Module 13

CONTAINMENT

OBJECTIVES:

After completing this module you will be able to:

13.1 State the two types of containment systems in use with CANDU reactors and identify the poised system common to both types. *⇔ Page 5*

13.2 State how pressure is normally maintained subatmospheric for a Pressure Suppression Containment system. *⇔ Page 6*

13.3 State two functions that the total water inventory in containment must provide in the event of a LOCA. *⇔ Pages 6, 11*

13.4 For a pressure suppression containment (PSC) system, describe the functions of the dousing system and how dousing is initiated. *⇔ Page 6*

13.5 For a PSC system, describe the function of the vault coolers (normal operation and during a LOCA). *⇔ Pages 6, 7*

13.6 For a PSC system, describe what containment box-up/button-up is, and how it occurs. *⇔ Page 7*

13.7 Describe the operation of a PSC system during:

- a) A small LOCA, *⇔ Page 7*
- b) A large LOCA. *⇔ Page 7*

13.8 For a negative pressure containment (NPC) system describe the function of:

- a) Pressure relief duct, *⇔ Page 9*
- b) Upper vacuum chamber, *⇔ Page 11*
- c) Main vacuum chamber, *⇔ Page 12*
- d) Dousing, *⇔ Page 12*
- e) Main and upper chamber vacuum pumps, *⇔ Page 11*
- f) Pressure relief valves, *⇔ Page 12*
  - Small or instrumented
  - Large
- g) Vacuum duct (2 functions), *⇔ Page 13*
- h) Vault coolers. *⇔ Page 14*

13.9 For an NPC system, describe:

Pages 11-12 ⇔
a) How vacuum is maintained in the main and upper chamber,
Page 12 ⇔
b) Conditions which cause the PRVs to operate,
Page 14 ⇔
c) What containment box-up / button-up is and how it occurs,
Page 15 ⇔
d) How dousing is initiated.

13.10 Describe the operation of an NPC system during:

Page 15 ⇔
a) A large LOCA,
Page 16 ⇔
b) A small LOCA.

Page 16 ⇔
13.11 State the purpose of airlocks for both types of containment systems.

Page 17 ⇔
13.12 Explain the purpose of the Filtered Air Discharge System (FADS).

Page 18 ⇔
13.13 Explain the purpose of the hydrogen igniters.

Page 19 ⇔
13.14 State how pressure is normally maintained subatmospheric for a Negative Pressure Containment system.

Page 19 ⇔
13.15 Explain why a containment system should be available at all times when a unit is at power. List the required unit state if the containment system is to be made unavailable.

* * *

INSTRUCTIONAL TEXT

INTRODUCTION

The containment system protects the public, station personnel and equipment against the adverse conditions following an increase in reactor building pressure, usually as a result of a LOCA. This module will discuss the types of containment systems, the types of containment structures, the function and operation of containment components.

The containment system is designed to contain:

a) The energy released as heat and pressure.
b) The activity released, eg, tritium and fission products to within limits.

The LOCA, which usually triggers the use of the containment system, may have been caused by such events as:

a) Mechanical failure of the HTS, for example, as a result of long term poor chemical control or a system transient.

b) Loss of Regulation Accident (LORA) with failure to shut down the reactor quickly enough with subsequent pressure tube failure.

c) Loss of Class IV power with failure to shut down the unit, again, followed by pressure tube failure.

For events such as (b) and (c), failure of both shutdown systems must occur (such a combination of failures highly unlikely). Due to failure to shutdown the reactor, the amount of energy released to containment under these two circumstances would be much higher than that from a LOCA in which reactor power is terminated by shutdown system action.

Let us recall, from Module 12, the events following a LOCA into containment at full power. The Heat Transport System (HTS) D_2O at high pressure and temperature, will be released, and a portion of it will flash to steam. The reactor building temperature and pressure will increase. (Pressure may be above atmospheric for a few minutes, whereas temperature may rise to as high as 95°C for several hours.)

The containment structure must provide the initial heat sink under these conditions until alternate long term heat sinks can be made available (eg. ECIS Recovery Heat Exchangers) following ECIS operation to rewet and cool the fuel.

The amount of fission products released will depend on how rapidly the power pulse was terminated, how the fuel was operating prior to the LOCA and how well the ECIS has performed. When the ECIS is fully functional and copes with the LOCA, a large number of fuel failures is unlikely, and the quantity of fission products released will be small. (Remember, the primary function of ECIS is to maintain fuel cooling, which will prevent/minimize fuel failures following a LOCA.) However, a LOCA can cause tritium releases in the reactor building in the order of tens of thousands of times the Maximum Permissible Concentration in air *(MPCa).

* **Recall, from radiation protection training, that working in 1 MPCa tritium concentration for 40 hrs/wk for 1 year will give the maximum permissible annual dose for whole body exposure.**

If for any reason ECIS is unable to fully cope with the LOCA, a large number of fuel failures are almost certain and a large release of fission products is to be expected. Higher than normal radiation fields will occur inside containment.

Containment is basically a structural envelope which contains the reactor and high pressure components of the HTS. At various locations interfacing with other systems will occur, eg. boilers. The interfacing depends on how much equipment is located within containment.

In earlier CANDU stations and at 600 MW units, all boilers and HTS circulating pumps are totally within containment. This naturally increases the size of the reactor buildings required to house these components.

In the case of the older CANDU units, a larger containment structure is required to accommodate the larger volume of the reactor vaults.

At newer stations, the decision was made, following a detailed safety study, to relocate various equipment items and thereby reduce the size of containment required. For example, only the main HT pump bowls and boiler bases are within containment. Figure 13.1 below shows the extension of the HTS beyond the containment boundary.

