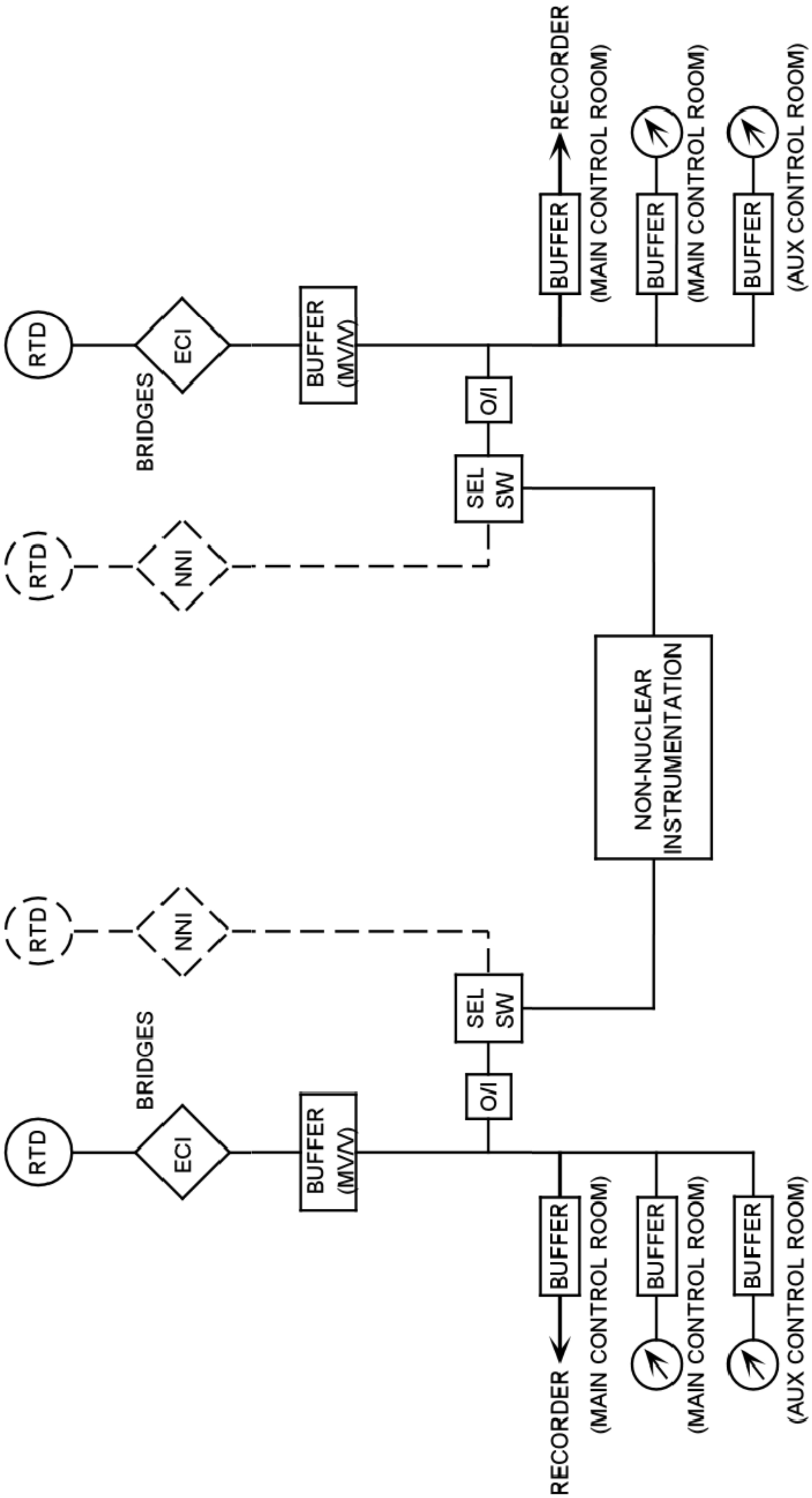

Figure 8.2-1 Reactor Coolant Temperature Block Diagram

