Module 7

HTS PRESSURE & INVENTORY CONTROL

OBJECTIVES:

After completing this module you will be able to:

7.1 Explain the concern of HT pressures that are:

- a) Too high and, ⇔ *Page 3*
- b) Too low. ⇔ *Pages 3-4*

7.2 Explain two concerns with blocked or restricted coolant paths. ⇔ *Page 4*

7.3 a) State the three effects of boiling in the HTS and, ⇔ *Page 4*

- b) State when boiling in the HTS is permissible at some stations. ⇔ *Page 4*

7.4 State why it is necessary to have HT system pressure/inventory control. ⇔ *Page 4*

7.5 State four purposes of the feed and bleed system for units with a pressurizer while in "solid" mode pressure control. ⇔ *Pages 5-6*

7.6 State the purpose of the pressurizer during "normal" heat transport operational mode. ⇔ *Page 6*

7.7 Explain how a pressurizer maintains HT system pressure to a predetermined set point. ⇔ *Page 6*

7.8 State five purposes of the feed and bleed system for units with a pressurizer while in "normal" mode pressure control. ⇔ *Page 8*

7.9 State five purposes of the feed and bleed system for units without a pressurizer. ⇔ *Page 8*

7.10 a) Explain the three reasons why the pressurizer level is controlled. ⇔ *Page 9*

- b) State how the pressurizer level varies with reactor power. ⇔ *Page 10*
- c) For units with a pressurizer, explain how shrink and swell are made up between cold pressurized and zero power hot. ⇔ *Page 11*

7.11 a) Explain the two methods how feed and bleed system demands are minimized during operation on units that do not use pressurizers. ⇔ *Page 11*

Page 12 ⇔ b) For units without a pressurizer, explain how shrink and swell are made up between cold pressurized and zero power hot.

Page 12 ⇔ 7.12 a) Explain the two major purposes of the interunit D_2O transfer system.

Page 13 ⇔ b) Explain the three major purposes of the HT D_2O storage tank.

Page 13 ⇔ i) Explain two reasons that a lower operating limit is placed on the D_2O storage tank level.

Page 13 ⇔ ii) Explain two reasons that an upper operating limit is placed on the D_2O storage tank level.

Page 15 ⇔ 7.13 a) State the two methods for controlling bleed condenser pressure.

Page 15 ⇔ b) Specify which method is used as a backup and explain two reasons why it is the backup method.

Page 16 ⇔ 7.14 State the method used to control degasser condenser pressure.

Pages 17-18 ⇔ 7.15 For both types of HT system (pressurizer and no pressurizer) state the response during slow power manoeuvres, of:

a) HTS Pressure,
b) HTS Average Temperature,
c) Feed and bleed flows,
d) Pressurizer level,
e) Boiler pressure.

Page 19 ⇔ 7.16 State why it is necessary to have HT system pressure relief.

Page 20 ⇔ 7.17 Explain the concern over rapid increases in HTS pressure.

Page 20 ⇔ 7.18 State the two major causes of HTS over-pressurization and give an example of each type of over-pressurization.

Page 21 ⇔ 7.19 Explain the concern over heat sink capability reduction.

Page 21 ⇔ 7.20 a) Explain what is meant by direct pressure reduction and,

Page 21 ⇔ b) State two methods of direct pressure reduction.

Page 22 ⇔ c) Explain how each of these two methods affects HTS pressure.

Page 23 ⇔ 7.21 a) State the type of events the HTS pressure relief valves are sized for.

Page 23 ⇔ b) Explain why these relief valves are not sized to handle all types of overpressure events.

NOTES & REFERENCES

7.22 a) Explain what is meant by indirect pressure reduction. ⇔ ***Page 21***

b) State how this method of pressure reduction is achieved. ⇔ ***Page 22***

c) Explain how this method affects HTS pressure. ⇔ ***Page 22***

7.23 Explain the concerns and possible consequences of:

a) A failed open pressure relief valve, ⇔ ***Page 25***

b) A feed pump failure,

c) A steam bleed valve failed open (pressurizer system), ⇔ ***Page 26***

d) Failed HT main circulation pump(s), ⇔ ***Page 26***

e) Isolation of bleed condenser on high temperature. ⇔ ***Page 27***

* * *

INSTRUCTIONAL TEXT

INTRODUCTION

As stated in Module 6, the primary role of the Heat Transport System (HTS) is to transport the heat generated by fission and decay heat from the reactor to the boilers, which produce steam to run the turbine generator.

The turbine requires saturated steam at a pressure of approximately 4.5 MPa. If the HT system is to remain subcooled, ie. a liquid, this means that the HTS must also be a pressurized system. Also, taking into account the ΔT required to transfer heat from the HT system to the boilers, the HTS has to be pressurized to approximately 9 to 10 MPa.

These high pressures dictate the need for a pressure control system with operating requirements which must satisfy both mechanical and nuclear concerns.

PRESSURE CONTROL

Mechanical Concerns

⇔ ***Obj. 7.1 a)***

The HT system is a pressure boundary and must remain intact. Operating at a **higher pressure** than normal in the HT system increases the likelihood of a **rupture** of the HT system and thus, a **Loss Of Coolant Accident** (LOCA). A LOCA results in a loss of coolant inventory, which may also result in insufficient coolant being available to cool the fuel.

Nuclear Concerns

Obj. 7.1 b) ⇔

Obj. 7.3 a) ⇔

On the other hand, operating at too **low a pressure** in the system will result in excessive boiling. This inevitably would lead to **fuel overheating** either as a direct result of **film boiling** (dryout) or through **loss** of coolant **flow** in the channels caused by pump cavitation. In addition, due to the positive void coefficient, channel voiding leads to large increases in reactor power output, which will tend to further promote boiling and fuel overheating if no protective action is taken. Note that excessive boiling, resulting in **fuel overheating and voiding**, can also occur at normal system pressures with **blocked or restricted coolant passages**.

Obj. 7.2 ⇔

Obj. 7.3 b) ⇔

Note that this requirement, ie, to avoid excessive boiling, still allows for the HTS, at most stations, to be operated at high power with a **limited** amount of boiling (nucleate boiling) occurring at the exits of some channels. Typically, in a number of channels, 3-5% boiling occurs. This improves heat transfer from the fuel and adds to the extractable heat available to the boilers.

Even at stations where limited boiling occurs at full power, it ceases once the reactor power output falls to ~<90% FP.

Obj. 7.4 ⇔

Given a totally enclosed heat transport system, **pressure** will **vary directly** with the average **temperature** of the HTS. Coolant pressure increases due to swell as the average temperature increases during reactor power increases. Conversely, pressure decreases as a result of coolant shrinkage during power reductions.

Coolant **swell and shrink** are a major phenomena. A typical unit's HTS swell may be as much as 60 m^3 on warmup with an additional 10 to 20 m^3 as power is raised from 0 to 100% full power. Given the incompressible nature of the coolant, the addition of even 1 m^3 of coolant to a non-boiling pressurized heat transport system would increase pressure significantly.

These conditions dictate the need for HTS **pressure and inventory control system.** This system ensures that there is adequate coolant at the correct conditions to remove the heat from the fuel.

HEAT TRANSPORT PRESSURE CONTROL

In the previous module we discussed the normal operational states of the HTS. Recall that it is necessary for the HTS pressure to be controlled at all power levels - from a cold shutdown condition to 100% Full Power.

We have already mentioned in this module, the relative amount of D_2O inventory changes which occur as the unit is maneuvered between 0%

full power cold and 100% full power hot and vice versa. It was also stated that the major inventory change occurred on warmup of the unit to about 250°C(approximately three times that change which occurs between 0% and 100% FP).

This latter fact is the reason why two methods of pressure control are required on most CANDU reactors, depending on the power level of the reactor.

