Replacement Research Reactor Project

SAR CHAPTER 7
ENGINEERED SAFETY FEATURES

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7 ENGINEERED SAFETY FEATURES

This Chapter of the Safety Analysis Report identifies and provides a summary of the types, locations and functions of the Engineered Safety Features (ESF) provided throughout the facility.

As a general statement, ESF are provided as part of ensuring the safe shutdown of the reactor, the provision of adequate heat removal from the core and rigs, or the limiting of the release of radioactive material to the environment (see Section 2.4.10).

The following systems are identified as ESF:

- Reactor Protection Systems
- Post Accident Monitoring System
- First Shutdown System
- Second Shutdown System
- Core Cooling by Natural Circulation
- Rigs Cooling by Natural Circulation
- Reactor Pool Coolant Boundary
- Reactor Containment System
- Emergency Control Centre Ventilation and Pressurisation System
- Standby Power System

In order to enhance the readability of the Safety Analysis Report (SAR), full details on the Reactor Containment System only are provided in this Chapter. For the other systems, a brief description is included together with a reference to the section in the SAR where full details are given.

As a general basis, the ESF comply with the criteria listed in Chapter 2, Section 2.4.8. In addition, each ESF complies with its own specific criteria outlined in Chapter 2 and addressed in the chapter where the system is discussed.

All ESF are Safety Category 1.

7.1 REACTOR PROTECTION SYSTEMS

The Reactor Protection Systems (RPS) are described in detail in Chapter 8, Section 8.2, as part of the Instrumentation and Control Systems.

The RPS comprise the instrumentation systems that initiate the actions that safely shutdown the reactor, and isolate the containment when radioactive discharges in the stack are above safety settings. The RPS have priority in establishing reactor operational states and provide status and control signals to other systems such as the RCMS. The RPS also incorporate interlocks that prevent reactor start-up unless certain systems and/or conditions are met. The RPS are separated into two different systems: the First Reactor Protection System (FRPS) (computer based system) and the Second Reactor Protection System (SRPS) (hardwired system).

The safety parameters monitored by the RPS can be grouped according to their function. Different components (e.g. sensors), measurement principles and methods are employed according to the process parameter monitored. Instrumentation that inputs into the RPS is qualified to Safety Category 1 requirements.

The measurement channels are:

a) nucleonic channels
b) thermal-hydraulic channels
c) radiation protection channels
d) seismic channels
e) pneumatic transfer channels
f) cold neutron source channels
g) containment system controls
h) electrical power channels

End of Section

7.2 POST ACCIDENT MONITORING SYSTEM

The Post Accident Monitoring (PAM) system is described in detail in Chapter 8, Section 8.6, as part of the Instrumentation and Control Systems.

The PAM system provides the necessary information needed for operators to monitor, and take actions during, and after an accident condition. In addition, it provides information to indicate whether plant safety functions are being accomplished and it is a very important tool for implementing manual recovery actions. The PAM system comprises the electrical devices and circuitry involved in generating the PAM signals for display in the Main Control Room and the Emergency Control Centre.

PAM is based on double redundant trains. Some primary sensors are shared with the FRPS and SRPS, and signals are supplied to the RCMS (through appropriate isolators) to also display the PAM parameters.

The measurement channels are:

a) First Shutdown System

b) Second Shutdown System

c) Primary Cooling System and Reactor and Service Pool Cooling System Flap Valves (for natural circulation)

d) Reactor and Service Pool Level

e) Emergency Makeup Water System (storage tank water level)

f) Nucleonic Instrumentation System

g) Emergency Control Centre Ventilation and Pressurisation System

h) Radiation Monitoring System

i) Standby Power System

j) Reactor Containment Systems

End of Section

7.3 First Shutdown System

The First Shutdown System (FSS) is described in Chapter 5, Section 5.5.3, as part of the reactor description, and the system instrumentation in Chapter 8, Section 8.3, as part of the Instrumentation and Control Systems.

The FSS shuts down the reactor by rapidly inserting the five control rods into the Core. The control rods are connected to the Control Rod Drives (CRDs) via electromagnets. The absorber plates and control rod stems are guided and protected from flow induced forces and seismic induced strains.

The system complies with the single failure criterion.

End of Section

7.4 SECOND SHUTDOWN SYSTEM

The Second Shutdown System (SSS) is described in Chapter 5, Section 5.5.4, as part of the reactor description, and the system instrumentation in Chapter 8, Section 8.4, as part of the Instrumentation and Control Systems.

The SSS is capable of shutting down the reactor by automatically dumping the heavy water stored in the Reflector Vessel. This system provides an alternate shutdown system, completely independent to the First Shutdown System.

The system is connected to the Reflector Vessel through a pipeline that conducts heavy water to a distribution header. The distributor diverts heavy water through valves in a parallel configuration. A header collects the heavy water from the valves and discharges into the heavy water storage tank belonging to the Reflector Cooling and Purification System (RCPS). Pressure equalisation lines for helium connect the Reflector Vessel with the heavy water storage tank through the RCPS (for further details refer to Chapter 6).

The SSS shuts down the reactor by partial dumping of the Reflector Vessel water and leaving the Core in a sub-critical condition. The reduction of heavy water level in the Reflector Vessel causes neutron reflection to be reduced increasing the neutron leakage from the Core thus stopping the nuclear chain reaction.

The system complies with the single failure criterion.

End of Section

7.5 CORE COOLING BY NATURAL CIRCULATION

Core Cooling by Natural Circulation is described in Chapter 6, Section 6.2.4, as part of the Reactor Cooling Systems description.

The portion of the Primary Cooling System (PCS) inside the Reactor Pool participates in the Core Cooling.

