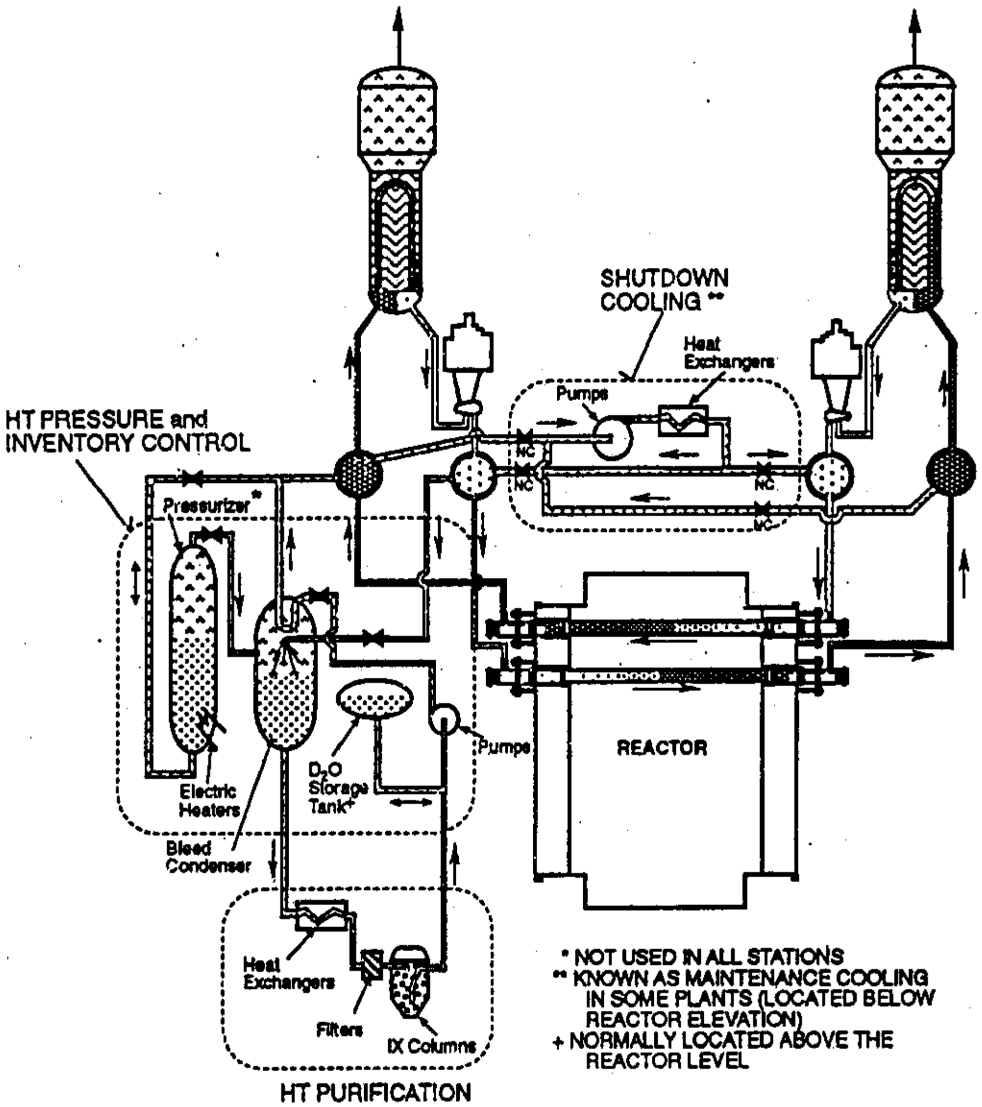
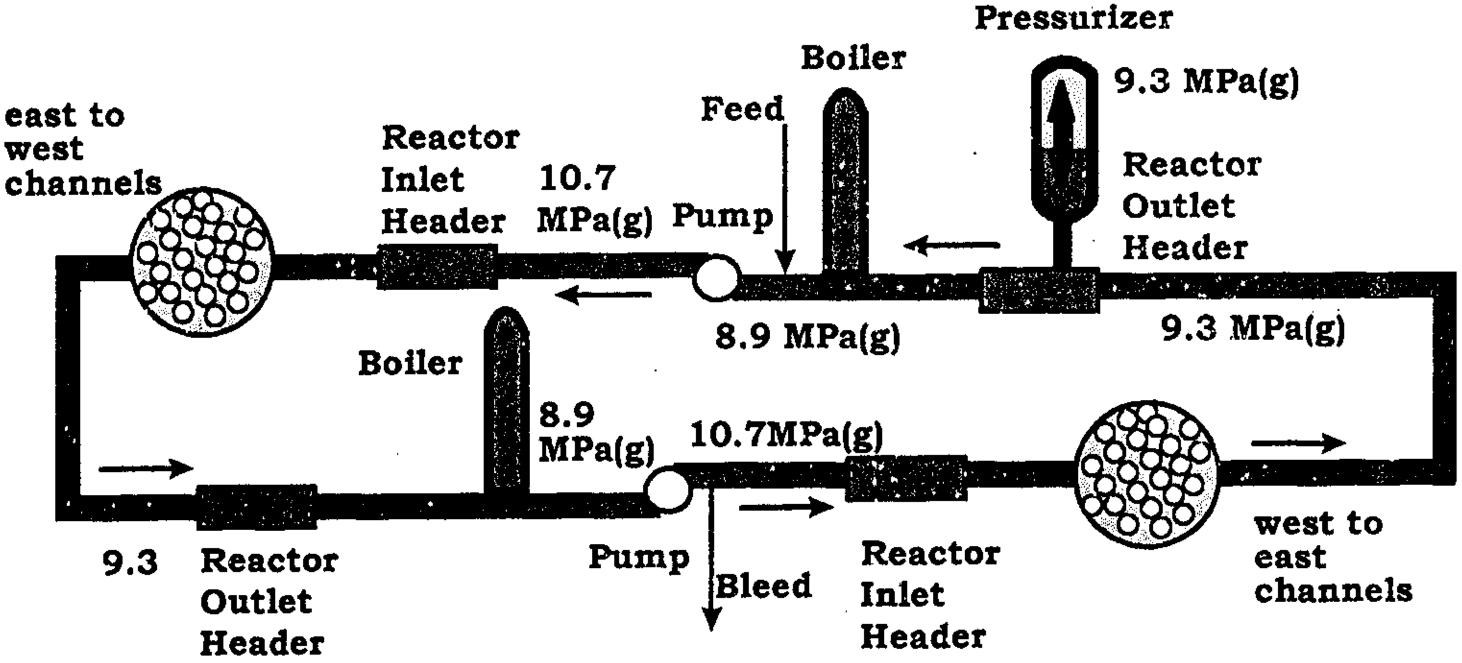
1.0 INTRODUCTION

- The purpose of the Heat Transport System is to:
  - Transfer heat from fuel to heat sink
  - Maintain fuel cooling during upsets (e.g. leaks)
  - Maintain equilibrium heat transfer balance to minimize pressure and temperature transients
  - Safely contain D2O at FP pressure & temperature and during high pressure transients
  - Containment barrier to radioactivity release
  - Fuel support structure & promote fission process
  - Allow chemistry monitoring & corrosion control
- In order to perform its functions, the Heat Transport System must be operated at a pressure that is in the order of 10MPa: the HT Pressure and Inventory Control System is designed to supply and maintain the pressure in the main circuit

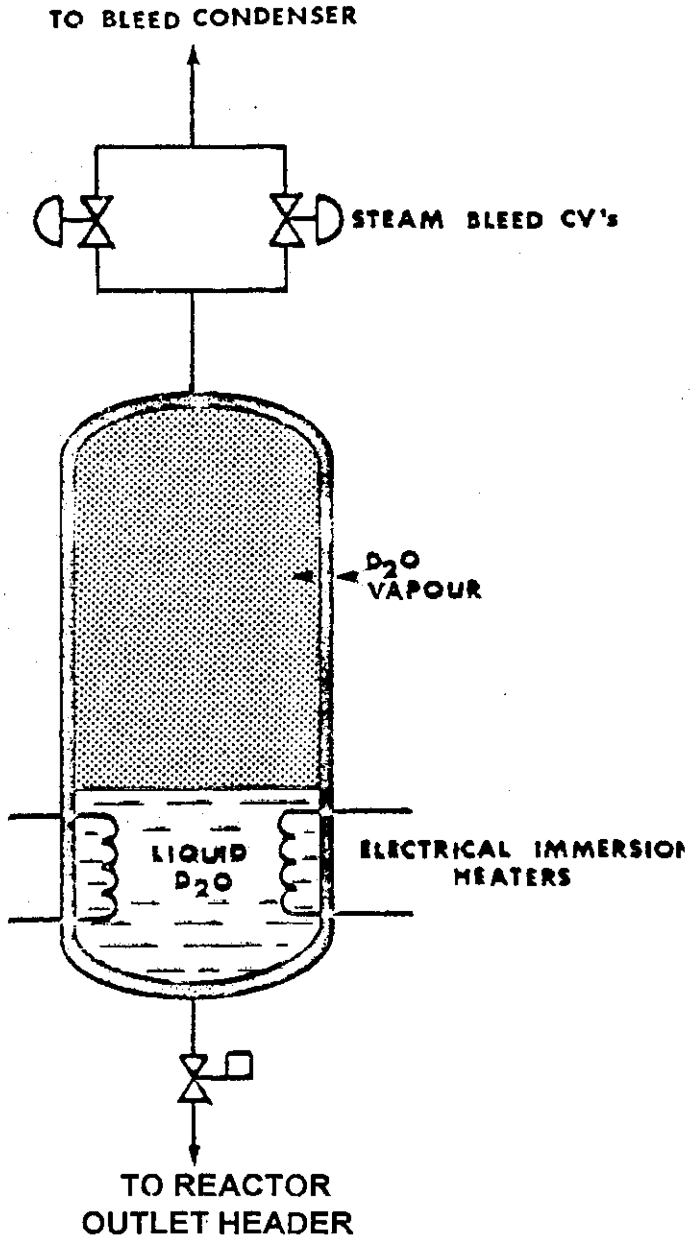


2.0 PRESSURE CONTROL REQUIREMENTS

- the pressure control system must meet the usual control system requirements to be able to:
  - maintain pressure at the setpoint despite internal and external disturbances
  - increase or decrease pressure to follow setpoint changes
  - operate over the wide range of pressure requirements from atmospheric to full power
  - provide protection for people and equipment
- the pressure control system of the main heat transport (reactor coolant) must ensure:
  - adequate saturation margin in the reactor outlet headers (which in turn ensures sufficient fuel cooling for all temperatures and power levels)
  - the required net positive suction head for the heat transport circulating pumps
  - the main circuit is always filled with coolant

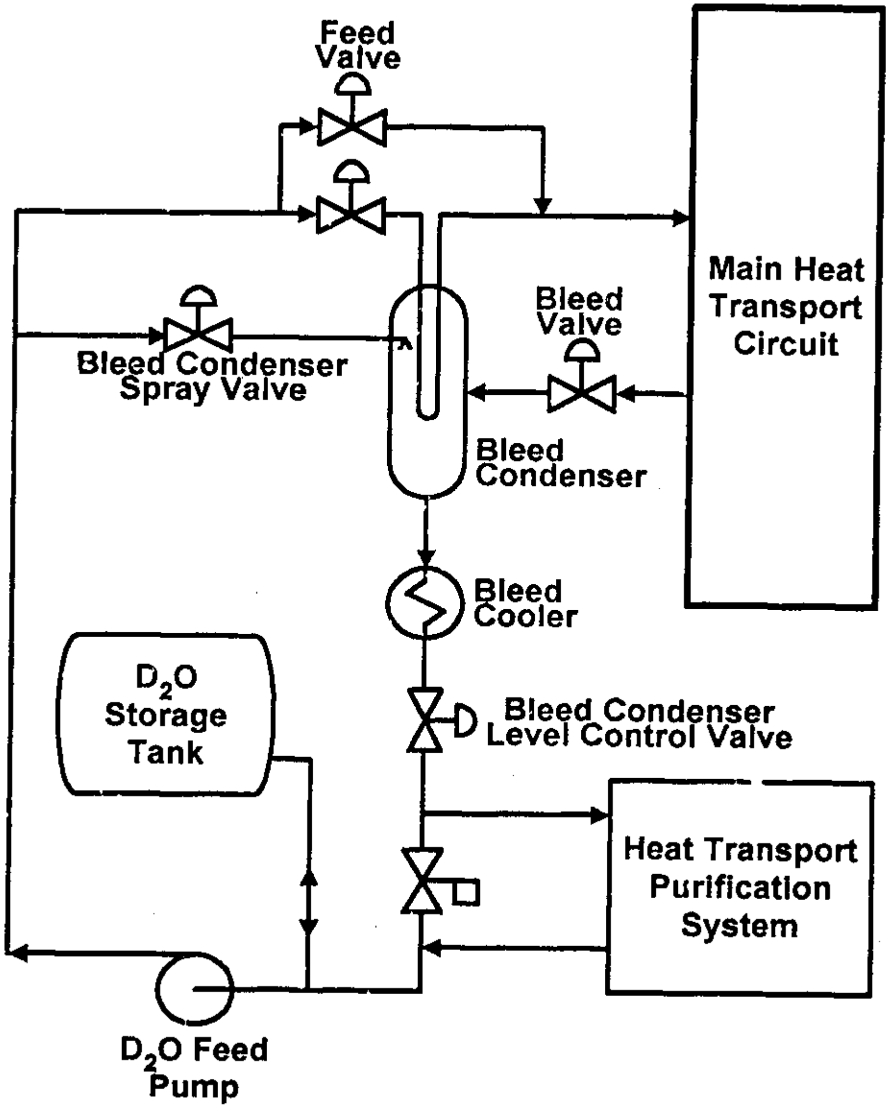


2.1 PRESSURIZER



- The pressurizer is basically a large vessel with a steam space above a variable liquid level, and connected via a motorized valve to the heat transport system.
- The pressurizer's liquid and steam are kept at saturation, and at a pressure that is slightly higher than the saturation conditions in the reactor outlet header at 100 % full power.
- Pressurizer (and hence heat transport) pressure can be raised by adding heat to the liquid via electric heaters, and the pressure can be reduced by bleeding steam out of the pressurizer.
- Consider what happens if there is a reduction in reactor outlet header pressure or temperature (i.e. a reduction of volume):
  - there will be coolant flow from the pressurizer to the main circuit under the force of the steam pressure above the pressurizer liquid surface;
  - such a flow will reduce the liquid volume and hence level, expanding the steam space and lowering its pressure, which in turn will convert more liquid to steam, and the steam pressure will reach a new equilibrium value below its setpoint, as will the level;
  - the pressure control system will add heat to the liquid to raise its temperature and hence its pressure back to the pressure setpoint, and the level control system will add more liquid to raise the level to the level setpoint.

2.2 FEED AND BLEED



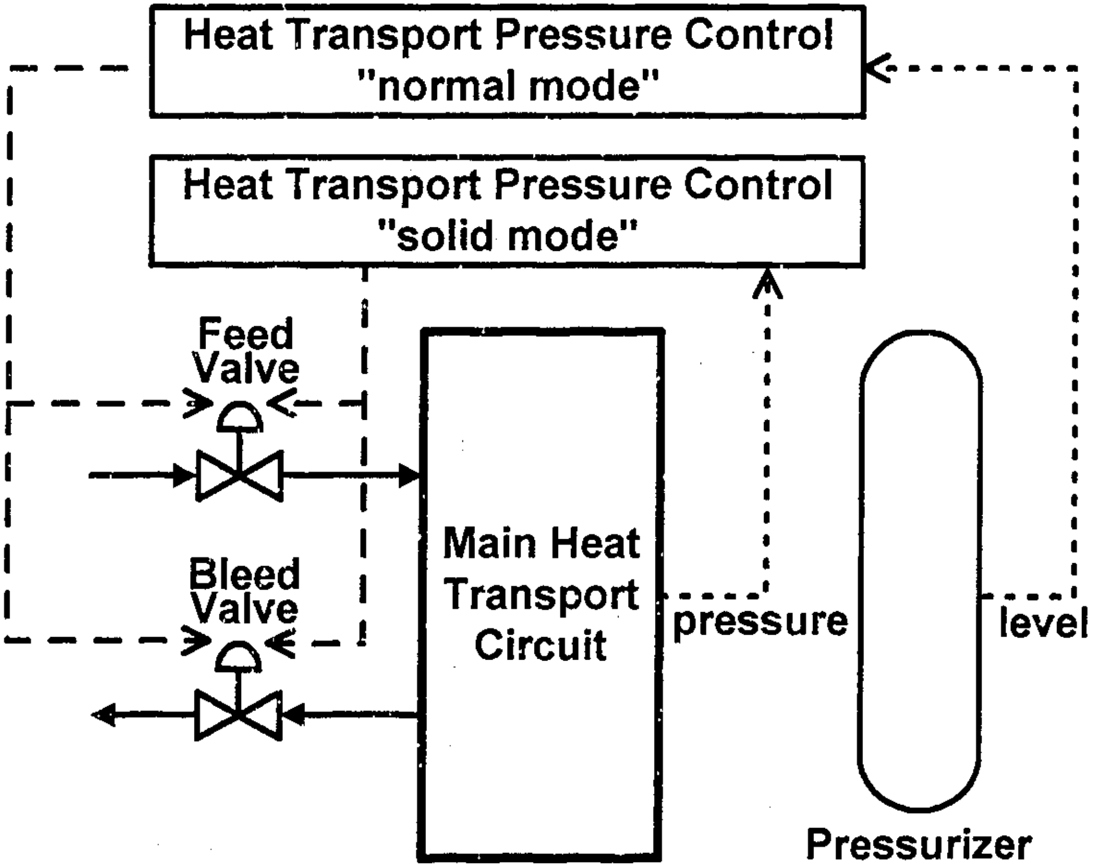
- In order to pressurize the heat transport system without raising its temperature a system other than a pressurizer is needed; it is also possible to design a heat transport pressure control system without a pressurizer at all.
- By using a source of coolant that has the capability to operate at pressures higher than the main heat transport system, it is possible to raise heat transport system pressure by simply forcing more liquid into it; pressure reduction is achieved by removing some of the liquid, i.e. relying on the tensile strength of the vessels and piping that make up the main circuit, and on the slight but finite compressibility of water.
- Such a heat transport pressure control system is called a “feed and bleed” system, and it requires a source of high pressure coolant and a sink that can accept coolant at the operating temperatures and pressures of the heat transport system.
- An integral part of the feed and bleed system (whether used with or without a pressurizer) is the ability to purify the coolant removed from the heat transport system and a storage tank at ambient conditions for storing the coolant required to make up for the shrink and swell as a function of operating temperature.

3.0 INVENTORY CONTROL

- the volume of coolant changes as a function of temperature and hence system operating conditions
- under normal operations temperature changes are relatively slow (in the order of minutes)
- under certain abnormal conditions temperature changes can be very rapid (in the order of seconds)
- to ensure satisfactory pressure control the volume of inventory available to the main heat transport system must be adequate for all design conditions
- an overall unit control scheme that changes boiler pressure so as to maintain average heat transport temperature constant is one way to minimize shrink and swell of the coolant volume; for such a unit a "feed-and-bleed" type of pressure control can provide the necessary inventory control
- use of a "pressurizer" is required if boiler pressure is held constant and hence the average temperature of the coolant is allowed to vary, with the provision of sufficient volume of water in the pressurizer to compensate for all normally expected volume changes: i.e. a level control system is needed, with the level setpoint being ramped as a function of reactor power
- for controlling rapid changes in inventory a pressurizer is the preferred method
- for all long term inventory control a sufficient source of coolant must be readily available (i.e. from a storage tank, having been chemically treated)

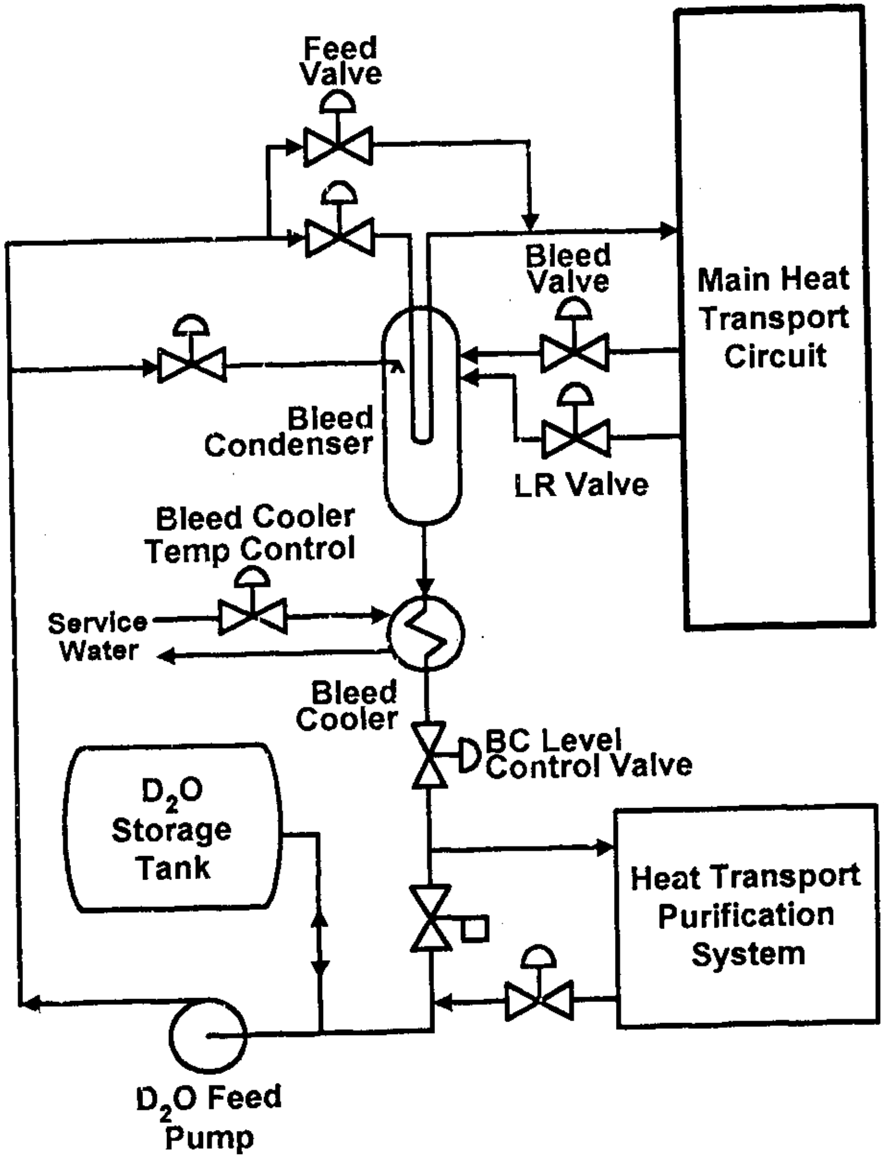
3.1 INVENTORY CONTROL IN CANDU

- inventory control is achieved via the feed and bleed system, whether the pressurizer is controlling heat pressure (NORMAL mode) or the feed and bleed system determines heat transport pressure (SOLID mode)
- note that the same equipment i.e. feed and bleed circuit is used for inventory control in either mode, but in NORMAL the setpoint is pressurizer level, and in SOLID mode the setpoint is heat transport (SOLID mode) pressure