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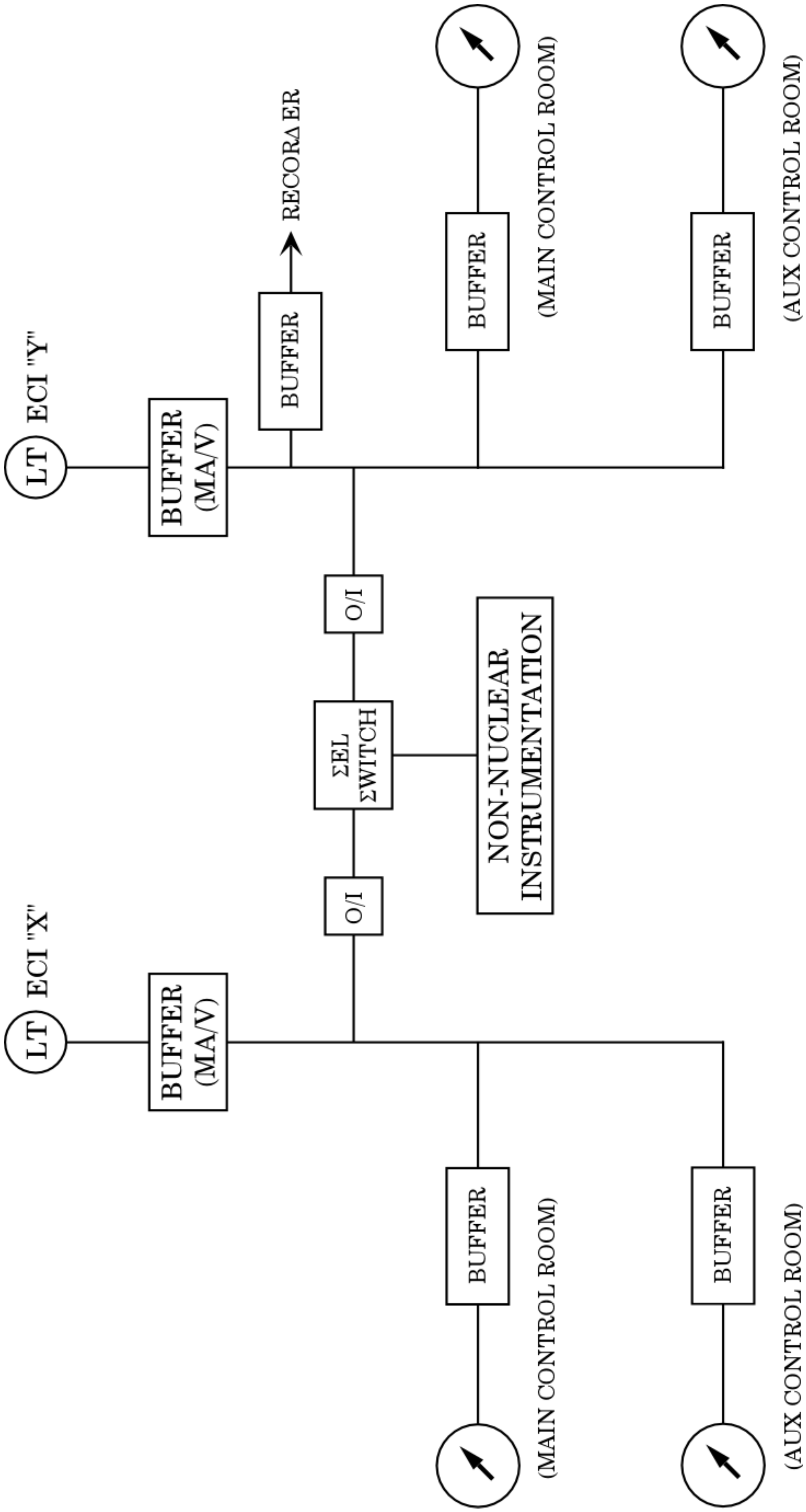