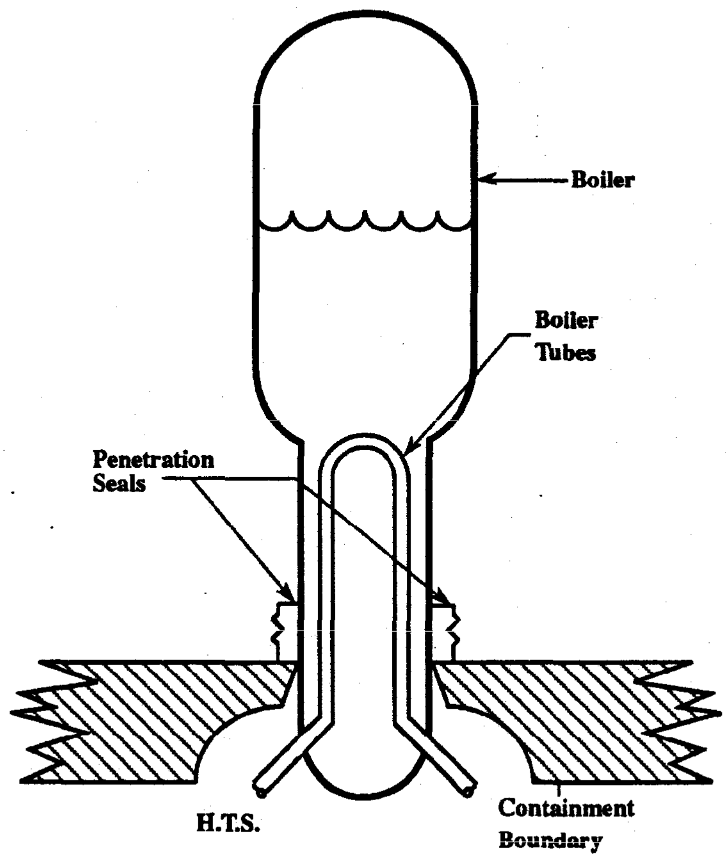

Figure 13.1
Typical Boiler Configuration

The larger containment structure of older stations has areas that have some accessibility on power (with and without using access control, depending on the area). This feature is not present at the newer stations.

Containment effectiveness is determined by the leak rate from the structure during an accident situation. The basic principle is, therefore, to eliminate or minimize leaks and, if leakage occurs, it must be in a controlled manner and monitored. This is one reason why containment is maintained subatmospheric. Any leakage is inward. An exhaust flow is maintained to keep the pressure subatmospheric. This exhaust is filtered and monitored.

Note that all containment penetrations (piping, cables, airlocks, transfer chambers, etc.) have seals to prevent leakage. A periodic pressure test is also performed to verify containment integrity.

Outleakage will occur if containment pressure is above atmospheric. If pressure exceeds design limits, containment structural damage can occur.

TYPES OF CONTAINMENT

⇔ *Obj. 13.1*

Two types of containment systems are currently employed in CANDU reactors:

1) **Pressure suppression** - used in CANDU 600 MW single unit stations.
2) **Negative pressure** - used at all Ontario Hydro multi-unit stations.

The effectiveness of both types of containment is dependent upon having a **poised ECI system** available to limit the longer term energy input in the event of a LOCA.

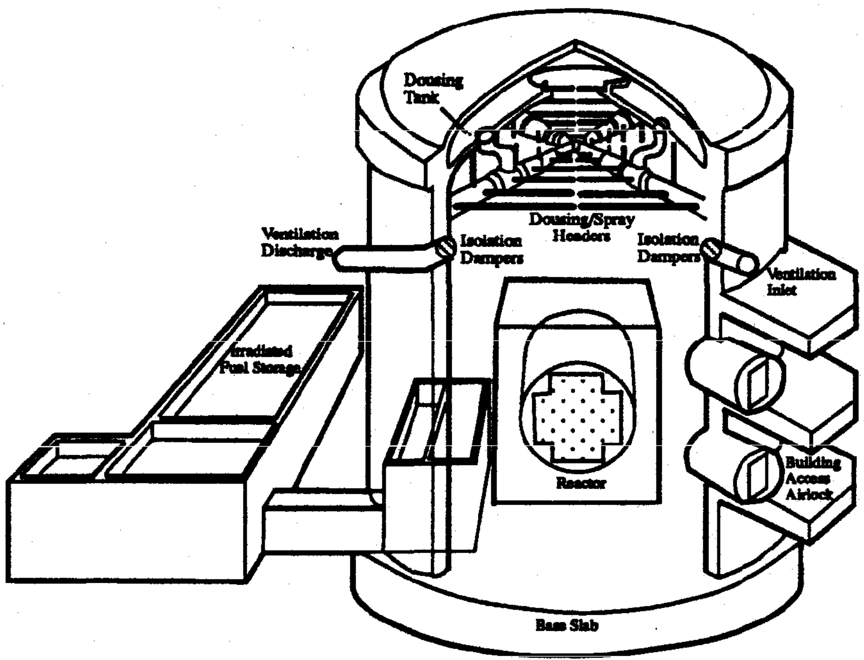

Figure 13.2
Typical Pressure Suppression Containment System

PRESSURE SUPPRESSION CONTAINMENT (PSC)

A general schematic of a pressure suppression system is shown in Figure 13.2 at the bottom of the previous page.

Containment consists of a prestressed concrete structure with a domed roof, a dousing system, airlocks and a closure system. The concrete walls are over 1 metre thick.

All internal surfaces of the containment structure, eg, the upper dome, outer walls, and base slab, the outer surfaces of the irradiated fuel discharge bay and airlocks normally form part of the containment boundary (during fuel transfers, the boundary extends to the surfaces of the irradiated fuel storage bay).

Obj. 13.2 ⇔

During normal operation, the **pressure** within containment is maintained **slightly subatmospheric** by **ventilation system** operation.

When, for any reason, the containment pressure increases above atmospheric, and especially during a LOCA, the leakage from containment must be limited. The release of tritium and fission products to the environment is kept below the maximum permissible level by not exceeding a specified leak rate. For any size of LOCA, the overpressure should not exceed the limit of ~120 kPa(g).

Obj. 13.3 ⇔

Obj. 13.4 ⇔

* Recall from Module 12 that a portion of the dousing water is reserved for ECI injection.