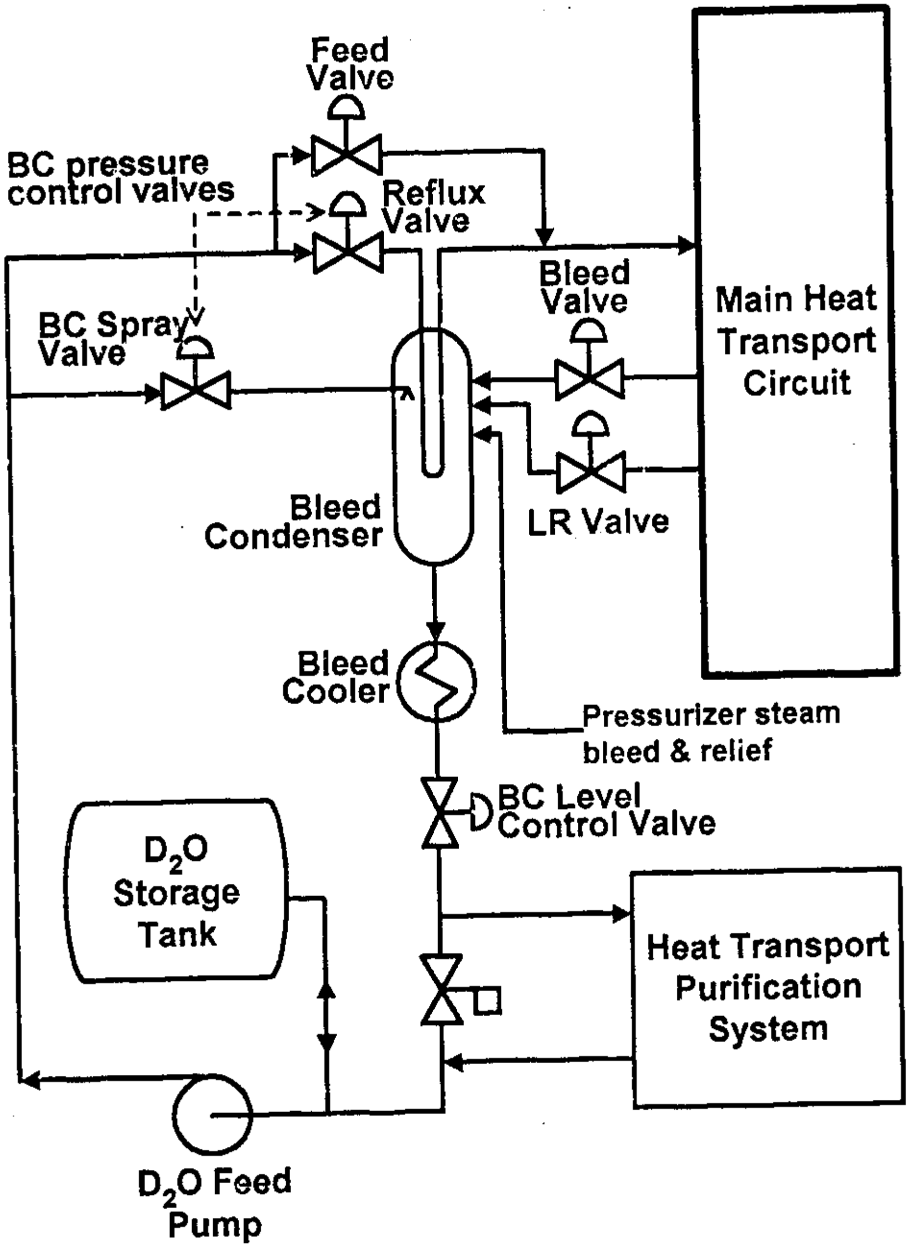
4.0 STORAGE AND CHEMICAL CONTROL

- for a "feed-and-bleed" type pressure control system there must be a source and sink for the volume of coolant added to or removed from the main circuit
- even for a unit that uses a "pressurizer" for main circuit pressure control there is a need for the storage of inventory during system warm-up and cooldown, and in case of certain abnormal operations
- the temperature and pressure of the "bleed" flow from the heat transport system must be reduced to essentially atmospheric conditions in order to
    - purify the coolant
    - transfer coolant to long-term storage
- in order to "feed" high pressure coolant into the main circuit, its pressure must be above main circuit pressure at point of injection
- required equipment includes:
    - bleed condenser
    - bleed cooler
    - purification circuit
    - storage tank
    - feed (or pressurizing) pumps
    - valves and controllers



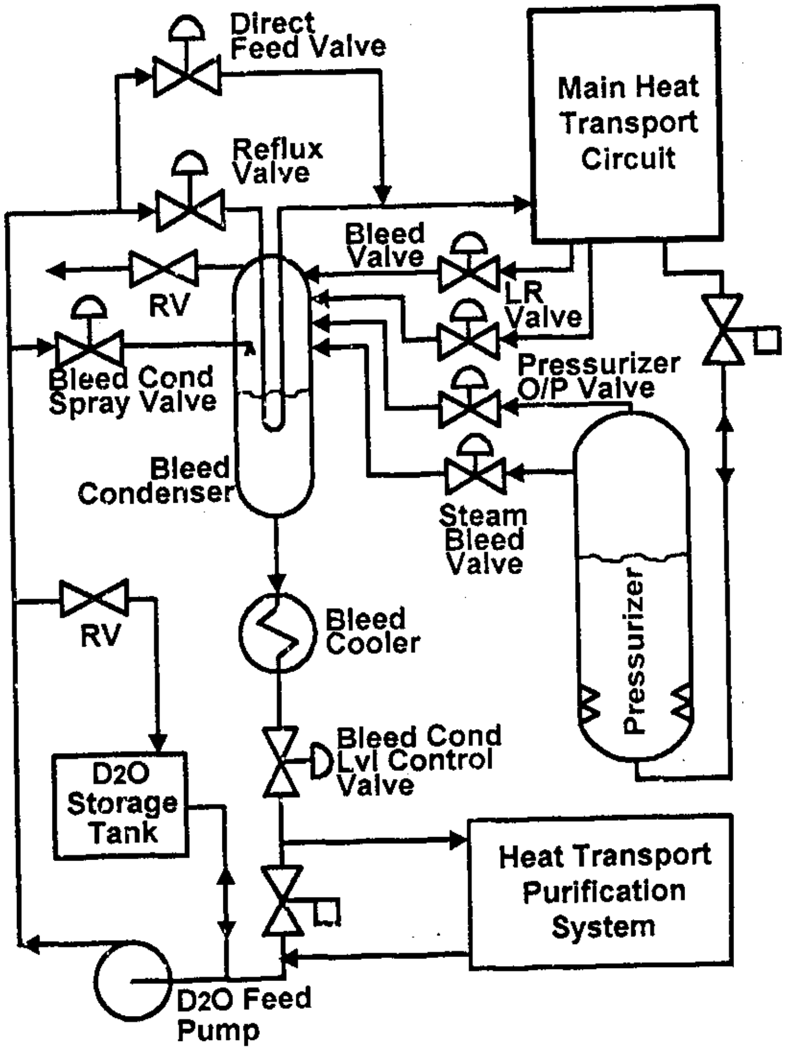
4.1 BLEED CONDENSER

- under normal operating conditions the bleed condenser receives liquid bleed flow from the main heat transport system and steam bleed flow from the pressurizer
- by allowing the incoming liquid to expand and, along with any steam flow, be condensed, a large pressure reduction is achieved (~ 7.5 MPa)
- pressure is regulated by cooling the saturated steam/water mixture
- normal cooling is by the reflux flow, with the flow regulated by the reflux valve to control bleed condenser pressure
- under conditions of abnormally high flow into the bleed condenser, additional cooling is provided by spray flow, controlled at a pressure setpoint somewhat above that of reflux valve
- level in the bleed condenser is controlled by regulating the outflow via the bleed cooler



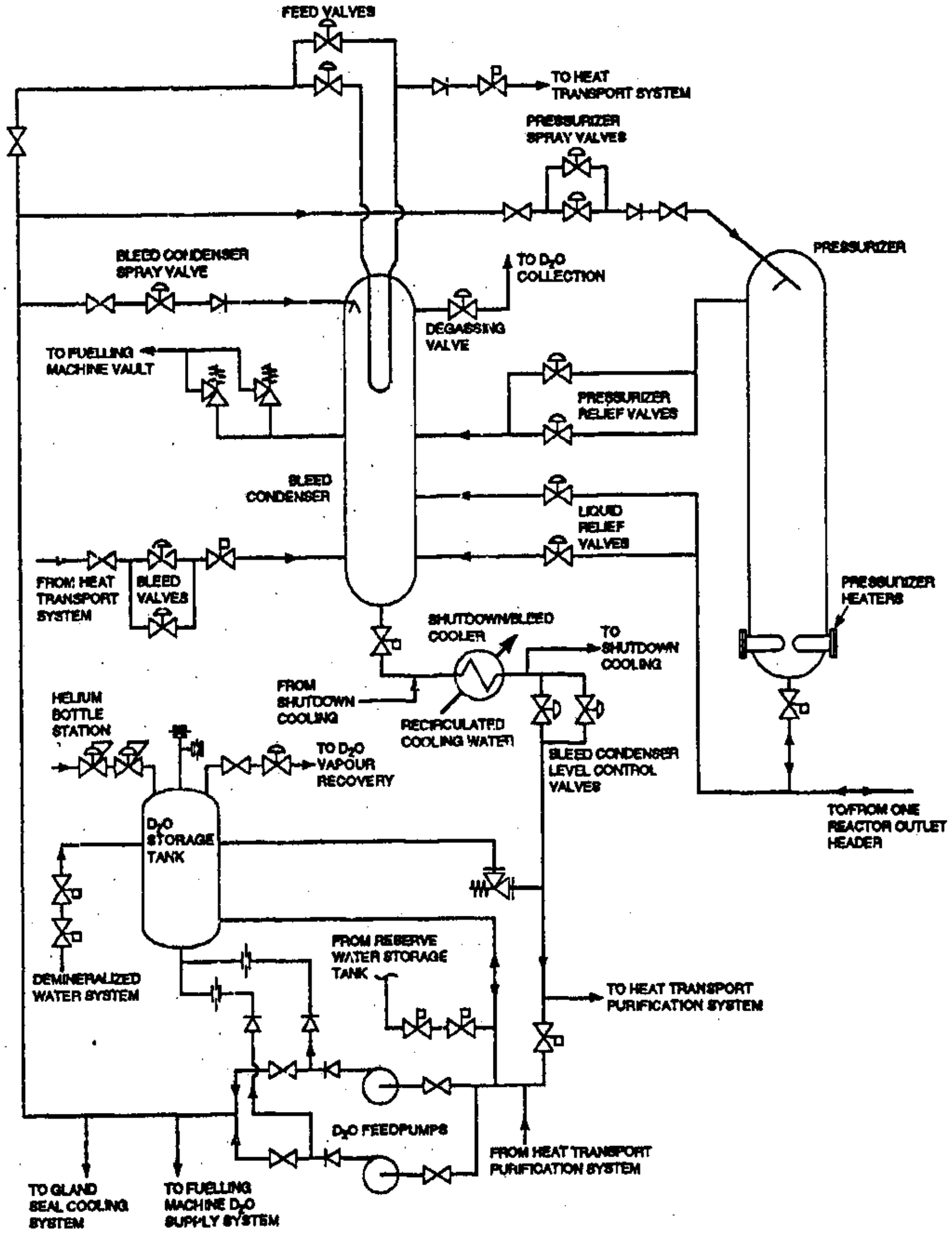
5.0 HEAT TRANSPORT OVER-PRESSURE PROTECTION

- to prevent main heat transport high pressure transients exceeding system limits
  - need liquid relief (LR) valves to bleed condenser
  - otherwise will get high HT pressure reactor trip;
- to provide pressure relief for the pressurizer in the event of equipment failure (i.e. heaters remaining on) or control failure results in a high pressure transient
  - need pressurizer over-pressure (O/P) relief valves to the bleed condenser
- to provide pressure relief valve (RV) for the bleed condenser; for example if it goes solid and becomes the heat transport boundary, must prevent heat transport pressure exceeding system limits
  - bleed condenser relief valves to the reactor building
- to prevent over pressure (and temperature) damage to the purification circuit by by-passing purification if inlet pressure exceeds limits)
  - bleed cooler
  - HT purification relief valve
- to prevent over pressure damage to the reflux feed line by relieving to the storage tank tie line)
  - reflux feedline overpressure protection



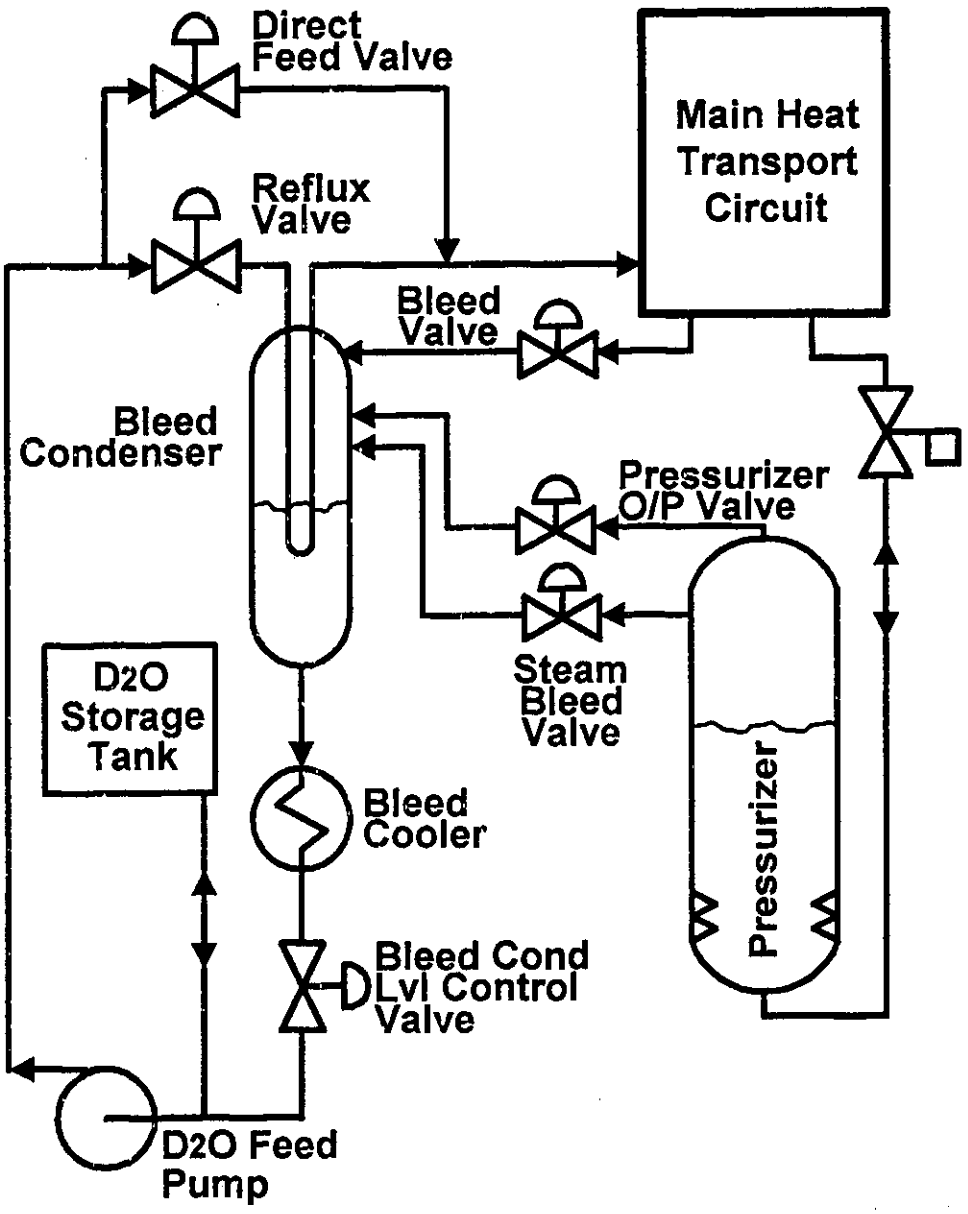
6.0 PRESSURE CONTROL IN CANDU

- early CANDUs, designed in the 1960s, used feed and bleed as the only method of pressure control, in order to save the cost of the pressurizer and to minimize the required inventory of heavy water
- all CANDUs designed since the 1970s use pressurizer as the "normal" mode of control at-power, with feed and bleed as the "alternate" mode, used principally for warmup and cooldown
- a typical pressure and inventory control system, with all the equipment described in this module, is shown on the diagram



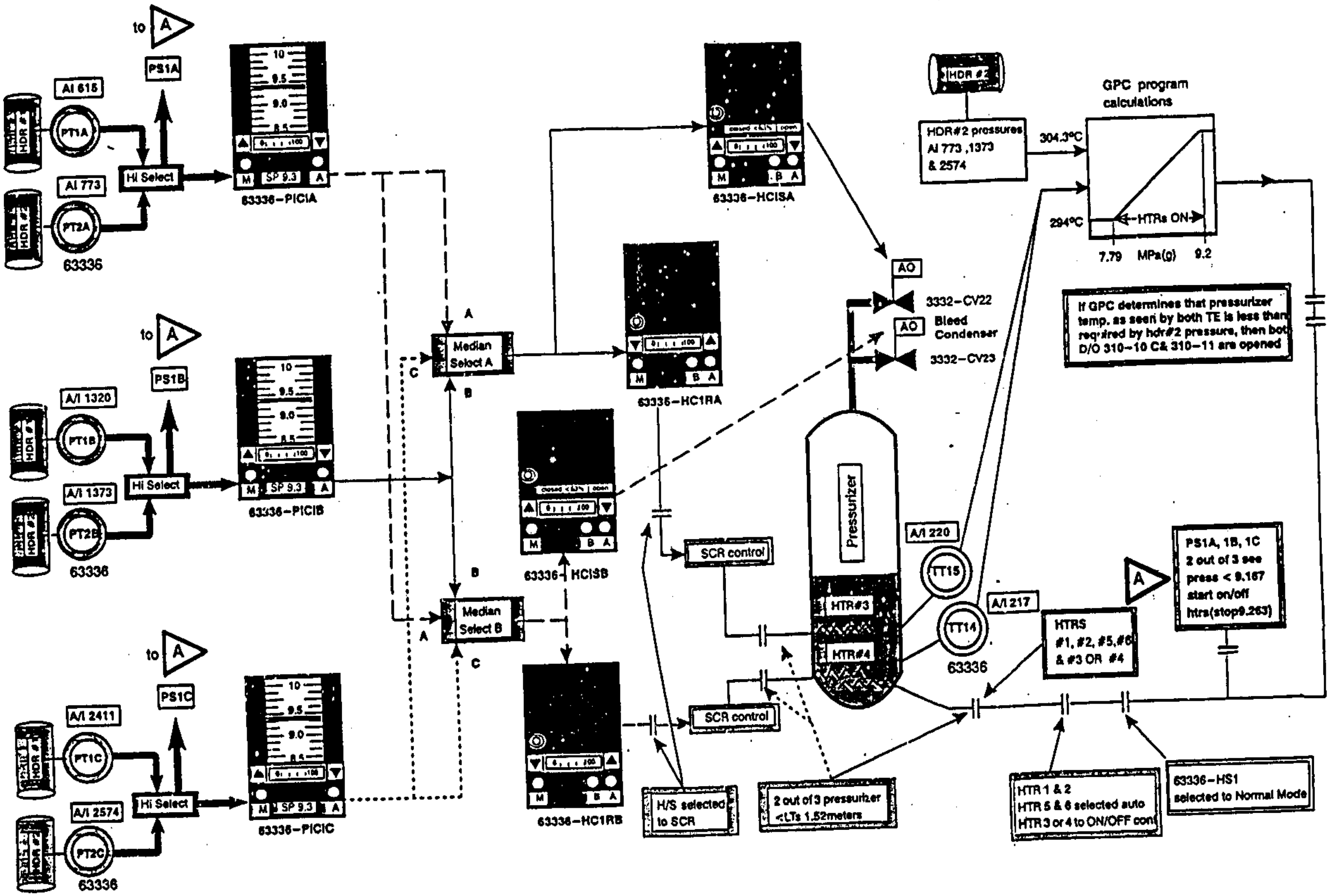
1.0 INTRODUCTION

- nuclear power plants using a pressurizer for heat transport system pressure control will have the following three control systems associated with the pressurizer:
  - pressurizer pressure control, that includes
    - heating elements in order to raise pressurizer pressure
    - spray cooling and/or steam relief whenever pressurizer pressure needs to be reduced
    - pressurizer over-pressure relief
  - pressurizer level control, that includes
    - calculation of level setpoint as a function of reactor power
    - ability to raise level (i.e. some form of feed)
    - ability to lower level (i.e. some form of bleed)
    - protection of heaters in case water level drops too low for safe heater operation