Figure 8.2-2 Pressurizer Level Indication

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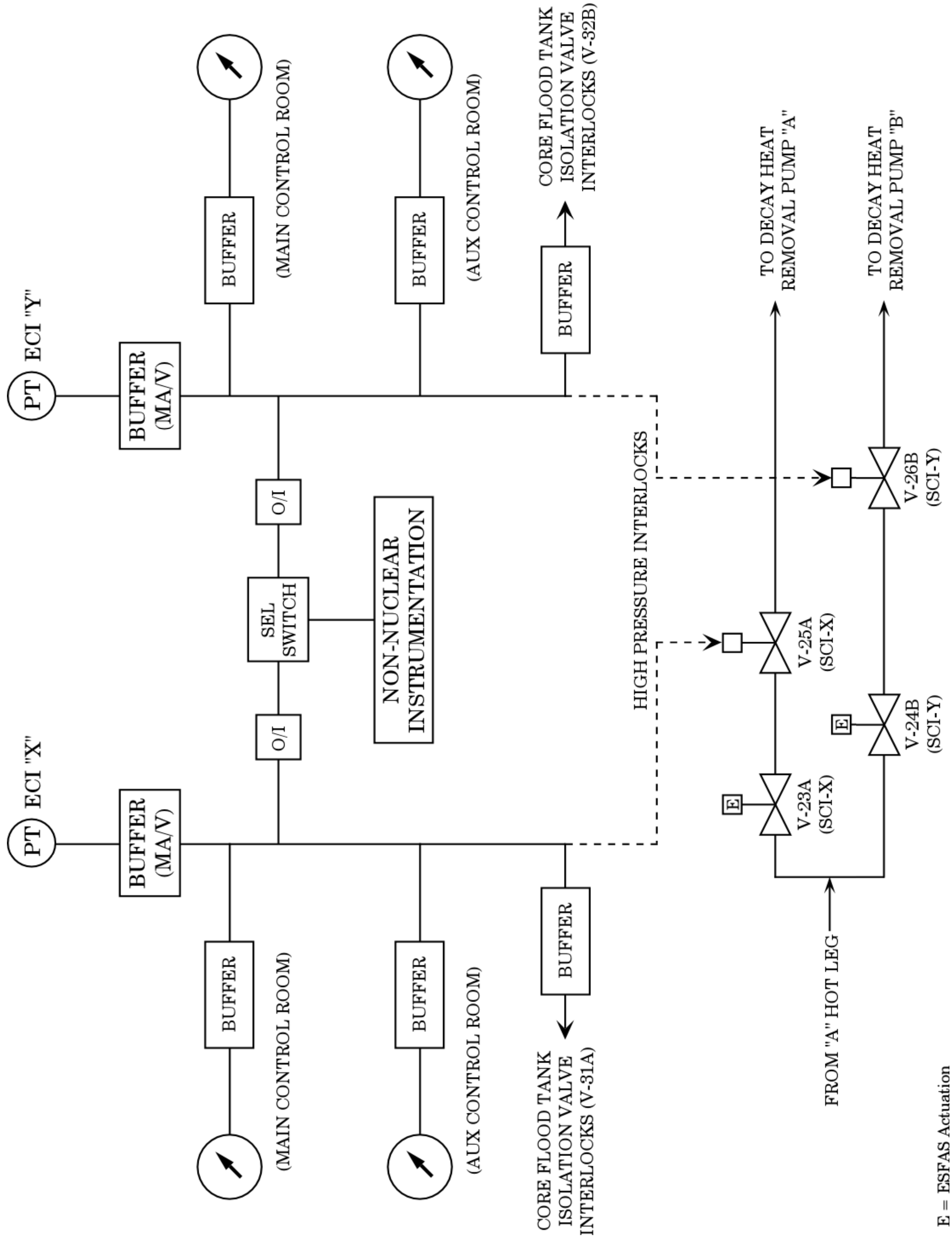