These two pressure control methods are known as **solid mode** and **normal mode.**

Solid Mode Pressure Control

⇔ *Obj. 7.5*

Solid mode describes the pressure control of the HTS while the pressurizer is isolated (in stations using pressurizers). In this mode, **pressure control** is by **feed and bleed action**, ie. inventory addition and removal. The significance of the word 'solid' is that no compressible vapour space exists within the system to 'cushion' pressure transients (the system is totally non-boiling and the pressurizer is isolated).

With the HTS pressure at its setpoint, neither feed nor bleed action is required. If pressure rises above the setpoint, bleed action will remove inventory from the HTS and lower the pressure. Should pressure fall below the setpoint, the opposite occurs, ie. feed valve opens and inventory is added to the HTS (refer to Figure 7.1 for a simplified feed and bleed controller).

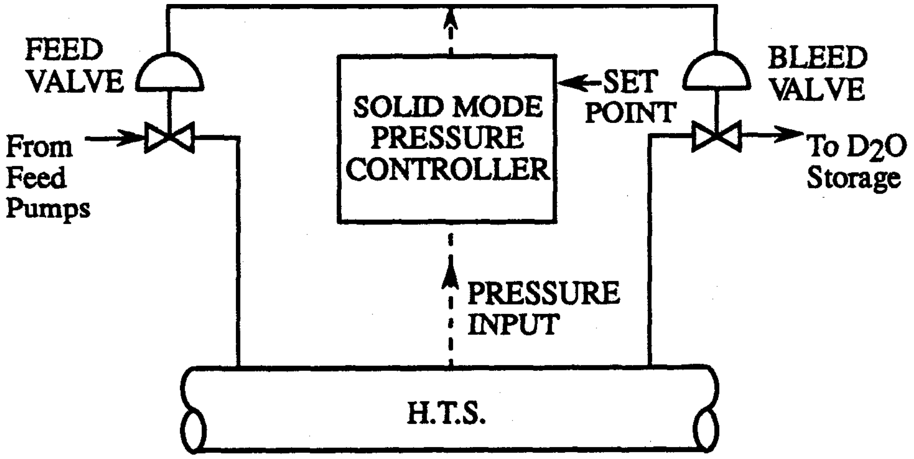


Figure 7.1
Simplified Feed and Bleed Controller

Note that during unit warmup, the bleed valve will be at or near the fully open condition to remove the swelling D_2O from the HTS. On unit cool down, the opposite will occur, ie. the feed valve will be open fully.

In practice, it is desirable to have a percentage of the HTS D_2O circulated through the **purification** system to remove crud, fission products, and impurities. The bleed valve is biased open a small amount to achieve this (except for CANDU 600, which is discussed later in the module). This will result in a drop in system pressure so the feed valve will be opened by the controller to maintain system pressure at the setpoint.

During solid mode operation, the feed and bleed system, in addition to the above, performs the following functions:

a) It supplies **D_2O to the Pump Gland Seal** Cooling System.

b) The bleed condenser (or degasser condenser in some stations) **accepts coolant discharge from the HTS** (bleed valves, HT relief valves, steam bleed valves, pressurizer relief valves, depending on the station). This ensures that this coolant is available for use when required.

During **solid mode** operation, the **pressurizer** is **isolated** from the HTS by a motorized valve. At this time, saturation conditions are established in the pressurizer at normal operating pressure by manipulation of the electric heaters and steam bleed valves (in preparation for valving into the HT system).

Normal Mode Pressure Control

Obj. 7.6 ⇔

Normal mode control is selected during "normal" operation. In this mode, the pressurizer is no longer isolated and HTS **pressure** is **controlled** by the **pressurizer** (sometimes called the surge tank).

The pressurizer is shown in Figure 7.2. It is connected to the HTS, at a reactor outlet header, by means of a large diameter pipe.

Obj. 7.7 ⇔

Heat transport system pressure is controlled by **regulating the steam pressure in the vapour space** above the liquid.

To **increase** HT system **pressure**, the steam pressure must be increased. This is achieved by switching on the **electric heaters**, thus increasing the temperature of water in the pressurizer. This causes the saturation temperature, and hence pressure to increase.

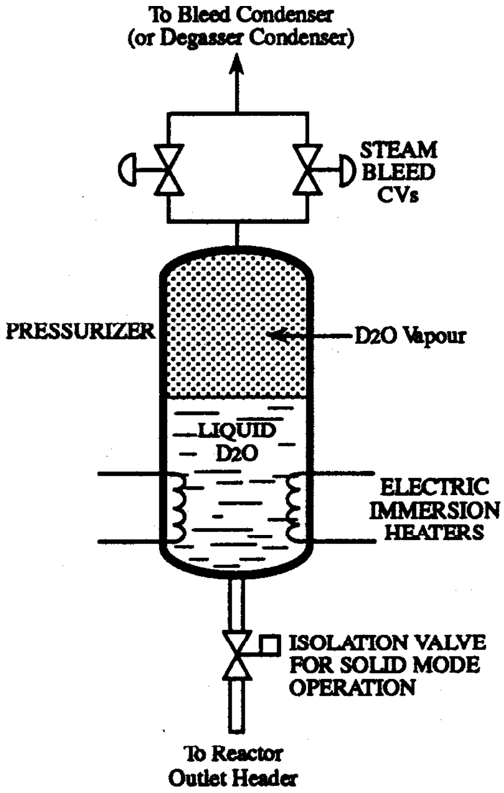


Figure 7.2
Typical Pressurizer

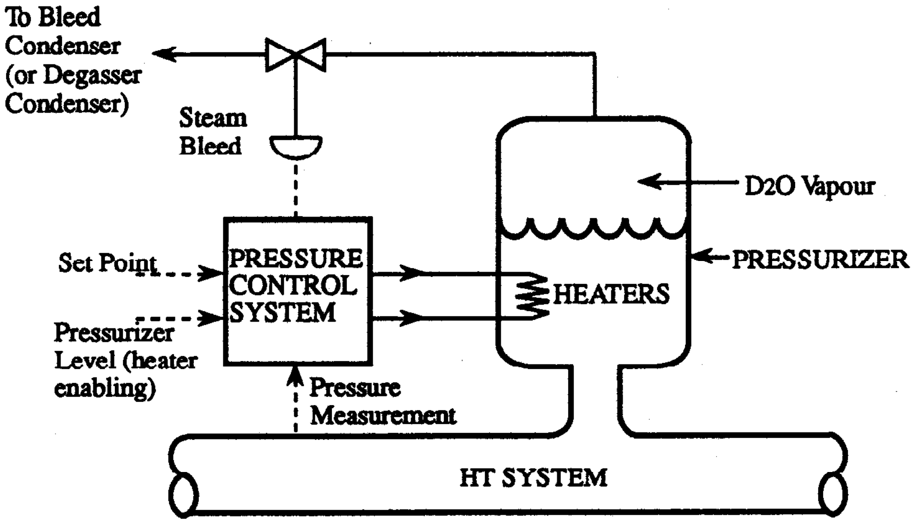


Figure 7.3
HTS Pressure Control (Normal Mode)

To **reduce HT pressure, steam** is **discharged** from the pressurizer's vapour space to the bleed condenser (or degasser condenser in some stations) via the steam bleed valves. This causes the the saturation temperature and pressure to decrease. The control system is shown in Figure 7.3.

Obj. 7.8 ⇔

During normal mode operation, the feed and bleed system doesn't control HTS pressure, but performs the following functions.

a) It adjusts coolant inventory to **maintain pressurizer D_2O level** at its setpoint (see following section on level control);

b) It returns D_2O to the system (via feed) to **make up for losses** via steam bleed valves (or degas flow in some stations);

c) It supplies cool D_2O to the **purification system** in most stations;

d) It supplies **D_2O to the Pump Gland Seal** System;

e) The bleed condenser (or degasser condenser in some stations) **accepts coolant discharge from the HTS** (bleed valves, HT relief valves, steam bleed valves, pressurizer relief valves, depending on the station). This ensures that this coolant is available for use when required.