A dousing tank is located in the dome of the containment building. It holds light water for both **dousing** (~2000 m^3) and medium pressure **emergency coolant injection** (~500 m^3)*. Dousing is **accomplished by the opening of the dousing valves.** With these valves open, water flows by gravity from the storage tank to the spray headers to cause dousing. (These valves are channelized and require a majority vote to initiate dousing). **Dousing** condenses the released steam and thus:

1) **Absorbs the heat energy in the steam;**

2) **Reduces the magnitude and duration of the containment overpressure** pulse;

3) **Dissolves soluble fission products** (eg, I^{131}), and **entrains insoluble fission products**, minimizing the airborne spread of contamination.

Note that noble gas fission products, like Krypton 88, will be unaffected by dousing.

Obj. 13.5 ⇔

The containment structure is normally **cooled and dehumidified by vault coolers.** This is necessary due to sources of heat (HTS piping, boilers, etc.) and humidity (small leaks of D_2O, H_2O) within containment.

PSC Button-up/Box-up

⇔ *Obj. 13.6*

During a LOCA, the containment structure can be isolated from the environment by **closing the isolation points**. The isolation points are **dampers** at the ventilation penetrations and **valves** on the piping penetrations. This is termed "button-up" or "box-up". This is done to prevent leakage above permissible levels (as discussed in the previous section).

Button-Up (Box-Up) is typically initiated by any of the following signals:

- High containment radioactivity,
- High containment pressure,
- High exhaust and stack radioactivity or loss of stack monitoring.

Operation of PSC During a Small LOCA

⇔ *Obj. 13.7 a)*

In the case of a small LOCA, the energy release will be smaller but will likely occur over a longer period. Containment pressure will slowly increase, and **box-up** will occur on one or more of the initiating parameters. The **vault coolers** may condense the resulting steam (and limit containment pressure) such that pressure to initiate dousing is not reached.

⇔ *Obj. 13.5*

If pressure continues to rise to the dousing setpoint (~14 kPa(g)), some **intermittent dousing** action will occur as the dousing valves open and close on staggered setpoints, as shown in Figure 13.3.

Under these conditions after the initial period of dousing, which will cease when pressure falls to the dousing "OFF" setpoint (~7 kPa(g)), pressure will probably again increase and further dousing cycles may be required until pressure remains below the "OFF" setpoint. As energy input from the LOCA falls (due to depressurization of the HTS), condensation on walls, and vault coolers becomes a major factor in keeping containment pressure low.

Operation of PSC During a Large LOCA

⇔ *Obj. 13.7 b)*

For a large LOCA containment pressure and temperature increase rapidly. Containment **button-up** (and a reactor trip) occurs at a containment pressure of about 3.5 kPa(g) and **dousing commences** at an overpressure of approximately 14 kPa(g).

For a large LOCA, there will be a period of continuous dousing which will quickly reduce containment pressure towards atmospheric. Further reduction in containment pressure will be effected by the **vault cooling** system and further periods of dousing as required. This response is also shown in Figure 13.3.

Once pressure has returned to near atmospheric, efforts can be made to clean up the containment atmosphere.

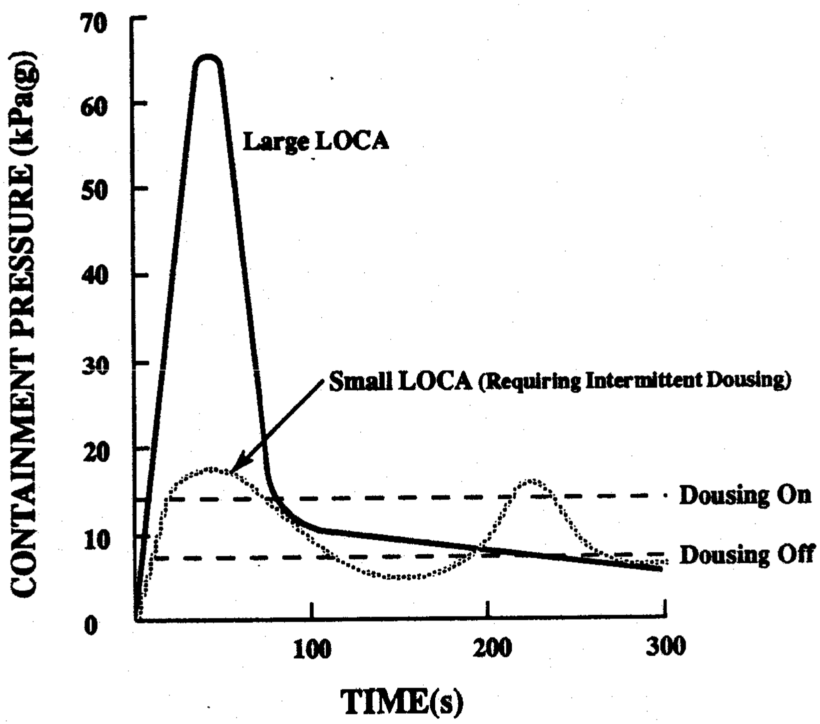

Figure 13.3
Typical Response of Pressure Suppression Containment To Large and Small LOCAs

SUMMARY OF THE KEY CONCEPTS

- Two types of containment are pressure suppression containment and negative pressure containment. A poised system common to both is the ECI system.
- PSC pressure is normally maintained subatmospheric by the ventilation system.
- The dousing system limits containment pressure by condensing steam released as a result of a LOCA. Also, soluble and insoluble fission products will be dissolved/entrained in the water.

