

CHAPTER 6: HEAT TRANSPORT CONTROL SYSTEMS

MODULE 1: FEED AND BLEED PRESSURE CONTROL

Introduction

The purpose of the Heat Transport System (HTS) is to transfer the heat generated by the fission process in the reactor to the steam generators.

The heat transfer medium is pressurized heavy water and the principle control for this system will be the regulation of the pressure within the heat transport system. The heat transport system must be able to respond to disturbances from either the reactor or turbine side of the energy balance.

The means of pressure control varies and is either a feed and bleed or a pressurizer vessel as the primary control system, but with feed and bleed under certain operating conditions. Both methods will be discussed.

Feed and Bleed Pressure Control

The HTS is essentially an enclosed loop system (Figure 1) normally maintained at a pressure of 8 - 9 MPa. Any deficiencies in pressure will be rectified by feeding additional D₂O into the system by the pressurizing pumps. Conversely, any excess of pressure will be countered by bleeding D₂O from the system.

The system must be capable of being controlled over the range 0 - 9 MPa, i.e., a cold shutdown state to fully operational conditions. To attempt accurate control over this wide range with a single control system would not be feasible. Control therefore is divided into two ranges: wide and narrow.

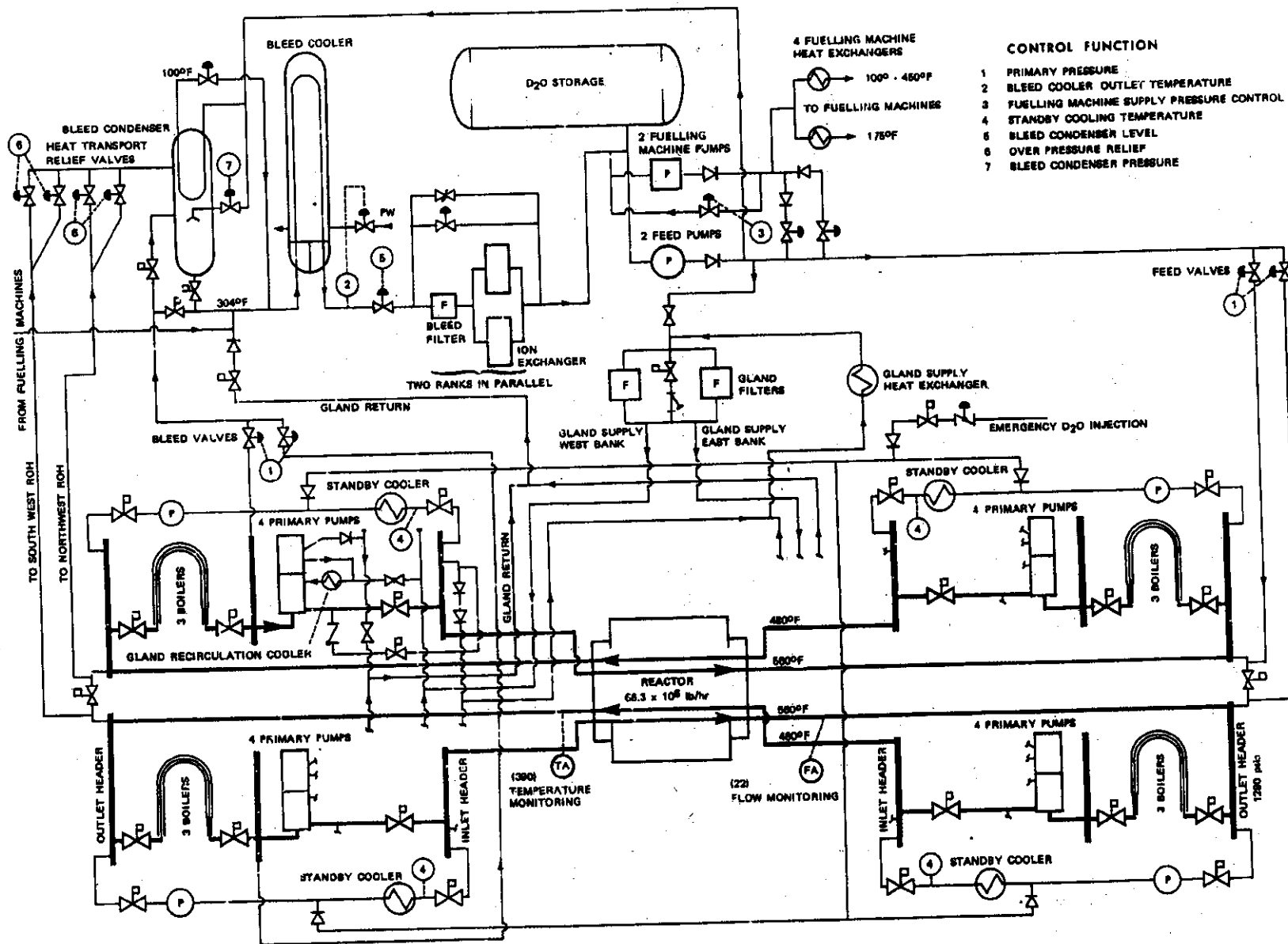


Figure 1: 500 MW CANDU Heat Transport System with Feed and Bleed Pressure Control.

Control Ranges

- (a) **Wide Range Control** is used when bringing the system up to or down from its normal operating state. It is a "coarse", low gain, control system.
- (b) **Narrow Range Control** is used to control the system pressure at its normal operating setpoint, i.e., a "fine", high gain, control system.

