CHAPTER 6: HEAT TRANSPORT CONTROL SYSTEMS

MODULE 3: HEAT TRANSPORT BLEED CONTROL

Introduction

Any bleed flow from the Heat Transport System as a result of either too high a pressure or deliberately induced bleed flow for clean up purposes must be reduced in pressure and temperature before passing through the ion exchange systems and on to D_2O storage.

This is accomplished by the combination of the bleed condenser and bleed cooler. Their control requirements are as follows:

(a) To lower pressure and temperature from approximately 9.0 MPa and 300°C to approximately 2 MPa and 210°C in the bleed condenser, i.e., Bleed Condenser Pressure Control.

(b) To maintain an adequate inventory in the bleed condenser, i.e., bleed condenser level control.

(c) To lower the temperature of Bleed from the bleed condenser to approximately 30°C before passing through the I/X columns, i.e., temperature control of bleed cooler.

(d) In order to avoid breakdown of IX resins by a bleed temperature in excess of approximately 50 - 60°C, to provide a means of effective temperature control of the bleed cooler at the expense, if necessary, of the control function listed in (b), i.e., temperature override of bleed condenser level control.

Bleed Condenser Pressure Control

- The preferred method of bleed condenser pressure control is by throttling the reflux valve (CV111).
- The backup method of pressure control, spray valve (CV113) regulation, is not desirable because it results in extra flow through the IX columns and promotes degassing of the D_2O in the condenser.
- Both the reflux and the spray valve are equipped with air to open actuators.

- The set points of the two pressure control loops are staggered with the reflux set point the lowest (approximately 1.9 MPa).
- As long as the pressure is successfully controlled by the reflux method, the spray valve will not be opened.
- The set point for the spray controller is approximately 2.1 MPa or 200 kPa above the reflux set point.
- Should the bleed condenser pressure rise unchecked by the reflux system, the spray controller will begin to drive the spray valve open.
- A high bleed condenser pressure condition will be annunciated when the bleed condenser pressure rises to 2.24 MPa.

