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6.2 PRESSURIZER LEVEL CONTROL SYSTEM

Learning Objectives:

1. State the purpose of the pressurizer level control system (PLCS).
2. List the purpose of each PLCS input.
3. Explain the reason pressurizer level is programmed.
4. List the devices that are controlled by pressurizer level.
5. Explain the purpose of the pressurizer low level interlock.

6.2.1 Introduction

The pressurizer is designed to accommodate the changes in Reactor Coolant System (RCS) volume that are caused by changes in RCS temperature. The pressurizer is not large enough to accommodate the total increase in volume resulting from the change in T_{avg} occurring from 0% to 100% power (532°F to 572.5°F).

The design of the containment must take into account the volume of the RCS. In general, the larger the RCS volume the bigger the containment must be in order to accept the pressures that result from a loss of coolant accident. The maximum size of the pressurizer is limited by the containment building design and, therefore, cannot accommodate the entire expansion volume resulting from the temperature change which occurs from 0% to 100% power.

However, if the pressurizer volume is too small the pressure changes associated with a change in temperature could be unacceptable. For example, the temperature change associated with a loss of load transient could result in filling the pressurizer and reaching an associated high pressure condition. Or, the decrease in temperature following a reactor trip could empty the pressurizer resulting in an unnecessary initiation of safety systems by a low pressurizer pressure signal. The pressurizer design volume is a compromise between these two limits.

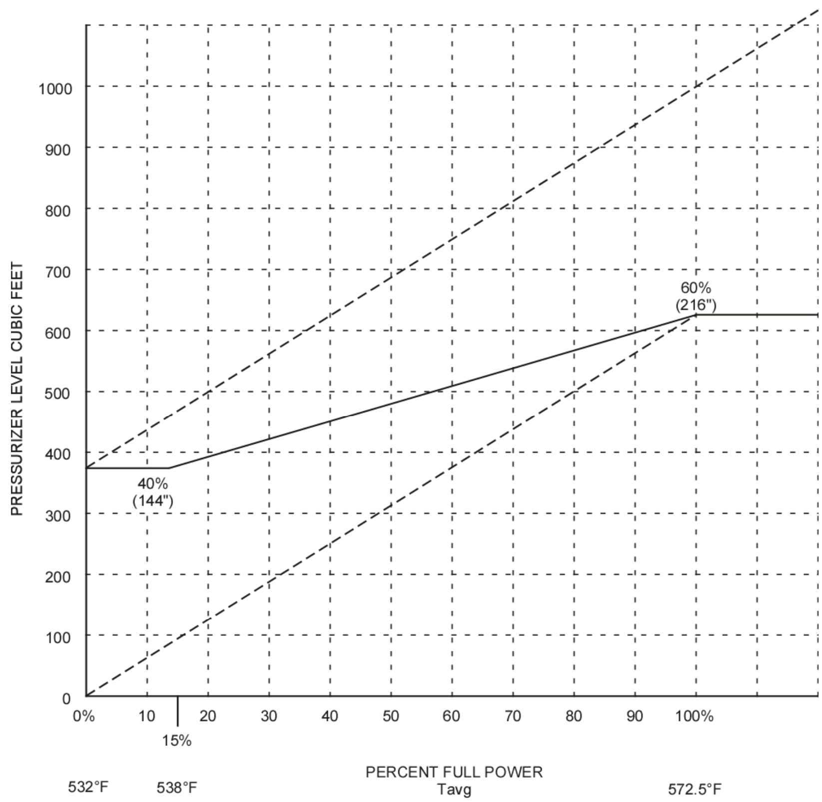

Figure 6.2-1 Pressurizer Level Program

A minimum volume of 40% must exist in the pressurizer to allow the unit to be maneuvered at the design rates at low power levels. The design maneuvering rates are a 5% per minute ramp or a 10% step load change. As shown in Figure 6.2-1, if pressurizer level is at its minimum and charging and letdown are maintained at equal values and power is escalated from 0 to 100%, the expansion volume would result in an unacceptable high level. In fact, the pressurizer would be almost completely filled with water. Any temperature increases from this point would completely fill the pressurizer and cause a large unacceptable increase in RCS pressure.