Note that functions (c), (d) and (e) are carried out by the Feed and Bleed system in either control mode.

One of the major **advantages of pressurizer control** is that it provides a **faster control** in response to HTS pressure transients than a feed and bleed system. (ie. Large quantities of coolant can be quickly transferred to/from the pressurizer through the large diameter connection to the HTS. This is in comparison to using a feed and bleed system, which will have a more limited capacity.)

Pressure Control Totally by Feed And Bleed

Obj. 7.9 ⇔

The HTS used at some stations is **non-boiling and solid. Pressure control** in these stations, at all power states, is by **feed and bleed control** (ie. inventory transfer). Basically, this is the **same as solid mode** control at other locations. The feed and bleed system may also provide a **D_2O supply** for the **fuelling machines.**

However, in this case the pressure control function is divided into two ranges, termed **wide and narrow range**.

The wide range covers the warmup and cooldown of the system when the pressure can range from full working pressure to a much lower pressure, ie. control uses a low gain, resulting in **coarse control - Wide Range.**

For normal full power operation, when "tight" control about the setpoint is required, control is switched to a higher gain, resulting in **finer control - Narrow Range**. More details of this control system will be presented in Instrumentation and Control courses.

SUMMARY OF THE KEY CONCEPTS

- HT pressures that are too high can cause HTS ruptures (LOCA). Low HTS pressure will result in fuel overheating due to film boiling, and/or loss of coolant circulation due to pump cavitation. Voiding will promote fuel overheating because it introduces positive reactivity, thereby increasing heat production in the fuel.
- Fuel overheating due to film boiling is also possible at full system pressure if a coolant blockage or restriction exists.
- Pressure control is required since the pressure in the HTS varies directly with the HTS average temperature. Inventory control is required because of coolant shrink and swell as the HTS temperature varies.
- For units with pressurizers, the feed and bleed system controls HTS pressure in "solid" mode. It also provides purification flow (in most stations) and D_2O to the HTS pump glands. The bleed condenser (or degasser condenser in some stations) accepts D_2O from the HTS relief valves to prevent the loss of this coolant.
- For units with pressurizers, the feed and bleed system controls pressurizer level in "normal" mode. It also provides make-up for losses, purification flow (in most stations), D_2O to the HTS pump glands, and maintains the bleed condenser (or degasser condenser in some stations) as a pressure relief vessel.
- For units without pressurizers, the feed and bleed system controls HTS pressure. It also provides the same functions as it does in solid mode in units with pressurizers. It may also provide a D_2O supply for the fuelling machines.

Pressurizer Level Control

Level control of D_2O in the pressurizer is important for the following reasons:

⇔ ***Obj. 7.10 a)***

a) It **prevents** the **uncovering** of the **electric heaters** (on low level) therefore reducing the risk of burning out the heating elements (automatically switched off on low level). This results in the loss of pressure control (ie. cannot increase pressure without the heaters);

b) It **prevents** the system from **going solid** as a result of too high a level. Loss of the vapour space results in loss of pressure control;

c) Taking account of the limits imposed by a) and b), **maintains** a **maximum** HTS **inventory.**

Obj. 7.10 b) ⇔

An additional function carried out by the **level controller** is to **ramp up level in the pressurizer as reactor power is increased.** This means that **shrink or swell** as a result of power maneuvers can be accommodated directly by transfer **to and from the pressurizer** with minimal resort to feed or bleed action. A simplified control system is shown in Figure 7.4.

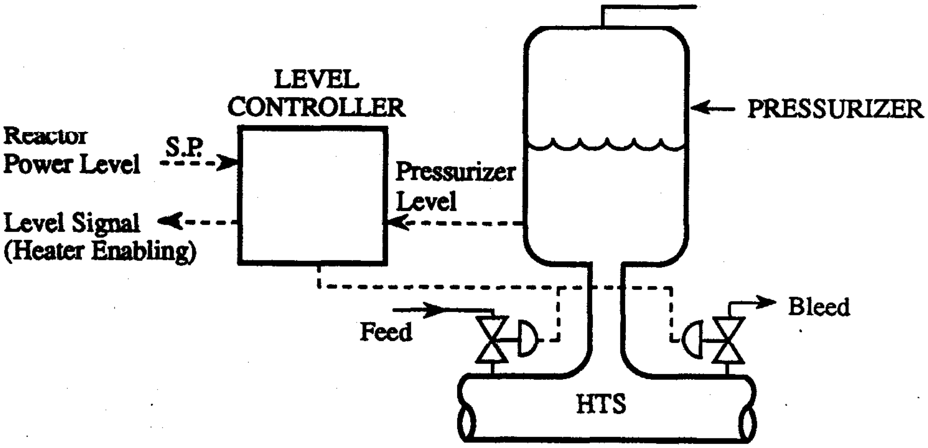


Figure 7.4
Pressurizer Level Control

* This is discussed in the 234 Turbine and Auxiliaries course.

Similar to boiler level changes with reactor power *, the level is at its lowest at low power. This is because the HT inventory will swell as reactor power is increased. The low level leaves room for the "excess" coolant that will enter the pressurizer. The requirement to make up shrinkage while at low power is a minimum, hence a lower level is not a major operating concern. On the other hand, the level is highest at full power. This takes into account the shrinkage that could occur if power is reduced. While at full power, the risk of further swell is minimal, hence the higher level in the pressurizer is not a major operating concern.

Pressurizer level is controlled by use of the feed and bleed valves.

For example, on a **power increase**, the pressurizer level **set point** will be **ramped upwards**. The **swell**, as a result of the power increase, will be **accommodated within the pressurizer** and will **satisfy** the increased **level requirement**. **Feed and Bleed** system **action** will be minimized to adjust HTS inventory. The opposite is true for a reduction in reactor power. The HTS shrink will be supplied from the pressurizer.

An additional **advantage**, achieved by ramping pressurizer level upwards as power increases, is that, should a reactor trip occur, the resultant **shrink** in the HTS can be **replenished quickly** from the pressurizer. Note that it is not practical to provide a pressurizer that is sufficiently large enough to accommodate all the swell from 0% power cold to 100% full power hot. It does, however, handle the inventory changes that occur in the on-power condition (zero power hot to full power), with minimum recourse to feed and bleed action. The inventory transfer between **cold pressurized and zero power hot**, to accommodate shrink and swell, is via the feed and bleed system and D_2O storage tank inventory.

⇔ ***Obj. 7.10 c)***

Another advantage of the use of a pressurizer is that it results in addition/removal of inventory at HTS operating temperature directly to/from the pressurizer during transients. This minimizes heat losses and thermal stresses as compared to a solid system (ie. where inventory is cooled as it leaves the system and heated as it returns to the system via the bleed/feed path).

Response of Feed And Bleed Systems To Reactor Power Changes

For fine control using feed and bleed, and at the high working pressures used in the HTS, fairly small sized valves are used. Inventory transfer rates, and thus control of pressure transients, are limited.

⇔ ***Obj. 7.11 a)***

At stations **without pressurizers**, the **demands on the Feed and Bleed** system are **reduced by** using the following techniques:

a) **Operating the station** (for the maximum possible time) as a **base load unit**, thus reducing the need for power manoeuvres and resulting changes in HTS temperature, and therefore pressure changes.

b) **Maintaining HTS average temperature** essentially constant in the at-power condition. This is achieved **by ramping down boiler pressure**, and therefore boiler temperature, as reactor power is increased. Boiler temperature and reactor inlet temperature can be assumed equal, since there should be little ΔT between the HT D_2O at the boiler outlet and the boiler temperature. Thus, as reactor outlet temperature increases (with an increase in reactor power) reactor inlet temperature, under the same conditions, will decrease. The average HTS temperature, ie. the mean of the inlet and outlet temperatures, will remain essentially constant over the power range. System shrink and swell, and therefore feed and bleed requirements, are thus minimized. This effect is shown in Figure 7.5 at the top of the next page.