- Dousing, for a PSC system, will be initiated by high vault pressure and occurs via the opening of dousing valves, which are located in the distribution lines below the dousing tank.
- Box-up (button-up) is a means of isolating the containment structure from the enviroment. Ventilation and piping penetrations are closed to prevent leakage above permissible levels.
- Following a large LOCA, for a PSC system, containment pressure quickly starts to rise. Box-up (or button-up) is initiated on one or more of the initiating parameters. The dousing valves will open to initiate dousing to cope with the large pressure increase. As containment pressure reduces, dousing stops, but will restart as required to maintain pressure low.
- Following a small LOCA, for a PSC system, containment pressure slowly starts to rise. Box-up (or button-up) is initiated on one or more of the initiating parameters. The vault coolers will act to condense the steam and will cool the vault atmosphere. This may limit the containment pressure increase to the point where no dousing action is required. If containment pressure continues to rise, dousing will start and stop intermittently to keep containment pressure low.
- Vault coolers normally act to cool and dehumidify the containment atmosphere.
- The water in the dousing tank is for both dousing and ECI injection.

NEGATIVE PRESSURE CONTAINMENT

This form of containment is used for all multi-unit CANDU stations, with some site variations.

The system is characterized by a vacuum building which, as its name suggests, is normally held at a pressure well below atmospheric, typically 7-14 kPa(a). The reactors themselves are housed in separate reinforced concrete buildings. The two structures are connected by a **pressure relief duct**, which allows any steam/air mixture in the event of a LOCA to travel to the vacuum building. The vacuum building (see Figure 13.4) is normally isolated from the relief duct (more specifically, the pressure relief valve manifold) by a number of pressure relief valves. The reactor buildings (and pressure relief duct) are normally maintained at a slightly subatmospheric pressure to minimize outleakage of potentially contaminated air during normal reactor operation (by purge driers, or ventilation systems *, depending on the station).

⇔ Obj. 13.8 a)

* More information is provided on page 19.

At older stations the reactor containments are larger than those of other sites. This dictates that the vacuum building must have a larger volume.

The vacuum building concept is unique to multi-unit CANDU stations for which it offers an economical advantage over individual unit containment systems.

One disadvantage of a Negative Pressure Containment System (NPC) is that following a LOCA on a single unit, the vacuum building becomes unavailable to the other units, and shutdown of these unaffected units is required. Note also that the ECIS is no longer available for injection to the other units, hence a shutdown would be required anyway.

Following a LOCA, the subsequent rise in pressure in the pressure relief duct will cause the pressure relief valves, to open. The air and steam/contaminants produced by the LOCA are then drawn from the reactor vaults into the vacuum building. This means that the affected unit is purged of its contaminated atmosphere in a relatively short period (30-60 seconds). Containment pressure in the affected unit can return to subatmospheric once again. This minimizes both the contamination of equipment within the reactor building and any uncontrolled releases.

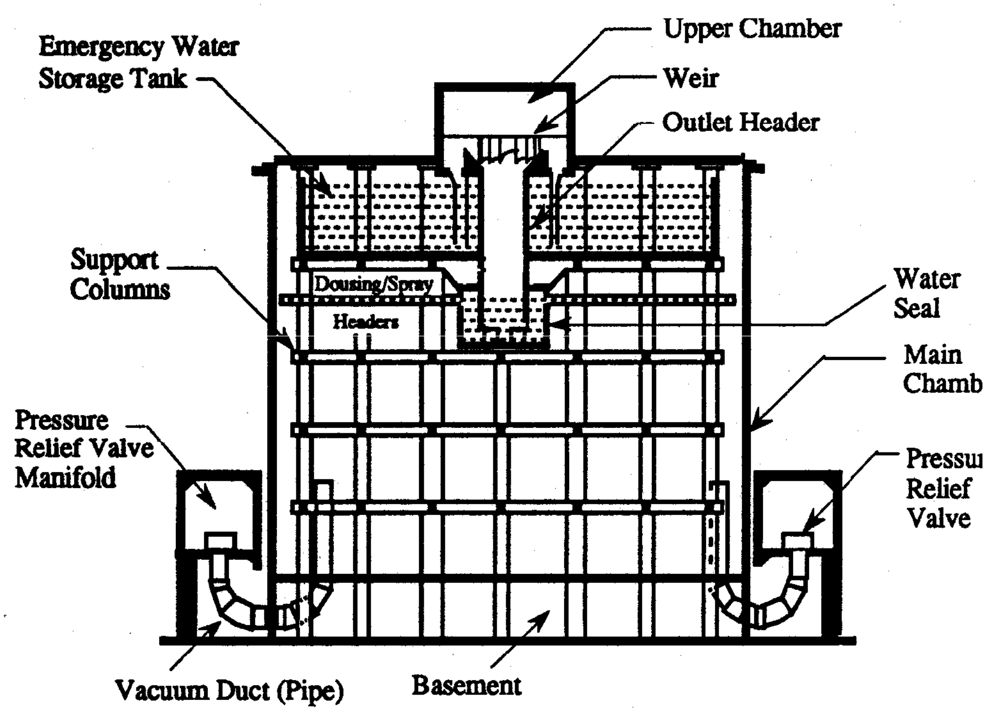

Figure 13.4 : Typical Vacuum Building

One additional note to make here is that the requirement to remove the steam/air mixture from the reactor vaults requires a clear passage to the vacuum building. This is why the fuelling machines should not be parked side by side in the fuelling machine duct (part of the pressure relief path to the vacuum building). Improper parking of the fuelling machines with a LOCA in progress could restrict steam/air movement, which would allow pressure on the LOCA side of the fuelling machines to build up. This could cause damage to the reactor vault due to overpressurization.

Note that this containment structure will leak at a higher rate during the short overpressure during a LOCA. But, this is only short term (ie. NPC has a higher leak rate for short term versus PSC which has a lower leak rate, but for a longer time).

Vacuum building

The vacuum building greatly reduces the chance of leaks from the containment area, by limiting containment overpressure during a LOCA. Without it, even the short duration overpressure transient (30-60 seconds) in the containment area following a LOCA would result in unacceptable leakages to the environment.

The building is a reinforced concrete structure of sufficient volume to accommodate all of the air and steam drawn in from the reactor building and pressure relief duct in the event of an accident.