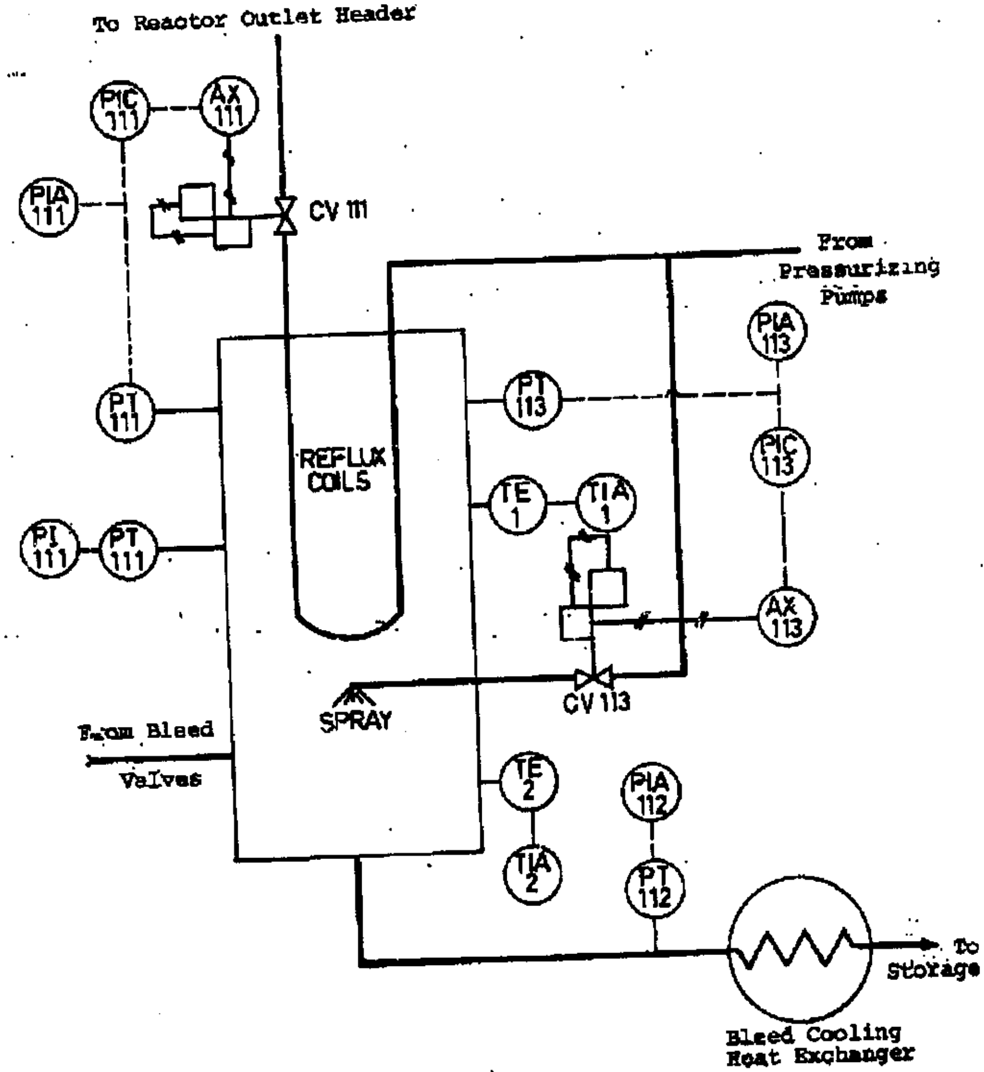

Figure 1: Bleed Condenser Pressure Control.

Bleed Condenser Level Control

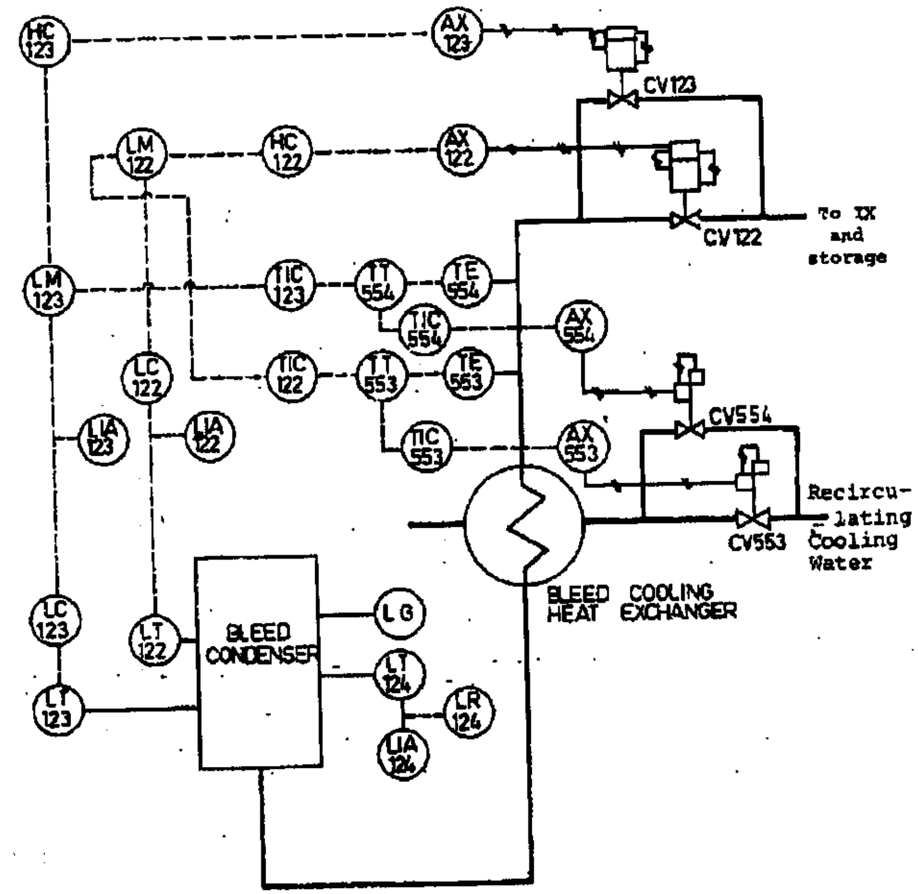

Figure 2: Bleed Condenser Level and Bleed Temperature Control.