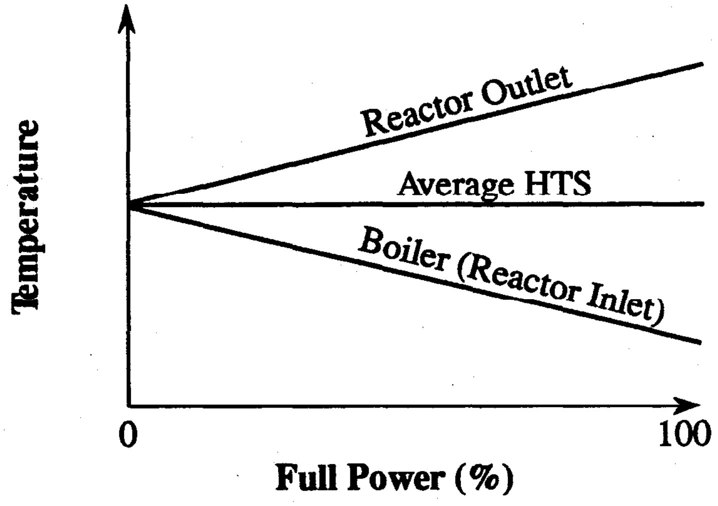


Figure 7.5
Reactor, Boiler and HTS Temperature Trends

Obj. 7.11 b) ⇔

The inventory transfer between **cold pressurized and zero power hot**, to accommodate shrink and swell, is via the feed and bleed system and D_2O storage tank inventory.

D_2O TRANSFER AND STORAGE

Obj. 7.12 a) ⇔

D_2O Transfer System (Interunit Tie)

At a typical CANDU generating station (single or multi-unit), provision must be made to ensure that **sufficient quantity and quality of D_2O is available for extended, and safe unit operation.**

Each station (multi-unit) has a **central D_2O storage facility** to receive shipments of D_2O from the manufacturing plants. It can be **pumped** from this central location to the reactor systems as required. This facility is also capable of **holding** the D_2O from one moderator or one HTS, should a reactor system require draining.

This central supply and distribution system reduces handling of D_2O **drums** and, therefore, reduces personal exposure to tritium from any spills that may occur. It is also a **faster** method of transferring D_2O. It also allows transfer of D_2O **between units.**

Separate storage is supplied for any **downgraded** D_2O which may have escaped or have been removed from the reactor systems. This is the usual source of D_2O for the station upgrading facility. Note, that since **HTS** D_2O has a lower tritium content than the **moderator, separate storage** is provided for each system.

D_2O Storage Tanks

⇔ *Obj. 7.12 b)*

Each unit's HTS has its own individual D_2O storage tank. Its **purposes** are to:

a) Provide enclosed **storage** for D_2O to **makeup leakage** from the HTS.

b) **Accommodate** system D_2O **shrink and swell** during reactor power manoeuvres.

c) Provide a **positive suction head** to the HTS feed (pressurizing) pumps.

As indicated in (b) above, the storage tank level will vary with reactor operating state.

⇔ *Obj. 7.12 b) i)*

It is important to maintain a **minimum level** in order to ensure **adequate feed pump suction head**, and to provide an inventory to **cover expected "normal" losses.**

⇔ *Obj. 7.12 b) ii)*

Too high a level at low power may result in the tank being completely filled by the swell as power increases. The tank forms part of the sealed HTS system, even though at a lower pressure (typically 10-20 kPa(g)). The **vapour space** above the D_2O is filled with **helium** and providing both a non corrosive, non explosive atmosphere with the ability to remove any D_2 (produced by radiolysis) by purging. This space would be lost on very high level, allowing this tank to pressurize. Any **overpressure** is relieved initially by **valving** to the recovery/collection system. Extreme overpressure protection is provided by a rupture disc, which will **discharge** excess **coolant to containment.**

SUMMARY OF THE KEY CONCEPTS

- Low pressurizer level could cause exposing the electric heaters to the steam causing burnout. Also the level must be maximized to ensure that there is sufficient inventory for rapid shrinkage make-up. High pressurizer level could cause the pressurizer to go solid, hence losing pressure control.
- Pressurizer level is ramped with power changes to accommodate shrink and swell and to minimize feed and bleed requirements.
- Feed and bleed requirements are minimized for systems without pressurizers by ramping down boiler pressure as reactor power is increased. This maintains HTS average temperature constant to minimize swell. To further help, these units are run as base load units.
- The feed and bleed system provides the inventory transfer between the cold pressurized state and zero power hot conditions.

- The purpose of the inter-unit D_2O tie is to centrally store and distribute D_2O and allows transfers of D_2O between units.
- The purpose of the D_2O storage tank is to provide D_2O for loss make-up, accommodate shrink and swell and provide a positive suction head to the feed pumps. A minimum level must be maintained to make-up D_2O for losses and to ensure adequate suction head at the feed pump. A high level could cause the tank to go "solid" resulting in loss of coolant to collection/recovery or to containment through the rupture disc.

Pages 29-32 ⇔

You can now work on **assignment questions 1-18.**

BLEED FROM THE SYSTEM

We have already mentioned that a **portion of the HTS inventory** is diverted from the system on a continuous basis, and put through a **purification** process.

This clean up will be performed by a combination of **filters, ion exchange columns and strainers**. Ion exchange resins are generally **not able to tolerate excessive temperatures.** Temperatures greater than ~60°C may cause resin efficiency to decrease and perhaps cause resin breakdown with the release of, typically, fluorides and chlorides. These ions can promote stress corrosion cracking in the zirconium and stainless steel components of the HTS (discussed in the Materials course). Note that in some stations purification is performed at full system pressure, at other stations it is performed at a reduced pressure.

The purified D_2O is either returned to the HT system or it can be held in the D_2O storage tank at nearly atmospheric pressure and cooled (as previously mentioned). This tank is maintained at a pressure close to atmospheric. It also accommodates the excess D_2O due to swell on a unit warmup from a cold state (the D_2O transfer and storage system is used, as required, to maintain the D_2O storage tank level in the correct range).

Therefore, for storage at all stations and purification at most stations, it is necessary to both cool and depressurize any bleed from the HTS. This is accomplished differently at different locations, but there are two basic methods described below.

Bleed/Purification Using Bleed Condensers

A representative pressure and inventory control/purification system is shown in Figure 7.6 *.

* This diagram is provided at the end of the module. It can be unfolded and kept in sight for your reference.

The bleed condenser has two major roles:

a) To reduce the pressure and temperature of any bleed from the HTS from approximately 9-10 MPa and ~300°C (8 MPa, 250°C at some stations) to 2 MPa and ~200°C.

b) To accommodate any discharge of D_2O from the HTS. This can be in either liquid (via the HT pressure relief valves) or vapour (from the pressurizer via the steam bleed valves).

The bleed condenser will, as its name implies, condense any bleed flow from the HTS. There are **two methods** of achieving this condensing action:

⇔ *Obj. 7.13 a)*

Reflux Cooling

a) This is achieved by taking a flow of already cooled and purified D_2O which is being recirculated or returned to the HTS by the pressurizing (feed) pumps and passing it through a tube bundle located in the bleed condenser. As well as condensing the steam, this heats the D_2O that is returning to the HTS, thus efficiently recovering this heat.

Spray Cooling

b) This is achieved by spraying cooled D_2O into direct contact with the incoming bleed flow (note the bleed flow will flash to steam as it encounters the lower pressure of the bleed condenser).

Spray cooling is used as a backup to reflux cooling, should reflux cooling not be able to maintain the process at its required setpoint. If the reflux flow is at a maximum and pressure continues to increase in the bleed condenser, spraying will commence. This direct contact method of condensing should quickly lower pressure but at the **expense of mixing already cooled and purified D_2O with that yet to be treated.** This places a **heavier load on the purification circuit**. Spray cooling would also likely add to degassing of the coolant in the bleed cooler. This will result in the impairment of reflux cooling. This will also lead to **level control problems** in the bleed condenser, since the incoming bleed will be at a high rate, with spray cooling adding to the inventory.