Note that the upper portion of the vacuum building contains an emergency water storage tank (see Figure 13.4), which contains water for both dousing and the ECIS (in some stations). This water also provides the necessary vacuum isolation between the upper and main chambers plus the water seal in the spray (or dousing) header. ⇔ *Obj. 13.3*

The vacuum building is divided into:

a) Upper Vacuum Chamber

This chamber is **isolated by watersealing** and held at a low subatmospheric pressure, typically ~7 kPa(a), by means of **vacuum pumps** located in the vacuum building basement. Its main **purpose is to provide a ΔP to automatically initiate dousing** action following a LOCA. ⇔ *Obj. 13.8 e) & 13.9 a)* ⇔ *Obj. 13.8 b)*

b) Main Chamber

This has a much larger volume than the upper chamber (typically 60-70 times larger), and again, is maintained at a pressure of approximately ~7 kPa(a). This **pressure is maintained by vacuum** ⇔ *Obj. 13.8 e)*

Obj. 13.9 a) ⇔

pumps, similar to those used for the upper chamber, which are also located in the vacuum building basement. **Isolation from the upper chamber** is by a **water seal**, and **isolation from the containment** structure is by the **pressure relief valves**.

Obj. 13.8 c) ⇔

Obj. 13.8 d) ⇔

The **main vacuum chamber** accommodates the steam-air mixture from a LOCA (or steam line break into containment). It is in this chamber that the dousing will occur. As noted for a PSC system, **dousing** condenses the steam, limits vacuum building pressure increases and dissolves and entrains fission products (except for noble gases).

Pressure relief valves

Obj. 13.8 f) ⇔

The pressure relief valves form the **isolation between the pressure relief duct and the vacuum building**. They are designed to **open automatically** when the pressure in the relief duct rises to just above atmospheric (typically at ~3.5–7 kPa(g)).

Obj. 13.9 b) ⇔

There are, typically, 12 to 20 such valves depending on the station. The majority are termed Pressure Relief Valves (PRV), and three or four, depending on the station, are **Instrumented Pressure Relief Valves (IPRV)**. As the pressure rises in the pressure relief valve manifold (directly connected to the relief duct) to the required setpoint, the pressure acts directly on the PRVs and IPRVs, causing the valves to open (see Figure 13.5 on the next page). This will allow the high pressure air-steam mixture to enter the vacuum building from containment.

When the pressure falls (typically to +3.5 kPa(g)), all PRVs will close while the IPRVs remain open until pressure falls to a subatmospheric level (~ -2 kPa(g)). The IPRVs will then modulate between an open and closed position as pressure varies in a range from -1 kPa(g) to -2 kPa(g).

The **IPRVs can be manually controlled** because the "top" of the valve can be subjected to a vacuum from the vacuum building, causing the valve to open.

At some stations, in addition to PRV's and IPRV's, there are Auxiliary Pressure Relief Valves (APRV) which are physically smaller, and are capable of handling the pressures generated by small LOCA's. Their operating setpoints are lower than those of the larger PRV's. Typically, they open at +1.5 kPa(g) and will reclose as pressure falls to about -6.5 kPa(g). They then will modulate as pressure varies between the closed value and -3.5 kPa(g) when they will once again be fully open.

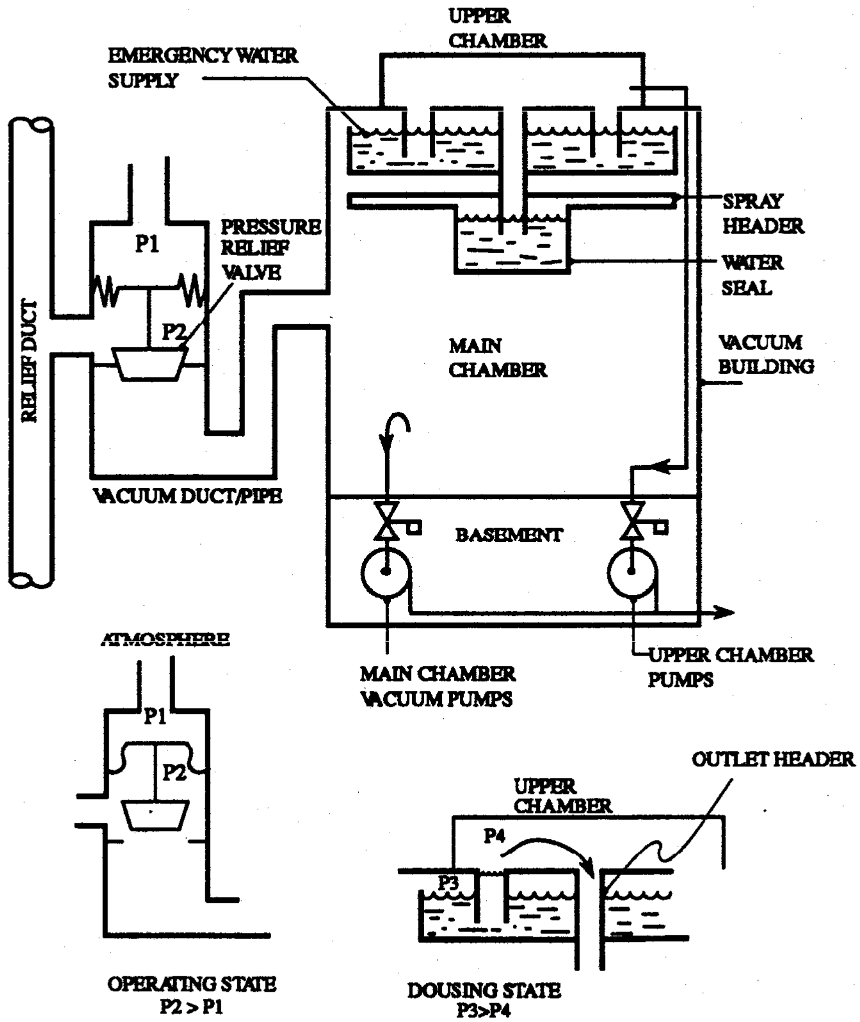

Figure 13.5
Schematic of Typical Negative Pressure Containment System

Note that in the case of a large LOCA, *all* PRVs, IPRVs, and *any* APRVs will open.