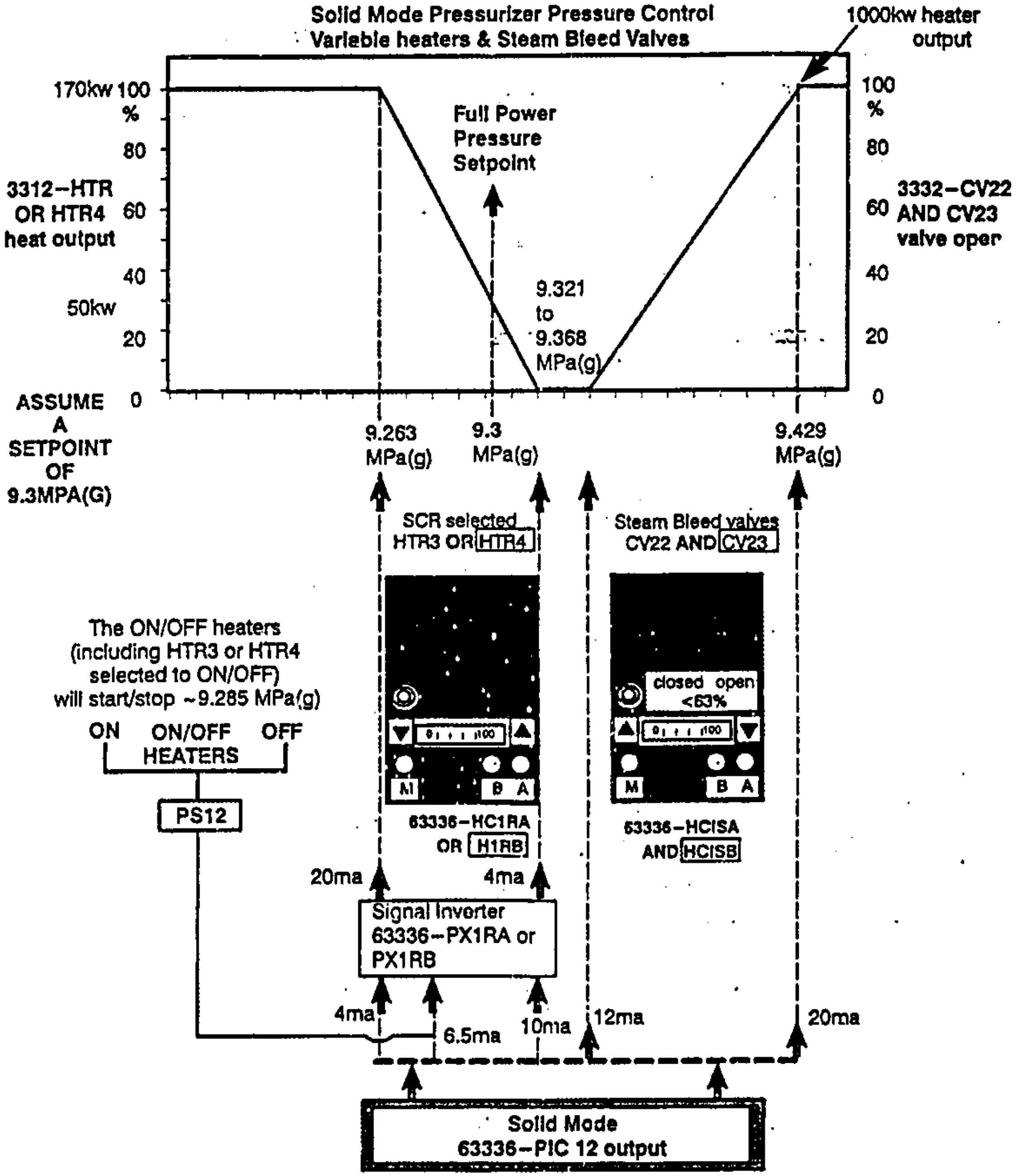
2.0 PRESSURE CONTROL IN NORMAL MODE (Bruce-B example)

- Figure 1 provides an overview of the pressure control scheme in 'NORMAL' mode
- to provide redundancy and reliability, there are three pressure transmitters (PT) per outlet header
- each PT generates two signals: one signal becomes a computer analog input, the other is sent to a high selector
- each of the three high selectors compares a header #1 pressure signal to a corresponding header #2 pressure signal and a high signal selection is done
- each of the three high select signals is sent to a pressure switch and a controller
    - the pressure switches are used in a 2 out of 3 logic scheme to start the ON/OFF heaters in the event that pressure drops low relative to the setpoint
    - the signal fed to the controller (PICIA, B & C) is compared to the controller setpoint, generating a pressure error signal
- all three error signals are then fed-to two median selectors
- the median selectors A & B determine the median error signals and each generate a signal proportional to the determined error
- the output from each median selector goes to two device controllers, to operate either one variable heater or one steam bleed valve, depending on the value of the error signal


to A
PS1A
AI 615
PT1A
HDR #1
Hi Select
AI 773
PT2A
HDR #2
63336
SP 9.3
63336-PICIA
to A
PS1B
A/I 1320
PT1B
Hi Select
A/I 1373
PT2B
63336
63336-PICIB
to A
PS1C
A/I 2411
PT1C
Hi Select
A/I 2574
PT2C
63336
63336-PICIC
A
Median Select A
C
B
B
Median Select B
A
C
63336-HCISA
63336-HC1RA
63336-HCISB
63336-HC1RB
AO
3332-CV22
AO
Bleed Condenser
3332-CV23
Pressurizer
HTR#3
HTR#4
SCR control
SCR control
H/S selected to SCR
2 out of 3 pressurizer <LTs 1.52meters
A/I 220
TT15
A/I 217
TT14
63336
HDR #2
HDR#2 pressures AI 773 ,1373 & 2574
GPC program calculations
304.3°C
294°C
HTRs ON
7.79
MPa(g)
9.2
If GPC determines that pressurizer temp. as seen by both TE is less than required by hdr#2 pressure, then both D/O 310-10 C& 310-11 are opened
HTRS #1, #2, #5, #6 & #3 OR #4
A
PS1A, 1B, 1C 2 out of 3 see press < 9.167 start on/off htrs(stop9.263)
HTR 1 & 2 HTR 5 & 6 selected auto HTR 3 or 4 to ON/OFF con
63336-HS1 selected to Normal Mode

2.1 SPLIT-RANGE CONTROL OF HEATERS AND STEAM BLEED VALVES

- Through the device controller, the output from each median selector operates either one steam bleed valve or one variable heater.
- Median selector "A" operates CV22 and HTR #3; Median Selector "B" operates CV23 and HTR #4.
- To control both a heater and a steam bleed valve, the device controllers are split range and only operate over part of the median selectors' 4 to 20 ma output range.



2.2 SPLIT-RANGE CONTROL OF HEATERS AND STEAM BLEED VALVES

- Each of the variable heaters (HTR3/4) can be controlled by an individual Silicon Controlled Rectifier (SCR). SCR control allows the heater output to be ramped in a smooth linear fashion rather than as an ON/Off step change.
- Since both the SCRs and the pressure controllers are direct acting, signal inverters (HCIRA/RB) are needed. As HT pressure falls, the signal to the SCR unit increases, causing increased heater output.
- Normally only one heater is selected to SCR, which allows its output to be ramped. The other heater is selected to be controlled by the ON/OFF heater control logic.
- With a controller pressure setpoint of 9.3 MPa(g), the 4 to 20 ma output range of the median selectors corresponds to a heat transport pressure range of 9.263 to 9.429 MPa(g).
- If heat transport pressure drops from 9.321 to 9.263 MPa(g), the median selector's output would drop from 10 ma to 4 ma and cause the SCR selected heater to ramp fully on (via the signal invertor).
- If pressure rises from 9.321 to 9.368 MPa(g) (which corresponds to a median selector output of 10 ma to 12 ma) there is a dead band in which neither heaters or steam valves are operated.
- As can be seen on Figure 2, when heat transport pressure is at setpoint 9.3 MPa(g) the median select output will be 8 ma, which generates a 30% output from the heater controllers. This corresponds to a heater output of 50 kw which is designed to match the expected steady state pressurizer heat loss.
- As pressure increases from 9.368 to 9.429 MPa(g) the median selectors output goes from 12 ma to 20 ma and the controllers for CV22 (HCISA) and CV23 (HCISB) ramp fully open the steam bleed valves.
- There are meters on the controllers which display controller output in 0 to 100%. The 12 to 20 ma signal required to ramp fully open the valves corresponds to the meter indication going from 63% to 100%.
- For the normal pressure control scheme, the pressure range required to go from heaters full on, to steam bleed valves full open is ~0.262 MPa(g)

3.0 PRESSURIZER LEVEL CONTROL (Bruce-B example)

- Figure 3 shows the control equipment for the pressurizer level control system
- There are three pressurizer level transmitters: LT20A, B & C are used to measure pressurizer level; and each transmitter generates a level signal which is converted into:
  - A/I for computer X & Y input and display: these are used by RRS to initiate a reactor setback if 2 out of 3 readings are > 7.8 meters, with reset taking place when level falls < 7.4 meters.
  - a unique pressurizer level signal to each of three level controllers
  - a feed a signal to alarm units, LA20A, 20B & 20C: if 2 out of 3 alarm units read levels < 1.52 meters the pressurizer heaters are tripped
- Each level signal is designed to feed one of the three controllers: LIC20A, LIC20B and LIC20C
- Before the signals reach the controllers, a DCC calculated pressurizer level setpoint is subtracted from the process indication. This subtraction is performed by external wiring as the process indication and the DCC generated level setpoint are converted into voltage signals. The net voltage signals are then input to the controller as the 'new' process indication. The controller will attempt to bring this artificially 'low' process value to setpoint. By bringing the 'low' process indication up to setpoint, the 'actual' process value is raised above the controller setpoint.
- All three error-signals are then fed into three median selectors. Each median selector compares the three signals to determine a median and then generates a control signal to a different valve or valves.
- median selector A feeds CV6 (one of the two bleed valves),
  median selector C feeds CV5 (the other bleed valve)
  median selector B feeds CV12 (the direct feed valve), and CV11 (the reflux feed valve).

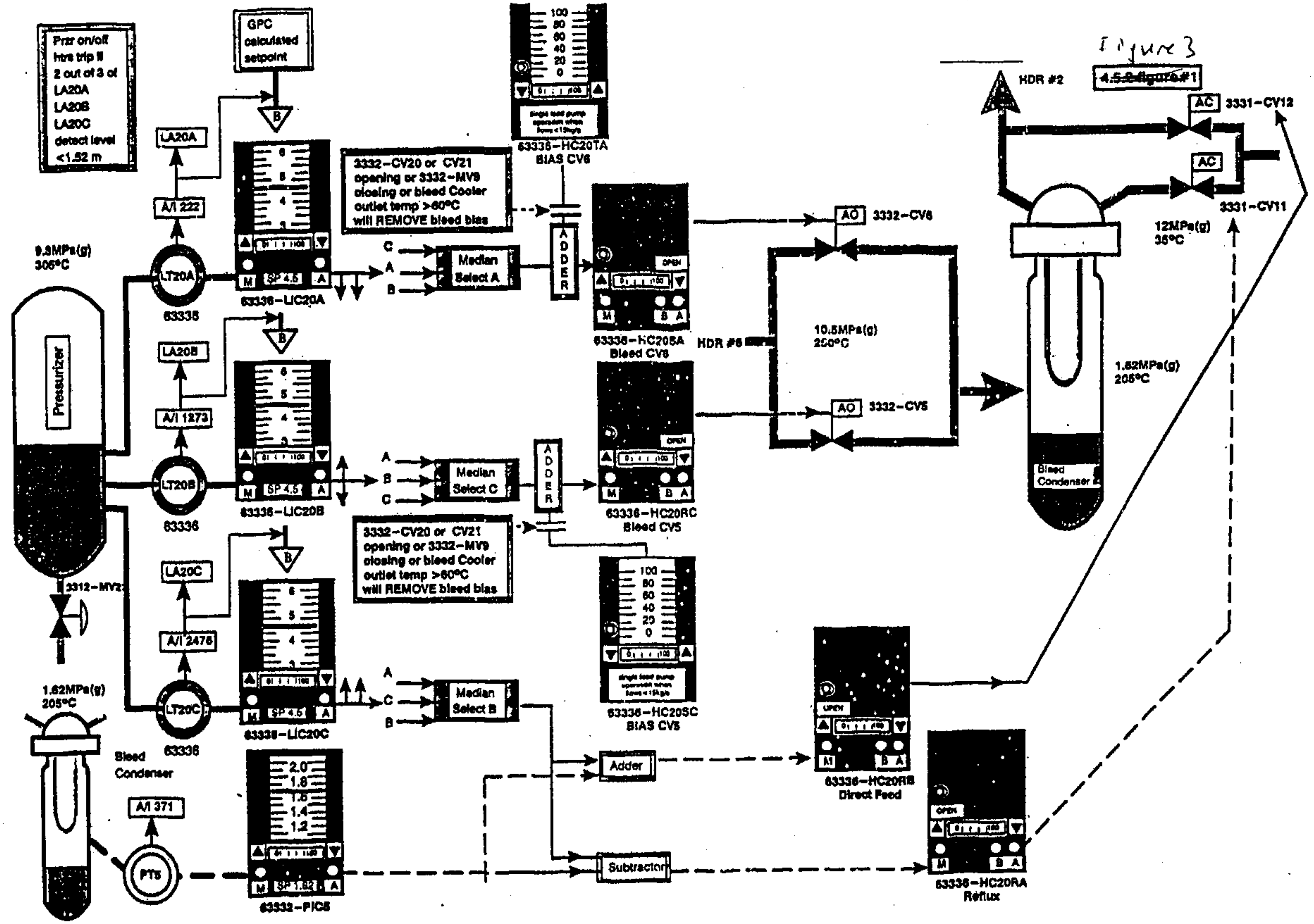
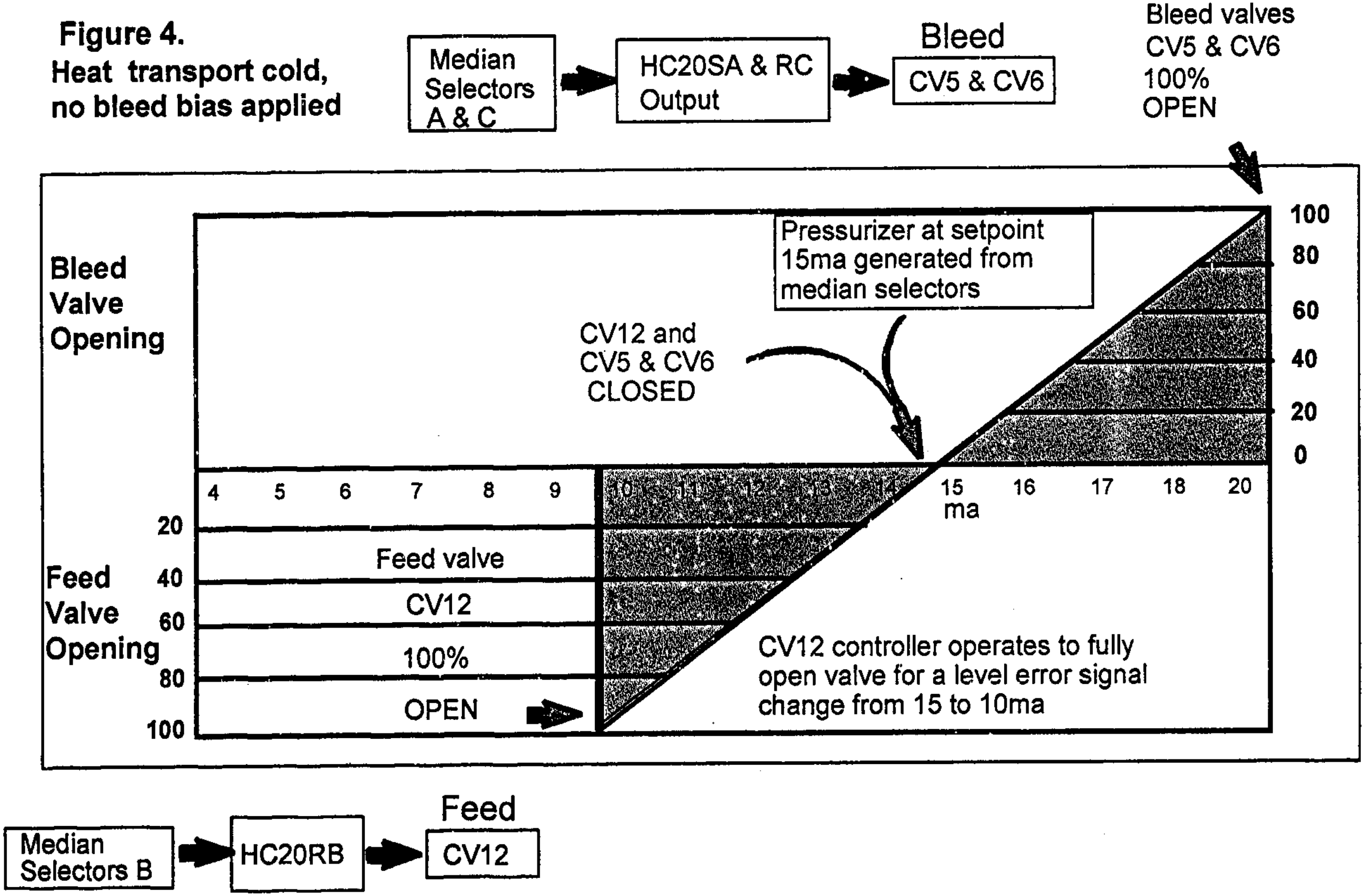


Figure 3
~~4.5.8 figure#1~~

3.0 PRESSURIZER LEVEL CONTROL (continued)

- The error signal for the bleed valves is applied to each valve's controller (HC20RC for CV5 and HC20SA for CV6) to generate a valve opening signal via adder units.
- To establish a purification flow, a bias signal can be applied to each valve by using HC20SC and HC20TA.
- The error signal for the feed valves is applied to each valve's controller (HC20RB for CV12 and HC20RA for CV11). A negative level error will generate a valve opening signal to CV12.
  - If there is no bleed or the heat transport is < 165°C, then CV11 will be fully closed and CV12 will be responding strictly to pressurizer level error signals;
  - If the heat transport is hot, and a bleed flow does exist, then CV11 will be opening to control bleed condenser pressure.
  - But as CV11 is opened, the control scheme will close in on CV12, so that total feed flow does not change.
- The control signals for the feed and bleed valves are generated via split-range control, as shown in Figure 4, in the case of zero bleed bias, with a proportional controller:
  - the feed valve (CV12) and bleed valves (CV5 & CV6) open and close directly proportional to the error signals generated by the median selectors; (CV11 is not directly part of the pressurizer level control scheme and will remain closed in this situation, with no heat load on the bleed condenser)
  - if the pressurizer level is at setpoint, a 15 ma signal is generated from the median selectors and both the feed and bleed valves are fully closed
  - if the pressurizer level error is detected as going high (from 15 to 20 ma) or low (15 to 10 ma), either the bleed valves or feed valve will go open to compensate, while the other valve(s) are closed
  - this control range of +5 ma corresponds to ~ a +0.4 meters in the pressurizer

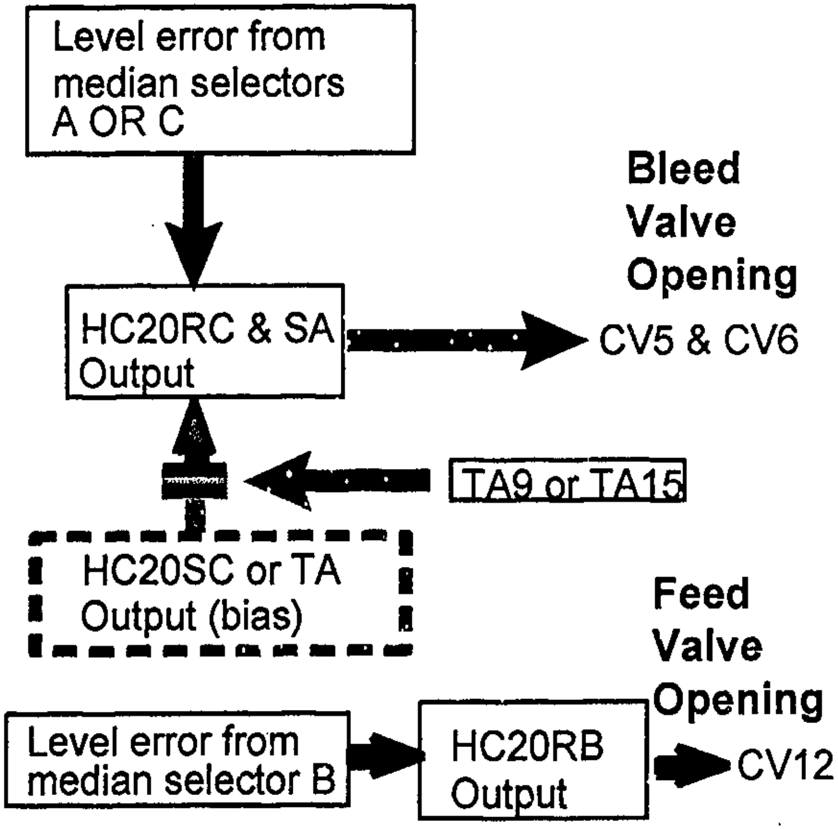
Figure 4.
Heat transport cold, no bleed bias applied



3.0 PRESSURIZER LEVEL CONTROL (continued)

- If a demand for feed, (i.e. adding bleed bias) is not created, then the control scheme would result in an on-off valve response: when the level increases above the setpoint the feed valves would close and bleed valves open, while the converse would occur if the level drops below the setpoint; to prevent this type of cycling, a feed demand must be established using bleed bias (the bleed bias is also needed to supply flow to the purification system).
- Bias is applied by increasing the output signal of HC20SC for CV5 and HC20TA for CV6, which is added to the level error signal going to HC20RC and HC20SA causing CV5 and CV6 to open; (the resultant increased bleed flow will cause a corresponding increase in feed flow in order to maintain pressurizer level at the setpoint).
- Referring to Figure 5, the effect of the bias signal is to move the bleed valves' operating point from 15 ma down, such that even though the level error may initially be zero (15 ma), the bleed valves begin to open. Applying full bias will move the operating point for the bleed valves down to 5 ma and fully open the two valves; the resultant level error will then open the bleed valve to compensate, as further explained below.
- As the bleed bias is applied and the bleed valves open, a real level error would be created. The median selectors detect this error. B median selector will generate a level error signal to HC20RB. The controller begins to open CV12 as the level error signal drops below 15 ma. As the bleed bias is increased the level offset, hence, level error increases and the opening signal to CV12 is increased. The net result, if full bias is applied, is that the pressurizer level will stabilize at ~ 0.4 m below the calculated setpoint with CV5 & CV6 as well as CV12 fully open. In reality, only 15-20% bias would be applied, to establish a bleed flow of 15-20 kg/s (for purification). The pressurizer would operate with a small level offset (~0. 1 to 0.2 m) with the feed and bleed valve(s) only partly open. With the bleed condenser cold there is no requirement for CV11 to open.