⇔ *Obj. 7.13 b)*

As previously noted, the D_2O leaving the Bleed Condenser will be at a pressure of approximately 2.0 MPa and a temperature of about 200°C.

Further cooling to less than 50°C, required before passing to the ion exchange columns, is performed by the Bleed Cooler.

Details of the control systems used in the bleed condenser and cooler will be covered in the I&C Course 236. The control requirements cover bleed condenser level and pressure, plus bleed cooler exit temperature.

Note that electric immersion heaters can be used to establish the initial saturation conditions in the bleed condenser (only at some stations). **Relief valves** are necessary to provide pressure relief for the bleed condenser, when the level rises enough to cause the bleed condenser to go "solid". The bleed condenser relief valves **discharge into recovery sumps** (or tanks in some stations) within containment. (These component are not shown in Figure 7.6.)

BLEED/PURIFICATION USING A DEGASSING CONDENSER

A representative pressure and inventory/purification circuit using a degassing condenser is shown in Figure 7.7 *.

* This diagram is provided at the end of the module. It can be unfolded and kept in sight for your reference.

Note that purification in this type of arrangement is conducted at full system pressure. Because this purification flow is driven by the HT pumps, it is independent of the bleed circuit. Hence bleed flows can be quite small during system operation. This type of purification will be discussed in more detail in a later module of this course.

For this system the degassing condenser has the following major roles:

a) To accommodate any discharge of D_2O from the HTS. This can be in either liquid (via the HT pressure relief valves) or vapour (from the pressurizer via the steam bleed or steam relief valves).

b) To reduce the pressure and temperature of any flows from the HTS from approximately 9-10 MPa and ~300°C to 1.2 MPa and ~190°C.

c) To degas flows from the HTS. This degassing function will be discussed in a later module of this course.

Obj. 7.14 ⇔

The degasser condenser will condense flow from the HTS by **spraying cooled D_2O** into direct contact with the incoming flows (which will flash to steam as it encounters the lower pressure of the degassing condenser).

Further cooling to less than <~70°C (typically ≤30 °C) will be performed by the Degassing Cooler before the D_2O is returned to the HTS or D_2O storage tank. This further cooling is required because high temperatures at this point would cause net positive suction head problems at the feed pump. Note there is no temperature control on the degasser cooler (other than the high temperature over-ride on the level control valves). The recirculating cooling water is always at a maximum flow rate to ensure maximum cooling.

Note that the electric immersion heaters can be used to maintain the conditions in the degasser condenser for degassing (when steam bleed flows are insufficient to maintain pressure). Just like the bleed condenser, **relief valves** are necessary to provide pressure relief for the degasser condenser when the level rises enough to cause the degasser condenser to go "solid" (these are not shown in Figure 7.7). The degasser condenser relief valves discharge into **recovery sumps** within containment.

POWER MANOEUVRES

Figures 7.6 and 7.7 show, in a very simple format, two types of pressurizer systems and a feed and bleed system fitted to CANDU units. We can use these diagrams to explain how the different systems will respond to normal power manoeuvres (between 0% and 100% FP) and a limited number of system upsets.

Pressurizer System

⇔ *Obj. 7.15*

As mentioned previously, an **increase in reactor power** raises **average HTS temperature.** This causes a corresponding **coolant swell** causing an increase in pressure. The increase in pressure and inventory will cause:

a) Additional D_2O **inventory** to **enter** the **pressurizer,**

b) The **steam space** above the liquid in the pressurizer to be further **compressed.**

Effect (b) will be countered by the control system **opening the steam bleed valves** in the pressurizer until pressure is once again at the setpoint.

Since pressurizer level setpoint is ramped upwards as reactor power increases, the inventory transferred to the pressurizer will provide the extra D_2O required to bring the level to its new setpoint. Any **discrepancy will be made up with bleed valve opening.**

The steam discharged to the bleed condenser, plus any additional bleed flow input, will cause **pressure and level in the bleed condenser to increase.** In the case of the **degasser condenser,** the steam discharge and any additional degassing flow will similarly cause its **pressure and level to rise.**

Pressure will be returned to setpoint by some **additional reflux flow** while the bleed condenser input is at its increased level. **Spray action is not likely** to occur for a normal power manoeuvre. For the **degasser condenser case,** the pressure reduction will be performed by **spray cooling.**

The increase in bleed condenser/degasser condenser level will be removed by an increased **opening of the level control valves.**

The additional outflow from the bleed condenser/degasser condenser will **increase the loading on the bleed/degasser cooler**. In the case of the bleed cooler, **additional cooling water flow** will be required to maintain the temperature at its setpoint. For the degasser condenser, **the temperature at the degasser cooler outlet will increase** slightly as the thermal load increases (recall that RCW valves are always fully open).

Once the new steady state power has been established, it is probable that reflux, level and cooling water control valves (if any) will return to their pre-manoeuvre positions.

On a large power reduction, HTS coolant shrink will result in a decrease in pressurizer level and a slight pressure reduction in the pressurizer steam space. Pressurizer heaters will come on to restore system pressure to setpoint.

Obj. 7.15 ⇔

Feed and Bleed System

For a feed and bleed system, an **increase in reactor power** output will cause a new, **lower boiler pressure setpoint to be generated.** Recall that this is intended to keep the average heat transport system temperature relatively constant during normal power maneuvering. However, the range of boiler pressure adjustment is limited - to achieve reasonable thicknesses of boiler vessels (high pressure limit) and maintain high thermal efficiency of the cycle (low pressure limit).

Because of these limitations, average **heat transport system temperature will increase slightly** during reactor loading. Therefore, HTS pressure will also increase. **Opening the bleed valve** will be necessary to reduce pressure to the setpoint.

The additional bleed flow will bring about a similar response (as discussed earlier in the pressurizer section) from bleed condenser pressure and level controllers and bleed cooler temperature controller.

Note that for a reduction in power, an opposite response will occur. HTS average temperature will reduce, resulting in a drop in HTS pressure. This pressure decrease will require feed action to restore pressure to the setpoint.

Bleed action will reduce, resulting in less reflux flow to prevent bleed condenser pressure falling. Outflow from the bleed condenser will be reduced to maintain level which will in turn reduce loading on the bleed cooler.

SUMMARY OF THE KEY CONCEPTS

- Bleed condenser pressure is controlled by condensing D_2O by reflux cooling and spray cooling. Spray cooling is used as a backup since it increases load on the purification circuit and creates level control problems. For stations using a degasser condenser, cooling is by spray cooling only.
- As reactor power increases, pressurizer systems will respond as follows:
  - HTS temperature increases, causing swell and an increase in HTS pressure,
  - Steam bleed valves open to reduce HTS pressure,
  - Pressurizer level increases due to swell (level setpoint is also ramped up),
  - Bleed condenser (or degasser condenser) level increases and load on the bleed (or degasser) cooler increases,
  - Bleed system action should be minimized.
- As reactor power increases, for a feed and bleed system (no pressurizer), response will be as follows:
  - Boiler pressure is ramped downward to maintain HTS average temperature constant, hence HTS pressure increase is minimized,
  - Bleed condenser level increases due to increased bleed flow and load on the bleed cooler increases.

You can now work on **assignment questions 19-21.**

⇔ ***Pages 32-33***

HT Pressure Relief

⇔ ***Obj. 7.16***

Pressure relief must be provided to **prevent overpressurization,** with subsequent rupture of components in the HTS.

Rupture of components could result in one or a combination of the following:

1) A HT coolant spill requiring Emergency Coolant Injection if the loss of coolant is large enough (ie. loss of heat transfer medium),

2) Fuel failures due to the decrease in cooling capacity (as a result of voiding in the HTS due to reduced system pressure),

3) A reactor power increase due to an increase in reactivity as a result of the positive voiding coefficient. This situation would require the operation of shutdown systems to reduce power if the Reactor Regulating System (RRS) is not capable of control.