The basic method of control both in wide and narrow ranges is to drive the feed and bleed valves from a single controller, i.e., a split range control system.

- The reactor outlet header pressure is sensed by the pressure transmitter (PT).
- Its signal is fed to the direct acting pressure controller (PIC) whose output feeds an air to open (A/O) bleed valve and an air to close (A/C) feed valve via two current to pressure transducers (I/P).
- With the pressure at the setpoint (50% - 12 mA signal) neither feed nor bleed action is required and both valves would be closed.
- If the pressure is too high the increased signal from the PIC would drive the bleed valve open.
- The opposite would be true for too low a pressure in the HTS, i.e., feed valve opens on the decreasing signal from the pressure controller.

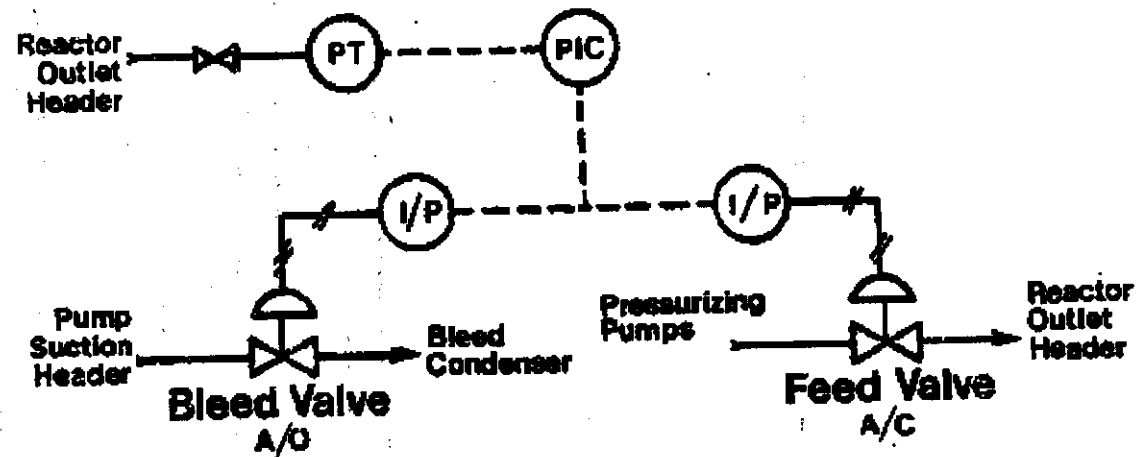


Figure 2: Simplified Split Range Feed and Bleed Control System.

HTS Pressure Control by Feed and Bleed

Wide Range Control

Refer to Figure 3 and locate:

- the two pressure transmitters on Headers 6 and 12, i.e., one on the north loop and one on the south.
- Each transmitter provides a signal for a pressure controller, (PI8A-PIC1, PI8B-PIC1) each of which drives a feed and bleed valve combination.
- Note that the bleed valve signal is routed via hand (manual) controllers HC1 and HC2. The use of these controllers will be discussed later.

As already mentioned, this wide range control is used only for warmup and cool down operations. Essentially in the warmup condition the bleed valve will be opened continuously in response to the rising pressure in the system causing inventory swell. This excess D₂O is routed via the bleed valves to the D₂O storage tank.

During cool down operations the feed valve will need to be opened to provide makeup D₂O in order to maintain the HTS inventory as it shrinks.