The portion of the PCS outside of the Reactor Pool does not participate in the Core Cooling and is defined as Safety Category 2 system.

This system has both a normal cooling function, in cooling the reactor in the Physics Test and Shutdown states, and also an emergency cooling function during abnormal events following reactor trips and the stopping of the PCS pumps. The Safety Category 1 function of this ESF is essential to remove Core decay heat in the event that the PCS circulation pumps are out of service and in the event of a loss of Electric Power. The action of this system depends on the opening of flap valves provided on each of the PCS return lines. The ultimate heat sink for the decay heat removed by this system is the Reactor Pool itself. The description of the thermal-hydraulic design for this system is given in Chapter 5, Section 5.7.

End of Section

7.6 RIGS COOLING BY NATURAL CIRCULATION

The Rigs Cooling by Natural Circulation is described in Chapter 6.

The portion inside the Reactor Pool that performs the function of Rigs Cooling by Natural Circulation is defined as Safety Category 1 ESF. The portion of the system that does not participate in Rigs Cooling by natural circulation is defined as Safety Category 2 system.

If the pump in service fails, the flap valves open and natural circulation is established through the Rigs Cooling branch ensuring appropriate cooling. The ultimate heat sink for the heat removed by this system is the Reactor Pool itself. The description of the thermal-hydraulic design for rigs cooling, transition from forced circulation to natural circulation, and opening of flap valves is described in Chapter 5, Section 5.8.

End of Section

7.7 REACTOR POOL COOLANT BOUNDARY

The Reactor Pool Coolant Boundary is described in detail in Chapter 4, Section 4.5.

The Reactor Pool is the ultimate heat sink for the Core Cooling by Natural Circulation and for the Rigs Cooling by Natural Circulation, and this is ensured by the opening of the flap valves. The water inventory is ensured even in events with loss of coolant by the provision of siphon effect breakers in the PCS and RSPCS.

The Reactor Pool is an open cylindrical pool. The Reactor Pool tank is embedded in a large concrete block that receives the loads acting on the pool. The load is transferred to the concrete through the lateral wall of the pool and through the bottom plate, which rests on the concrete block. Carbon steel stiffness rings are welded at different heights on the external face of the lateral wall of the tank to provide structural stiffening and to provide the means for lateral fixation to the concrete block, by means of anchoring elements fixed on the stiffening rings.

The Reactor Pool is made of ASTM A 240 Grade 304 L stainless steel, which has the required resistance to corrosion for the temperature and water quality in the pool. Irradiation damage effects will be insignificant given the low neutron flux on this component.

End of Section

7.8 REACTOR CONTAINMENT SYSTEM

7.8.1 Introduction

The Containment represents the third and last barrier to prevent an uncontrolled release of fission products to the environment in the event of a beyond design basis accident.

It provides a barrier against the uncontrolled release of radioactivity from the reactor core, reactor coolant boundary, and reactor irradiation facilities.

For the radioactive products contained in the fuel elements, the two previous barriers are the fuel matrix with fuel plate cladding, and the reactor pool boundary.

The system is design to restrict the release of air from the containment atmosphere to the environment through the leakage from the building. Under Design Basis Conditions, this limit is set at 3% of the volume within the containment per day. Considering that the mass release to the environment is a function of the containment pressure with respect to the environment, the design of the Reactor Containment System is based on two key aspects:

a) Design of the boundary with the least technically achievable permeability in order to limit leak rates.

b) Design of the heat removal system capable of limiting the pressure increase due to thermal expansion of the air within the containment.

The Containment encloses the main parts of the reactor and includes a number of interconnected rooms.

The Containment consists of a physical barrier (the Containment itself), the Containment Isolation Valves (CIV), the Containment Energy Removal System (CERS), the Containment Pressure Relief and Filtered Vent System (CPRFVS), and the Containment Vacuum Relief System (CVRS).

The physical barrier consists of the walls, floors and ceilings that form the external boundary of the Containment, the access ways through that boundary, and the service penetrations of that boundary.

The CIV consists of valves that can seal pipes that penetrate the Containment, and an instrumentation system, which initiates, when appropriate, automatic closing of those valves under accident conditions for which the RCS is required to provide a protective function.

The CERS consists of a re-circulating chilled water system, closed to the Containment atmosphere, which is designed to minimise pressure increase within the Containment by removing heat from the Containment atmosphere under isolation conditions.

The CPRFVS is a backup system that consists of pressure relief valves designed to limit the differential pressure between the isolated Containment and the outside atmosphere. Additionally it provides a flexible means to manage accidents by permitting the venting of filtered air from the Containment to the stack when this might be an appropriate accident management measure.

The CVRS is a backup system that consists of a set of vacuum relief valves designed to limit the differential pressure between the outside atmosphere and the isolated Containment.

Figure 7.8/1 shows a schematic of the Reactor Containment System.

Some Category 2 auxiliary systems related to the air movement during normal and abnormal conditions are mentioned throughout this chapter. They are the Reactor Air Supply System, the Reactor Air Exhaust System, the Hot Cells Ventilation System and the Heavy Water Room Ventilation System. These are all part of the Reactor Containment Ventilation System and are described in Chapter 10.

7.8.2 System Requirements

7.8.2.1 System Categorisation

Classification of Containment Subsystems is as shown below:

Sub-systems	Safety	Seismic	Quality
Containment			
Boundary	1	1	A
Access ways	1	1	A
Service penetrations	1	1	A
Containment Isolation Valves			
Valves and actuators	1	1	A
Instrumentation and control (FRPS & PAM)	1	1	A
Containment Energy Removal System	1	1	A
Containment Pressure Relief and Filtered Vent System			
Valves, valve actuators and controls	1	1	A
Filters	2	2	B
Containment Vacuum Relief System	1	1	A

7.8.2.2 Safety Functions

Each of the listed sub-systems has to fulfil specific functional requirements according to its safety categorisation.