The 100% level of 60% is based on accepting a load rejection from 100% power without the pressurizer going solid and accepting the cooldown associated with a reactor trip without initiating a safety signal. If a power decrease from 100% to 0% is made with the pressurizer at 60% level and charging and letdown maintained at equal values, the pressurizer would be emptied. The pressurizer level control program is a compromise between these two extremes. The purpose of the PLCS is to control pressurizer level at the desired setpoint.

6.2.2 Pressurizer Level Control System Inputs

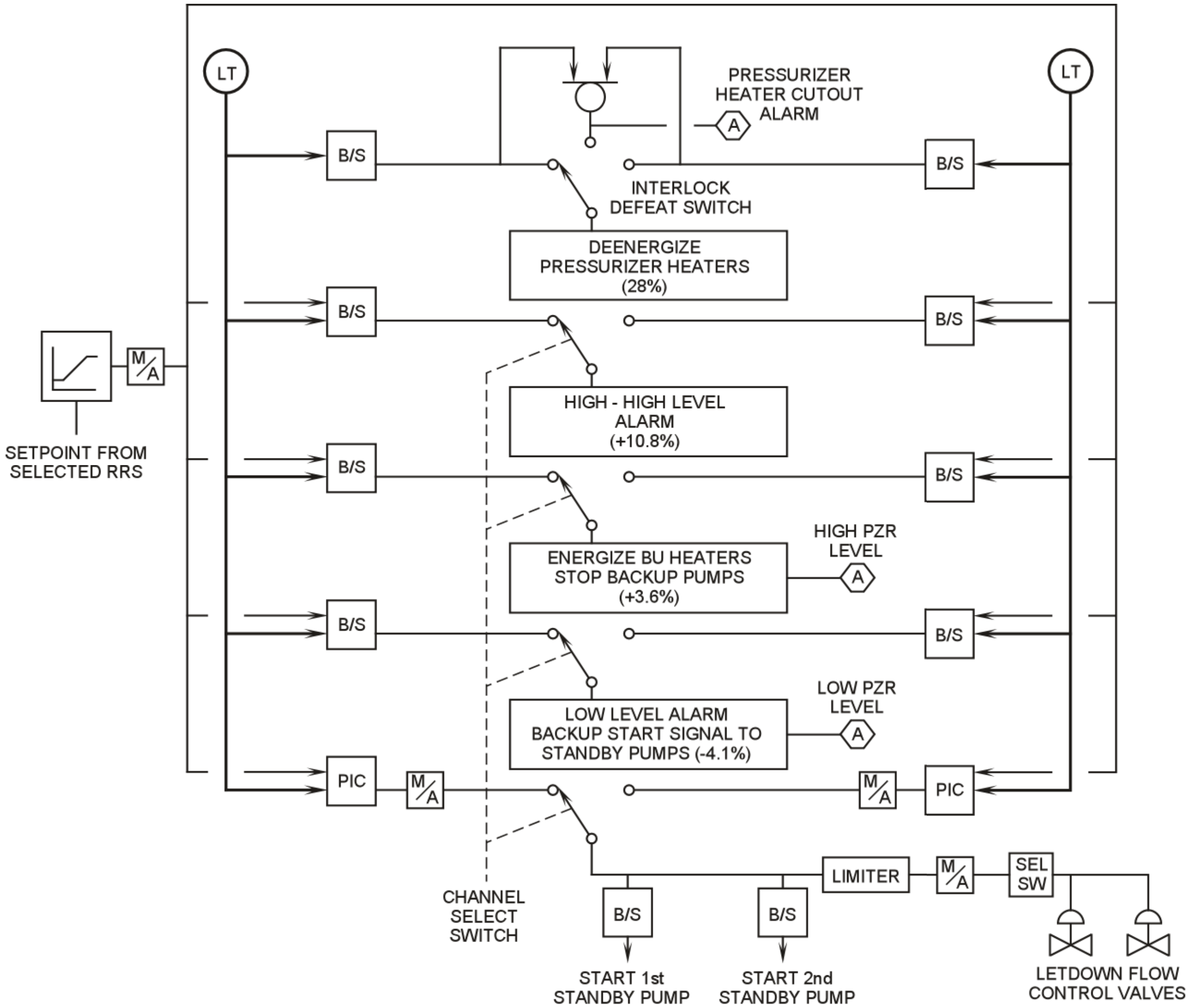

Figure 6.2-2 Pressurizer Level Control System

The desired value of pressurizer level is generated as a function of average coolant temperature in the Reactor Regulating System (RRS). The level setpoint from the selected RRS is supplied to the PLCS. A manual/automatic control station is installed in the signal path to allow the operator to manually supply the setpoint if desired. The setpoint is compared with actual pressurizer level as sensed by two pressurizer level transmitters. The result of the comparison is supplied to the pressurizer level control devices via a channel selector switch. As shown in Figure 6.2-2, two types of control signals are used. The first type of signal is an analog control signal generated by the proportional-only controller. This signal is used to control the position of the letdown flow control valves and to start the standby charging pumps. The second signal type is supplied by bistables and is used to control the pressurizer heaters and to provide backup start and stop signals for the charging pumps.