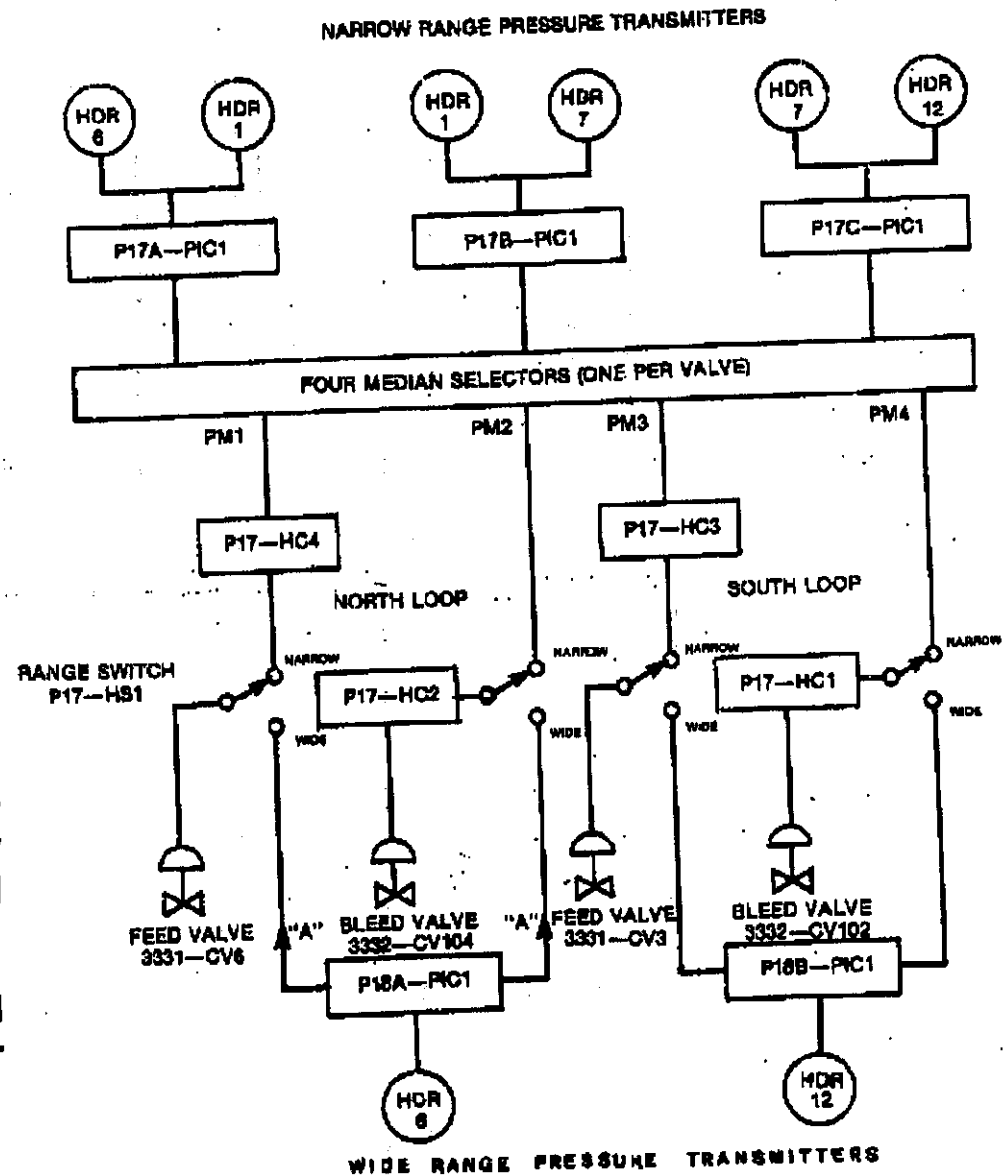


Figure 3: Heat Transport Pressure Control Scheme.

Narrow Range Control

Narrow range pressure control of the HTS is required at the operating state to provide the necessary pressure regulation and to prevent large pressure transients. The narrow range pressure control system drives the feed and bleed valves with a median (in order to reject irrational values) control signal selected from three controllers which accept averaged signals from six pressure transmitters (Figure 3). The narrow range system can be considered as consisting of three measurement branches: P17A, P17B, and P17C.