Figure 5. Heat transport cold, full bleed bias applied



Level error from median selectors A OR C

HC20RC & SA Output

Bleed Valve Opening

CV5 & CV6

TA9 or TA15

HC20SC or TA Output (bias)

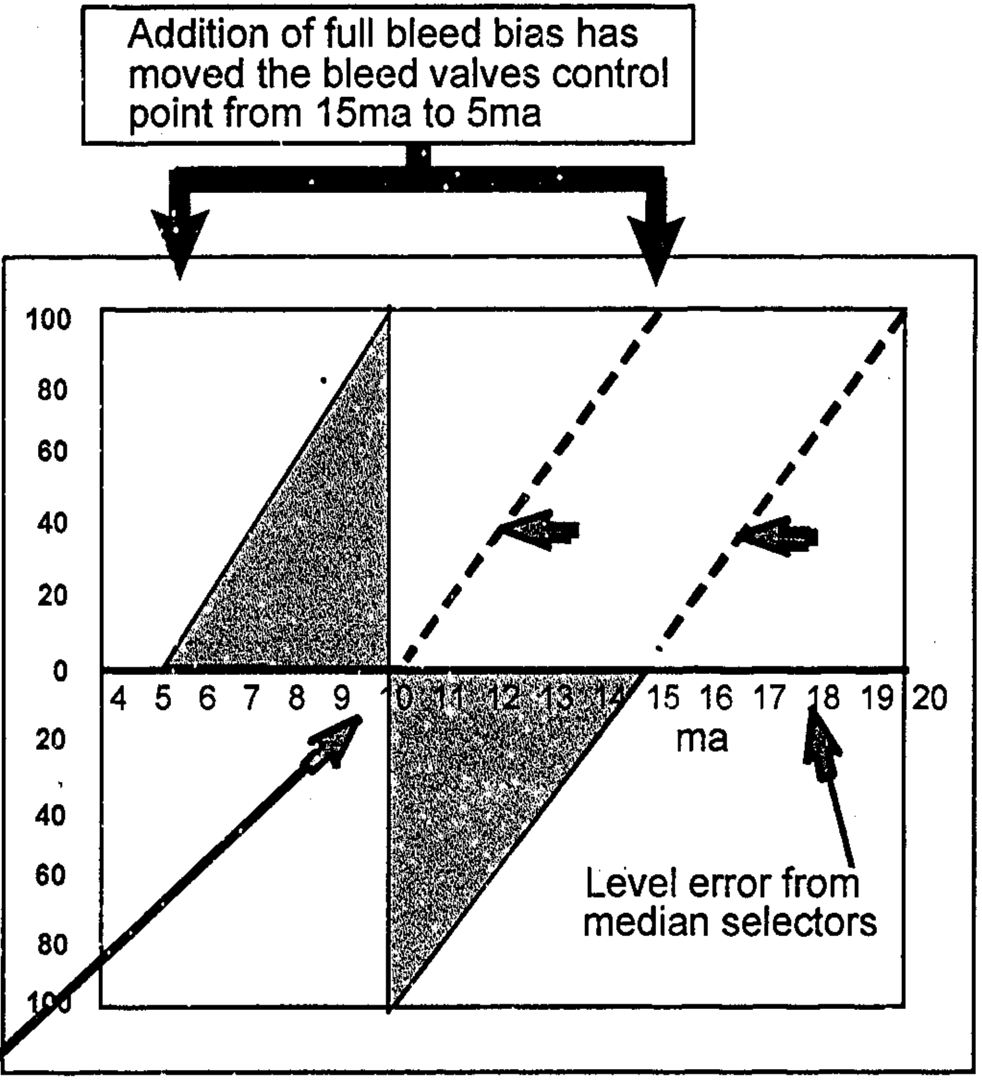
Feed Valve Opening

Level error from median selector B

HC20RB Output

CV12

Addition of full bleed bias has moved the bleed valves control point from 15ma to 5ma



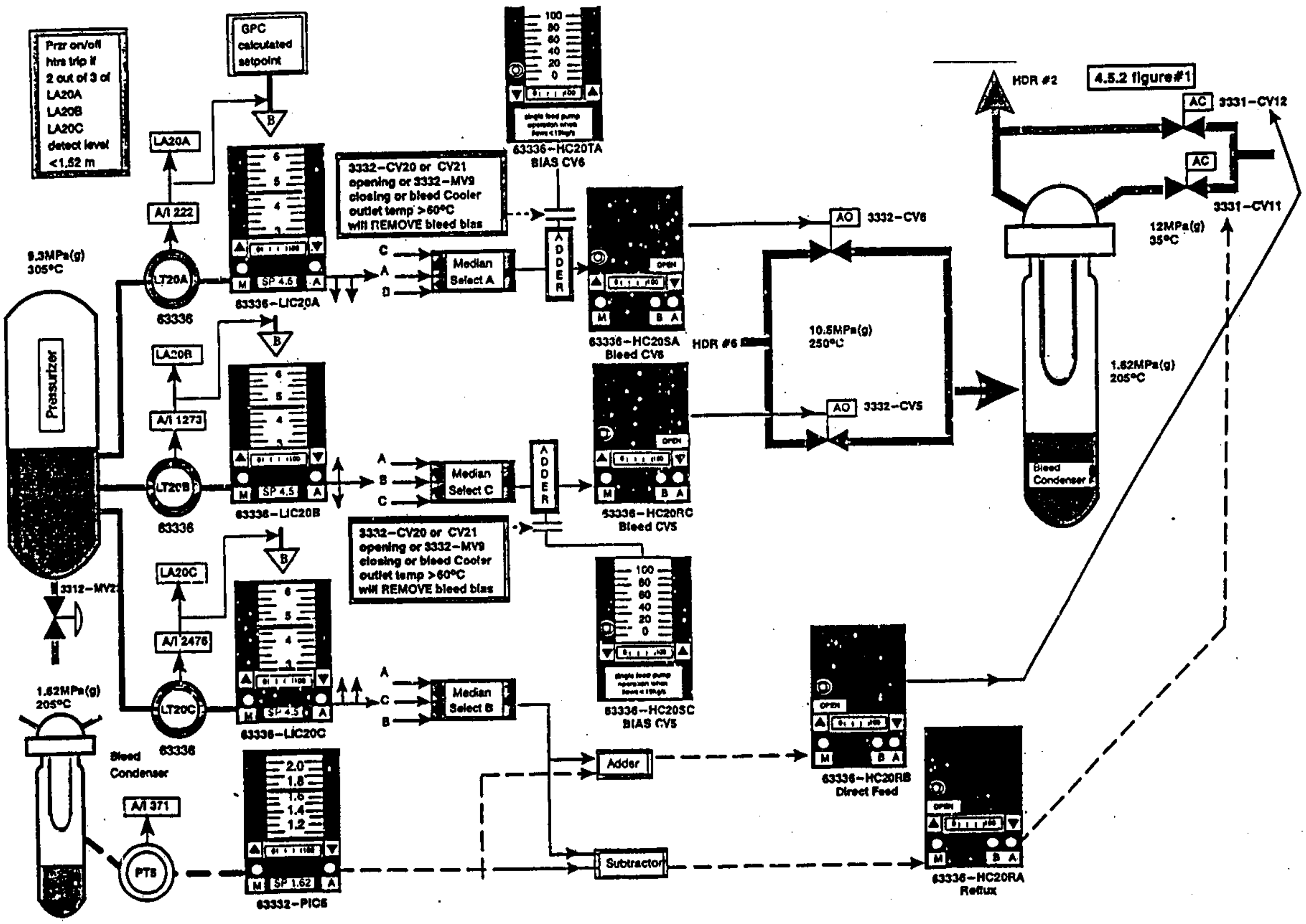
Level error from median selectors

With full bleed bias on & heat transport cold, pressurizer operates with a small level error (5ma < 0.4m)

CV12 controller operates to fully open valve for a level error signal change from 15 to 10ma (~0 to 0.4m level error)

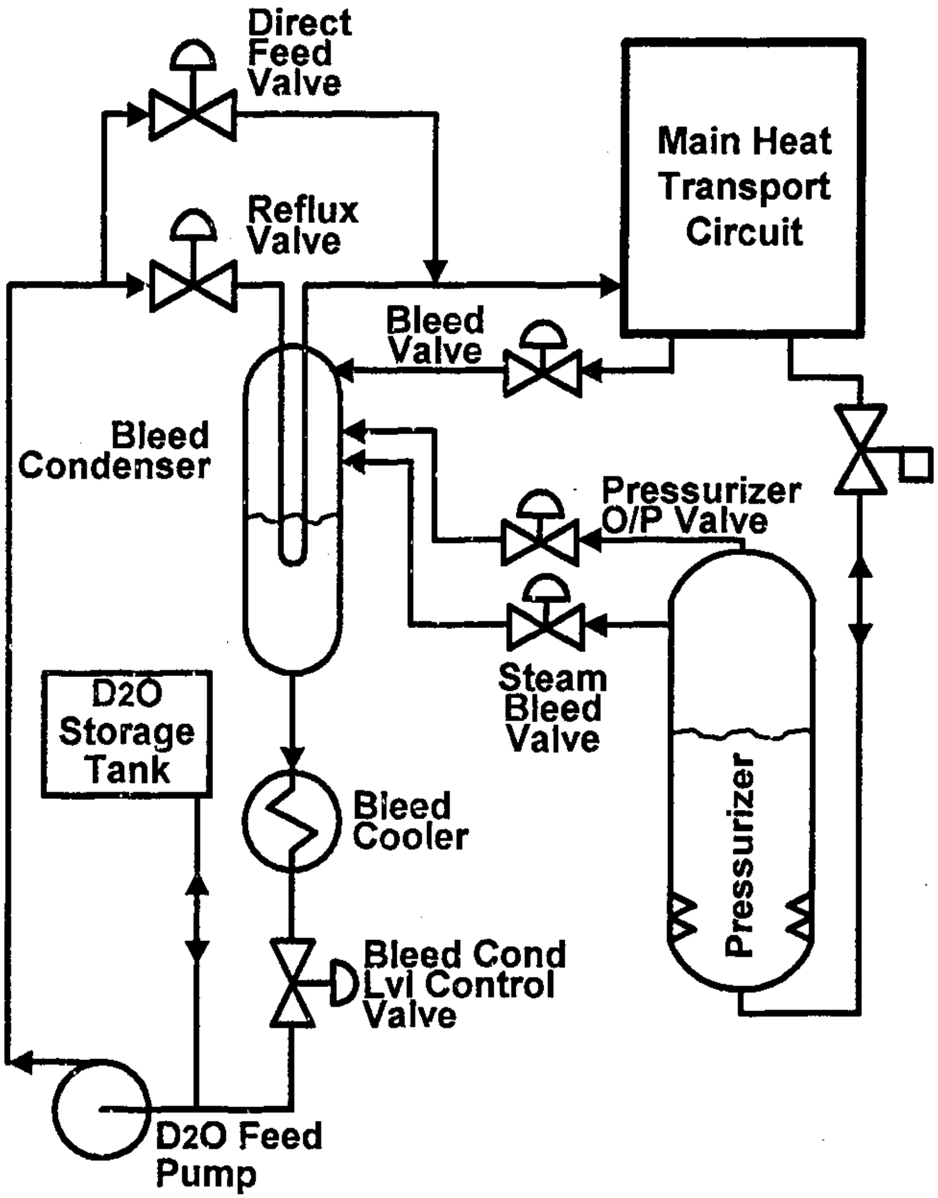
4.0 HEAT TRANSPORT SOLID MODE PRESSURE CONTROL (Bruce B example)

- When the pressure control mode hand-switch is selected to 'SOLID' mode, two independent pressure control schemes are activated: the heat transport solid mode pressure control and pressurizer pressure control.
- The solid mode pressure control scheme is designed primarily to control heat transport pressure in the initial stages of a unit start-up or final stages of a unit shutdown, but it can also provide an alternate method of control during at-power operations of there are problems with the pressurizer.
- The controller controls heat transport pressure by manipulating the feed or bleed of coolant into or out of the main circuit (note that in NORMAL mode the same valves were used to control pressurizer level!).
- Referring to Figure 6, the system uses one pressure transmitter per outlet header for input and performs a high signal selection.
- The high selected signal is sent to PIC3, which is a wide range controller that allows the heat transport setpoint to be adjusted from 0 to 10 MPa(g).
- PIC3 pressure control range is 0.2 MPa and controls to ±0.1 MPa of the manually set controller setpoint.
    - As an example, if the controller setpoint was set at 8.5 MPa(g), and there was no bleed bias established, then both the feed and bleed valves will be closed when system pressure is at setpoint (PIC3 controller generating a 12 ma signal).
    - If pressure were to rise to 8.6 MPa(g) (PIC3 generating a 20 ma signal), then the bleed valves would be fully opened.
    - Conversely, if the system pressure were to drop to 8.4 MPa(g) (PIC3 generating a 4 ma signal), then the feed valves would be fully opened.


4.5.2 figure#1
Przr on/off htrs trip if 2 out of 3 of LA20A LA20B LA20C detect level <1.52 m
GPC calculated setpoint
B
LA20A
A/I 222
9.3MPa(g) 305°C
LT20A
63336
SP 4.5
63336-LIC20A
3332-CV20 or CV21 opening or 3332-MV9 closing or bleed Cooler outlet temp >60°C will REMOVE bleed bias
C
A
B
Median Select A
ADDER
100
80
60
40
20
0
single feed pump operation when flows < 10kg/s
63336-HC20TA
BIAS CV6
OPEN
63336-HC20SA
Bleed CV6
AO
3332-CV6
HDR #6
10.5MPa(g) 250°C
AO
3332-CV5
HDR #2
AC
3331-CV12
AC
3331-CV11
12MPa(g) 35°C
1.62MPa(g) 205°C
Bleed Condenser
Pressurizer
LA20B
A/I 1273
LT20B
63336
SP 4.5
63336-LIC20B
A
B
C
Median Select C
ADDER
63336-HC20RC
Bleed CV5
3332-CV20 or CV21 opening or 3332-MV9 closing or bleed Cooler outlet temp >60°C will REMOVE bleed bias
63336-HC20SC
BIAS CV5
3312-MV2
LA20C
A/I 2476
LT20C
63336
SP 4.5
63336-LIC20C
A
C
B
Median Select B
1.62MPa(g) 205°C
Bleed Condenser
A/I 371
PT8
2.0
1.8
1.6
1.4
1.2
SP 1.62
63332-PIC8
Adder
Subtractor
63336-HC20RB
Direct Feed
63336-HC20RA
Reflux
M
A
B

4.1 HEAT TRANSPORT SOLID MODE PRESSURIZER PRESSURE CONTROL

- The pressurizer pressure control is the second pressure control scheme activated when the mode hand-switch is selected to 'SOLID'.
- The pressure control scheme is used to raise pressurizer pressure from cold ambient conditions up to an acceptable operating level so that normal pressure control can be entered; this pressure control scheme uses the same equipment as the normal heat transport pressure control scheme.
- The pressurizer heaters are used to raise pressure and steam bleed valves to reduce pressure.

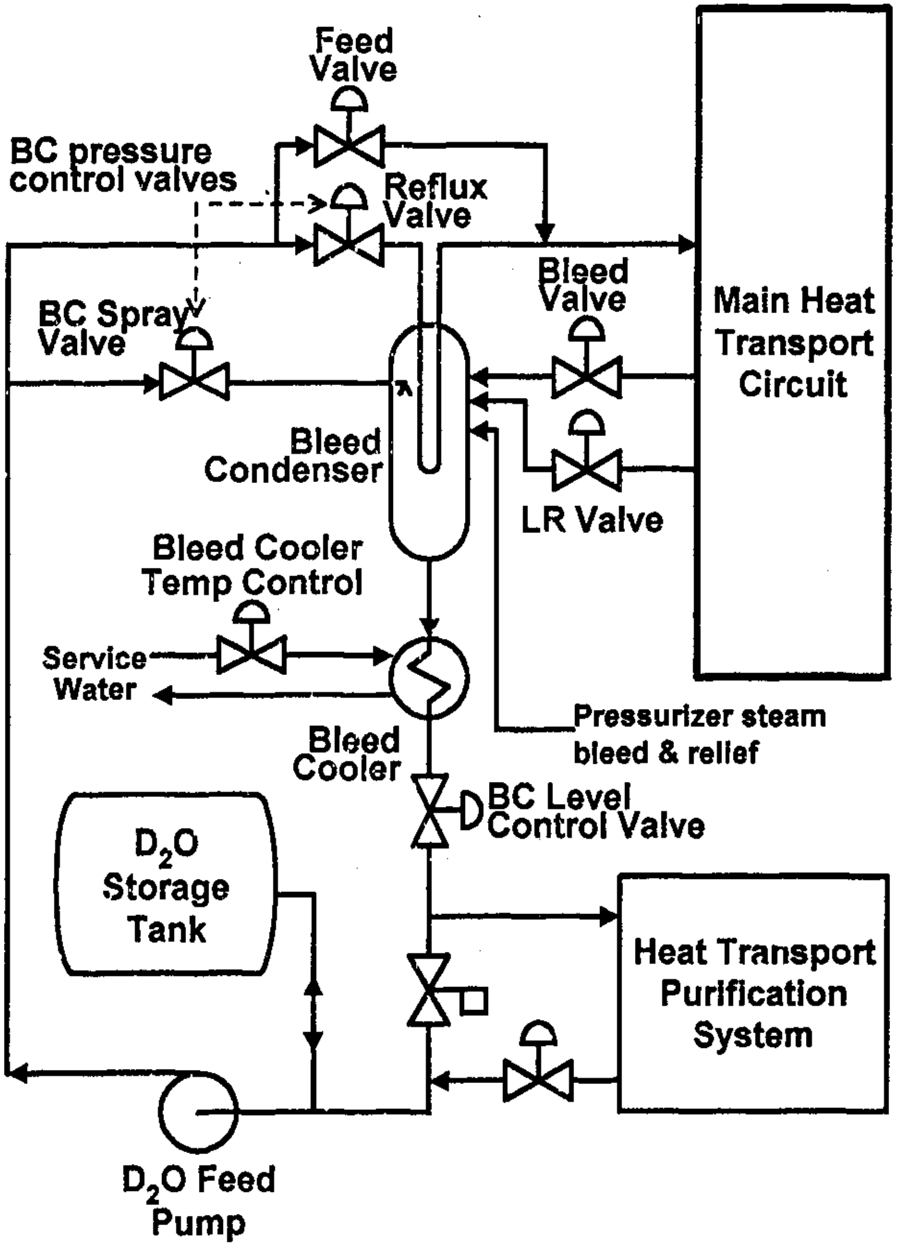


4.1 HEAT TRANSPORT SOLID MODE PRESSURIZER PRESSURE CONTROL (continued)

- The SCR selected heater only generates ~ 170 kilowatts of heat, and given the large volume of water and metal mass of the pressurizer, it would take an unacceptably long time to bring the pressure up to the required setpoint, so the ON/OFF heaters are used accelerate the heat-up process.
- The ON/OFF heaters are turned on by a pressure switch, PS12. Because the setpoint of PIC12 can be set anywhere from 0 to 10 MPa(g), PS12 is not activated by a preset pressure, but rather is operated as a function of PIC12 output.
- If the difference between pressure and controller setpoint has PIC12 generate a control signal < 6.5 ma, PS12 activates to turn all the ON/OFF heaters on (including the variable heater selected to ON/OFF control).
- To provide over-pressure protection CV46 and CV47 will operate if pressure as seen by two out of three pressure switches are > 9.76 MPa(g).
- Referring to Figure 7, PIC12 is a wide range controller (0 to 10 MPa(g)). The pressure control range for PICI12 is 0.2 MPa or ±0.1 MPa of the dialed in setpoint.
- The SCR-selected heater and steam bleed valves respond the same way to changes in pressurizer pressure as they do to changes in heat transport pressure.
- The controllers for the SCR selected heaters and steam bleed valves operate over only part of the 4-20 ma control signal generated by PIC12:
  - the controller has a 2 ma (10 to 12 ma) dead band about the setpoint where neither the heater nor the steam bleed valves are called upon to operate;
  - if the pressure drops by 0.1 MPa (towards 4 ma), then PIC12 will ramp the SCR heater fully on as pressure drops;
  - if the pressure rises by 0.1 MPa (towards 20 ma), then PIC12 will ramp fully open the steam bleed valves as pressure rises;

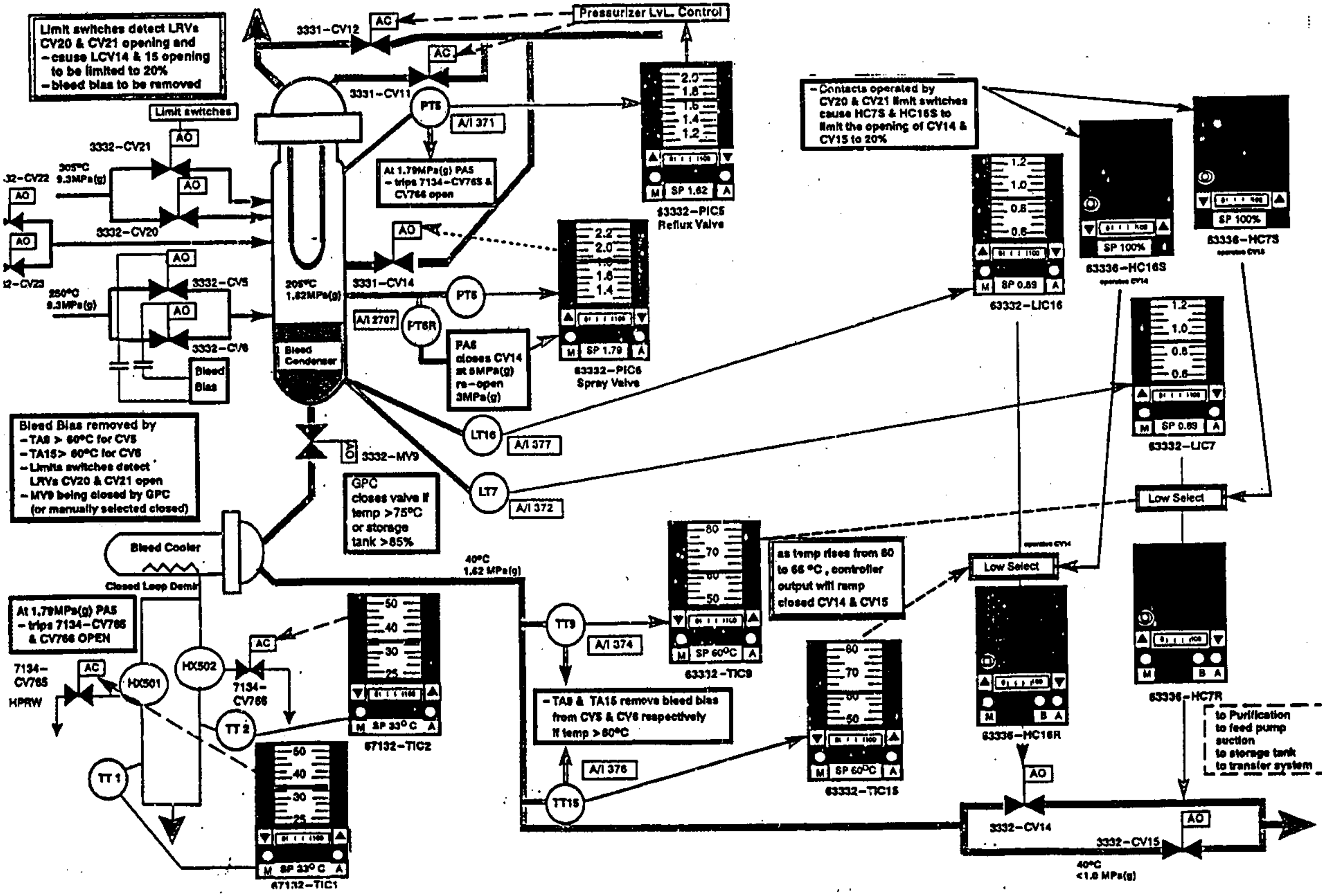
1.0 INTRODUCTION

- The bleed condenser, bleed cooler and associated equipment (called the "bleed flow conditioning system") are needed to reduce the pressure and temperature of the coolant removed from the main circuit so that it can be safely purified, transferred or stored. The system is designed to cover three operating situations:
  - normal bleed flow conditioning requires that the 250°C D_2O exiting the H.T. at 9.3 MPa(g) is reduced to ~ 40°C and < 1.0 MPa(g);
  - suppress and limit duration of expected transients such as the opening of' the liquid relief valves; steam bleed valves or pressurizer steam relief valves;
  - limit and control the effects of expected failures such as the failure of a liquid relief valve, steam bleed, steam relief, bleed valves, bleed condenser level control valves open or a loss of bleed cooler cooling
- The three key control systems that accomplish the required D_2O conditioning are:
  - bleed condenser pressure control
  - bleed condenser level control
  - bleed cooler temperature control.