6.2.3 Pressurizer Level Control Devices

6.2.3.1 Letdown Flow Control Valves

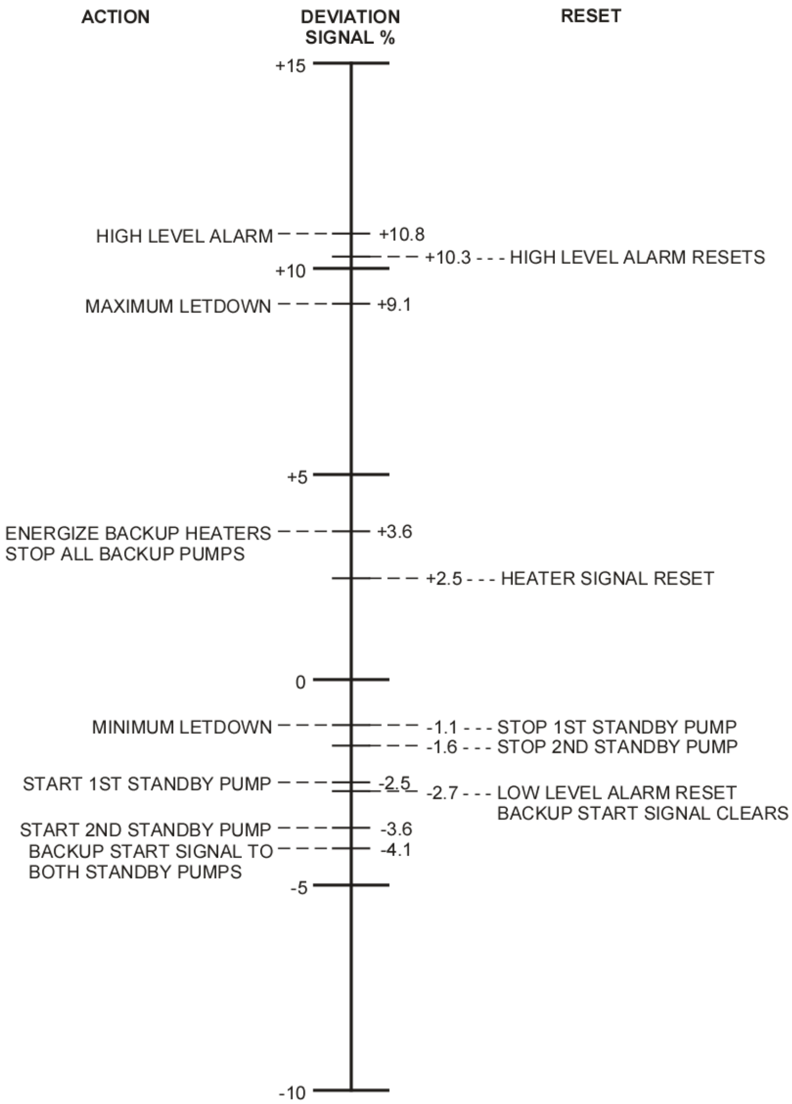

Figure 6.2-3 Control System Actions

The output of the selected controller is supplied to the letdown flow control valves. Normally only one of the two letdown flow control valves is used to control letdown flow. When pressurizer level is at setpoint, the selected letdown flow control valve is positioned to allow a letdown flow rate of 40 gpm. If pressurizer level increases above setpoint, the output of the controller will increase letdown flow by positioning the letdown flow control valves. As shown on Figure 6.2-3, letdown flow will increase from 40 gpm when the pressurizer is at its level setpoint to a maximum of 128 gpm when level increases to 9.1% above setpoint. When pressurizer level decreases below setpoint, the selected controller will decrease letdown flow by closing the letdown flow control valves. Letdown flow will decrease from its normal value of 40 gpm to its minimum of 29 gpm as pressurizer level drops from its setpoint value to 1.1% below setpoint. It should be noted that the operator can control the letdown flow rate by taking manual control of the selected controller. Also, the limiter in the circuit for the letdown flow control valves is used to set the minimum and maximum values of letdown flow. The effects of the limiter can be bypassed if the operator positions the control station for the letdown flow control valves to manual.

Figure 6.2-4 Letdown Controller

The letdown flow controller is equipped with a bias adjustment. It is necessary to adjust the letdown flow controller bias when it is desired to continuously run more than one charging pump. Recall that the pressurizer level controller is proportional-only. The only way to increase controller output is to establish a deviation between level and level setpoint. Consider that a second charging pump is manually started to increase the dilution rate. This will make pressurizer level rise. The resultant pressurizer level deviation causes letdown flow to rise. But, without a bias adjustment, the deviation required to raise letdown flow to 84 gpm will trip the backup charging pump, making it impossible to dilute at a rate greater than 44 gpm. To enable continuously running more than one charging pump, the operator adjusts the letdown flow controller bias until letdown flow matches charging flow at programmed pressurizer level.