The Containment physical barrier and the CIV are required:

a) To act together to limit release of radioactive material during and after an accident condition.

The CIV Instrumentation is required:

a) To initiate automatic closure of the CIV when appropriate.

b) To provide information on whether it has operated successfully.

The CERS is required:

a) To limit and control pressure within the Containment to minimise leakage of radioactive material from the Containment.

b) To keep pressure within the Containment below its design limit.

The CPRFVS is required:

a) To limit the differential pressure between the isolated Containment and outside atmosphere.

b) To provide a means for managing accidents.

The CVRS is required:

a) To limit the differential pressure between the outside atmosphere and the isolated Containment.

7.8.2.3 Design Requirements

7.8.2.3.1 Containment Physical Barrier

The main safety design requirements of this system are:

a) To provide a barrier against the release of radioactive products from the building that could have been released from the reactor core, reactor coolant boundary, or reactor utilisation activities.

b) To withstand the initial and long-term pressures and temperatures resulting from a beyond design-basis event.

c) To minimise the containment permeability by the provision of special doors and gates and appropriate wall surfaces.

7.8.2.3.2 Containment Isolation Valves

The main safety design requirements of this system are:

a) To isolate the Containment from the environment during and after design basis accidents.

b) To provide two isolation valves for each of the ventilation pipelines that penetrate the Containment boundary, one valve at each side of the boundary.

c) To provide one isolation valve at the intake point and one at the exit point for re-entrant lines not directly connected with containment atmosphere.

d) To provide seals of through wall penetrations to the Containment boundary.

e) To provide automatic closure of containment isolation valves on systems directly connected to the containment environment. Closure is commanded by the FRPS when activity in the ventilation stack exceeds the established limit.

f) To incorporate facilities for testing and surveillance of the system.

7.8.2.3.3 Containment Energy Removal System

The main safety design requirements of this system are:

a) To minimise the pressure increase within the Containment following an event requiring Containment Isolation such that the release to the environment is below 3% of Containment volume in any 24 hour period.

b) To allow periodic testing and in-service inspection.

c) To keep local environmental conditions within design basis limiting conditions for components, structures and systems following a Containment Isolation event.

d) To have high reliability, high availability and ease of maintenance.

The main non-safety design requirements of this system are:

a) To remove the sensible and latent heat from containment areas to keep local environmental conditions within design basis limiting conditions for components, structures and systems.

7.8.2.3.4 Containment Pressure Relief and Filtered Vent System

The main safety design requirements of this system are:

a) To limit the differential pressure between the isolated Containment and the outside atmosphere.

b) To provide a manual means of venting filtered air from the Containment to the stack accident management purposes.

7.8.2.3.5 Containment Vacuum Relief System

The main safety design requirements of this system are:

a) To limit the differential pressure between the outside atmosphere and the isolated Containment.

7.8.2.4 Codes and Standards

The systems are designed considering the guidelines in the relevant parts of the following Codes and Standards:

Building Code of Australia (BCA) with NSW amendments

Relevant Australian Standards

ASHRAE

Relevant Regulations of Work-Cover Authority NSW

See Chapter 2 for detailed description and features of these codes and standards.

The design, documentation, construction, installation, testing and inspection of these systems and associated services are consistent with best practice. Reactor HVAC-related systems conform to the standards or Codes of Practice identified as applicable and other nuclear design requirements.

7.8.3 Design Description

7.8.3.1 General

The RCS comprises those systems and sub-systems that constitute the third and last barrier to the release of radioactive products to the environment. It consists of the Containment Building, the CIS, the CERS, the CPRFVS, and the CVRS.

7.8.3.2 Containment Physical Barrier

The Containment physical barrier comprises Containment walls, ceilings and floors, all of which are built in reinforced concrete. Doors, windows and different types of conduits are also part of the Containment boundary.

The Reactor Hall is inside the Containment. Containment areas are connected via a service duct and CERS air ductwork, allowing for integration among these levels and sharing common air.

The Containment physical barrier is designed to minimise leaks from the Containment to the environment. Containment leak tightness is provided through the following components:

a) walls, floors and ceilings that form the external boundary of the Containment

b) windows

c) access ways through that boundary including doors and floor hatches

d) penetrations for:

   (i) electric power cables
   (ii) instrumentation and control cables
   (iii) communication cables
   (iv) piping (water, gases, waste)
   (v) ventilation ducts
   (vi) radioisotope transport tubes and elevators

A relevant performance parameter of the Containment physical barrier is its degree of air-tightness. The air-tightness is represented by the containment permeability factor which is the relationship between the pressure difference across the Containment physical barrier and the airflow rate through the physical barrier. Containment permeability is thus a physical property of a building and its value depends on the building and penetration design, construction and maintenance.

The relationship between the airflow through the containment building envelope (Q) and the pressure difference Δp between the pressure inside and outside the containment is called the Permeability Coefficient.

As the Containment and its penetrations are designed to provide an appropriate leak-tightness, the air leakage paths will be minor and of reduced dimensions; typically labyrinthic paths having small hydraulic diameters. Therefore the air flow will be laminar.

For these conditions the flow equation is expressed as:

$$Q = c\Delta p$$

where *c* is the Containment Permeability coefficient:

$$c = \frac{Q}{\Delta p}\left[\frac{m^3}{s.Pa}\right]$$

7.8.3.2.1 Walls, Floors and Ceilings

All the walls that define the Containment were built taking into consideration the leak-tight requirements. The surfaces of the Containment were treated to seal pores and imperfections. Special attention was paid to joints between successive concrete pours, floor-to-wall joints, wall-to-wall joints and wall-to-ceiling joints.