2.0 BLEED CONDENSER

- A pressure drop of ~ 7.5 MPa(g) between the upstream side of the bleed valves and the bleed condenser is created by allowing the bleed flow to "flash" (turn into steam) as it enters the bleed condenser: the expanded volume forces the pressure to drop and the decreased saturation pressure of the D_2O causes a corresponding drop in the saturation temperature.
- Referring to (4.5.3) Figure 1, to maintain the desired bleed condenser pressure (and hence, temperature), the pressure controller PIC5 has a setpoint of 1.69 MPa(g). As pressure (read by PT5) begins to rise above the setpoint, PIC5 generates an error signal to the controllers for reflux valve CV11 and direct feed valve CV12. while CV11 will open further to send additional cool D_2O through the bleed condenser cooling coils, while CV12 begins to throttle to keep the total feed constant, the increased cooling flow removes heat from the steam space and returns the pressure to the setpoint. The temperature of the reflux D_2O will increase from ~ 40°C to > 180°C as the flow enters the main heat transport loop.
- To control pressure in this manner, a steam space must be maintained: the steam space is maintained by controlling level.



Limit switches detect LRVs CV20 & CV21 opening and
- cause LCV14 & 15 opening to be limited to 20%
- bleed bias to be removed

At 1.79MPa(g) PAS
- trips 7134-CV765 & CV766 open

PAS closes CV14 at 5MPa(g) re-open 3MPa(g)

Bleed Bias removed by
- TA8 > 60°C for CV5
- TA15> 60°C for CV6
- Limits switches detect LRVs CV20 & CV21 open
- MV9 being closed by GPC (or manually selected closed)

GPC closes valve if temp >75°C or storage tank >85%

At 1.79MPa(g) PAS
- trips 7134-CV765 & CV766 OPEN

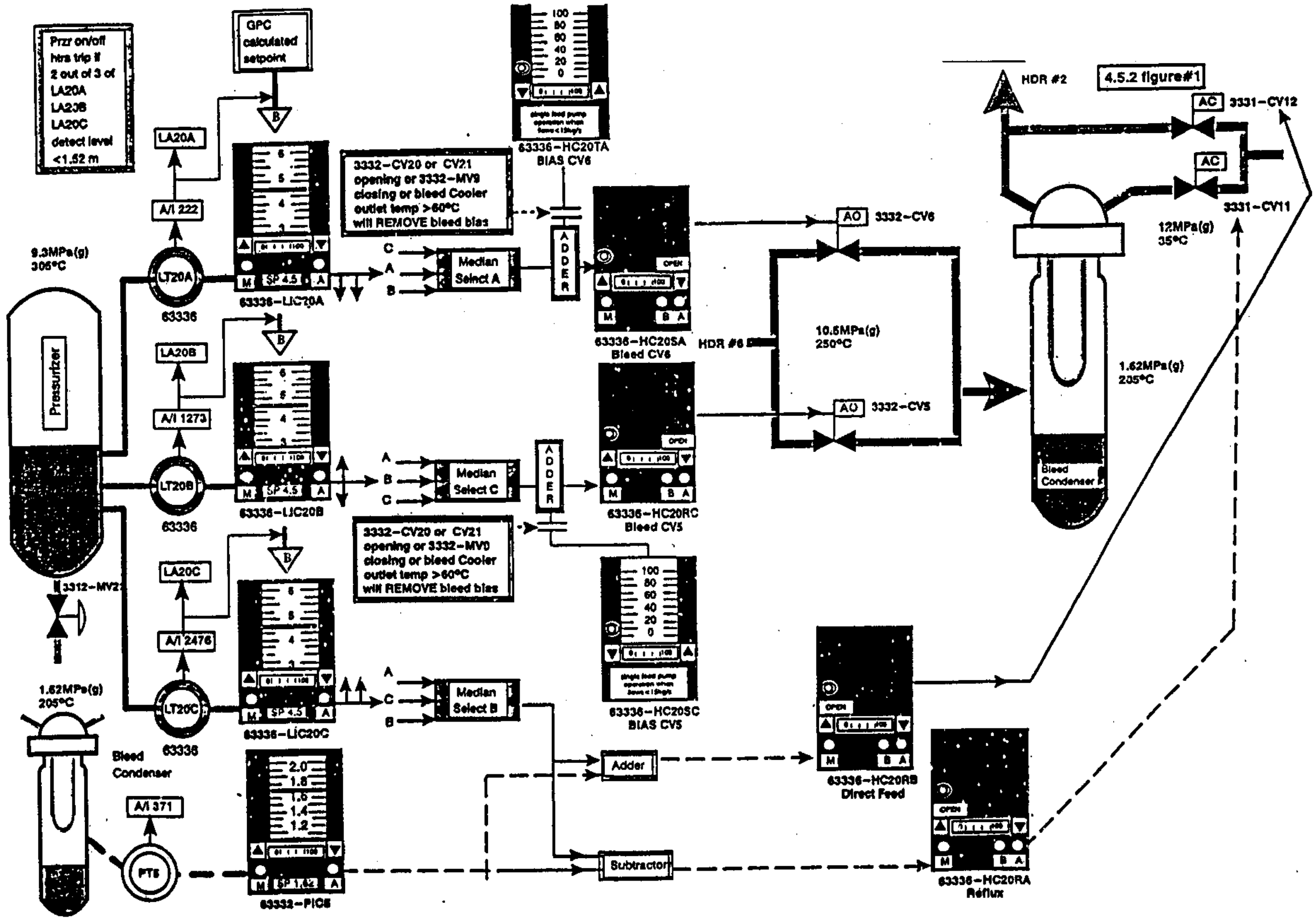
- TA8 & TA15 remove bleed bias from CV5 & CV6 respectively if temp > 60°C

- Contacts operated by CV20 & CV21 limit switches cause HC7S & HC16S to limit the opening of CV14 & CV15 to 20%

as temp rises from 60 to 66 °C, controller output will ramp closed CV14 & CV15

2.1 BLEED CONDENSER PRESSURE CONTROL

- Reflux Flow Control
  - Since CV11 (and to a lesser extent CV12) are involved in both bleed condenser pressure control and in pressurizer level control in NORMAL mode and HT pressure control in SOLID mode, the interactions of these control signals has be understood.
  - Figure 3 of module 2B is shown again as Figure 2 in this module: note that the output signal of bleed condenser pressure controller PIC5 is added to the pressurizer level signal from Median Select B and sent to control the direct feed valve CV12, while the same pressure error signal is subtracted from the output of Median Select B and is used to control Reflux valve CV11.
  - The primary or "base" control signal for CV11 and CV12 is therefore pressurizer level error, since no matter what is the signal coming from the bleed condenser pressure controller, the total bleed flow will be as determined by the pressurizer level controller.
  - The amount of reflux flow needed to control bleed condenser pressure is achieved by altering the relative flows between CV11 and CV12: the flow required to control bleed condenser pressure is supplied through CV11, with a corresponding reduction in the flow going through CV12.
- Spray Control
  - When reflux flow is inadequate to control bleed condenser pressure, typically during large inflows of liquid and/or steam, additional pressure suppression is provided by spraying cool D_2O into the steam space of the bleed condenser.
  - The setpoint for the Spray Valve Controller is set at least 0.1 MPa above the setpoint for reflux valve control, so the spray will not operate until the range of control provided by the reflux has been fully utilized.



Przr on/off htrs trip if 2 out of 3 of LA20A LA20B LA20C detect level <1.52 m

3332–CV20 or CV21 opening or 3332–MV9 closing or bleed Cooler outlet temp >60°C will REMOVE bleed bias

3332–CV20 or CV21 opening or 3332–MV0 closing or bleed Cooler outlet temp >60°C will REMOVE bleed bias

2.2 BLEED CONDENSER LEVEL CONTROL

- Two level transmitters LT7 & LT16 each control a level control valve CV14 and CV15 respectively. The level setpoint for these controllers is 0.89m. At this level the valves are fully closed. As the level rises above the setpoint, the controllers which are direct acting proportional, will open the valves proportional to the level error. The level rising from 0.89 m to 1.41 m will cause the level transmitters output to ramp up from 4 ma to 20 ma and fully open the CVs. Normally the bleed flow is in the range of 10 to 15 kg/s, which results in a bleed condenser level slightly above the setpoint.
- As the bleed condenser level control valves open to control level, the D_2O (when the heat transport system is hot) exits the bleed condenser at 205°C and 1.62 MPa(g), and flows to the bleed cooler to reduce the temperature to 40°C.
- The amount of heat load that the bleed cooler must accommodate, is a function of the amount of flow CV14 & CV15 are passing to maintain bleed condenser level.

2.3 BLEED COOLER TEMPERATURE CONTROL

- The cooled D_2O after the bleed cooler passes into the purification circuit (under normal conditions), where it passes through filters and ion exchange columns, before being sent to the storage tank or returned to the heat transport system via the feed pumps, valving and piping.
- The bleed cooler is designed to cool adequately up to 60 kg/s of D_2O.
- In the bleed cooler the D_2O passing through the tube side of the bleed cooler is cooled by a constant flow of Closed Loop Demineralized water flowing through the shell side.
- The heat acquired by the Closed Loop Demin circuit is rejected to the High Pressure Recirculation system across 7132-HX501 & HX502.
- Each HX outlet has a temperature control loop, which is used to adjust a CV and modulate HPRW cooling flow to maintain Closed Loop Demin/bleed D_2O temperature at setpoint: 67132-TIC1 controls CV765 for HX501 and 67132-TIC2 controls CV766 for HX502.
- The setpoint for the temperature controllers is ~33°C, at which point the controllers will begin to open up 7134-CV765 & CV766 to increase the flow of HPRW to the heat exhangers. The temperature controllers are reverse acting using proportional control.

3.0 PROVISIONS FOR NON-STANDARD OPERATING CONDITIONS

3.1 Use of Reflux Valve Control

- There are occasions when, due to the operating conditions or transients, that the steam bleed or liquid relief valves will open to relieve HT pressure. The opening of these valves (especially the liquid relief valves) will result in a large amount of steam being dumped into the bleed condenser in a very short time span.
- The normal pressure control scheme does not have the capability to control pressure under these conditions. In fact the opening of the liquid relief valves means that SDS1 has tripped on HI HT pressure.
- The effects of these two protective actions is to cause a large shrink in the HT system due to both the shrink of HT D_2O as power drops and due to the removal of D_2O from the system when the LRVs effectively open up a hole.
- This transient will lead to the pressurizer level dropping significantly below its setpoint. The pressurizer level control scheme will fully open CV12 and the bleed condenser pressure control will fully open CV11 but with only one feed pump on it will be a substantial time before the pressurizer level returns to normal.
- Reflux flow will be inadequate to control bleed condenser pressure. While this is going on, the bleed condenser is being subjected to ~ 100 kg/s of steam expanding in the bleed condenser steam space, which was initially at 1.69 MPa(g).
- To handle this transient a quick acting pressure capability of spray control has been provided.
- Referring to Figure 4.5.3 #1 PIC6 has a setpoint of 1.79 MPa(g) for the Spray Valve, only 0.1 MPa above the setpoint for the Reflux Valve.
- As the pressure rises above 1.79 MPa(g), PIC6 opens CV14 to inject a cool D_2O spray directly into the bleed condenser's steam space. The quenching effect of spraying cool D_2O is adequate to handle the transient opening of the LRVS, as long as they re-close.

3.2 HT Liquid Relief Valve Operation

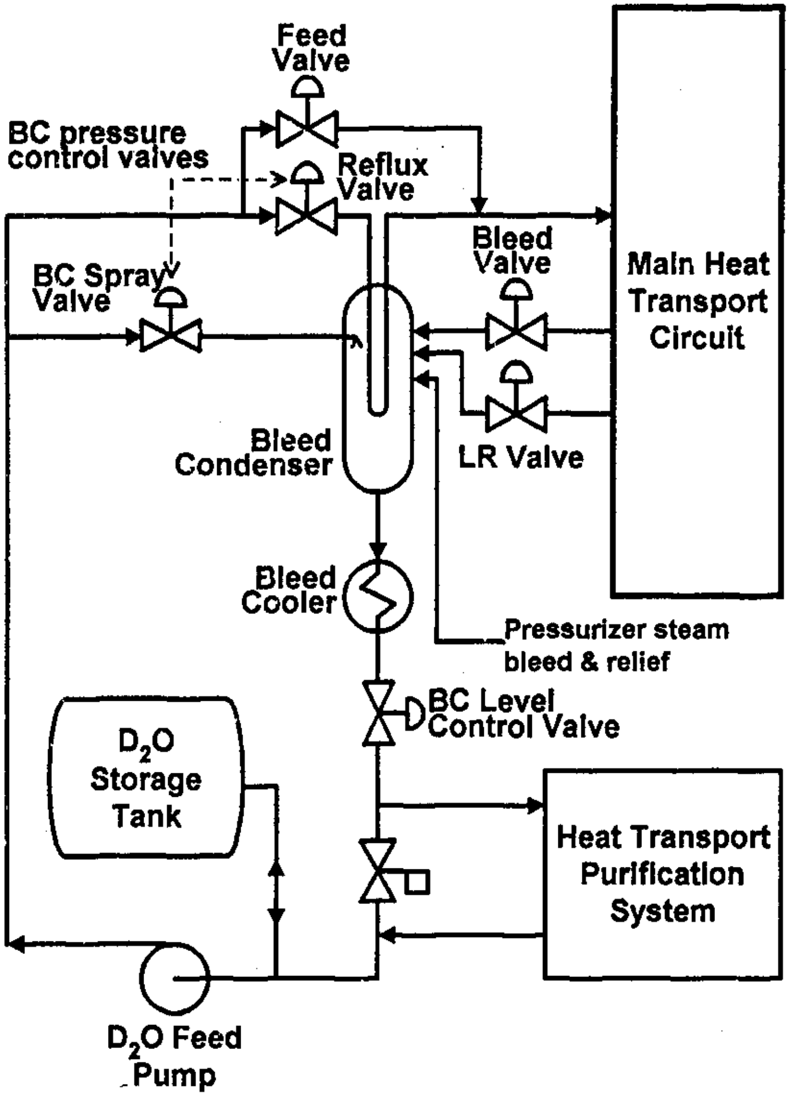
- To help minimize the consequences of the LRVs opening, two logic schemes are initiated by the LRV limit switches (see Module 4D for LRV Operation & Logic):
    - to help limit the pressure transient in the bleed condenser, the bleed bias is removed;
    - to reduce the outflow from the bleed condenser, level control valves CV14 & CV15 maximum opening is limited to 20%, so that the bleed cooler will be capable of maintaining cooling
    - when the LRVs close logic is reset and normal level control resumes.
- Automatic actions are also required to handle the temperature transient in the bleed cooler as both the flow and temperature of D_2O exiting the bleed condenser increases.
- When bleed condenser pressure rises to 1.79 MPa(g), PA5 is used to de-energize the air supply solenoids to CV765 and CV766.
- As the CVs are air to close valves, they are tripped full open to provide maximum cooling during the transient.
- Bleed condenser pressure dropping below 1.79 MPa(g) will reset the logic and return temperature control to normal.
- It is also likely that the increased flow would cause the purification inlet pressure to increase to 1.1 MPa(g), which would cause the DCC to open MV38 and prevent over-pressurization of the purification circuit.

3.3 Bleed Condenser goes 'solid'

- Failure of the liquid relief valve(s), steam bleed valves or pressurizer relief valves, loss of bleed cooler capability, bleed or bleed condenser level control valves open could all lead to purification resin damage.
- Due to high temperatures, bursting of purification rupture disc due to high pressure, loss of feed pumps due to cavitation, excessive loss of HT inventory such that pressure and inventory control of the heat transport is lost, lifting of RV17 & RV18 leading to loss of coolant to the vault or overfilling of the storage tank such that D_2O is dumped into confinement.
- The heat transport pressure and pressurizer level begin to drop, while the bleed condenser pressure and level rise rapidly.
- The first protective actions taken are activated by limit switches detecting the liquid relief valve(s) open (see Module 4D Heat Transport Liquid Relief Valve Operation).
- The first action initiated is to remove bleed bias to limit pressure and inventory demands on the bleed condenser pressure and level control schemes.
- The second scheme initiated limits the opening of the bleed condenser level control valves to 20%, but if the relief valves continue to be open, in order to prevent a high purification inlet temperature or high storage tank level protection, MV9 will close, boxing up the bleed condenser.
- When this occurs the bleed condenser level rapidly fills, i.e. goes "solid".
- When solid, the heat transport and bleed condenser pressures are equalized and the resulting physical shock to the bleed condenser can cause the bleed condenser relief valves RV17&RV18 to lift.
- Since these valves dump D_2O into the vault and have a history of the seats being damaged (when the RVs try to re-close), it is preferable that this not occur.

3.4 Limits on Spray Valve Operation when Bleed Condenser goes 'solid'

- The dropping pressurizer level will cause CV12 to be fully opened. This will impair normal bleed condenser pressure control via CV11 as both feed paths are rated for ~ 40 kg/s and a single feed pump can only deliver ~ 21 kg/s.
- As the pressure rises above 1.79 MPa(g), PIC6 opens CV14, the bleed condenser spray valve, to inject a cool D_2O spray directly into the steam space: although this helps to reduce bleed condenser pressure, the inflow of additional D_2O increases the bleed condenser fill rate.
- The open spray valve ties a ~ 12 MPa(g) pressure supply from the feed pumps to the bleed condenser.
- When the bleed condenser goes solid, this pressure source would cause the RVs to lift.
- To protect against this possibility PA6 trips closed CV14 when bleed condenser pressure rises to 5.0 MPa(g). The valve is released for pressure control when pressure drops to < 3.0 MPa(g).



3.5 Bleed Cooler Temperature Control Override

- The rising pressure and temperature of D_2O that exits the bleed condenser will put a severe strain on the bleed coolers cooling capability.
- To maximize cooling, PA5 operates at 1.79 MPa(g), to de-energize the air supply solenoids to CV765 and CV766.
- As the CVs are air to close valves, they would be full open during the transient to provide maximum cooling.
- Bleed condenser pressure dropping below 1.79 MPa(g) will reset the logic and return temperature control to normal.

3.6 Purification Circuit Temperature Override

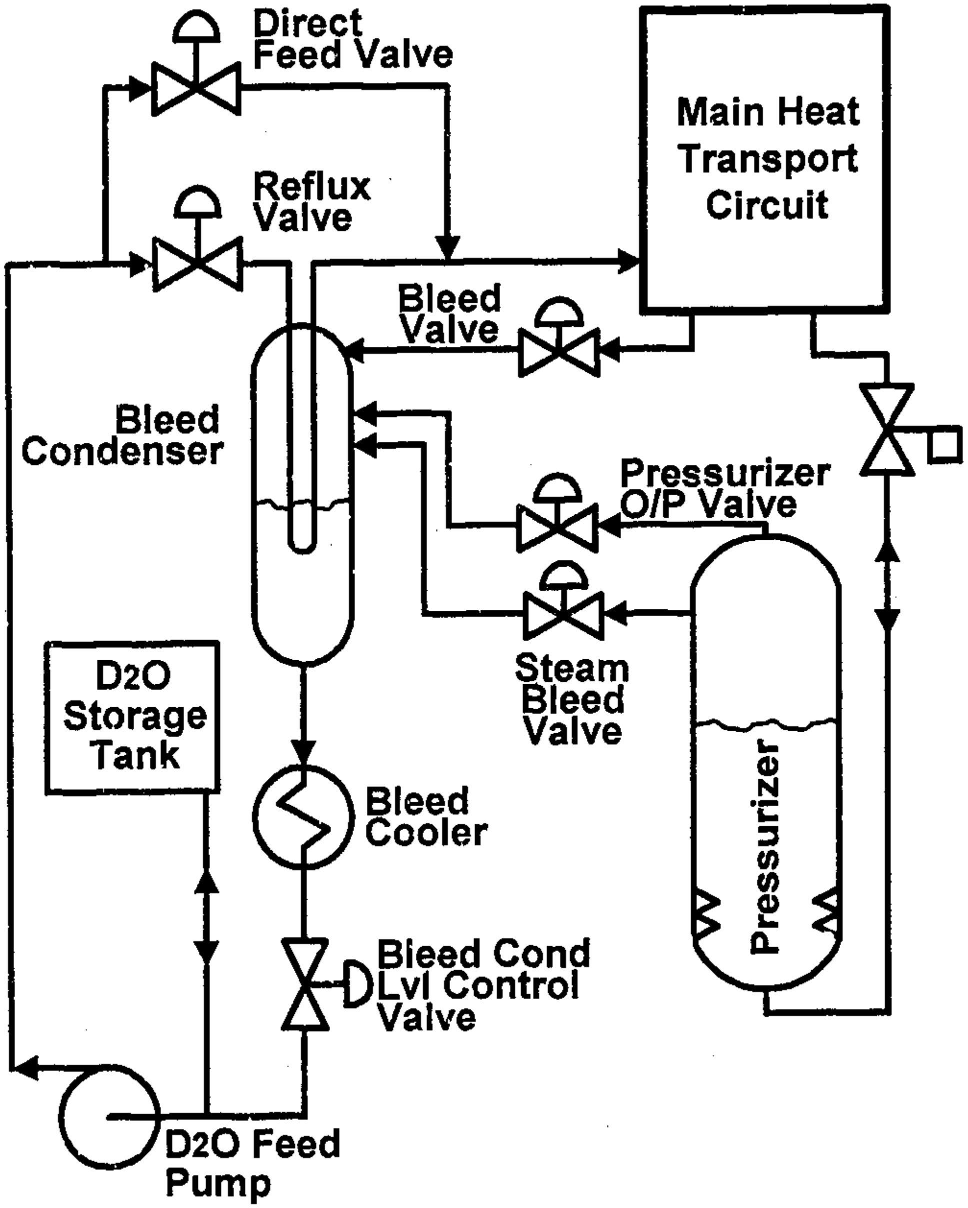
- If the D_2O which exits the bleed cooler is not adequately cooled, there are three temperature protection schemes that could be initiated before the hot D_2O reaches the purification circuit:
  - first, when the bleed cooler outlet temperature reaches 60°C, temperature switches TA9 & TA15 operate to remove bias from CV5 & CV6 respectively;
  - second, temperature override controllers TIC9 and TIC15 begin to ramp CV14 & CV15 closed as temperature rises from 60 to 66°C; as liquid relief valve opening logic has previously limited the valve opening, the valves will be closed from the 20% open position;
  - third, DCC will close MV9 if the average of TT-9 (A/I 374) and TT-15 (A/I 376) exceed 75°C.