Vacuum duct

The vacuum duct (or vacuum pipe) is the **passage from the PRVs into the main vacuum chamber**, allowing the air/steam mixtures following a LOCA to enter the vacuum building. From Figure 13.4 you will notice their shape, and hence the reason for their other name, "J-Tubes".

⇔ *Obj. 13.8 g)*

Their shape serves another **purpose**:

> The duct allows isolation of a PRV from the vacuum building by filling the vacuum duct with water. The filling of the duct forms a water seal between containment and the vacuum building, allowing for maintenance/manual opening of the valve.

Note that the ducts opening is well above, or extends well above, the main chamber floor. This prevents water on the floor (after a douse) from flooding these tubes and forming a water seal. Flooding of these tubes would make the vacuum building unavailable to keep containment pressure subatmospheric.

NPC Button-up/Box-up

Obj. 13.9 c) ⇔

The button-up/box-up method is similar to that previously mentioned for PSC systems, ie. dampers and valves on penetrations close. But for a NPC system, this **will also automatically turn off all vacuum pumps** for both upper and main vacuum chambers (to prevent discharge of contaminated air).

Vault cooling

Obj. 13.8 h) ⇔

As for a PSC system, the containment structure is **cooled and dehumidified** by vault coolers. This is necessary due to sources of heat (HTS piping, boilers, etc.) and humidity (small leaks of D_2O, H_2O) within containment. This system normally maintains containment between 35-40°C.

SUMMARY OF THE KEY CONCEPTS

- Vacuum pumps maintain the vacuum building upper and main chamber pressures at a very low level. This maintains the effectiveness of the vacuum building as an energy sink following a LOCA.
- The main chamber provides an area to which the reactor vault atmosphere is drawn following a LOCA. The steam will be condensed there by the dousing action as pressure increases.
- The upper chamber maintains a ΔP which allows an increase in main chamber pressure to automatically cause dousing.
- PRVs isolate the pressure relief duct from the vacuum building main vacuum chamber. These valves will open automatically to control containment pressure increases following a LOCA. Large and small PRVs actuate to cope with large LOCAs, by allowing a large

amount of air/steam mixture to enter the vacuum building. After the pressure has been reduced, the small PRVs will modulate to maintain containment pressure subatmospheric in the "longer term". Instrumented PRVs can be operated from the control room. This is accomplished by applying a vacuum to the top of the valve (from the vacuum building).

- The vacuum duct connects the pressure relief duct to the main vacuum chamber (isolated by the PRVs). This duct allows maintenance on a PRV, when the duct is filled with water, by forming a water seal.
- The pressure relief duct connects the reactor containment structures (vaults) to the pressure relief manifold.
- The upper chamber is isolated to maintain a ΔP from the lower chamber by a water seal. Vacuum is maintained by the vacuum pumps, which remove any air inleakage.
- The PRVs operate when containment pressure exceeds a design limit. Increasing pressure acting directly on the valve will cause the valve to lift off of its seat.
- Box-up or button-up will be initiated by containment high pressure, containment high radioactivity or stack monitoring high radioactivity/out of service. This action closes all potential leakage points out of the containment structure by closing valves, dampers, etc.
- Vault coolers normally provide cooling and dehumidification to containment.

NPC operation during a large LOCA

⇔ ***Obj. 13.10 a)***

A large LOCA will generate large volumes of high temperature steam (~100°C) as the HTS coolant escapes from the break. Pressure and temperature within containment will quickly increase and initiate **containment box-up (button-up).**

As relief duct pressure increases to the design pressure of the **PRVs** (APRVs first, where installed, followed by the IPRVs and main PRVs), they will **open**, and the high pressure, high temperature air/steam mixture will be drawn into the vacuum building through the vacuum ducts.

⇔ ***Obj. 13.9 d)***

The **increase in vacuum building pressure acts on the water** in the emergency storage tank and **water is forced into the upper vacuum chamber** (refer back to Figure 13.5). Note that the water seal prevents the main chamber atmosphere from entering the upper chamber (through the outlet header) as main chamber pressure increases. The filling of the upper chamber with water allows flow over a weir into the outlet and spray headers, thus **initiating dousing** into the main chamber. The spray of cold H_2O into the steam/air mixture (in the main chamber) will condense the steam. This will reduce pressure as the volume of the steam decreases.

Note that, in most stations, the weir design in the upper chamber (as shown in Fig. 13.4 on page 10) prevents the formation of syphon, by preventing the air in the upper chamber from being carried into the outlet header. If the air in the upper chamber is lost, a syphon will form. If a syphon forms during dousing, it will not stop until the tank is empty.

As a result of the pressure decrease during dousing, **PRV closure will occur**. PRVs initially, then followed by APRVs and IPRVs. Containment pressure will then be maintained subatmospheric by the IPRVs or APRVs and vault coolers, as described earlier. A typical pressure transient for a large LOCA is shown in Figure 13.6 on the next page.

* This is discussed on page 18.

In the long term, to retain the containment pressure subatmospheric, the Filtered Air Discharge System * is initiated by the operator.

Obj. 13.10 b) ⇔

NPC operation during a small LOCA

In this instance, the pressure rise within containment will be smaller, and it is likely that the opening pressure of the large PRVs will not be reached.

The overpressure in containment in this instance will be **handled by the IPRVs or APRVs**, depending on the station. When containment pressure is reduced, the APRVs will close, but will modulate to maintain containment pressure negative. If the LOCA is small enough, the opening pressure of any relief valve may not be achieved, and the increase in pressure and the return to subatmospheric conditions will be handled by the **vault coolers** (provided enough steam is condensed).

Dousing during a small LOCA will be dependent upon the pressure rise in the vacuum building, and, **if dousing occurs, it will cycle** following the modulation of the IPRVs or APRVs.