7.8.3.2.2 Windows

Windows that are part of the Containment physical barrier have a single thickness of glass set in a frame which allows testing of the air tightness of the assembly seals. There are no windows in the Containment physical barrier visible from outside the facility.

The main windows are:

a) Main Control Room to Reactor Hall

b) Meeting Room to Reactor Hall

c) Above Pool Hot Cells Area to Corridor

7.8.3.2.3 Access Ways

Containment access ways include:

a) Safety Access Systems (SAS).

b) Equipment Hatches.

7.8.3.2.3.1 Safety Access Systems

Each SAS consists of a small room with two doors, one connecting to the containment and the other one to the containment surroundings. These doors are generally used during reactor operation as the normal means of access for operators and plant staff. They are interlocked to prevent their simultaneous opening. The SAS room between the doors is capable of being over and under-pressurised to test the door seals. Door seals are rubber.

7.8.3.2.3.2 Hatches

These conduits for equipment, containers and other elements have double-seal lids and allow the possibility of leak tests by pressurising the space between seals (positive and negative pressure with respect to the environment). They are not opened during reactor operation and have to be tested after every opening. In the case of large hatches that close by their own weight, the design considers the drop/rise of the closing force due to the pressure effect.

7.8.3.2.4 Penetrations

Every penetration to the Containment is designed, manufactured and assembled to ensure a high degree of leak tightness. The number of penetrations has been minimised in the design. Every penetration to the Containment is identified and classified by penetration type.

Penetrations are grouped, as feasible, in a few places. As far as reasonably achievable, penetrations are in accessible areas. When it is impossible to access them, a means of verifying their air tightness is considered in their design. As far as reasonably achievable, penetrations are capable of being independently tested.

Penetrations are classified as dynamic or static. Dynamic penetrations are those that may be operated during reactor operation or shutdown, provided with adequate valves to provide containment isolation when needed. Static penetrations are those that have no moving parts, such as a cable through the walls of the Containment.

7.8.3.2.4.1 Electric Cable Penetrations

Electric cables in and out of the Containment traverse the walls by through-wall type penetrations. Each cable penetration is built of a fire rated component that tightly adjusts around the cable. The penetrations are grouped and fitted into modular frames cast into the concrete allowing multiple cables to run through it.

7.8.3.2.4.2 Instrumentation and Control and Communication Lines

Leak tight penetrations for transferring low voltage/current signals and data are provided. Their characteristics are similar to electric cable penetrations.

7.8.3.2.4.3 Piping Penetrations

Piping penetrations are appropriately sealed in a manner that depends on their size. Small pipes are preferably grouped to enter the Containment through a few easily accessible and identifiable positions. Penetration plates are used for small size pipes when appropriate. When appropriate, small pipes use a system similar to the one for cables.

For pipes several sealing options are available: either sealing the gap surrounding the pipe with elastomeric material or enclosing both ends of the tube at the walls sides with a rubber cap, or embedding the pipe in the concrete.

Every pipeline penetrating the Containment in a re-entrant manner (that is, not directly connecting to the Containment environment, as is the case of the Secondary Cooling System (SCS)) is provided with one isolation valve on each of the penetration points. The valve is located as near as feasible to the Containment wall. Valves are either pneumatically or manually operated, as appropriate for the corresponding line.

7.8.3.2.4.4 Ventilation Penetrations

The penetrations of the ventilation system ducts are built in a way to ensure a level of leak-tightness similar to that specified for process piping.

Ventilation lines are provided with one isolation valve on the inner side of the Containment and another one on the outer side. The volume enclosed between the two valves is provided with a connection to carry out verification of leak tightness during commissioning and during normal plant surveillance tests.

7.8.3.3 Containment Isolation Valves

Piping and ventilation penetrations to the Containment are provided with isolation valves. These valves have remote indication of their status. In the event of detection of very high levels of radioactivity in the stack, the reactor protection system will initiate, when appropriate, automatic closure of these valves to isolate the Containment atmosphere from the outside environment.

Process systems where the fluid is in direct contact with the Containment atmosphere have two isolation valves, one located outside and the other located inside the Containment.

Systems where the process fluid is not in direct contact with the Containment atmosphere have one isolation valve located outside the Containment.

7.8.3.3.1 Containment Isolation Valve Groups

The Containment Isolation action depends on the type of system.

GROUP 1: systems which meet both of the following criteria:

a) System either has direct communication with the containment’s atmosphere (e.g. ventilation ducts), has the potential for communication with the containment’s atmosphere, or has the potential to produce pressurisation of the containment (e.g. instrumentation compressed air in modulating control valves), and

b) Isolation of the system will not result in a reactor trip in the short term, the disabling of an accident management system, or the potential for damage to reactor facility components.