Pressure relief obviously reduces the possibility of these undesirable events occurring.

Obj. 7.17 ⇔

Note that events causing slow HTS swell (pressure increases) are not normally of major concern since these events are handled within the capacity of the pressure and inventory control system. On the other hand, **rapid pressure increases** (beyond the capacity of the pressure and inventory control system), if not counteracted, will cause serious overpressurization.

Obj. 7.18 ⇔

Overpressurization in the HTS can be caused by:

1) **Mechanical Compression of the Coolant**

   This could be the result of the pressurizing feed pumps supplying D_2O to the system at a rate above that which pressure and inventory control can accommodate (eg. insufficient bleed from the HTS due to bleed valve malfunction).

   In some stations this condition is also possible during refuelling due to overpressurization by the fuelling machine pressurizing pumps. This would only be a concern if the overpressure relief devices on the fuelling machines failed to function.

2) **Coolant Swell Due to Increases in HTS Temperature**

   If the coolant swell, as a result of an increase in HTS average temperature, cannot be contained by the pressure and inventory control systems, major overpressurization of the HTS can occur.

   These events are potentially more hazardous than mechanical over-pressurization, because the levels of over pressure achievable may be very large (ie. greater than the capacity of the relief valves).

   Events leading to this type of overpressurization include:

   a) Pressurizer heaters failing to turn off as the HTS pressure setpoint is reached. The increased boiling in the pressurizer will increase D_2O pressure in the pressurizer. Since the pressurizer and HT system are connected, pressure will also increase in the main HTS.

   b) Loss of reactor regulation leading to reactor power increasing above normal full power setpoint. Assuming that the heat production rate is greater than the heat removal rate, this results in HTS swell and accompanying pressure rise (protected against by shutdown system trip).

   c) Loss of HTS circulating pumps while at power. The loss of coolant flow will result in an immediate increase in HTS average temperature leading to high HTS pressure (again protected against by shutdown system trip- Protected by both low HT flow and high HT pressure trips.).

d) Conventional (Boiler) System Upsets

i) Cessation of steam flow from boilers due to turbine trip or load rejection. This occurrence is normally countered by providing an alternate heat sink (steam discharge) and by reducing the heat input to the system by means of a reactor stepback or setback. If the remedial measures do not occur, heat removal from the HTS will be impaired, resulting in an increase in HTS average temperature and a corresponding rise in HTS pressure.

⇔ Obj. 7.19

ii) Loss or reduction of boiler feedwater and consequent loss of **heat sink capability**. As heat sink capacity in the boilers reduces, HTS temperature and pressure will increase rapidly. This is mainly due to the loss of the cooling effect from the preheaters (approximately 20% of the heat sink).

Further details on unit upsets will be given in Module 18 of this course.

Methods Of Reducing HTS Pressure

Two basic methods of obtaining pressure reductions exist:

1) **Direct** pressure reduction,
2) **Indirect** pressure reduction.

⇔ Obj. 7.20 a)

Direct pressure reduction refers to methods which are **applied directly** to the HTS.

⇔ Obj. 7.22 a)

Indirect methods are **secondary effects** from actions to control the **steam system.** By first influencing the steam system, there will be a variation in heat sink capacity, which affects HTS D_2O pressure.

Basically, direct pressure reduction mechanisms can handle HTS over-pressures resulting from both mechanical and HT temperature increases while indirect methods are capable of handling only events resulting from HTS temperature increases. The reason for this limitation is explained later in this section.

DIRECT PRESSURE REDUCTION

HTS pressure, usually measured at the reactor outlet header, is used to initiate the various relief actions. These are shown in Figure 7.8 on the next page.

HT Pressure Relief Valves

The **HT pressure relief valves** are the first line of defence against an uncontrolled pressure rise. There are generally a number of them, *Obj. 7.20 c)* ⇔

bj. 7.20 b) ⇔

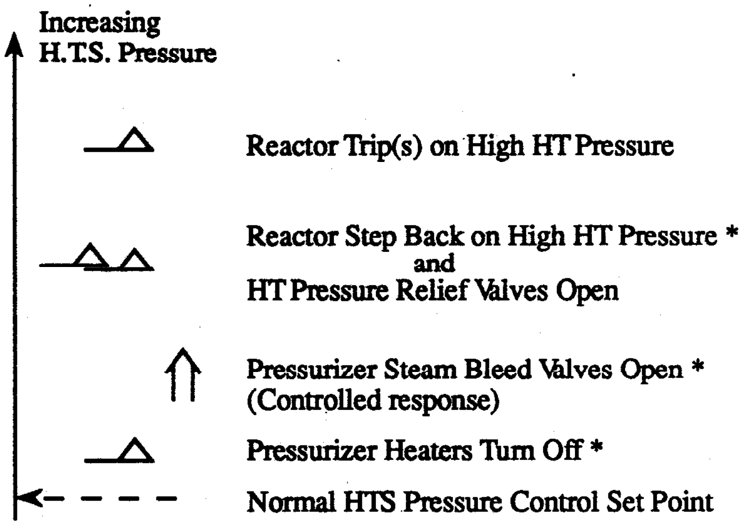
mounted in parallel, discharging from the reactor outlet header(s) into the bleed condenser (or in some stations, the degasser condenser). These valves **discharge** the "excess" **coolant** from the HTS, thus **limiting the over-pressure.** Although the boiler safety valves must be capable of discharging the steam produced by 100% or greater reactor power output, the HTS relief valves have only a limited discharge capacity.

Obj. 7.21 a) ⇔

Obj. 7.21 b) ⇔

The reason for this apparent discrepancy is that the HT relief valves are **sized** to match the overpressurization capability caused only by **mechanical** (pump) **methods.** To provide sufficient relief valve capacity for all likely events would not be desirable as it would increase the risk of **overrelief,** with excessive **loss of inventory**. This would lead to saturated conditions being reached in the main HTS and excessive boiling in the HTS. This could lead to **steam blanketing** and **fuel overheating.**

Note that the relief valves may have staggered set points to provide progressive action as HTS pressure increases.



* Not in all stations

Figure 7.8
Some Direct Methods of H.T.S. Pressure Reduction

Reactor Power Reductions

Obj. 7.20 b) ⇔
Obj. 7.20 c) ⇔

If the pressure relief valves are unable to stop the pressure rise, reactor power may be **stepped back**, ie. a step decrease in reactor power (typically 30%). This would result in a rapid coolant **shrink** with associated rapid drop in HTS pressure. This feature is only available for reactors fitted with control absorbers .

At stations without control absorbers, initial attempts to reduce HTS pressure is by coolant discharge via bleed and pressure relief valves. This will cause a high level in the bleed condenser. This will result in a reactor setback on high bleed condenser level. A **setback** is a power ramp down which results in a more gradual coolant **shrink** than that achieved by a stepback, ie. pressure reduction will be slower than that for a stepback.

A pressure rise not terminated by either relief valves or reactor setback/stepback will eventually **trip** the reactor. This quickly reduces thermal power to decay levels (~ 7% FP) causing a **rapid** HTS D_2O **shrink** and pressure reduction.

Indirect Methods Of Pressure Reduction

⇔ *Obj. 7.22 b)*

⇔ *Obj. 7.22 c)*

Indirect methods, as mentioned earlier, reduce HTS average temperature by first affecting the steam system. This temperature decrease results in coolant shrink which in turn leads to a decrease in HTS pressure.

The temperature reduction is achieved by **lowering boiler pressure** (and therefore boiler temperature since the boilers are saturated). The higher ΔT between HTS D_2O and boiler H_2O will result in a higher rate of heat transfer from the HTS and therefore, a reduction in the average HTS D_2O temperature.