AIRLOCKS

Obj. 13.11 ⇔

Airlocks are penetrations in the containment boundary that are provided to allow the **passage of personnel and equipment, without breaching the containment boundary**. This is accomplished by the use of a double set of doors for each airlock. By having only one door open at any time, the containment boundary is not breached. Each of the airlock doors are sealed by using an inflatable seal. Operating procedures and built in interlocks are used to ensure that the containment boundary is not breached when airlocks are used.

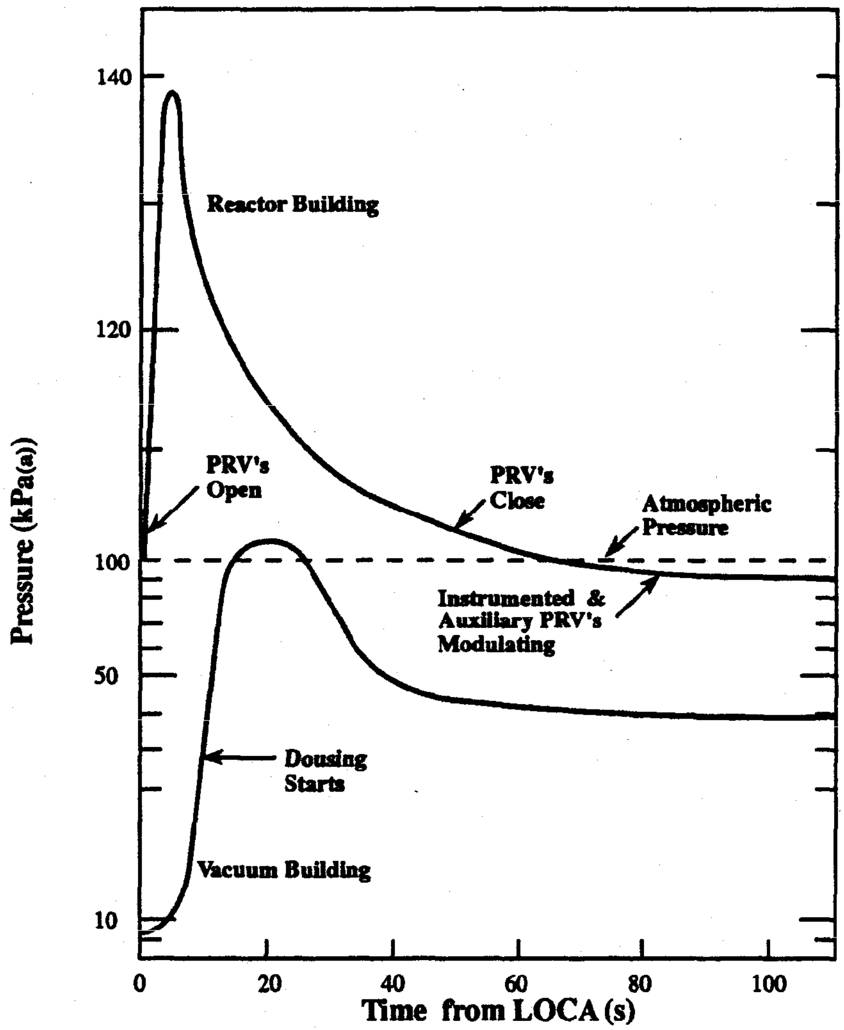

Figure 13.6
Typical Pressure Transients in Reactor and Vacuum Buildings following a LOCA, (50% HT D_2O loss)

Larger penetrations, for the transfer of very large pieces of equipment, are called transfer chambers. They are similar to an airlock, but are constructed of concrete, rather than steel. Their operation is also the same as an airlock, with a very few being sealed by bolted connections.

FILTERED AIR DISCHARGE SYSTEM

Following a LOCA event, containment will gradually repressurize due to air inleakage (small holes in containment seals, air system leakage, etc.). Filtered air discharge is initiated to keep containment or the vacuum building subatmospheric. Containment **air is evacuated via the FAD** (Filtered Air Discharge) system instead of via the normal operation filter (through the contaminated exhaust system). FAD consists of demisters (which remove entrained water droplets), heavy

⇔ ***Obj. 13.12***

duty High Efficiency Particulate in Air (HEPA) filters to remove particulates and charcoal adsorbers to remove radioiodines. Once the air discharge is established through FAD, the containment atmosphere can be maintained in a subatmospheric state (note that these FAD units are not 100% efficient, and will release small amounts of particulates and radioiodines, tritium and all the noble gas activity).

HYDROGEN IGNITERS

In the event of a LOCA with a coincident failure of ECIS, high fuel sheath temperatures will result. If the fuel temperature exceeds ~1100°C, steam/zirconium oxidation will cause the formation of D_2/H_2 by the following reaction:

$$Zr + 2D_2O \longrightarrow ZrO_2 + 2D_2$$

Obj. 13.13 ⇔

To prevent high D_2/H_2 and O_2 concentrations from forming, and igniting, within containment, a **hydrogen ignition** system is used.

The principle behind its use is to deliberately ignite the D_2/H_2 and O_2 mixture in **low** concentrations in a steam environment. The ignition of D_2/H_2 at low concentrations prevents severe pressure/temperature transients that could cause damage to the containment envelope (which could occur if high concentrations of D_2/H_2 were allowed to build up to explosive levels and ignite).

The hydrogen igniters are heating coils, similar to a heating coil on a stove, which will heat to ≥750°C to cause the ignition of the D_2/H_2. In the Bruce and Darlington units, these igniters are located at several different elevations within the reactor vault* and, in the Pickering units, they are in the fueling machine vaults and service rooms.

* At Darlington there are also igniters located in several SDC rooms.