Valves corresponding to this group have four means of actuation, namely:

(i) Automatic action (automatic CIS action) through the FRPS responding to a trip signal from very high activity in the stack
(ii) Remote manual action from the control rooms (MCR/ ECC) by means of a hardwired hand switch through the FRPS
(iii) Remote manual action for maintenance (Shutdown state) actuated through the RCMS
(iv) Local manual action (by means of the actuator handwheel) for emergency cases

Fault position of valves: Fail closed

GROUP 2: systems which meet any of the following criteria:

a) System does not have either direct communication with the containment's atmosphere, potential for communication with the containment's atmosphere or with the primary coolant, or potential to produce pressurisation of the containment, or

b) Isolation of the system would result in a reactor trip in the short term or in the disabling of an accident management system, or

c) Systems in which the closing of automatic valves would lead to the damage of reactor facility components

Valves corresponding to this group have three means of actuation, namely:

(i) Remote manual action from the control rooms (MCR/ ECC) by means of a hard hand switch through the FRPS (no automatic action on CIS)
(ii) Remote manual action for shutdown state actuated through the RCMS
(iii) Local manual action (by means of the actuator handwheel) for emergency cases

Fault position of valves: Fail as-is

GROUP 3: a subset of Group 2 systems which meet the following criteria:

a) System does not have either direct communication with the containment's atmosphere or with the primary coolant, potential for communication with the containment's atmosphere, or potential to produce pressurisation of the containment, and

b) System has a high grade pressure boundary (ASME or similar), e.g. Secondary system, and

c) Spurious isolation of the system results in a significant reactor transient or disabling of the containment system.

CIS action: None. Valves corresponding to this group are manually actuated locally, normally opened and locked

Fault position of valves: Not applicable.

GROUP 4: special cases that, due to their special requirements, must receive specific treatment.

GROUP 5: Systems which are seldom required, with CIS valves, usually closed and locked.

7.8.3.3.2 Air Supply/Exhaust Isolation Valves

The valves use compressed air to open and spring-force to close. Isolation valves are fail safe, so they will close automatically on loss of electric power or loss of compressed air. Isolation valves can also be closed manually from the MCR.

7.8.3.4 Containment Energy Removal System

The CERS is a Safety Category 1 system whose main function is to provide an assured heat sink for thermal loads inside the Containment, whenever the Containment is isolated, thus minimising pressure increase within the Containment. By controlling the pressure, the CERS minimises the amount of the containment atmosphere released to the environment. The CERS was designed to remove heat from within the isolated Containment.

Figure 7.8/2 shows a representation of the energy balance within the Containment system. In addition, in steady state operation, not all structures, systems and components within the Containment are at the same uniform temperature. During transient conditions, e.g., reactor start-up or shutdown, or a change of mode of the Containment System, temperatures in structures, systems and components may change with an accompanying redistribution of stored heat energy within the Containment.

A significant part of the heat load, which the CERS is required to remove from the Containment, in both Normal and Isolation Modes, is from electricity consumed within the Containment. This electricity demand is highest when normal power is available.

The CERS consists of two 100% capacity trains. A third chiller unit is provided as an installed spare. It can be aligned to either of the CERS trains in the event of the unavailability of an on-line chiller unit. This re-alignment is a manual action and would include the necessary tests and inspections to ensure that the installed spare is re-aligned correctly and available for operation.

Each train of the CERS is supplied from a different train of the Standby Power System (SPS). In the event of the installed spare chilling unit being aligned for use, it is supplied from the SPS train associated with the on-line chiller unit it is replacing.

The chiller units are located externally in a dedicated area immediately to the south of the Auxiliary Building/Reactor Facility Substation. They are appropriately qualified for the environmental conditions that they will experience as identified in Chapter 3, Section 3.2.3. Adequate separation is provided between the chiller units to avoid common mode failures generated internally or externally. The mounting locations for the chiller units are appropriately seismically qualified.

The chilled-water circuit is a closed circuit with its corresponding expansion tank and centrifugal pumps. It provides enough water flow to remove the required amount of heat from the cooling-coils. Manually actuated valves in each re-entrant line outside the containment are provided for isolation purposes. Interconnections are also provided between the two CERS trains and the installed spare chiller unit to enable it to be re-aligned when required. In addition, the two chilled water circuits share a common heat exchanger through which the standby circuit is maintained at a low temperature near to its normal operating temperature. This minimises the time taken for the standby circuit to reach the required heat removal rate following loss of the duty circuit. Note that there is no hydraulic connection between the two circuits.

The fans of the CERS establish the necessary air flow inside the Containment to ensure appropriate heat removal from the Containment air.

Treated air is distributed by standard galvanised metal sheet ducts and supply grilles and returns to the units by similar ducts and grilles. The distribution network efficiently transports air and humidity to the cooling-coils providing an adequate control of sensible and latent heat inside the Containment.

The CERS supplements the cooling capacity of the Containment HVAC System (a non-ESF) during normal operation to keep local environmental conditions within design basis conditions for components, structures and systems. Each branch of the ducting is provided with a dedicated heater for air conditioning purposes during normal operation conditions. They are able to supply sensible heat keeping environmental conditions within prescribed limits. These heaters are Safety Category 2. They are not an ESF and have no safety functions. However, Safety Category 1 switches actuated by the FRPS are provided to ensure that these heaters are switched off in the event of high temperature being detected within containment when the containment is isolated.

7.8.3.5 Containment Pressure Relief and Filtered Vent System

The Containment Pressure Relief and Filtered Vent System consists of an air duct connecting the atmosphere inside the Containment to the stack via a set of absolute and charcoal filters and a set of valves (see Figure 7.8/3). The Containment Pressure Relief and Filtered Vent System is a backup system in that the Reactor Containment System can fulfil its design functions without this system. The valves and their actuators are Safety Category 1 because they fulfil a containment isolation role. Because this system is only a backup system, its filters are Safety Category 2.

7.8.3.6 Containment Vacuum Relief System

The Containment Vacuum Relief System consists of an air duct connecting the atmosphere inside the Containment to the atmosphere outside of Containment via a set of valves (see Figure 7.8/4). The Containment Vacuum Relief System is a backup system in that the Reactor Containment System can fulfil its design functions without this system. The valves and their actuators are Safety Category 1 because they fulfil a containment isolation role.