6.2.3.2 Charging Pump Control

Three positive displacement charging pumps are installed in the Chemical And Volume Control System (CVCS) to supply normal RCS makeup requirements. Each pump has a capacity of 44 gpm. During normal operations, one charging pump is in service with the other two pumps in standby. Charging pump control is accomplished by four control switches. Three of these switches are used to determine the operating mode of the charging pumps, and the fourth switch is used to select the starting order of the standby charging pumps. The first three switches (one switch each for the 11, 12 and 13 pumps) have three positions; start, stop, and auto. The start and stop positions allow manual control of the pump while the automatic position allows the PLCS to control the operating status of the charging pumps. The last control switch is used to determine the starting order of the standby charging pumps. The switch has three positions (12&13, 13&11, and 11&12). In the 12&13 position, the 12 charging pump is the first standby charging pump and the 13 charging pump is the second standby charging pump. The control switch for the 11 charging pump would be in the start position and this pump would be supplying normal charging.

Two bistables are located on the output of the controller. The first bistable will start the first standby charging pump if the deviation signal exceeds -2.5%. The second bistable starts the second standby charging pump when the level deviation exceeds -3.6%. The reset points for the bistables are -1.1% and -1.6% respectively.

In addition to the analog controller signal, the bistable portion of the PLCS also provides start and stop signals to the charging pumps. One of the bistables is used to provide a backup start signal to both standby charging pumps if the level deviation exceeds -4.1%. This signal ensures that maximum charging flow is available to the pressurizer in the event of a controller failure. This bistable also provides a low pressurizer level alarm. The reset point for the bistable is -2.7%. The second bistable provides a backup stop signal for the standby charging pumps on a high level deviation of +3.6%. The high pressurizer level alarm and pressurizer backup heater actuation is also provided by this bistable. The reset point for these actions is +2.5%.