- During normal system operation, the bleed condenser level is regulated by throttling an outflow control valve (CV122 or CV123).
- This control problem can be considered, in general, as the level control of a tank by outflow regulation where the tank is supplied with a non constant inflow.
- A duplicated system is employed with staggered set points for the identical level loops.
- Consider the level loop identified with tag number 122 (LT-122 to CV122) in Figure 2. The control valve (CV122) on the outflow line is an air to open globe valve. If the level in the bleed condenser sensed by LT-122 is too high, the valve must be driven more open. The signal from the direct acting LC-122 is fed to a low select relay (LM-122) which will pass the lowest of the two signals applied, (e.g., 10 mA and 12 mA input, 10 mA output). Assume at this time that the level control signal is the lowest signal input to LM-122. The signal is directed from LM-122 to an auto/manual station (HC-122) so that manual control of the outflow valve is possible if the controller becomes inoperative. The control signal from the auto/manual station then drives an I/P transducer (AX122) which allows the electronic loop to be interfaced with the pneumatic actuator of CV122.
- The operation of the level loop tagged 123 is identical to 122 except that the set point of LC-123 is approximately twenty percent higher than the set point of LC-122. (LIC-122 set point: 60%, LIC-123 set point: 82%). As long as the level is regulated by loop 122, the back up loop 123 will appear inoperative and CV-123 will be closed.

Bleed Cooler Effluent Temperature Control

The effluent temperature of the bleed cooler is regulated by a duplicated system consisting of the control loops tagged 553 and 554. Consider the loop tagged 553 in Figure 3. The effluent temperature is sensed by an RTD which produces a change in resistance proportional to the measured change in temperature. This change in resistance is then converted to a corresponding mA signal by TT-553. The current signal from the temperature transmitter is applied as the input to two temperature controllers (TIC-553, TIC-122) which are connected in series in the transmitter circuit.

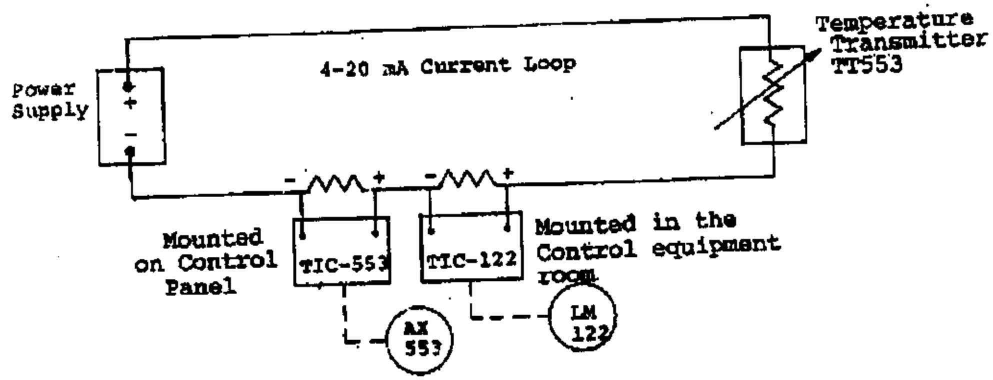

Figure 3: Two Controllers Monitoring the Same Current Signal.

The function of TIC-122 will be discussed in the next section on temperature override. Temperature controller 553 is direct acting so that an increase in effluent temperature will cause the air to open control valve (CV-553) on the recirculating cooling water line to be driven more open. The temperature control loops are identical but with staggered set points. The set point for the back up controller (TIC-554) is 30°C, approximately 6°C higher than the set point for TIC-553. For normal operation, TIC-553 will be able to maintain the desired temperature by throttling CV-553. Control loop 554 will appear inoperative with CV-554 closed unless the temperature begins to rise towards 30°C.