7.8.3.7 Instrumentation and Control

7.8.3.7.1 Containment Isolation System

The instrumentation and control of this system is mainly related to the operation of containment isolation valves. Valves classified Group 1 and 2 have control logic associated with the First Reactor Protection System. Valves corresponding to Groups 3 to 5 are only locally manually operated, and have I&C associated with position indications at the control rooms.

The First Reactor Protection System control logic, valve position indications, signals linked to PAM and RCMS indications and interlock logic are described in the following subsections.

7.8.3.7.1.1 Reactor Protection System Control Logic

The various actuation modes corresponding to Group 1 and 2 penetration valves were previously described in Section 7.8.3.3.1.

a) Functional logic and control of Group 1 Isolation Valves

   i) Automatic group closure through the FRPS due to “Very High activity air in the stack”

ii) Remote manual group closing action processed through the FRPS, via dedicated push buttons from the control rooms (MCR/ECC).

iii) Remote manual group reset action, processed through the FRPS, via dedicate push buttons from the control rooms (MCR/ECC). The time delay for remote manual reset is controlled by administrative procedures, when valves were automatically closed by FRPS.

b) Functional logic and control of Group 2 Isolation Valves

i) Remote manual group closing action with dedicated push buttons from the control rooms (MCR/ECC). The action is processed through the FRPS. This action triggers RCMS interlock logic. The remote manual closing of this group will only be possible when Group 1 valves have been closed.

ii) Remote manual group reset action with dedicated push buttons from the control rooms (MCR/ECC). The action is processed through the FRPS.

7.8.3.7.1.2 Position Indications of Isolation Valves

Isolation valves, with the exception of check valves and passive relief valves, have position indications in the control rooms (MCR/ECC). In most cases the position indication is “closed valve”, except for the following cases, in which the valves have two position indications: “open”/”closed”:

a) Contained Hydrant & Hose Reel and charcoal Filter Suppression System

b) Pre Action Sprinkle System

c) Inner isolation valves of both Containment Vacuum Relief and Containment Pressure Relief and Filtered Venting System

The position indication signals are processed with dual redundant logic to PAM (see below) and with an independent sensor to the RCMS.

7.8.3.7.1.3 Reactor Control and Monitoring System functional and interlock Logic

The containment isolation valves have the following functional and interlock logic associated with the RCMS:

a) Group 1 valves

i) Individual remote manual action for maintenance actuated when reactor is shutdown (through IFCMS for pneumatic systems like IPTS).

ii) Individual position indications to control rooms (MCR/ECC) with switches independent from PAM, and through the IFCMS for pneumatic systems like IPTS.

iii) No interlock logic associated with these valves.

b) Group 2 valves

i) Individual remote manual action for maintenance actuated when reactor is shutdown.

ii) Individual position indications to control rooms (MCC/ECC) with switches independent from PAM and through IFCMS.

iii) Remote group manual closing (reactor in operation) triggers the following RCMS interlock logic:
- Shutdown reactor (bank insertion)
- Inner neutron guide helium system blowers are shutdown

c) Group 3 valves

i) Individual position indications at the control rooms (MCC/ECC) with switches independent from PAM.

ii) No interlock logic associated with these valves.

d) Group 4 valves

i) Contained Hydrant & Hose Reel and Charcoal Filter Suppression System isolation valves: Remote manual closure or reset action through the fire panel interface at the control rooms (MCR/ ECC). They are not associated with any interlock logic. They also have remote manual actuation from the RCMS for maintenance purposes (with the reactor shutdown and fire extinguishing water network isolated).

ii) Pre Action Sprinkler System to upper levels isolation valves: Remote manual action (open/closed) through the fire panel interface at the control rooms (MCR/ ECC). They are not associated with any interlock logic. They also have remote manual actuation from the RCMS for maintenance purposes (reactor shutdown and fire extinguishing water network isolated).

iii) Pre Action Sprinkler System to lower levels isolation valves: manual action (opened/closed) through the fire panel interface at the control rooms (MCR/ ECC). They are not associated with any interlock logic. They also have remote manual actuation from the RCMS for maintenance purposes (reactor shutdown and fire extinguishing water network isolated).

iv) Containment Pressure Relief and Filtered Venting System and Containment Vacuum Relief System inner isolation Valves:
- Individual remote manual action (closing/reset) from control rooms (MRC/ECC).
- Individual position indications at the control rooms (MRC/ECC) with switches independent from PAM.
- No interlock logic associated with these valves.

v) Controlled Relief Valve of the Containment Pressure Relief and Filtered Venting System isolation valves: Remote manual action (reset/closing). No interlock logic associated with these valves.

vi) Transfer Pipes and Elevator isolation valves: Individual remote manual action (closing/reset) from control rooms (MCR/ECC).
- Individual position indications at the control rooms (MCR/ECC) with switches independent from PAM.

vii) Reactor Building Structures (airlock access):
- Individual position indications at the control rooms (MCR/ECC) with switches independent from PAM.
- No associated interlock logic.

7.8.3.7.1.4 Signals Linked to the Post Accident Monitoring System

The signals associated with this system, linked to the PAM are:

a) Group position indications from independent position switches. These signals are processed with dual redundant logic.

b) Indication of activity in the air discharged to the stack.

7.8.3.7.2 Containment Energy Removal System Instrumentation and Control

7.8.3.7.2.1 First Reactor Protection System Control Logic

The following are the main FRPS actions related to CERS operation:

a) Due to high temperature in the CERS air return duct, the FRPS triggers the shutdown of heaters.

b) Due to high temperature in the air supply duct of the CERS fans, indicating failure in the operating CERS unit (chilled water side), the FRPS triggers the changeover to the CERS unit on standby.

c) Due to low differential pressure in the air supply duct to containment areas, indicating loss of the fan of the operating CERS unit, the FRPS triggers the changeover to the CERS unit on standby.