6.2.3.3 Pressurizer Heater Signals

The bistable portion of the PLCS provides two signals that are used to control the pressurizer heaters. The first signal is the low level heater cutoff signal. This signal is set at 28% and prevents the heaters from being energized unless they are covered with water. This interlock is supplied from the level transmitters via an interlock defeat switch.

The interlock defeat switch allows the operator to remove a failed transmitter from the heater circuitry. The switch has three positions (x, both, and y). In the both position, the pressurizer heaters will be deenergized if either transmitter senses that the pressurizer level has decreased to 28%. These bistables also provide the low-low pressurizer level alarms. Alarm generation is independent of the position of the interlock defeat switch.

If pressurizer level increases to +3.6% above setpoint, a bistable in each channel will supply a high level deviation signal to the channel select switch. The selected channel will energize all pressurizer backup heaters. The reason for energizing the pressurizer heaters on a high level deviation is an anticipatory feature. The high level deviation is caused by an insurge of cold water into the pressurizer. The cold water will lower pressurizer temperature and pressure. The energy from the pressurizer heaters will raise the water to saturation temperature and minimize the pressure decrease. The reset point for this bistable is +2.5%.

6.2.3.4 High Level Alarm Generation

The last bistable in the PLCS is used to generate the pressurizer high level alarm. The alarm will be generated if pressurizer level deviation exceeds +10.8% and resets at +10.3%. The bistable setpoints are summarized on Figure 6.2-3.

6.2.4 System Operations

A reactor trip can be used to illustrate the operations of the pressurizer level control system. When the reactor trips, the Steam Dump And Bypass Control System (SDBCS) functions to decrease RCS temperatures to the no load T_{avg} value. As temperatures decreases, a pressurizer outsurge occurs. As pressurizer level drops below setpoint, the letdown flow control valves start to decrease letdown flow. When the deviation signal reaches -1.1% letdown flow is at its minimum value. Deviations of -2.5% and -3.6% will start the first and second standby charging pumps. If the deviation reaches -4.1%, a backup signal to start both standby pumps will be generated.

As T_{avg} is decreased, the pressurizer level setpoint will be decreased. This action, combined with the additional charging flow, will start to restore pressurizer level to its desired value. As pressurizer level increases, the deviation from setpoint will decrease. At -2.7%, the backup start signal and low pressurizer level alarm will reset. At -1.6%, the second standby charging pump will stop.

Next, at -1.1%, the first standby charging pump will stop. As the operating charging pump continues to raise pressurizer level, the letdown flow control valves will be positioned to control letdown at its normal value of 40 gpm.

Next, consider the response of the PLCS during a load decrease. Assume that the Control Element Assemblies (CEAs) are in manual and the load decrease is to be accomplished by borating the RCS. If turbine load is reduced faster than boration can decrease reactor power, then T_{avg} will increase because of the energy mismatch. As T_{avg} increases, the insurge increases pressurizer level. As pressurizer level goes above setpoint, the output of the selected controller increases letdown flow. If the insurge creates a level deviation of +3.6%, the backup heaters will be energized. Carrying the transient to extremes for discussion purposes; when the pressurizer level deviation reaches +9.1% letdown flow will reach its maximum of 128 gpm. At +10.8%, the high level alarm will annunciate. As the increase in letdown flow starts to restore level to normal, the following actions will occur:

1. At +10.3%, the high level alarm will reset,
2. As the error decreases below +9.1%, the letdown flow control valves will start to throttle down,
3. As level drops below +2.5%, the backup heaters are returned to pressure control and
4. Letdown flow is returned to 40 gpm when level reaches setpoint.

For discussion purposes, assume that a five gpm leak develops in the RCS. With 40 gpm letdown, four gpm control bleedoff flow, and five gpm leakage, the total outflow from the RCS is 49 gpm. Since only one charging pump is operating, level in the pressurizer will start to decrease. When the controller senses that level is below setpoint, the letdown flow control valves will decrease letdown flow. Charging will return level to setpoint.