Figure 8.2-3   Wide Range Pressurizer Pressure

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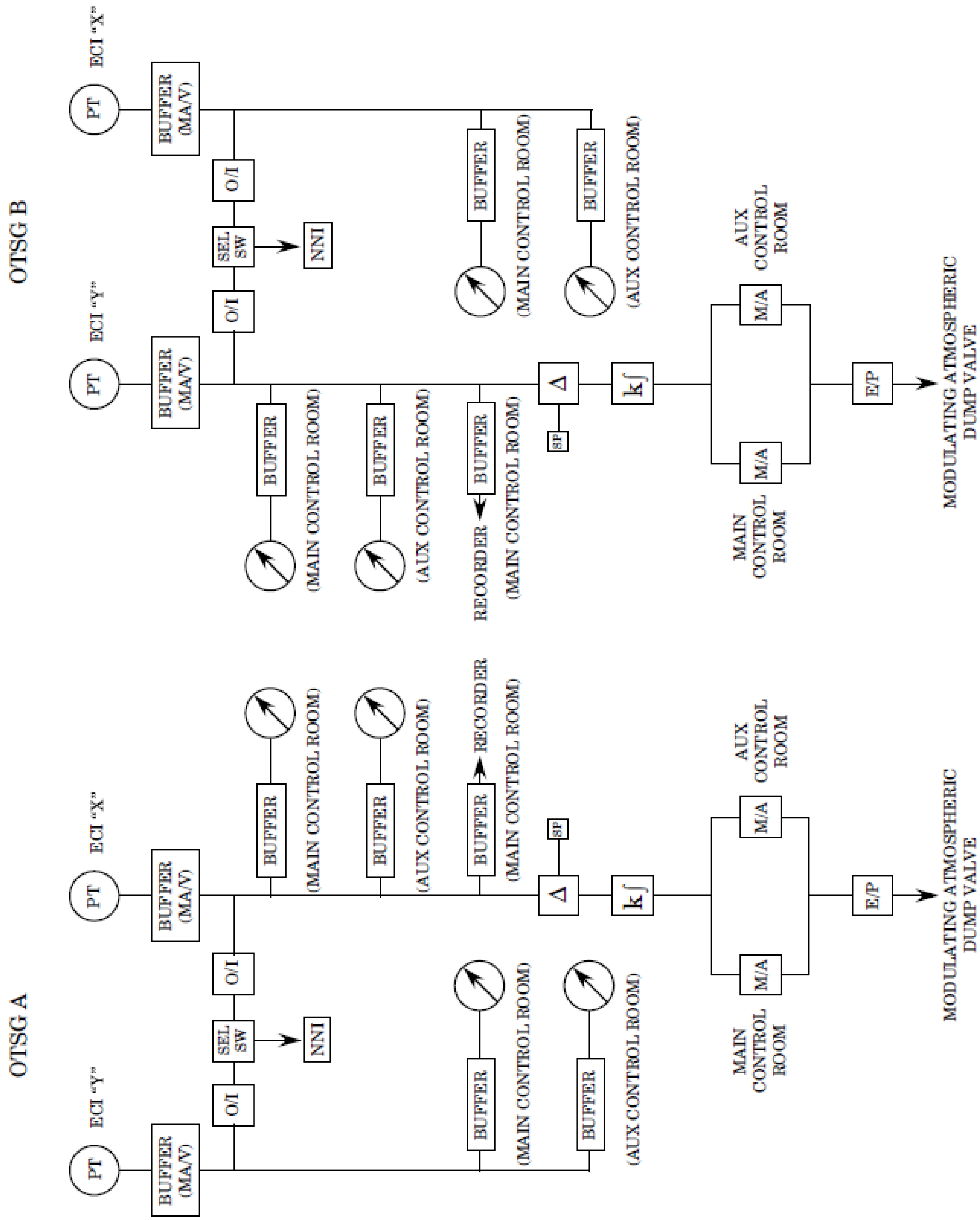