The execution of the “Reset trip signal” command from the FRPS enables the automatic restart of heaters from the RCMS.

When, due to signal of low differential pressure or a signal of high temperature in the air supply duct, the RPS triggers the changeover to the CERS unit on standby, the faulty unit moves to a HOLD state, indicating that it is not available for changeover.

Once the failure is repaired, it is possible to execute from the FRPS the “Reset HOLD state” command. This allows recovery of the faulty unit, which will move to standby state.

Reactor start-up is inhibited when the CERS FRPS logic is disabled. Inhibition is via the FRPS

When the CERS FRPS logic is enabled, no operation of the CERS chilled water pumps is allowed via the RCMS.

The FRPS logic is enabled only when the following conditions are given at the same time:

a) Execution of the FRPS logic enabling command

b) Lack of high air temperature signal at the discharge of the CERS fans.

c) Lack of low differential pressure signal in the air supply duct.

d) Lack of high air temperature signal in the CERS air return.

On the contrary, the disabling of the FRPS logic is possible only when the following conditions are met:

a) Execution of the FRPS logic disabling command

b) Reactor Shutdown signal.

c) Containment opening order

The changeover of the CERS units due to the triggering of FRPS signals is carried out one way or the other depending on the state of the containment.

When the containment is isolated, the changeover will be carried out maintaining the entire flow-rate of water chilled through cooling coils.

In accordance with the dynamic simulation of the system, this allows –together with the shutdown of water circulation pump related to the faulty unit – guaranteeing that the pressure increase within the containment due to volumetric air expansion will remain below 1000 Pa.

The full opening of the valve also eliminates the possibility of pressurizing the containment to undesired values due to failure in the related temperature control loop.

When the containment is open, changeover to the standby unit will be carried out enabling the air temperature control loop at the outlet of fans.

7.8.3.7.2.2 RCMS-related signals

Signals at CERS air side:

a) Temperature indication of the air at the inlet to the cooling coils
b) Temperature indication and alarm due to high temperature at the fan discharge of the fans (Temperature control point)
c) Air flow indication and alarm due to low air flow at the fan discharge of the fans
d) Temperature indication and alarm due to high temperature at the CERS air return duct
e) Alarm due to low differential pressure at the main air supply duct to areas of the containment
f) Temperature indication and alarms due to high and low temperature at the Reactor Hall air return duct (Temperature control point)
g) Temperature indication and alarms due to high and low temperature at the air return duct (Temperature control point)

Signals at CERS water side:

a) Alarm due to low water flow at the inlet to the chillers
b) Alarm due to low water level at the expansion tanks
c) Indication of water flow to the cooling coils
d) Temperature indication and alarm due to high temperature of the water supplied to the cooling coils
e) Temperature indication and alarm due to high temperature of the water at the outlet of the cooling coils
f) Alarm due to high level in the condensate collector pans of the cooling coils
g) Open and closed state indication in the containment isolation valves located in the chilled water pipelines

General alarms.

In situations in which the CERS standby unit is not available for operation, a maximum priority alarm will be raised.

The alarm is activated due to the following causes:

a) Low water flow signal at the inlet of the standby chiller unit, indicating water circulation pump stopped.
b) “Non-Healthy” indication in the standby chiller unit, indicating equipment not available for the operation.

c) “Non-Healthy” indication in standby fan, indicating equipment not available for the operation.

RCMS reactor start-up inhibition:

a) The RCMS inhibits reactor start-up when the CERS is not in normal mode of operation or it is not operating at a normal rate, i.e. operative CERS unit working with standby unit available for start-up and no RPS triggering signals.

b) Reactor start-up is inhibited on the following:

   (i) Low water flow-rate signal at the inlet of the standby chiller unit, indicating water circulation pumps shut down,
   (ii) “Not Healthy” signal from the standby chiller unit,
   (iii) “Not Healthy” signal from the fan of the standby CERS unit,
   (iv) High temperature signal in the water entering cooling coil of the standby CERS unit,
   (v) High air temperature signal at the discharge of the fans,
   (vi) Low differential pressure signal at the air supply duct, or
   (vii) High temperature signal at the CERS air return.

7.8.3.7.3 Air/Exhaust Supply System

This system is not associated with the Safety Function of the Containment. See Chapter 10, Section 10.4 for a description of this system.

7.8.4 Description of Operation

The Containment has two operating modes: Normal Mode and Isolation Mode. In Normal Mode, the CIS valves are open which permits the Containment HVAC to supply fresh air to, and exhaust air from, the Containment. In this mode a motorised damper which is part of the Air supply system will maintain a lower-than-atmospheric pressure inside the Containment.

Isolation Mode is automatically initiated by the First Reactor Protection System (FRPS) (or manually from the MCR or ECC) in the event of very high stack activity. In Isolation Mode, pipes and ducts directly connected to the Containment environment (de-mineralised water, drainage, etc.) are automatically isolated.

7.8.5 Testing, Inspection and Surveillance

The system is capable of being tested, inspected and maintained in order to ensure that it remains capable of performing its intended function.

7.8.6 Failure Analysis

7.8.6.1 Loss of Normal Power Supply

The loss of normal power supply automatically trips the reactor and initiates the change of the Containment to Isolation Mode.