SUMMARY OF THE KEY CONCEPTS

- Dousing occurs when increased pressure in the vacuum building main chamber forces water into the upper chamber, causing water to spill into the dousing headers.
- Following a large LOCA, for a NPC system, containment pressure quickly starts to rise. Box-up (or button-up) is initiated on one or more of the initiating parameters. All the PRVs (APRVs followed by main PRVs and IPRVs) will open to cope with the large pressure increase. Vacuum building main chamber pressure will increase. This will cause dousing to occur to reduce main chamber pressure. As containment pressure reduces, the large PRVs will close, followed by the IPRVs and APRVs. The IPRVs, and/or APRVs, depending on the station, will modulate to maintain pressure subatmospheric.

- Following a small LOCA, for a NPC system, containment pressure slowly starts to rise. Box up (or button up) is initiated on one or more of the initiating parameters. The vault coolers will act to condense the steam and will cool the vault atmosphere. This may limit the containment pressure increase to the point where no PRV action is required. If containment pressure continues to rise, the APRVs or IPRVs will open to reduce containment pressure. Once containment pressure is reduced, the APRVs will close, but will modulate to keep containment pressure below atmospheric.
- Airlocks allow for the passage of personnel and equipment into/out of containment without opening containment to atmosphere.
- The filtered air discharge system (FADS) will allow the contaminated air in the containment or vacuum structure to be discharged to atmosphere (at a controlled rate) after it is filtered to remove contaminants. This can maintain containment pressure subatmospheric.
- The hydrogen ignition system will ignite low concentrations of D_2/H_2 formed during a LOCA, thus preventing severe containment damage.

VAULT ATMOSPHERE

Purge driers

Recall from Module 9 that the purposes of the vapour recovery system are:

a) Collection and recovery of D_2O vapour present in containment as a result of normal HTS coolant leakage.

b) Removal of airborne tritium within containment.

c) Maintaining containment pressure slightly subatmospheric. ⇔ *Obj. 13.14*

Point c) is our concern here. After the vapour recovery stage in the vapour recovery system, air is either returned to containment or discharged to atmosphere through the **purge driers*** and the station stacks where it is further filtered and monitored by the contaminated exhaust system. **This air flow through the purge driers normally keeps containment pressure subatmospheric** (ie. removes the air that has leaked into containment).

* The purge driers are considered part of the vapour recovery system.

For a PSC system and older stations, a similar purge system to that mentioned above, maintains the containment D_2O areas at a slight negative pressure, relative to other accessible areas.

Availability

Obj. 13.15 ⇔

Containment (and all its associated subsystems, ie. vacuum building, dousing water inventory, etc) must be **available at all unit states** (except when the unit is in the guaranteed shutdown state) to **preserve the fourth barrier to radioactive releases to the environment.**

The containment system is considered to be available if it is capable of limiting radiation doses to the public to within legal limits.

To minimize the containment unavailability, the following measures have to be taken:

- The containment system shall not intentionally be removed from service unless HT system(s) are at or below 90°C and the reactor(s) are in a guaranteed shutdown state.
- At least one door of each airlock shall be kept closed at all times.
- The system has to be tested according to a testing schedule to demonstrate that it meets the unavailability targets.
- The necessary maintenance shall be performed in a timely manner.

Reliability

Containment (and all its associated subsystems), like the SDSs and ECIS, must be very reliable. High reliability is achieved by independence, redundance and selection of high quality components, as discussed in the previous two modules.

SUMMARY OF THE KEY CONCEPTS

- NPC pressure is maintained subatmospheric by the purge driers.
- Containment must be available at all times while the unit(s) operate to ensure that releases are minimized in the event of a LOCA.
- The reactor(s) must be shut down and cooled if the containment system is made unavailable.
- The shift supervisor must approve testing and maintenance of the containment systems.
- The reactors will be operating for normal testing of containment system components. But, in some cases, ie. leak tests, the unit(s) must be shut down for testing.

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You can now work on the assignment questions.

ASSIGNMENT

1. a) Two types of containment systems used in CANDU stations are:

   i) ______________________________

   ii) ______________________________

   b) The poised __________ system is available to limit the long term energy input into containment in the event of a LOCA.

2. The function of an airlock is to provide ____________________

   ____

   ____

3. Box-up or Button-up occurs by ____________________

   ____

   ______________________________. For a NPC system this also shuts down the ____________________ and the ______________________________. These actions occur to ______________________________

   ____

   ______________________________.

4. Vault coolers act to:

   a) Normally-______________________________.

   b) During a LOCA-______________________________.

5. Dousing systems act as follows:

   a) ______________________________.

   b) ______________________________.

   c) ______________________________.

6. For a NPC system,

   a) The upper vacuum chamber maintains a ________ such that ________________ will occur automatically when main vacuum chamber pressure increases.

b) The pressure in the vacuum building main chamber is maintained by the ______________________________.

c) The main vacuum chamber is where ______________ will occur.

d) PRVs normally ________________ containment from the vacuum building. During a LOCA, ____________________ in containment causes these valves to open.

e) The vacuum duct connects ________________________ to the ____________________________. This duct allows maintenance on the PRVs by __________________________________ ____.

f) The pressure relief duct connects the ____________________ to the ______________________________.

g) The vacuum in the upper chamber is maintained by the ______ _______________ seal. Any air inleakage is accommodated by the ____________________________.

7. For a NPC system, the dousing mechanism is:

____

____

____

____

____

8. For a PSC system, the dousing mechanism is:

____

____

____

____

____

9. The purpose of the Filtered Air Discharge System is: __________

10. The purpose of the Hydrogen Igniters is: __________

11. a) For a PSC system, a small LOCA will cause containment to:

11. b) For a PSC system, a large LOCA will cause containment to:

12. a) For a NPC system, a small LOCA will cause containment to:

b) Following a large LOCA, for a NPC system, containment ____
____
____
____
____
____

13. The containment system must be available with the unit at power because ____
____
______________________. If the containment system is to be made unavailable, the units must be ____________
____
____.

14. Dousing or emergency storage tank water is for ______________ and ______________________.

15. PSC pressure is normally maintained subatmospheric by the ______________________. NPC pressure is normally maintained subatmospheric by the ______________________.

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

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