- Locate the P17A branch with pressure transmitters on headers 1 and 6.
- These two current signals are averaged and input as the measurement signal for control P17A - PIC1.
- Similarly, the averaged pressure measurement signals are compared to the set points by the three controllers and corrective control signals are produced.
- The three narrow range pressure setpoints are staggered (e.g. 8.6, 8.7 and 8.8) to prevent the controllers 'fighting' for control.
- These control output signals are applied to four median select relays (PM-1, 2, 3, 4) which will select the median control signal (reject the high and low signals).
- The four median selectors should block any irrational signals caused by instrumentation faults.
- The normal setup will be for P17B-PIC1 to be set to the system setpoint as its inputs are from both the north and south loops of the HTS.

Narrow Range Control (continued)

- The median control signal passes to HC-1, and HC-2 (bleed valves) via the range switch contacts.
- This control signal is also fed directly to HC-3 and HC-4 (feed valves).
- The outputs of these manual stations are then passed through the range switch contacts to the feed valves.
- Note that the bleed valve hand stations are available in both wide and narrow ranges, while the feed valve hand station can only be used in narrow range.
- If narrow range pressure control is selected, the same median signal will be applied to all four control valves.
- The auto/manual stations for the bleed valves (CV102, CV104) have an adjustable bias provision so that an extra constant component can be added to the median signal.
- The bias value will cause the bleed valves to be more open than the median signal would request. Increasing the bias will increase the bleed rate, raising the purification flow.
- In case of a median selector relay malfunction, the auto/manual station can be switched to allow manual control of the valve position.

The pneumatic signals applied to the feed and bleed valve actuators are amplified (times 2) to 40-200 kPa(g) to provide the actuators with a larger working force.

The feed and bleed valves are single seated globe valves with linear flow characteristics.

These valves are split ranged from the median control signal as shown in the following table:

VALVE OPERATING RANGES

	OPEN	CLOSED
Feed Valve (A/C)	100 kPa	140 kPa
Bleed Valve (A/O)	200 kPa	140 kPa

The gain of the feed valve can be seen (Figure 4) to be greater than that of the bleed valve. If a pressure fluctuation causes a small change in control signal, the feed flow will be affected to a greater extent than will be the bleed flow.

The system response can be visualized with the feed valves throttling to correct minor pressure deviations, while the bleed valves pass a relatively constant flow. This constant outflow simplifies the problem of controlling the bleed condenser pressure. Under normal operation, the feed valves would appear closed (inflow supplied from reflux and gland in-leakage) with the bleed valves slightly open.

The dynamic rate of response, to pressure and temperature transients, of a feed and bleed type system is limited (2.8 °C/min). Inventory control during transient conditions is therefore similarly limited.

During normal power maneuvering, efforts are made to keep the average HTS temperature, and therefore pressure, relatively constant thus avoiding large changes in D₂O inventory.

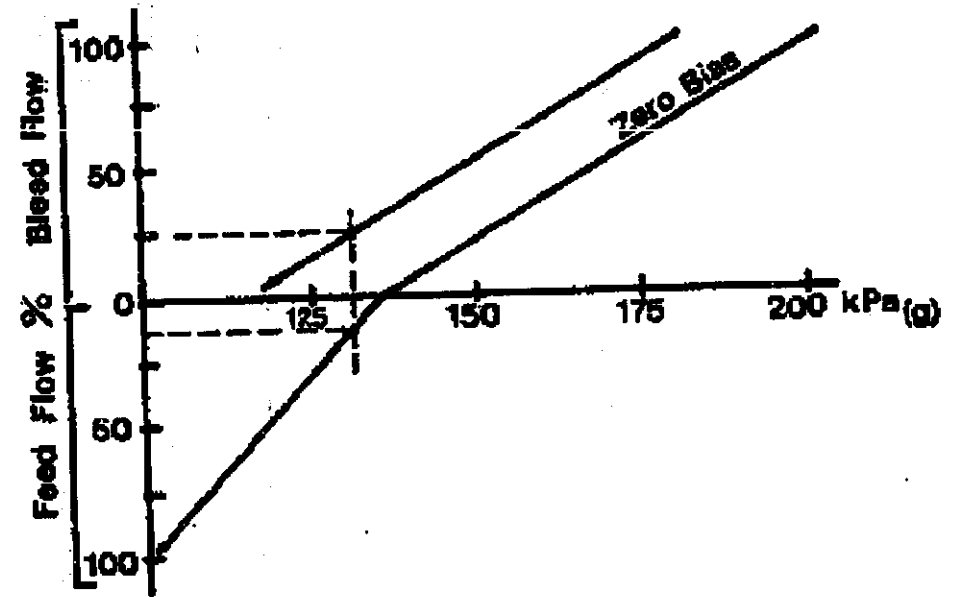


Figure 4: Feed and Bleed Flows vs Control Signal.