6.2.5 Summary

The PLCS maintains the water inventory of the RCS by varying both letdown and charging flow. In addition, the system will provide low and high level signals to the pressurizer heaters.

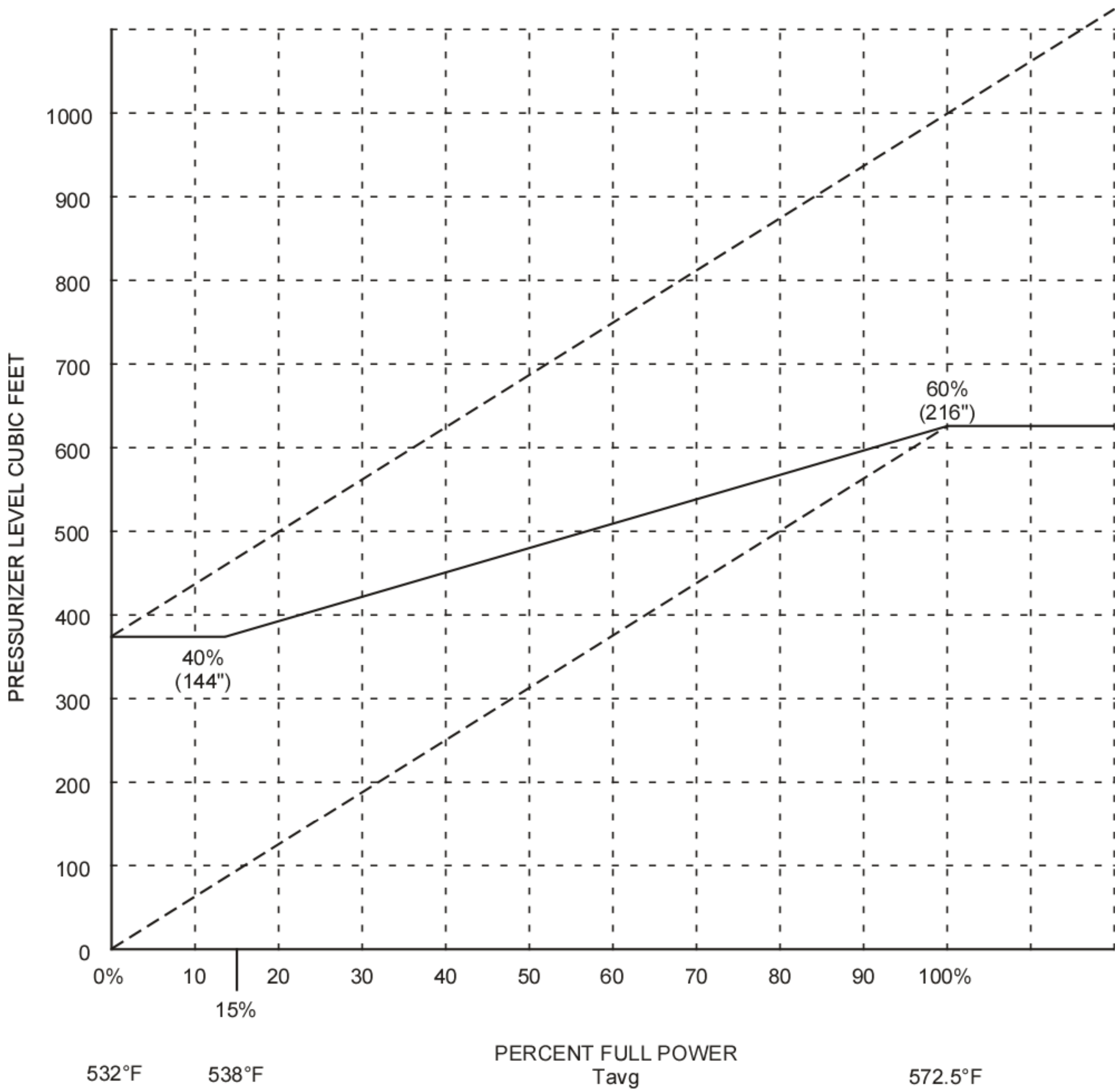

Figure 6.2-1 Pressurizer Level Program

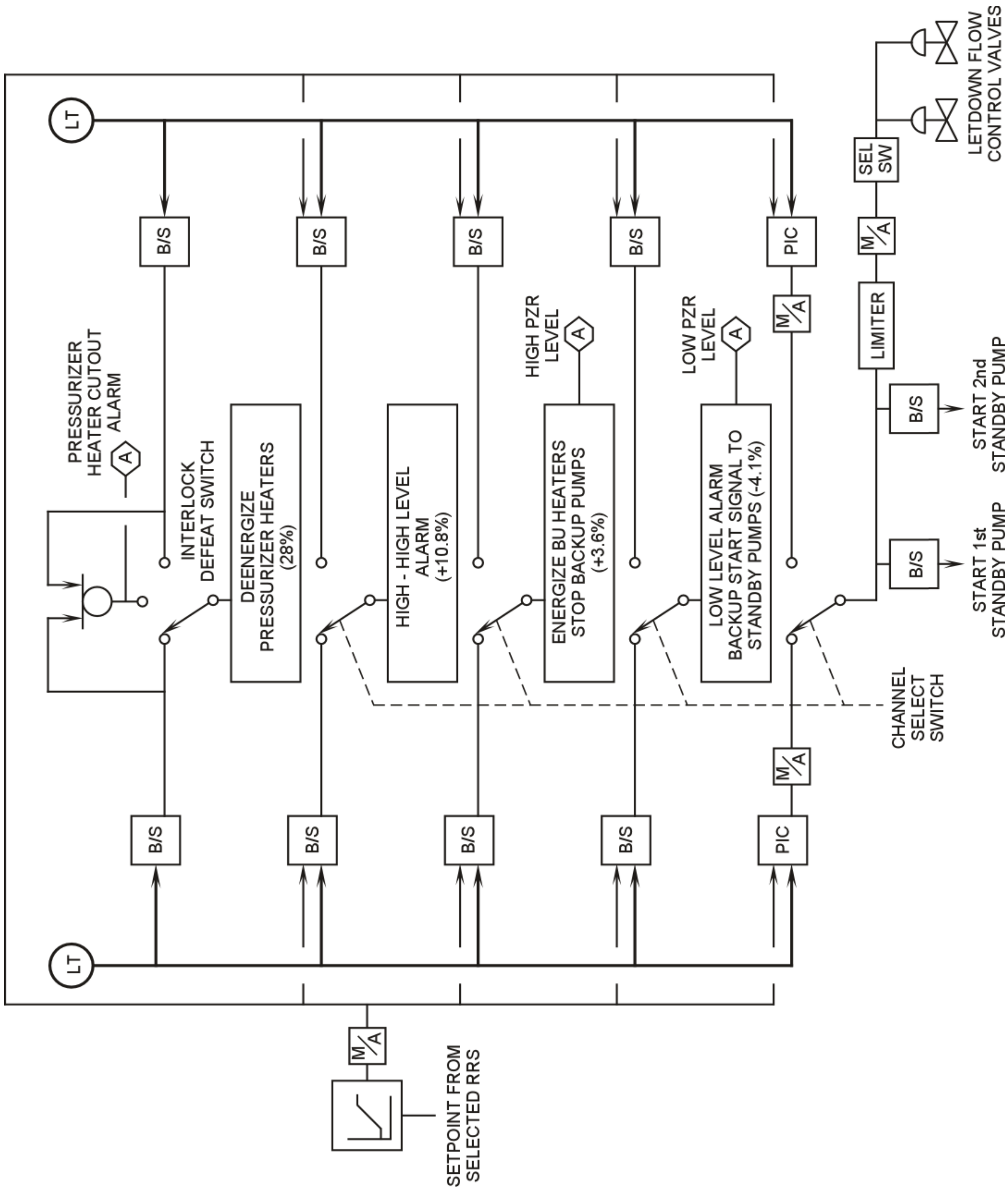