Boiler pressure is lowered by discharging steam from the secondary side. Figure 7.9 illustrates the methods available. Note that a rise in HTS pressure due solely to mechanical over-pressure mechanisms cannot be handled by indirect methods (unless manual intervention is used) and will not, by itself, cause any steam valves to open.

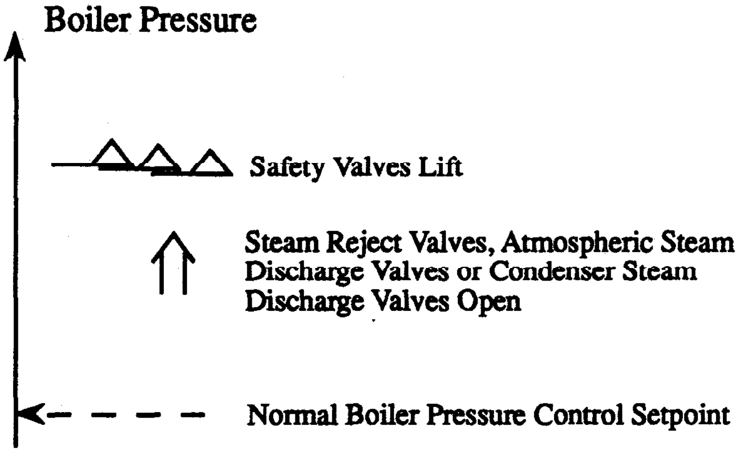


Figure 7.9
Indirect HT Pressure Reduction Methods

At most stations, atmospheric steam discharge valves and condenser steam discharge valves are used. The other stations use steam reject valves which discharge only to atmosphere. All plants, of course, use safety valves.

Discharging steam (to atmosphere or condenser) merely provides an additional or **alternative heat sink** to the turbine. If the heat removal provided by steam discharge is equal to power input to the boilers, then no HTS pressure rise will occur.

The **steam reject valves** at some stations, or the combined atmospheric and condenser steam discharge valves at other stations have at least 75% full power steam capacity. Thus, they are **capable of handling fairly large upsets.** However, should they prove inadequate to control steam pressure, the steam safety valves (set at higher relief pressures) will provide a further heat sink. The safeties are required by law to be capable of >100% steam power removal (ie, this takes into account reactor trip setpoints and channel power variation [ripple] effects).

Steam rejection can also be used, **together with direct methods** of pressure reduction, to cope with coolant swell upsets. In such cases, the steam reject valves (SRVs) could be opened manually by the unit operator. **Manual** SRV opening is a slow response, but the effect is of large capacity. Note that depending on the station, opening of the SRVs (or ASDVs) may also be used as an initiating parameter for a reactor setback to supplement the pressure reduction by reducing the heat input to the HTS.

Automatic opening of the SRVs could be employed on a HT pressure rise. But due to the time delay [~10 seconds] from steam discharge to HT average temperature change, rapid HT overpressures caused by primary system events could not be controlled automatically by this method. With the reactor shutdown and the **heat transport system cold, steam rejection is not capable** of assisting relief devices for heat transport mechanical overpressurization, since there will be no steam to discharge.

SUMMARY OF THE KEY CONCEPTS

- Pressure relief must be provided to prevent damage to the HTS.
- Rapid HTS swells are beyond the capability of the pressure and inventory control system.
- Over-pressurization is caused by mechanical compression of the coolant or by coolant swell.
- Direct methods of HTS pressure reduction act directly on the HTS D_2O (ie. relief valves, reactor power reduction causing HTS D_2O shrink).

- Indirect methods of HTS pressure reduction act on the steam system to control HTS pressure (ie. boiler pressure reduction also reduces HTS temperature, hence HTS D_2O shrinks).
- HTS pressure relief valves are sized for mechanical overpressure events only. To provide pressure relief capacity for all possible events would increase the risk of over relief yielding excessive inventory loss.

MAJOR UPSETS

Failed Open Pressure Relief Valve (PRV)

⇔ Obj. 7.23 a)

Should a PRV fail open, **coolant is being lost** from the system. **Heat transport pressure will fall** rapidly and efforts to restore pressure will commence, ie. pressurizer heaters on (where applicable), feed action to restore inventory.

The flow through the PRV will cause **bleed condenser (or degasser condenser) pressure and level to increase.** Control action, as discussed earlier in the module will be required. A setback on high bleed condenser level may result. High temperature over-ride of the bleed/degasser condenser is also possible *.

* This will be discussed later in this module.

Boiling in the HTS will occur when saturation conditions are reached. The **increased boiling** will impair fuel cooling due to film boiling and decreased coolant flow (due to pump cavitation caused by decreased suction head).

If the valve does not reclose, a **reactor trip** will eventually be generated on low pressurizer level (or low HT pressure where no pressurizer is installed).

Feed Pump Failure

⇔ Obj. 7.23 b)

On failure of the feed pumps, **no makeup to the HTS** will be available (assume for this example that no back-up pumps are available). Where pressurizers are installed, the pressurizer level will decrease while maintaining HTS pressure. This will continue until the level falls sufficiently to limit the pressurizer's ability to react to a major upset. The unit must then be shutdown and cooled down.

In units without pressurizers, heat transport pressure will immediately begin to fall. Boiling in the HTS will occur when saturation conditions are reached. The **increased boiling** will impair fuel cooling due to film boiling and decreased coolant flow (due to pump cavitation caused by decreased suction head).

If the feed pump is not restored, a **reactor trip** will eventually be generated on low HT pressure or HTS low flow while pumps are cavitating.

Obj. 7.23 c) ⇔

Pressurizer Steam Bleed Valve Fails Open

This fault will immediately reduce the pressure in the steam space of the pressurizer and HTS pressure will fall.

Boiling in the HTS will occur when saturation conditions are reached. The **increased boiling** will impair fuel cooling due to film boiling and decreased coolant flow (due to pump cavitation caused by decreased suction head).

In the pressurizer, the intensive boiling will cause the **level** in the **pressurizer to increase,** causing **feed valves to close and bleed valves to open** (ie. level increases due to boiling, but actual inventory is being lost through valve). A reactor **trip** on **low heat transport** system **pressure** is likely. Also, a setback on high pressurizer level is possible.

The flow through the steam bleed valve will cause **bleed condenser (or degasser condenser) pressure and level** to **increase.** Control action, as discussed earlier in the module will be required. A setback on high bleed condenser level may result. High temperature over-ride of the bleed/degasser condenser is also possible *.

* This will be discussed later in this module.

Obj. 7.23 d) ⇔

Failed HT Main Circulation Pump

The majority of operating CANDU reactors require the use of all (typically four) main HT pumps for full power operation. **Loss of one pump** or more will seriously **impair the heat removal capability of the HTS** due to low flow (ie. coolant circulation reduces while the heat input to the HTS continues). **Continued operation** at full power would result in **film boiling** in the fuel channels with a high probability of fuel failures and a large pressure increase.

On the loss of a single circulating pump at these units, **a reactor stepback** will occur to reduce reactor power output to approximately ~65% FP. Note that in two loop systems, trip of a symmetric pump will be required (in some situations, depending on which pump trips, a shutdown cannot be avoided).

At stations where normal operation requires 12 of 16 pumps to be operative (three out of each bank of four), the loss of any single pump in a bank, would require that a **standby pump be started.** Continued operation without sufficient coolant circulation would result in boiling and potential damage as stated above.

For a unit using a feed and bleed system, the resulting increase in pressure would probably overwhelm the bleed condenser capacity. The reactor may **trip** on **high HTS pressure or temperature** before the **high bleed condenser level setback** function is initiated.

Over-ride of Bleed/Degasser Condenser Level Control

⇔ ***Obj. 7.23 e)***

The description of bleed condenser and bleed cooler operation given earlier, indicates that bleed (or degasser) cooler loading is dependent upon flow (which controls level) out of the bleed (or degasser) condenser.