3.7 Storage Tank Level Override

- If the combination of throttling the level control valves and maximizing bleed cooler cooling is adequate to maintain the D_2O temperature less than 60°C, then the heat transport storage tank level will rise.
- This is because the outflow of D_2O from the heat transport will be greater than what the feed pumps can make-up, (especially when the spray valve is in operation).
- Depending on what the initial pre-event storage tank level was, it is likely that the storage tank will rise to 85%.
- DCC uses the average of A/I 421 and A/I 404 to monitor level; when calculated level exceeds 85%, the DCC initiates the closing of MV9.
- Boxing up the bleed condenser will cause it to go solid, stopping the loss of inventory from the heat transport and preventing the overfilling of the storage tank that would lead to D_2O being released into confinement.
- These are the protection schemes which are available to protect the sections of the systems not rated for high temperature or pressurizer D_2O. The protection schemes do not in themselves represent complete solutions to the various potential failures which can occur but are designed to either provide protection for specific components which can be damaged or by acting to increase the decision time available: so that the operator has time to analyze the situation and take action.

1.0 INTRODUCTION

- nuclear power plants using a pressurizer for heat transport system pressure control will have the following three control systems associated with the pressurizer:
    - pressurizer pressure control, that includes
        - heating elements in order to raise pressurizer pressure
        - spray cooling and/or steam relief whenever pressurizer pressure needs to be reduced
        - pressurizer over-pressure relief
    - pressurizer level control, that includes
        - calculation of level setpoint as a function of reactor power
        - ability to raise level (i.e. some form of feed)
        - ability to lower level (i.e. some form of bleed)
        - protection of heaters in case water level drops too low for safe heater operation

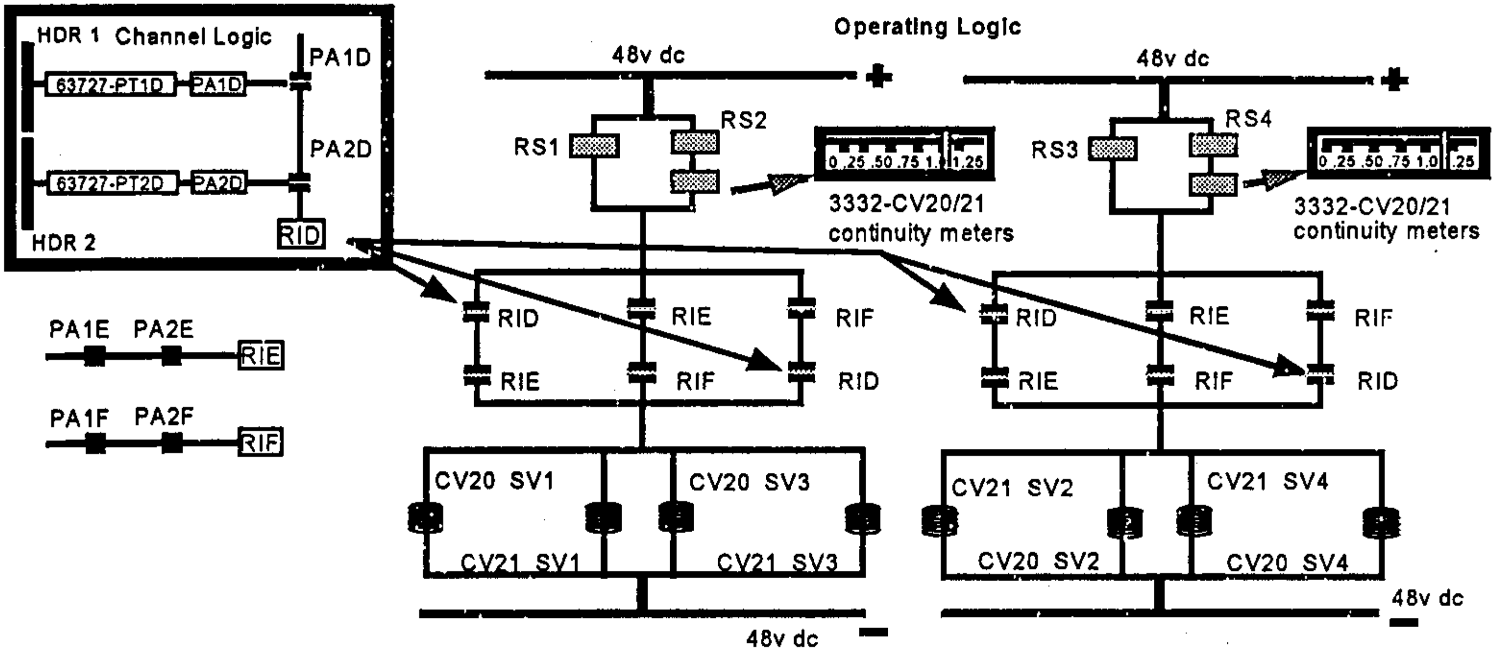


2.0 HEAT TRANSPORT LIQUID RELIEF VALVE (LRV) OPERATION (Bruce-B example)

- From the perspective of heat transport over-pressure protection, there are basically two operating situations - cold/hot and pressurized and at power. For each situation the major potential source of over pressurization is different.
- When the heat transport is pressurized and there is little or no reactor power, the major potential source of over-pressurization results from a failure of the feed and bleed system such that the full pressure and flow of the feed pumps is applied to the heat transport. The LRVs relief capacity is designed to handle this situation and reject sufficient D_2O to prevent over-pressure induced failures.
- At power, the major potential source of over-pressurization is due to reactor power. If a situation occurs where there is a significant imbalance between the heat generated in the fuel and heat removed by the heat sink, then coolant temperature will increase, increasing volume and pressure.
- The need for relief valve capacity during at power operation is limited by having reactor high pressure trips in SDS1 and SDS2 to terminate any HT over-pressure situation.
- Both the opening of the liquid relief valves and reactor trips are absolute in that, regardless of reactor power, both protection schemes are poised
- To ensure that as far as possible the relief valves operate both reliability and at the correct heat transport pressure, the valves are both air operated and are opened by an operating logic which is modelled after the channelized SDS1 trip logic.

2.1 LIQUID RELIEF VALVE OPERATING LOGIC

- Referring to Figure 2, the LRV operating logic uses the output from six SDS1 high pressure trip pressure transmitters for inputs to six pressure alarm units.
- There are three operating channels, each with 2 alarm units, i.e. PA1D and PA2D for channel D (same for channels E & F); under normal conditions their contacts are closed, the contacts on the corresponding relay RID (RIE & RIF) are also closed, and current is supplied to the solenoid valves keeping SV1 and SV2 open and SV3 and SV4 closed, and hence the LRV CV20m is also closed (similar circuit for CV21).
- When either pressure alarm unit in a given channel sees heat transport pressure as exceeding the setpoint of 9.76 MPa(g), it opens the associated contact in the channel logic chain.
- The open circuiting of the channel will de-energize the channel relay resulting in the opening of the 4 relays in the operating logic scheme: as long as only one set of contacts are open, the current flow is reduced but not interrupted and the LRVs remain closed.
- If two out of three channels are de-energized, then the current will be interrupted to the liquid relief valve air solenoids: for each liquid relief valve, there are four associated air solenoid valves; using CV20 as an example,
    - SV1 and SV2 are the two parallel connected air supplies, which are designed to go closed on loss of current
    - SV3 and SV4 the two connected in series vent valves and are designed to go open on loss of current;
    - the removal and venting of the air supply will allow the liquid relief valve to be forced open under spring tension.
- As soon as the heat transport pressure drops below 9.76 MPa(g), the relays are reset, solenoids energized and air applied to the CVs to again close them.



When PAID and or PA2D detect ROH# 1 or 2 press. >9.76MPa(g) contacts PAID or FA2D are opened to de-energize relay RID which then opens the 4 RID contacts in CV20 & 21 opening circuit. Contacts RIE & RIF have an identical operating arrangement
If two channels detect hi pressure then the operating logic is de-energized, which De-energizes the LRV solenoid valves,

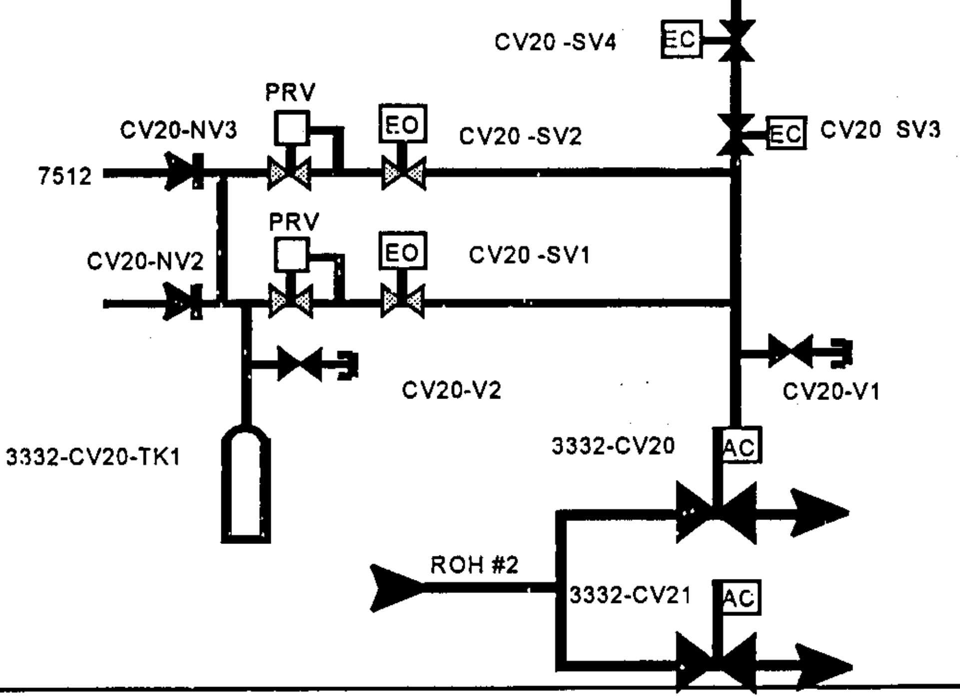


Figure 2
Liquid Relief Valve Operating Logic

NOTE Figure 1 is for 3332-CV20 only diagram for CV21 is identical

2.2 EFFECTS OF LIQUID RELIEF VALVE OPERATION

- The opening of these valves, when the unit is hot and/or at power, causes a severe strain on the bleed condenser pressure and level control schemes. The initial relief capacity of these valves is capable of removing in the order of 100 kg/s of inventory from the heat transport system.
- If the valves were opened because of a high-pressure transient, then the combination of reactor trips and liquid relief valves opening will rapidly reduce heat transport pressure.
- As soon as the pressure drops below 9.76 MPa(g), the valves will re-close, terminate the removal of heat transport inventory and overloading of the bleed condenser control schemes.
- However, if one or both valves were to fail open at power, the loss of D_2O to the bleed condenser (and from there to the HT storage tank as the bleed condenser level control valves will go full open) will cause the pressurizer level to drop low enough to initiate an SDS1 trip on low pressurizer level.
- The resultant shrink, along with the continuing loss of D_2O, would then cause the pressurizer to empty, resulting in the loss of the normal mode HT pressure control.
- In addition, HT pressure could drop below ECI initiation level and injection could occur on sustained HT low pressure.
- Logic has been installed to limit CV14/CV15 to a maximum of 20% open, when either LRV begins to open, as detected by its closed limit switch.
- This will allow the feed pumps to replace (to the HT system) the water lost in filling the bleed condenser and to maintain the pressurizer level stable.

2.2 EFFECTS OF LIQUID RELIEF VALVE OPERATION (continued)

- As can be seen on 4.5.6 Figure 2, when either CV20 or CV21 moves off its closed position, a limit switch is activated.
- The limit switch causes the de-energizing of two associated contacts in the logic scheme, which results in R11 dropping out.
- R11 dropping out closes an associated contact in the bleed condenser manual hand-controllers output (HC7S & HCl 6S), so that instead of generating 20 ma, they generate an adjustable signal (using variable pots RS8 & RS9) that limit the allowable opening to 20%. (Note this is actual valve open position in the field, not control room indication)
- This signal is forwarded by the low selector to HC7R (CV15) and HC16R (CV14) to limit the valves maximum opening to 20%, regardless of the output from the bleed condenser level controllers.
- When this logic operates there will be a CRT annunciation.
- Also as part of the LRV opening logic, another set of contacts are opened to remove the bias signal from the bleed valves so that the load on the bleed condenser is minimized.
- If the LRV goes closed, then the logic will reset and the bleed condenser level control valves will revert to normal control.
- If the valve opened as a result of a limit switch failure or conditions are such that the operator wants to return the bleed condenser level control valves to normal control, then he will press in the 'CV14, 15 OVERRIDE CANCELLED' push-buttons. As can be seen on Figure 3, pushing these buttons will energize and seal-in the R11 relay, thereby, maintain HC7S-and HC16S output at 20 ma. The push-buttons light up when they are pushed. It should be noted that these pushbuttons are alternate action push-buttons, which means that they are pushed in to activate and pushed again to de-activate. There is no automatic reset for the override logic.

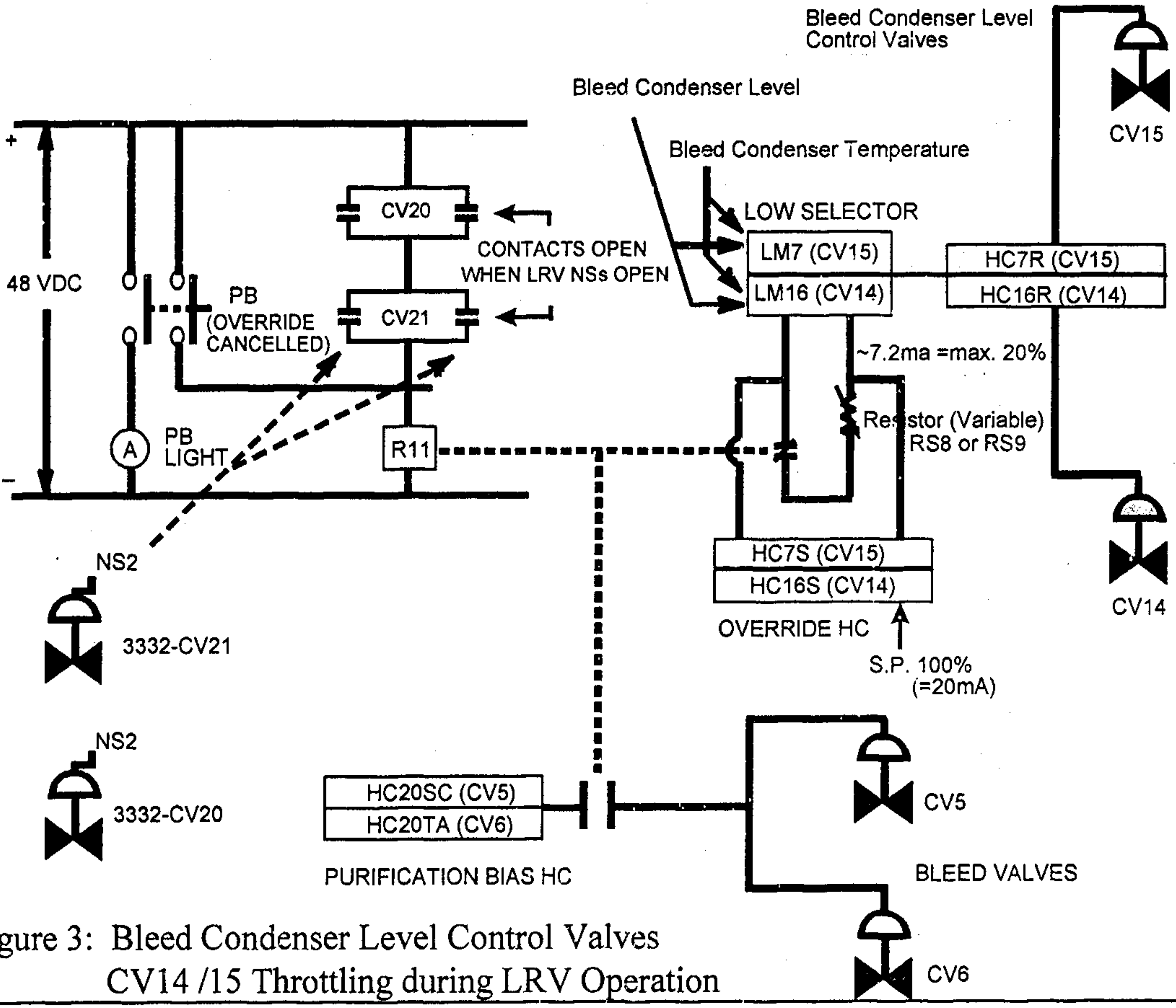


Figure 3: Bleed Condenser Level Control Valves
CV14 /15 Throttling during LRV Operation

3.0 PRESSURIZER STEAM RELIEF VALVES CV46 & CV47

- When the heat transport is in solid mode, the pressurizer is isolated from the heat transport and, therefore, not protected by the liquid relief valves (CV20 & CV21).
- If the pressurizer heaters where to be selected to or failed to 'ON', and for some reason the normal pressure control scheme not be in-service or also fail, then the pressure generated by the heaters could lead to over-pressure damage.
- The pressurizer steam relief valves CV46 and CV47 are designed to prevent this, or any other pressurizer over-pressure situation.
- Although CV46 & CV47 are considered to be relief valves, they operate as control valves in that there is a control logic scheme which must remove the air from the valve diaphragms before the valve can open under spring pressure.
- Referring to Figure 4, there are-three high pressure detection circuits composed of three pressure transmitters (PT13A, B & C) which feed three pressure alarm units (PA13A, B & C), that have a setpoint of 9.76 MPa(g).
- When the pressurizer pressure exceeds the setpoint, each PA operates a contact to de-energize a channelized relay (i.e. PA13A will open to de-energize R3).
- The de-energizing of a channel relay will result in the two associated contacts in each valve's operating logic to drop out (i.e. R3 relay de-energizing will open all four R3 contacts in both valves' operating logic).
- If two PAs detect a high pressure, then two channel relays will be de-energized, resulting in both valves' operating logic schemes being fully de-energized.
- The operating logic is in series with the relief valve air solenoids, so that open circuiting the operating logic will de-energize the solenoids
- It requires both operating logic schemes to be de-energized for all four solenoids to be open circuited.

3.0 PRESSURIZER STEAM RELIEF VALVES CV46 & CV47 (continued)

- When this occurs, the two three way air solenoids switch positions, so that both air supplies are isolated and the air tubing from the valves diaphragm is exhausted.
- The removal of air from the diaphragm allows the valve's spring to force open the valve, releasing steam to the bleed condenser.
- When the pressure drops below the PA's setpoint the logic schemes are reset, and air applied to re-close the valves.
- When each valve moves off its closed limit switch, a Control Room annunciation is generated.