Figure 8.2-4 Steam Pressure

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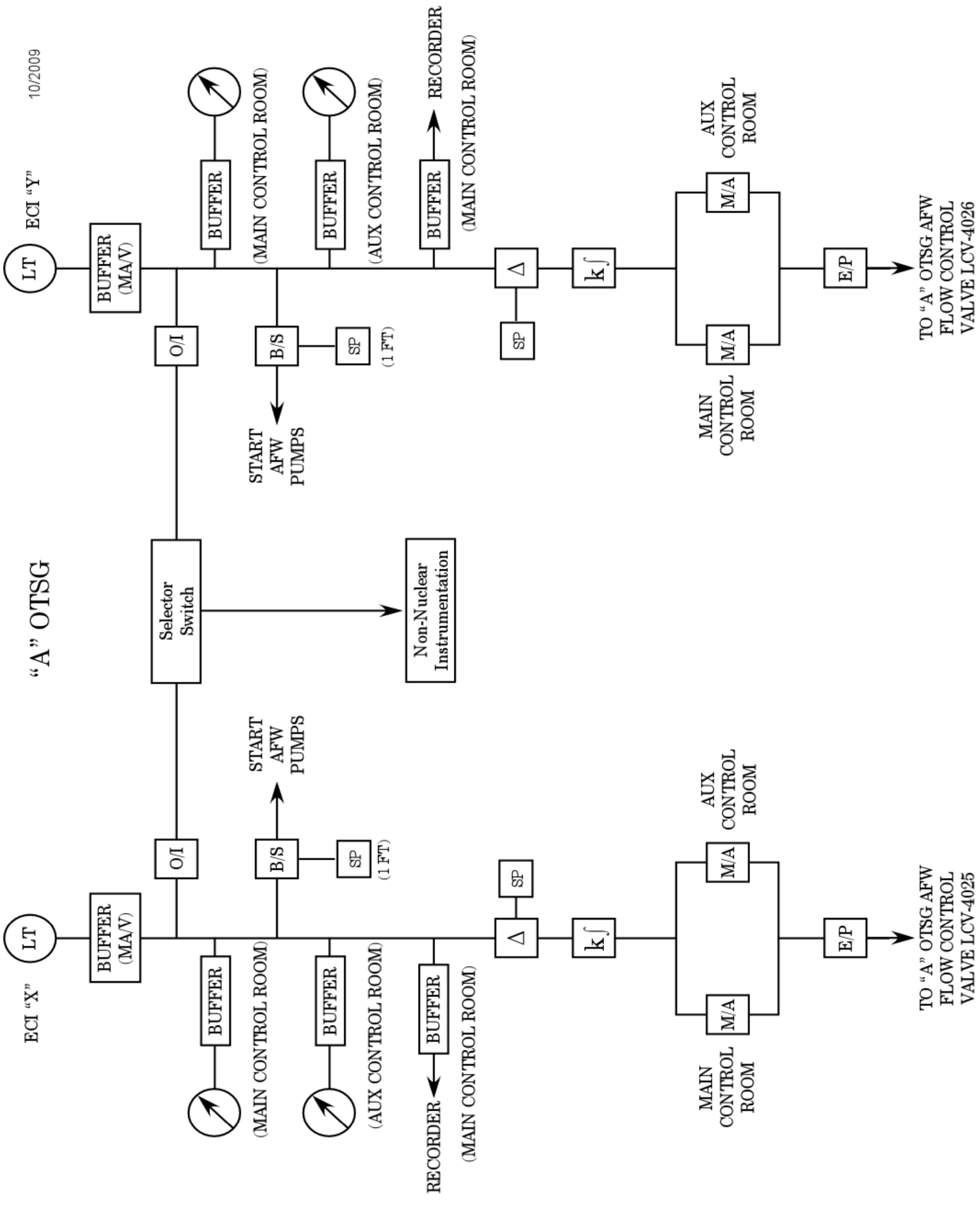

Figure 8.2-5 Steam Generator Startup Level (Typical of One OTSG)