Temperature Override of Level

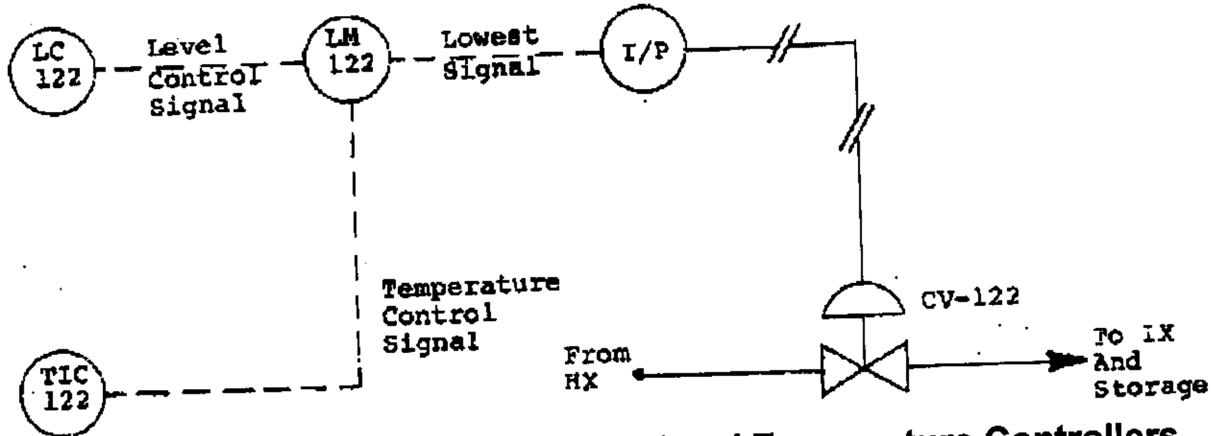

Figure 4: Interconnection of the Level and Temperature Controllers.

- The bleed cooler effluent temperature must not rise to 60°C or chloride ions will be released from the IX resin. (Chloride ions can cause stress corrosion cracking in the system materials.)
- For normal operation, the bleed cooler outflow valve (CV-122) is positioned as a function of the control signal from LIC-122. Temperature controller TIC-122 has reverse action, and this control signal is applied as one of the inputs to the low select relay (LM-122).

Assume that the bleed rate is increased due to some transient condition so that the bleed condenser level begins to rise. Since the level controller is direct acting, the level control signal will increase as the level rises, and CV-122 will be driven more open to increase the outflow rate.

The bleed cooler effluent temperature will now begin to rise due to the increased bleed flow. The controller TIC-122 is reverse acting so that as the temperature rises, the control signal decreases. The rising level control signal and the falling temperature control signal are input to the low select relay. The signal from TIC-122 now becomes the lowest of the two signals, and the temperature controller will be regulating the control valve (CV-122) position.

In this manner, the temperature control signal overrides the level control signal. The reduced flow of hot bleed and the increased flow of cooling water to the heat exchanger (requested by TIC-553) will now be able to return the effluent temperature to the set point. A low limit is set on the temperature controller signal (TIC-122) to limit the closing of the level valve (CV-122) to 10% of stroke. This prevents the complete closure of the level valve by the temperature override signal and the accidental lock-up of a hot pocket of bleed at the temperature detectors.

Response to a Reactor Trip

For a feed and bleed type system a reactor trip would cause, due to the gross energy mismatch that exists under such conditions, an increase in feed valve opening and bleed valves going to a minimum opening position in an attempt to prevent inventory shrinkage (turbine removing heat from system). Due to the limited response rate of this system the feed action must be augmented by the removal of the ultimate heat sink, i.e., a fast speeder gear run back.

The reduced bleed action may require a control response from the bleed condenser level controller. The reduced outflow from the bleed condenser will also reduce the load on the bleed cooler enabling a reduction in service water flow in the shell side of the cooler.

Where pressure control is by pressurizer the initial shrink in HTS inventory following the reactor trip will be supplied from the pressurizer. Recall that the level in the pressurizer was ramped up with power increases to provide this initial inventory replenishment. Again there will be a fast speeder gear run back to re-establish the energy balance at a lower level.

Response to Turbine Trip

In this case the energy input is greater than the output. The HTS system inventory will swell due to the increased temperature and pressure.

A feed and bleed system will require maximum bleed action with the feed valves going to the fully closed position.

This extra bleed will require additional pressure control action in the bleed condenser possibly by commencement of spray action. The additional bleed, plus any spray flow, will require an increased outflow from the bleed condenser to maintain level. This increased outflow will, in turn, increase the cooling requirements from the bleed cooler. It may, perhaps, be necessary to invoke the temperature override of bleed condenser level for a short period of time.

It is unlikely that the above actions will fully suppress the HTS temperature and pressure transient. There may well be some pressure relief from the HTS to the bleed condenser.