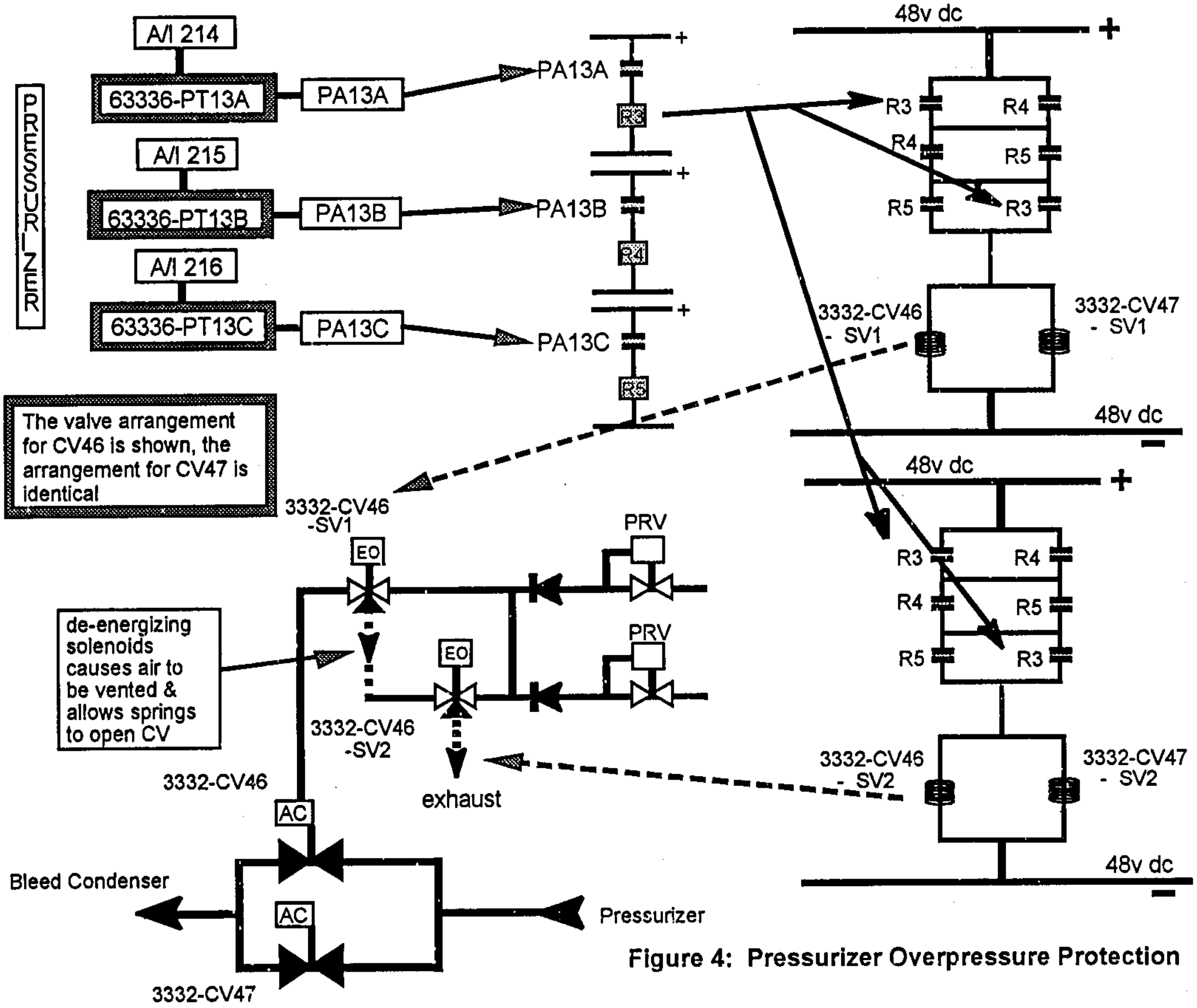


Figure 4: Pressurizer Overpressure Protection

4.0 BLEED CONDENSER RELIEF VALVES RV17 & RV18

- The Bleed. condenser is designed to be a relief path where both normal pressure control and over-pressure protection schemes can reject D_2O to both control and/or limit heat transport pressure.
- There are occasions when, due to failures or operating conditions, the bleed condenser outlet valve MV9 is either closed by the operator or by box-up logic.
- In these events, the bleed condenser will either go solid (fill with D_2O) or due to the rejection of D_2O liquid/steam, the pressure will rise to the heat transport pressure; if this occurs, then the bleed condenser can no longer provide a relief path for pressure control.
- To protect both the heat transport and bleed condenser, RV1 7 and RV1 8 are designed to lift and relieve pressure directly to the vault; this however creates, in effect, a loss of coolant situation.
- The seats of these RVs can be damaged when they reseat, leading to a continual loss of coolant until the unit is cooled down and de-pressurized.
- RV17 and RV18 both lift at 9.32MPa(g) and will reseat at approximately 6.5 MPa(g).

5.0 PURIFICATION OVER-PRESSURE PROTECTION VALVE RV16

- RV16 provides back-up over-pressure protection for the purification circuit in the event that MV38 fails to open or MV38's opening is not fast enough to prevent pressure rising to RV16's setpoint.
- If RV16 does open it relieves D_2O into the common feed pump suction/storage tie line.
- RV16 lifts at 1.31 MPa(g) and re-seats at 1.12MPa(g).

6.0 REFLUX FEEDLINE OVER-PRESSURE PROTECTION VALVE RV33

- To protect the reflux line from either being over-pressudzed by the feed pumps (12 MPa(g)) or from the bleed condenser heat source, RV33 is designed to lift and relieve D_2O into the storage tank tie line.
- RV33 is set to lift at 9.89 MPa(g) and re-seat at 8.88 MPa(g).

CHAPTER 4: HEAT TRANSPORT PRESSURE AND INVENTORY CONTROL

MODULE E: SIMULATOR EXERCISES

MODULE OBJECTIVES:

At the end of this module, you will be able to:

1. **Identify the parameters associated with the Heat Transport Main Circuit, Pressure and Inventory Control systems;**
2. **Respond correctly to the following events:**
   - **PHT Liquid Relief Valve (CV20) Fails Open**
   - **PHT Steam Bleed Valve (CV22) Fails Open**
   - **PHT Feed Valve (CV12) Fails Open**
   - **Pressurizer Surge Valve (MV1) Fails Close**
   - **PHT Bleed Valve (CV5) Fails Open**

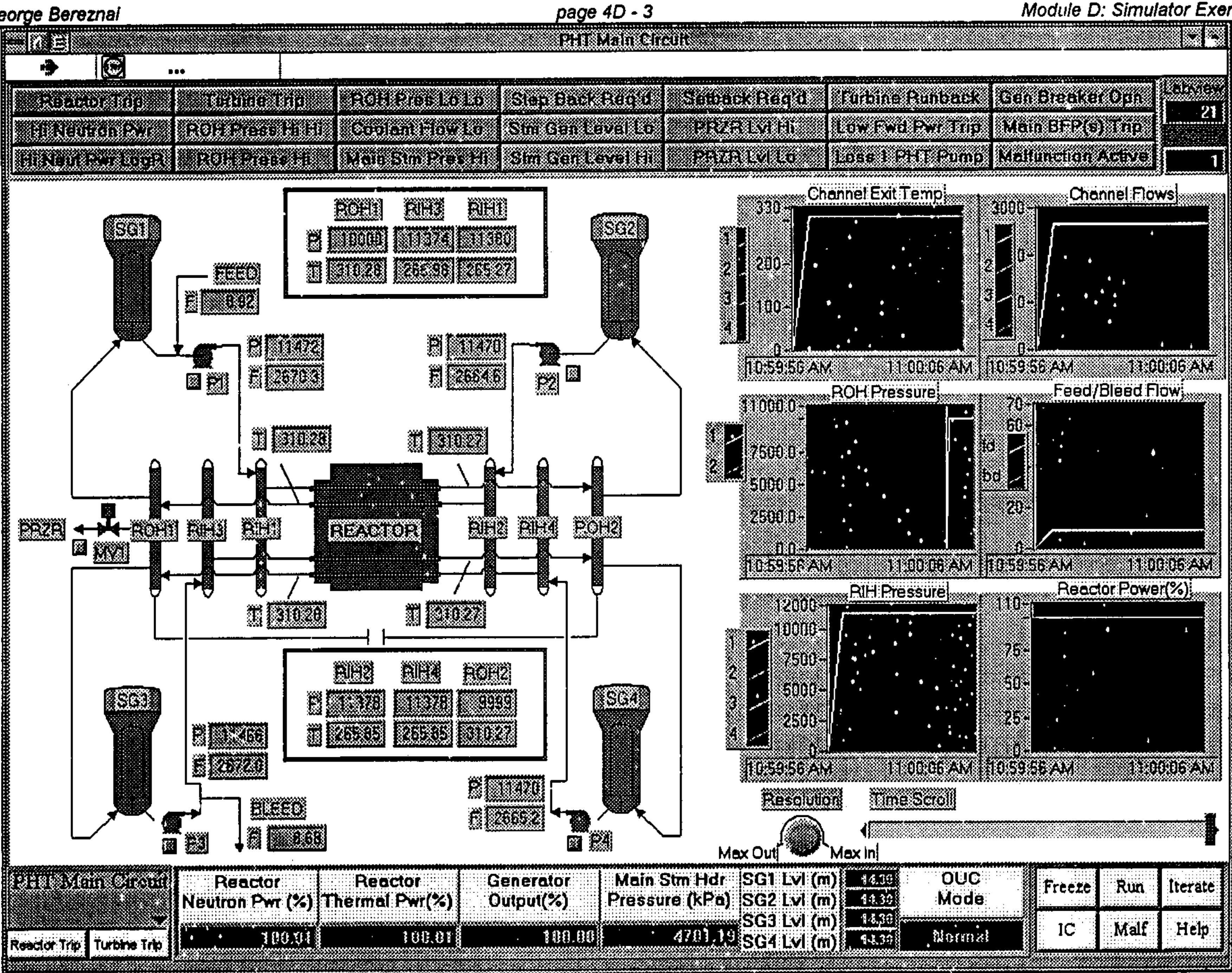
PHT MAIN CIRCUIT

This screen shows a simplified layout of the main heat transport system: the 480 coolant channels are represented by only four channels, two per loop showing the opposite directions of flow in the figure of eight configuration of each loop.

Starting from fuel channel number 1 at the reactor and following the direction of coolant flow, the system components and parameters shown are:

- average channel exit temperature (°C)
- ROH2 (note that ROH2 pressure and temperature are shown in the box below the reactor)
- SG2
- P2 (selection allows 'START', 'STOP' and 'RESET' operations)
- Pressure (kPa) and temperature (°C) at the outlet of P2
- RIH2 (note that RIH2 pressure and temperature are shown in the box below the reactor)
- fuel channel number 2
- average channel exit temperature (°C)
- ROH1 (note that ROH1 pressure and temperature are shown in the box above the reactor)
- SG1
- Feed flow into main loop (kg/sec)
- P1 (selection allows 'START', 'STOP' and 'RESET' operations)
- Pressure (kPa) and temperature (°C) at the outlet of P1
- RIH1 (note that RIH1 pressure and temperature are shown in the box above the reactor)
- flow returns to fuel channel number 1

The same equipment and parameters are shown in the lower loop, except that instead of feed flow into this loop there is bleed flow out (kg/sec).



	ROH1	RIH3	RIH1
P	10000	11374	11380
T	310.28	265.98	265.27

	RIH2	RIH4	ROH2
P	11378	11378	9999
T	265.85	265.85	310.27

Reactor Neutron Pwr (%)	Reactor Thermal Pwr(%)	Generator Output(%)	Main Stm Hdr Pressure (kPa)
100.01	100.01	100.00	4701.19

SG1 Lvl (m) 14.30
SG2 Lvl (m) 14.30
SG3 Lvl (m) 14.30
SG4 Lvl (m) 14.30

OUC Mode: Normal

PHT FEED AND BLEED

This screen shows the Heat Transport pressure control system, including the pressurizer, bleed (or degasser) condenser, pressure relief, feed and bleed circuits and D2O storage tank,

Starting with the storage tank at the bottom left hand corner, it level is displayed in meters. The tank supplies the flow and suction pressure for the Feed (or Pressuring) pumps P1 and P2: normally one pump is running, the popup menu allows START, STOP and RESET operations.

The Flow (kg/sec) and Temperature (°C) of the feed flow are displayed. Part of the flow goes to the Bleed Condenser to provide spray cooling (via CV14, kg/sec) and reflux cooling (via CV11, kg/sec), with the reflux flow being returned to the feed line past the feed control valve CV12; the feed flow then passes through the feed isolation valve MV18 before entering the main circuit at the suction of the main circulating pump 1.

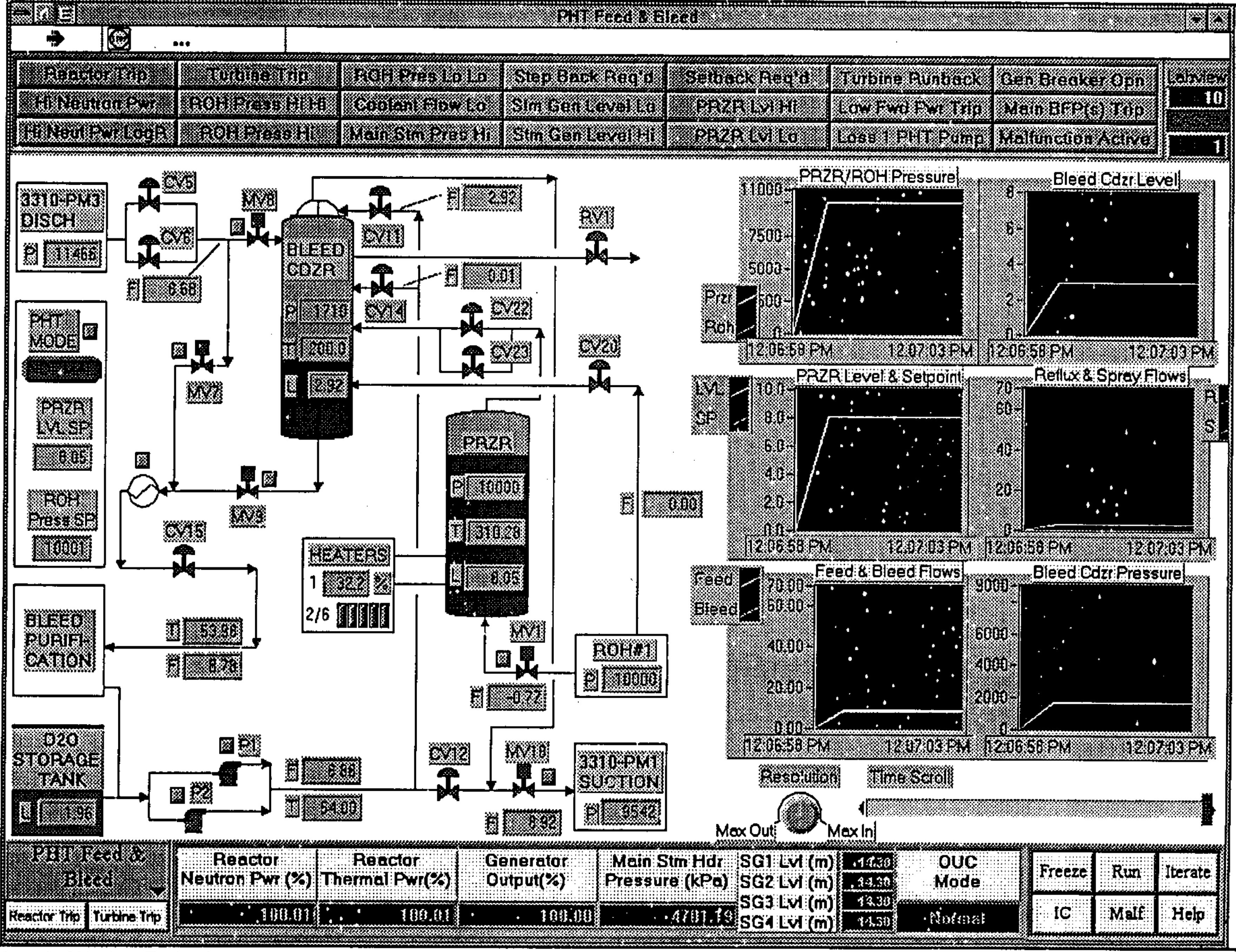
Proceeding in an anti-clockwise direction, the Pressure (kPa) and Temperature (°C) of ROH#1 are shown. Flow from the Outlet header is normally to and from the Pressurizer via MV1, a negative flow (kg/sec) indicating flow out of the pressurizer. In case of excessive heat transport header pressure, relief valve CV20 opens and discharges flow (kg/sec) to the Bleed Condenser. Pressurizer Pressure (kPa), Temperature(°C) and Level (m) are displayed.

Pressurizer pressure is maintained by heaters (in case the pressure falls) and by steam discharge valves CV22 and CV23 if the pressure is too high.

Bleed Condenser pressure relief is provided via RV1. Parameters displayed for the Bleed Condenser are: Pressure (kPa), Temperature(°C) and Level (m). Feed flow from main circuit pump 3 (header pressure in kPa) flows (kg/sec) via Bleed Control valves CV5, CV6 and MV8. Bleed Condenser by-pass is via MV7.

The outflow from the Bleed Condenser is via MV9, the Bleed Cooler and the Bleed Condenser Level Control valve CV15 to the Purification Circuit. The values of Temperature(°C) and Flow (kg/sec) into the Purification System are displayed.

Heat Transport pressure control in NORMAL mode is via the Pressurizer; via the PHT MODE popup menu SOLID mode can be selected. PRESSURIZER LEVEL SETPOINT and ROH PRESSURE SETPOINT are also shown.



Labview: 10

1

3310-PM3 DISCH P 11466

F 8.68

F 2.92

F 0.01

BLEED CDZR P 1710

T 200.0

L 2.92

PRZR LVL SP 8.05

ROH Press SP 10001

PRZR P 10000

T 310.28

L 8.05

HEATERS 1 32.2 %

2/6

F 0.00

T 53.96

F 8.78

ROH#1 P 10000

F -0.77

D2O STORAGE TANK L 1.96

F 8.88

T 54.00

F 8.92

3310-PM1 SUCTION P 9542

Reactor Neutron Pwr (%) 100.01

Reactor Thermal Pwr(%) 100.01

Generator Output(%) 100.00

Main Stm Hdr Pressure (kPa) 4701.19

SG1 Lvl (m) 14.30

SG2 Lvl (m) 14.30

SG3 Lvl (m) 13.30

SG4 Lvl (m) 14.50

OUC Mode Normal

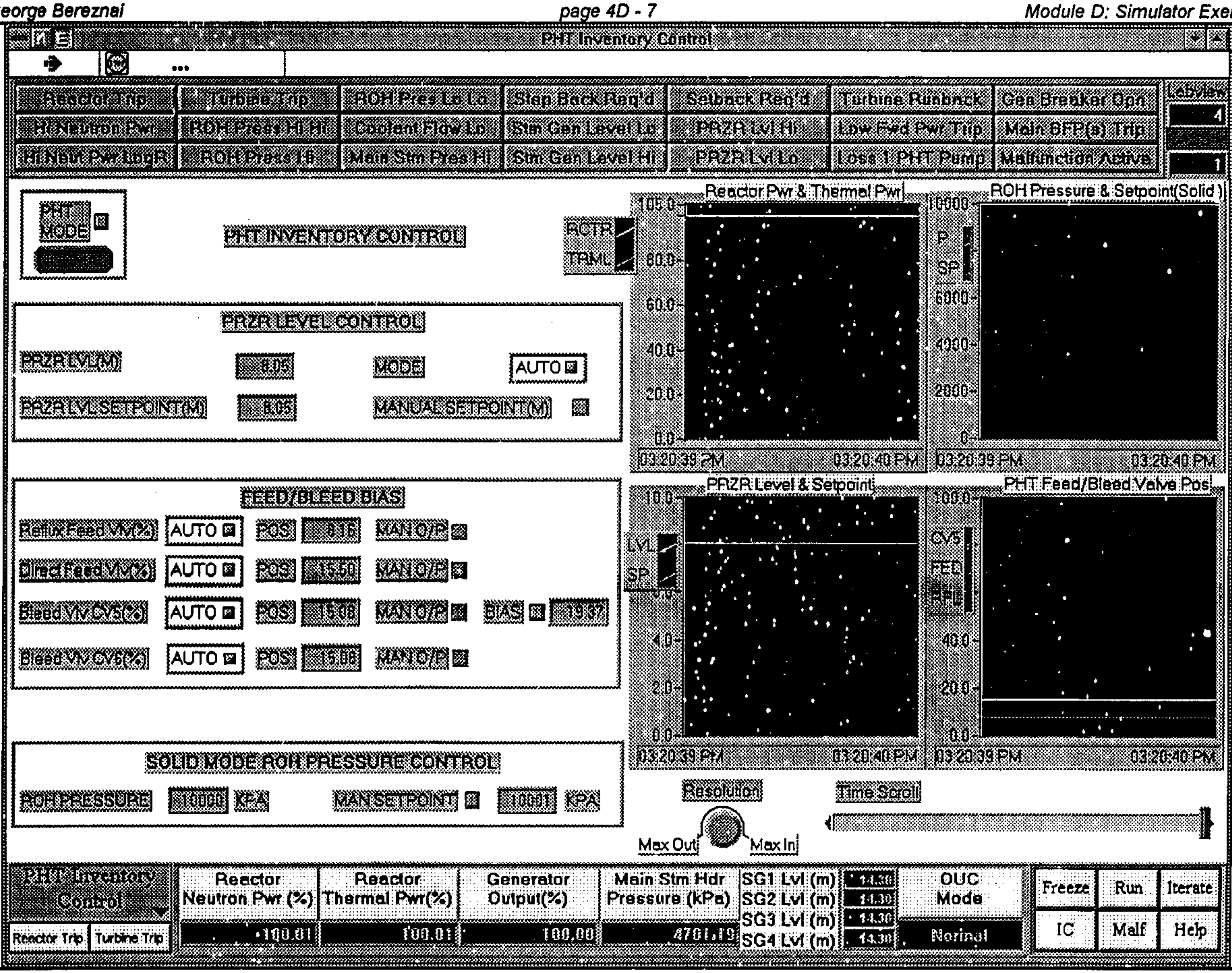
PHT INVENTORY CONTROL

The screen shows the parameters relevant to controlling the inventory in the main heat transport loop. Either NORMAL or SOLID modes of operation may be selected. Note that in NORMAL mode, inventory control is achieved by controlling Pressurizer Level, while in SOLID mode inventory control is by means of maintaining main heat transport pressure via the feed and bleed valves.

Pressurizer Level is normally under computer control, with the setpoint being ramped as a function of reactor power and the expected shrink and swell resulting from the corresponding temperature changes. Level control may be transferred to MANUAL and the SETPOINT can then be controlled manually.

The amount of feed and bleed is controlled about a bias value that is set to provide a steady flow of bleed to the Purification System. The amount of flow may be adjusted by changing the value of the BIAS. The positions of feed and bleed valves are normally under AUTO control, but may be changed to MANUAL using the popup menus.

In SOLID mode the ROH PRESSURE (kPa) may be controlled manually via the popup menu.