Thus, efforts to control a **high level** in the bleed condenser may produce **outflows**, such, that the bleed cooler **can no longer cool** the D_2O to 50°C or lower. Because ion exchange resins breakdown at high temperatures, additional control action is initiated to enable the bleed cooler to cool the D_2O to a temperature below that which could cause damage.

Since recirculating service water flow through the bleed cooler is always at a maximum, the only alternative to regain control is to **reduce the mass flow rate** of the hot D_2O through the bleed condenser (some stations have a normal fluctuating TCV on the bleed cooler). This mass flow reduction must remain in effect until the **temperature at the bleed cooler outlet is again acceptable**. This action will cause **level control to be lost** in the bleed condenser. If the condition causing the increased bleed flow is short term, things will soon return to normal. If the condition persists, rising bleed condenser level will eventually cause a **reactor setback** in some stations.

The details of this control system are given in the 236 Instrumentation and Control course .

Similarly, temperature protection for the degasser condenser/purification design is provided in two stages. The IX **resins are protected** from high temperature via a similar **high temperature override** at the **purification cooler outlet**. A **high temperature override** also exist at the outlet of the **degasser cooler** to **protect the feed pumps** from net positive suction head problems. If the steam bleed continues (ie. HT high pressure continues, or a valve failure occurs) a reactor **stepback** will occur on **high HT pressure** (the HT relief valves also open at this point).

SUMMARY OF THE KEY CONCEPTS

- A failed open PRV will cause HTS pressure to fall. Film boiling and fuel failures are possible. Bleed condenser pressure and level will increase, with a possible setback on bleed condenser high level and high temperature over-ride. A reactor low pressure/low pressurizer level trip is possible.
- A feed pump failure will cause the HTS pressure to fall . Film boiling and fuel failures are possible. A reactor will trip on low HTS pressure or low pressurizer level/low HT pressure.
- A failed open steam bleed valve will cause the HTS pressure to fall. Film boiling and fuel failures are possible. Bleed condenser pressure and level will increase, with a possible setback on bleed condenser high level and high temperature over-ride. A reactor setback on high pressurizer level and/or a reactor trip on low HTS pressure is possible.
- The loss of a HTS pump reduces coolant flow through the reactor. Continued operation at full power would result in film boiling. Reactor power reductions are required by either stepback on pump loss, setback on high bleed condenser level or high HT pressure or temperature trip.
- The bleed condenser has a high temperature over-ride to protect purification resins from damage, but this causes level control in the bleed condenser to be lost. If the HTS pressure is still high, bleed condenser level will continue to increase (bleed continues) until a setback on high bleed condenser level occurs.
- The degasser condenser has a high temperature over-ride to protect the feed pumps from damage, but this causes level control in the degasser condenser to be lost. If the HTS pressure is still high, degasser condenser level will continue to increase (steam bleed continues) until a stepback on high HTS pressure occurs (HT liquid RV's will also open at that point). Purification resins are protected from damage by a high temperature over-ride at the purification cooler outlet.

Pages 33-36 ⇔

You can now work on **assignment questions 22-31.**

ASSIGNMENT

1. a) The concern with HT pressure that is too low is ______________

   b) A HT pressure that is too high may cause ______________

2. Coolant flow blockages are a major concern because:

   a) ______________

   b) ______________

3. Boiling in the HTS is allowed in (large amounts / small amounts). This boiling (helps / hinders) heat transfer in the channels.

4. It is necessary to have a HT pressure and inventory control system to ensure that ______________

5. The purpose of the feed and bleed system for a unit with a pressurizer in "solid" mode of pressure control are:

   a) ______________

   b) ______________

   c) ______________

   d) ______________

6. The purpose of the pressurizer during "normal" heat transport pressure control mode is ______________________________

____

7. For a pressurizer system in normal mode a HTS pressure rise above the setpoint causes ______________________________

____

____

____

____

8. When HTS pressure reduces below the setpoint the pressurizer heaters will come (on / off) until pressure reaches ___________.

9. The purpose of the feed and bleed system for a unit with a pressurizer in "normal" mode of pressure control are:

   a) ______________________________

   b) ______________________________

   c) ______________________________

   d) ______________________________

   e) ______________________________

10. The purposes of the feed and bleed system for a unit without a pressurizer are the same as (normal / solid) mode control in units with a pressurizer. An additional function is to supply the ______ ______________________________ with D_2O.

11. a) Pressurizer level setpoint is ramped (up/down) for increases in reactor power. This minimizes the requirements for _____

    ____

    ______________________________.

    b) Low level protection is provided to prevent ______________

    ____

    ______________________________.

c) High level protection prevents ______________________________

____

____.

12. The operating concern for a pressurizer level that is too high is

____

____.

13. The operating concerns for pressurizer levels that is too low are:

a) ____

____

____.

b) ____

____

____.

14. For stations not using pressurizers, feed and bleed system requirements are (minimized / maximized) during increases in reactor power by:

a) ____.

This reduces system swell by (increasing / decreasing / maintaining) average HTS temperature which is achieved by (increasing / decreasing) D_2O temperature at the reactor inlet.

b) ____

____

____.

15. The purpose of the inter-unit D_2O transfer system is to:

i) ____

____.

ii) ____

____.

16. The purpose of the D_2O storage tank is to ______________________

____.

17. The problems with operating with a D_2O storage tank that is too low are:

    i) ____

    ____.

    ii) ____

    ____.

18. The problems with operating with a D_2O storage tank that is too high are:

    i) ____

    ____.

    ii) ____

    ____.

19. Two methods for controlling bleed condenser pressure are:

    a) ______________________________ which reduces

    pressure by ____________________________________

    ____.

    This method (is / is not) used as a backup.

    b) ______________________________ which reduces

    pressure by ____________________________________

    ____.

    This method (is / is not) used as a backup.

    c) The backup method is not preferred because:

    i) ____

    ii) ____

20. Degasser condenser pressure is maintained by the use of ________

    _______________, which reduces pressure by _______________

    ____

    ____.

21. For HT systems with and without pressurizers, indicate on the following table, where applicable, the response of pressurizer levels, feed and bleed flows, HTS pressure and temperature, feed/bleed response and boiler pressure for a reactor power increase.

	Units with Pressurizer	Units without Pressurizer
HTS Pressure		
HTS Avg. Temperature		
Boiler Pressure		
Feed and Bleed Action		
Pressurizer Level		

22. a) HTS pressure relief is required because ____.

b) Rapid changes to HTS pressure are a major concern because ____.

23. The two major causes of HTS overpressurization are:

a) ____

An example of this type of overpressurization is ____.

b) ______________________________

An example of this type of overpressurization is __________

______________________________.

24. a) "Direct " methods of HTS pressure relief means:

____

____

______________________________.

b) Two examples of direct methods of pressure relief are:

i) ______________________________.

This reduces the pressure by ______________________

____

ii) ______________________________

This reduces the pressure by ______________________

____

25. a) "Indirect " methods of HTS pressure relief. ______________

____

______________________________.

b) An example of an indirect method of pressure relief is

______________________________.

This reduces pressure by ______________________

____

____

______________________________.

26. The HTS pressure relief valves are sized for ____________________
______________________________________. The reason they
are not sized to handle all over-pressure events is ______________
____
____
____.

27. A failed open pressure relief valve will cause__________________
____
____
________________. In stations using bleed condensers, the reactor
may setback on ____________________________________.

28. A failed HT feed pump will cause __________________________
____
____
____
____
____. A reactor trip
will occur on ______________________ or _________________.

29. A failed open steam bleed valve will cause ____________________
____
____
____
____
____
____
____
____.

30. A failed HT pump will cause a ______________________________

____

____

____

____.

HTS pressure would (rise / fall) because ____________________

____

____.

31. The purpose of the bleed/degasser condenser high temperature override is ______________________________

____

____

____

____

____

Before you move on, **review the objectives** and make sure that you can meet their requirements.

Prepared by: D. Tennant, N. Ritter, WNTD
Revised by: P. Bird, WNTD
Revision date: June, 1992