Figure 6.2-2 Pressurizer Level Control System

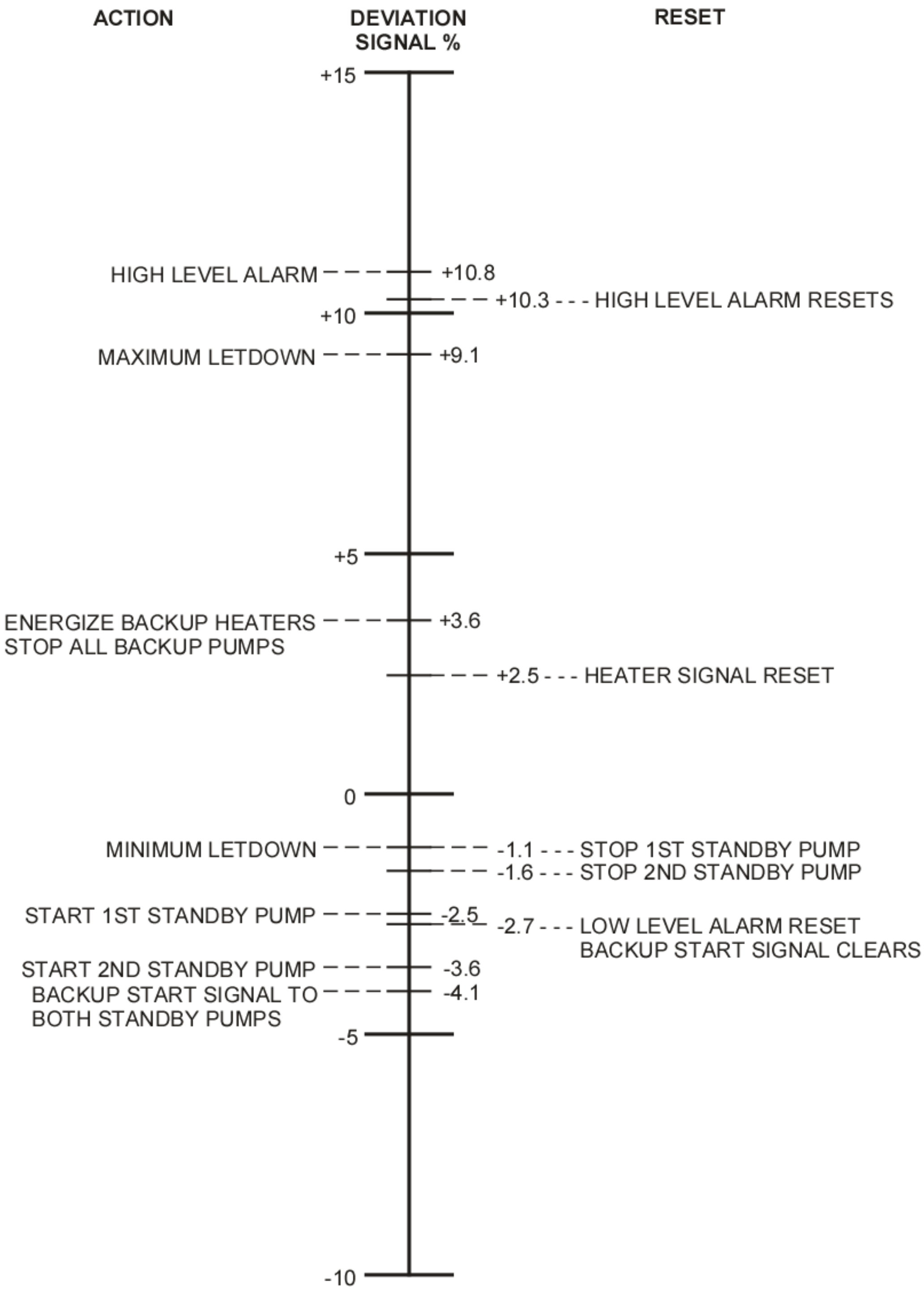

Figure 6.2-3 Control System Actions

Figure 6.2-4 Letdown Controller