PRZR LEVEL CONTROL

PRZR LVL(M) 8.05 MODE AUTO
PRZR LVL SETPOINT(M) 8.05 MANUAL SETPOINT(M)

FEED/BLEED BIAS

Reflux Feed Vlv(%) AUTO POS 8.16 MAN O/P
Direct Feed Vlv(%) AUTO POS 15.50 MAN O/P
Bleed Vlv CV5(%) AUTO POS 15.08 MAN O/P BIAS 19.37
Bleed Vlv CV6(%) AUTO POS 15.08 MAN O/P

SOLID MODE ROH PRESSURE CONTROL

ROH PRESSURE 10000 KPA MAN SETPOINT 10001 KPA

Reactor Neutron Pwr (%)	Reactor Thermal Pwr(%)	Generator Output(%)	Main Stm Hdr Pressure (kPa)
100.01	100.01	100.00	4701.19

SG1 Lvl (m) 14.30
SG2 Lvl (m) 14.30
SG3 Lvl (m) 14.30
SG4 Lvl (m) 14.30

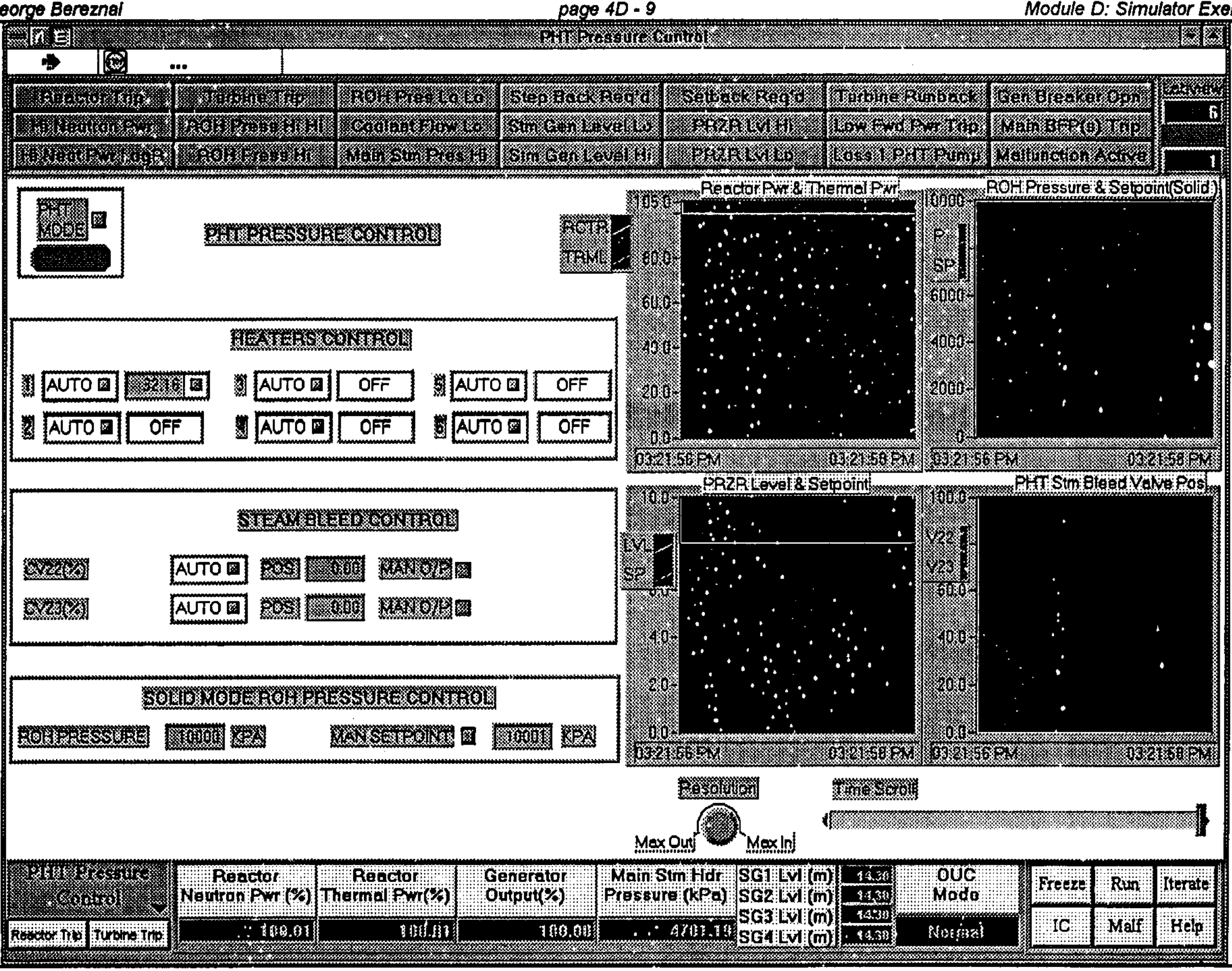
OUC Mode: Normal

PHT PRESSURE CONTROL

This screen is similar to the previous one in terms of the ability to select PHT Pressure Control MODE and SOLID MODE ROH PRESSURE CONTROL. The difference arise in the control of Pressurizer pressure.

The six HEATERS are normally in AUTO, with the variable Heater (#1) modulating. The other five heaters are either ON or OFF, and under AUTO control. Via the popup menus MANUAL operation can be selected, and each heater may be selected to START, STOP or RESET.

STEAM BLEED CONTROL is via CV22 and CV23. These are normally in AUTO mode, but may be placed on MANUAL and the valve opening manually controlled via popup menus.



Heater 1: AUTO 32.16
Heater 2: AUTO OFF
Heater 3: AUTO OFF
Heater 4: AUTO OFF
Heater 5: AUTO OFF
Heater 6: AUTO OFF

CV22(%) AUTO POS 0.00 MAN O/P
CV23(%) AUTO POS 0.00 MAN O/P

ROH PRESSURE 10000 KPA
MAN SETPOINT 10001 KPA

Reactor Neutron Pwr (%): 100.01
Reactor Thermal Pwr(%): 100.01
Generator Output(%): 100.00
Main Stm Hdr Pressure (kPa): 4701.19
SG1 Lvl (m): 14.30
SG2 Lvl (m): 14.30
SG3 Lvl (m): 14.30
SG4 Lvl (m): 14.30
OUC Mode: Normal

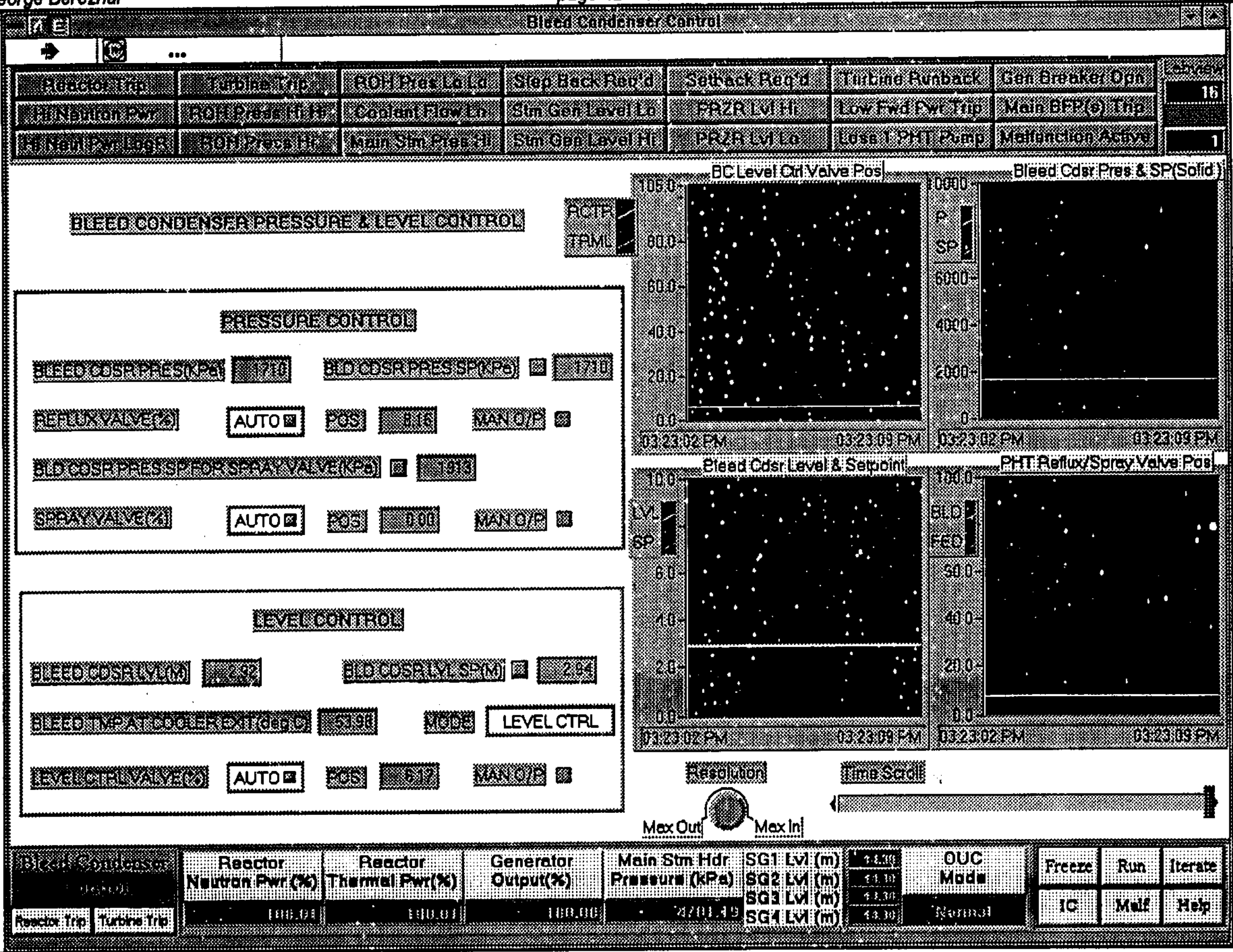
BLEED CONDENSER CONTROL

The parameters required to control Bleed Condenser Pressure and Level are shown on this screen.

PRESSURE CONTROL is normally achieved via altering the REFLUX flow, and SPRAY flow only takes place if REFLUX flow is unable to maintain pressure control. To achieve such a split mode of operation, the SETPOINT for the Reflux valve, denoted as BLEED CONDENSER PRESSURE SETPOINT (kPa) is set at a value lower than the BLEED CONDENSER PRESSURE SETPOINT FOR SPRAY VALVE (kPa). Both valves are normally on AUTO, but may be selected to MANUAL and the valve opening controlled directly via popup menus.

LEVEL CONTROL is normally in the AUTO mode about the specified SETPOINT. However if the BLEED TEMPERATURE AT COOLER EXIT exceeds a preset value (68°C), the control mode is switched to TEMPERATURE CONTROL mode, which restricts the valve opening so as to protect the ion exchanger resin.

The LEVEL CONTROL VALVE may be placed on MANUAL for direct control of the valve's position.



BLEED CONDENSER PRESSURE & LEVEL CONTROL

PRESSURE CONTROL

BLEED CDSR PRES(KPa) 1710 BLD CDSR PRES SP(KPa) 1710

REFLUX VALVE(%) AUTO POS 8.16 MAN O/P

BLD CDSR PRES SP FOR SPRAY VALVE(KPa) 1913

SPRAY VALVE(%) AUTO POS 0.00 MAN O/P

LEVEL CONTROL

BLEED CDSR LVL(M) 2.92 BLD CDSR LVL SP(M) 2.94

BLEED TMP AT COOLER EXIT(deg C) 53.98 MODE LEVEL CTRL

LEVEL CTRL VALVE(%) AUTO POS 6.17 MAN O/P

Bleed Condenser

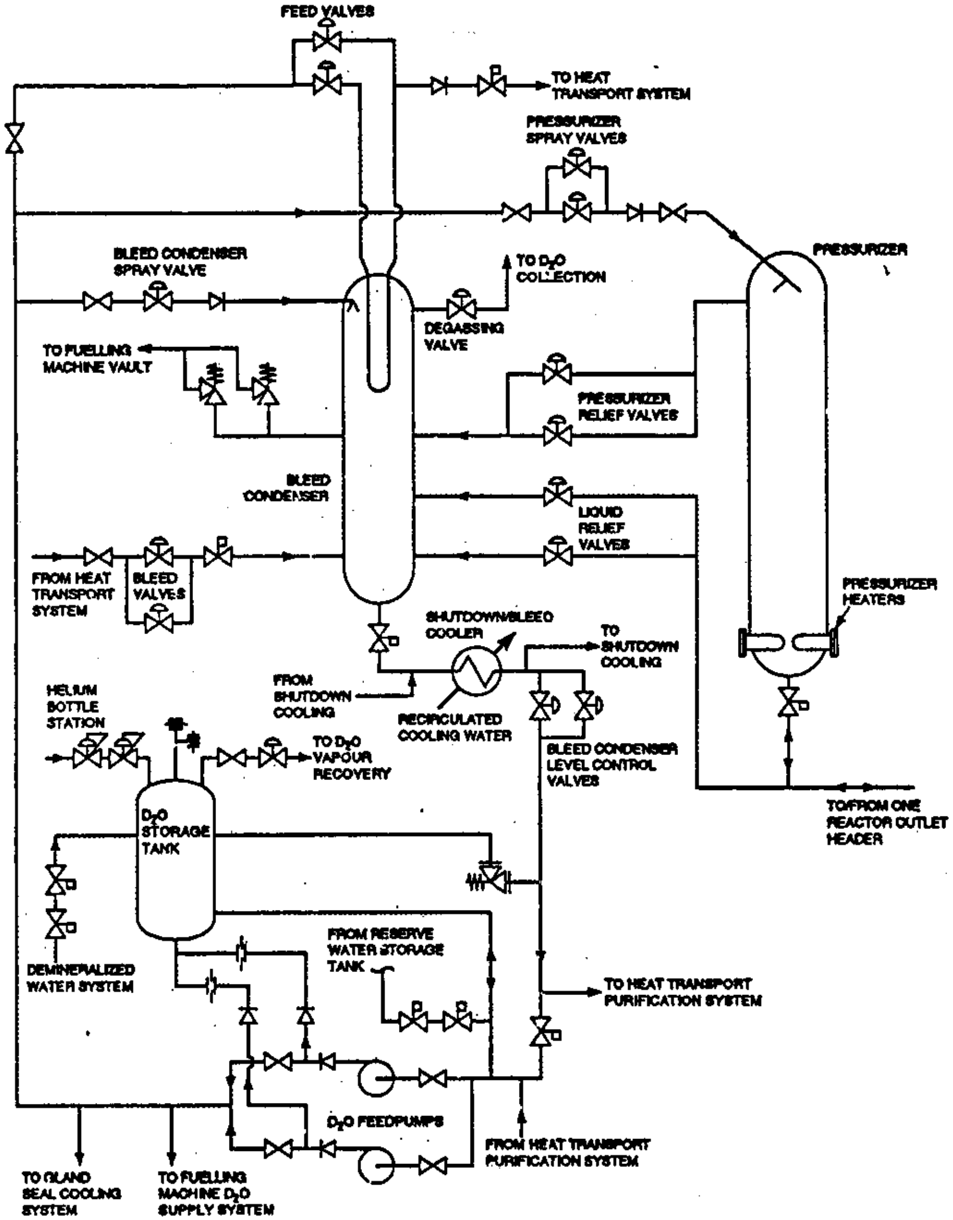
Reactor Neutron Pwr(%)	Reactor Thermal Pwr(%)	Generator Output(%)	Main Stm Hdr Pressure (kPa)
100.01	100.01	100.00	[illegible]

SG1 Lvl (m) [illegible]
SG2 Lvl (m) [illegible]
SG3 Lvl (m) [illegible]
SG4 Lvl (m) [illegible]

OUC Mode Normal

SIMULATOR EXERCISE 4.1

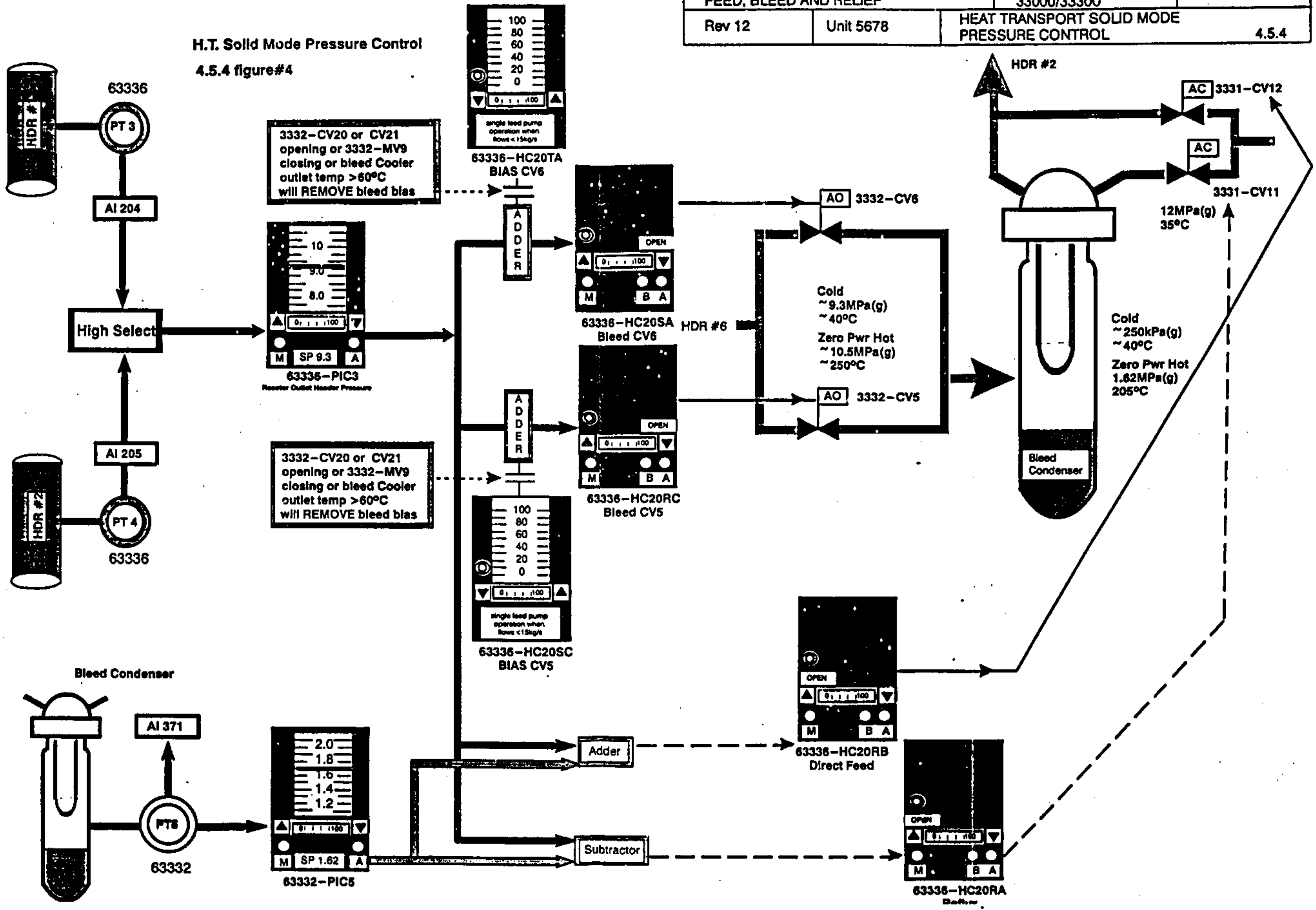
Using the CTI CANDU Simulation page PHT FEED & BLEED, identify the same equipment as well as note significant difference with the attached diagram.



HEAT TRANSPORT & FEED, BLEED AND RELIEF	BNGSB TM 33000/33300	Page 7 of 8
Rev 12 | Unit 5678	HEAT TRANSPORT SOLID MODE PRESSURE CONTROL 4.5.4	

H.T. Solid Mode Pressure Control

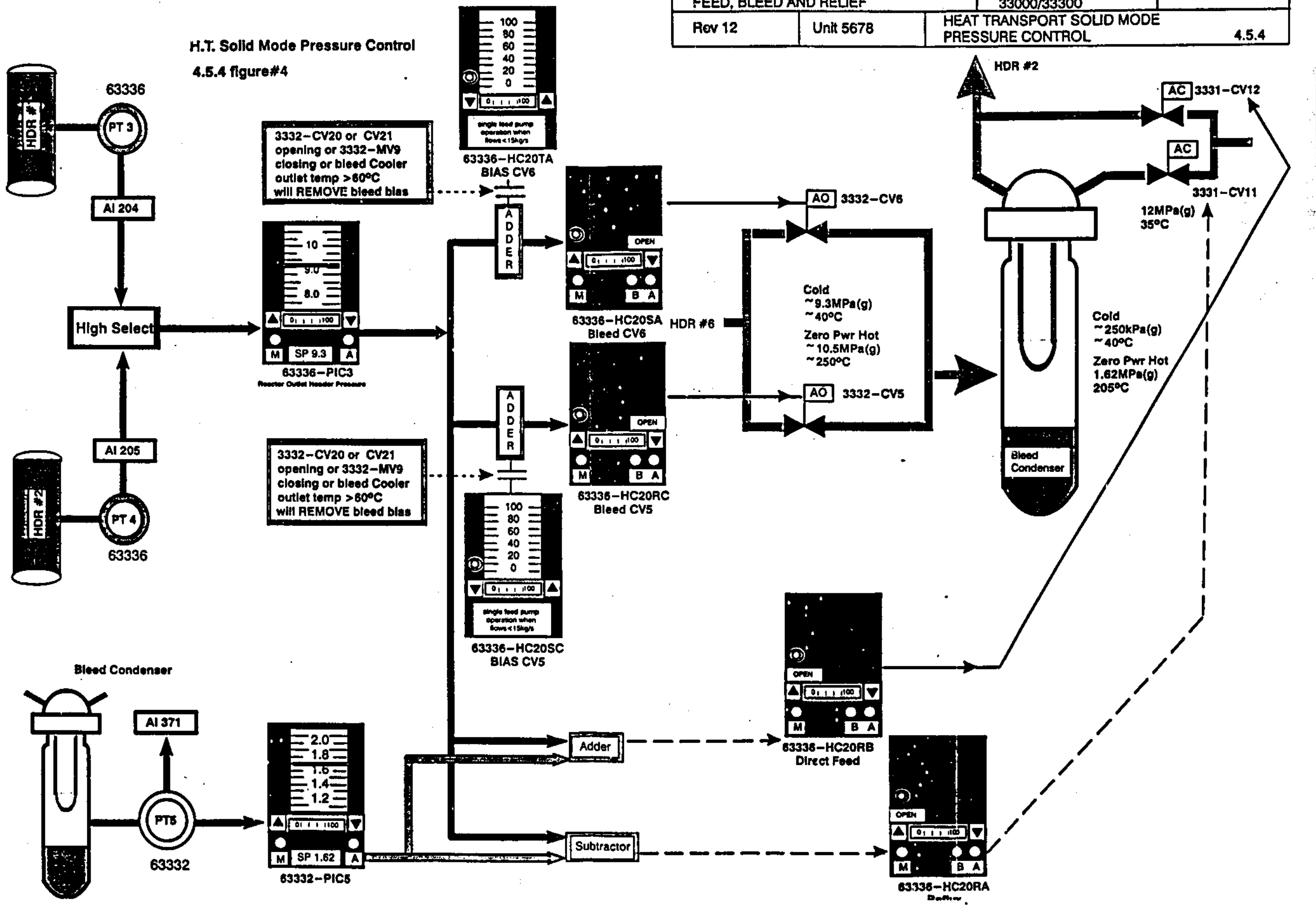
4.5.4 figure#4



HEAT TRANSPORT & FEED, BLEED AND RELIEF		BNGSB TM 33000/33300	Page 7 of 8
Rev 12	Unit 5678	HEAT TRANSPORT SOLID MODE PRESSURE CONTROL	4.5.4

H.T. Solid Mode Pressure Control

4.5.4 figure#4



3332-CV20 or CV21 opening or 3332-MV9 closing or bleed Cooler outlet temp >60°C will REMOVE bleed bias

3332-CV20 or CV21 opening or 3332-MV9 closing or bleed Cooler outlet temp >60°C will REMOVE bleed bias

H.T. Solid Mode Pressure Control

4.5.4 figure#4