The overall control situation will however be eased since the turbine trip will almost certainly cause the large SRVs to lift with a consequent setback in reactor power thus re-establishing an energy match at decay heat power levels.

For a pressurizer system the HTS swell will be accommodated by the pressurizer with the steam bleed valves opening to relieve the pressure. A turbine trip will initiate a reactor stepback thus reducing the energy input to the system. If, for any reason at all, this stepback does not happen, a high pressurizer level will cause a reactor setback.

Simplified Overall HTS Control Scheme

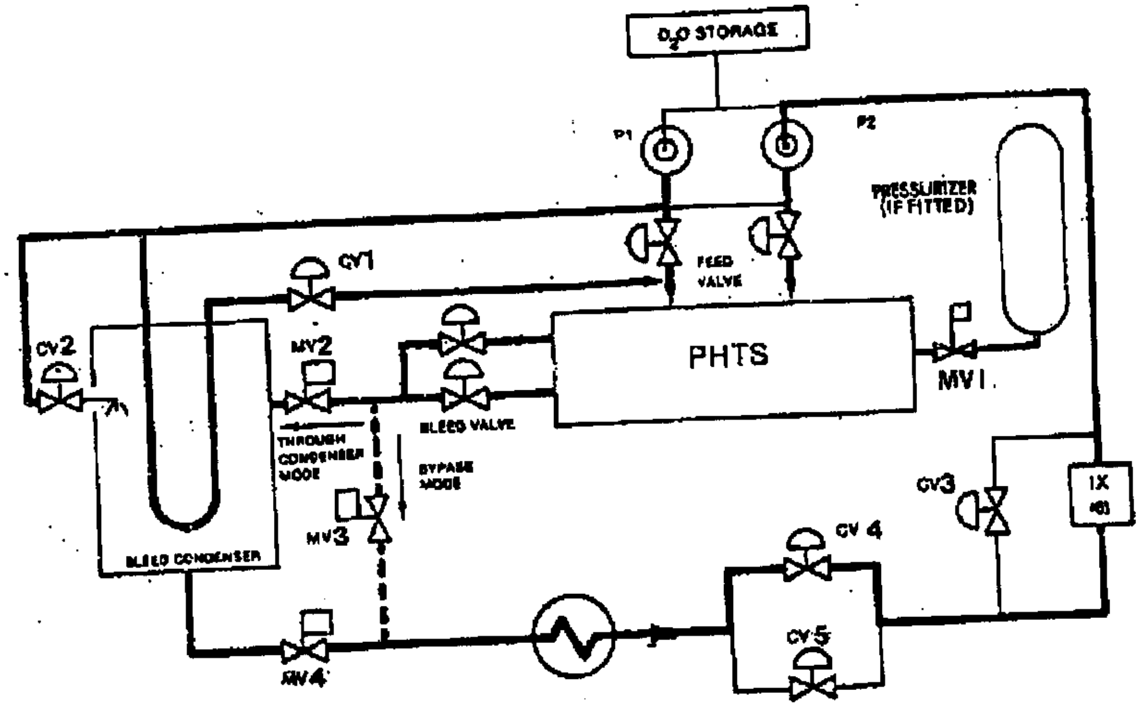

Figure 5: Overall Control Scheme for HTS.

The principle components and their role in the overall control scheme are as follows:

CV1 Reflux flow control valve - primary means of bleed condenser pressure control.

CV2 Spray flow control valve - secondary means of bleed condenser pressure control. Operates only when reflux control insufficient to limit pressure.

CV3 Ion exchange column bypass - opens to bypass IX when flow through columns limited by high DP.

CV4 Bleed condenser level control valves - control level in CV5 bleed condenser by throttling outflow. Normal level control is achieved with one valve fully closed. Second valve opens only when first valve fully open.

MV1 Isolation valve on systems fitted with pressurizer. Closed when in solid mode; opens in normal (at power) mode.

MV2 MV3 MV4 Establish bleed condenser working mode. During warm- up, when inventory swell is largest, condenser is bypassed with flow direct to D_2O storage via IX columns and bleed cooler. During bypass flow saturation conditions are established in the bleed cooler by immersion heaters. Under these conditions MV3 will be open with MV2 and MV4 closed. Under normal conditions bleed flow will be via the bleed condenser. MV3 will be closed with MV2 and MV4 open.