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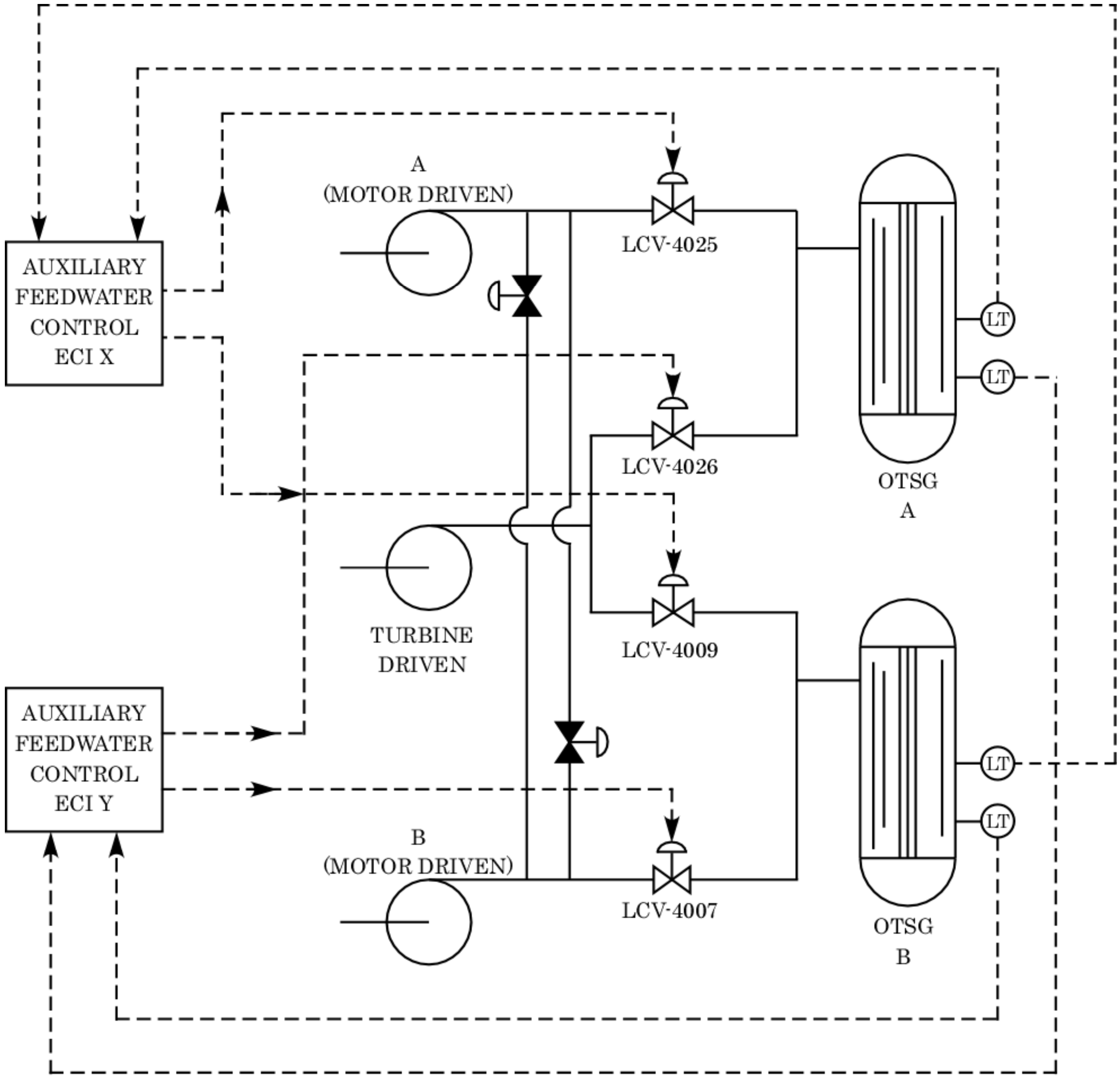

LT = LEVEL TRANSMITTER

LCV = LEVEL CONTROL VALVE

Figure 8.2-6 Auxiliary Feedwater Control

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