Due to the fact that both the containment isolation valves and the activity detector in the Air Exhaust System are diesel but not UPS backed, loss of class IV power supply (normal power supply) will cause the closure of Group 1 containment isolation valves due to the following reasons:

a) Activity detector trip in the AES, which will cause the FRPS to close valves of Group 1. The activity detector restarts automatically once the power supply is recovered (network or diesel).

b) Failure position of Group 1 valves (fail closed). As the closure signal of the containment isolation valves is due to power loss and not to activity detection, the operator may order the reopening of the isolation valves. If this is the case, the opening of the valves will re-establish the temperature control of the air supplied by the CERS, avoiding excessive cooling within the containment. Opening of the containment isolation valves will take place if the power supply is restored (network or diesel) and compressed air is available.

The decay heat from the core will be absorbed by the water contained in the Reactor Pool and it will be removed by the Long-Term Pool Cooling Mode of the SCS (Safety Category 2) once standby power is available.

The electrical heat load within the Containment will be significantly less than it would be if the normal power supply was available due to the shutdown of systems and components which are not provided with power from the standby power supply.

The CERS will function once standby power is available to remove sensible and latent heat and to thus limit pressure rise within the Containment. The pressure rise will be less than if normal power had been available, and leakage of air and any postulated airborne activity from the Containment would be less than 3% of the containment volume in a single day.

7.8.6.2 Failure of Secondary Cooling System

On failure of the SCS, the FRPS will automatically initiate a trip of the reactor due to the loss of the ultimate heat sink and the consequential effect on reactor parameters (e.g. core temperature). The decay heat generated at the core will be absorbed by the large volume of water contained in the Reactor Pool. The thermal capacity of the pool is sufficiently large that neither the pool surface temperature nor the evaporation rate from the pool will increase significantly.

Loss of the Secondary Cooling System in Isolation Mode represents the most burdensome event to be dealt with by the CERS in terms of heat removal capacity.

The loss of the Secondary Cooling System will lead to loss of the Reactor Ventilation Water System (normal power supply, no diesel backup).

In these conditions, all ventilation systems operate normally, powered by network power supply. The CERS continues removing the heat generated within the containment.

The temperature and humidity within the containment continue to be controlled by control loops, acting upon the control valve that regulates the water inlet to CERS cooling coil and the power supply to heaters.

A slight pressure increase will be registered in the containment due to the thermal expansion of the air within the Hot Cells, Heavy Water Room and Control Rod Drives Room, for the cooling of such areas is assisted by the Reactor Ventilation Water System (conventional chilled water).

As such, the failure of the secondary cooling system during Containment Isolation Mode will not affect the performance of the Containment System.

7.8.6.3 Failure of Isolation Valves

The Containment process system penetrations are fitted with two isolation valves if the system is open to the Containment and one if the system has a closed loop within the Containment. This is consistent with the requirements of its Safety Category 1 classification. As such the Containment would not be breached by the failure of any single isolation valve or closed loop.

7.8.6.4 Containment Energy Removal System Failure

The CERS consists of two independent 100% capacity trains. This is consistent with the requirements of its Safety Category 1 classification. As such, the CERS will be capable of fulfilling its function even in the event of a failure of one train.

As stated in section 7.8.3.4, the interconnections provided between the two CERS trains to the installed spare chiller unit will incorporate appropriate means of control to ensure adequate separation is maintained between the two redundant trains and to avoid common mode failures.

The common heat exchanger used to maintain the standby circuits temperature near to its operating temperature is acknowledged as an exception to the single failure criterion. However, this heat exchanger is a passive component that is in continuous operation designed, manufactured, inspected and maintained to a high quality level. There is no hydraulic connection between the two trains and since both trains are closed circuits at equal pressure, no leakage would occur between the two trains without a further failure affecting one of the trains. In addition, the heat exchanger is located in a secure and protected area, thus ensuring that it is not subject to internal or external events that could result in its failure. As such, its failure, whilst very unlikely, would most likely be slow to develop but if serious, would be readily identified and furthermore, any such failure would not result in the loss of more than one circuit. Thus, in accordance with Criterion 195 of ARPANSA Regulatory Assessment Criteria for the Design of New Controlled Facilities and Modifications to Existing Facilities, this exception is considered to be acceptable

A failure associated with the RCMS controlled valve within the chilled water circuits that results in overheating of the containment environment (eg spurious alignment due to valve failure or RCMS failure) would be detected by the FRPS and then tripped to its full-open position by the FRPS. In addition, the FRPS would also start the standby train of the CERS in the event of high containment temperature to mitigate the failure of any component within the duty train.

The loss of the operating CERS train could be caused by the following:

a) Stopping or failure of the operating CERS fan which recycles containment air

b) Stopping or failure of the operating chiller unit

c) Stopping or failure of the chilled water pumps or interruption of chilled water feed to CERS cooling coil for some other reason (e.g. failure of air temperature control loops)

d) Failure of valve.

In any case, the FRPS triggers the following actions:

- Shutdown of the operating CERS train
- Start-up of the standby CERS train

In the event of failure of the operating CERS train with the containment in Normal mode, the FRPS will trigger the changeover to the standby CERS train, controlling the fan outlet air temperature.

The time delay caused by the start-up of the standby CERS train will lead to a slight rise in temperature and absolute humidity within the containment.

Once the new CERS train is operating, the temperature control loop will respond to any deviations, restoring environmental conditions.

A failure of the operating fan is detected by low differential pressure switches placed in the air supply duct.

A loss of the chilled water pump (or interruption of the chilled water flow to operating CERS cooling coil) or the failure of the operating chiller unit is detected by high temperature signals in the main air supply duct.

In the event of failure of the operating CERS train when the containment is in Isolation mode, the FRPS will trigger the changeover to the standby CERS train with the control valve fully open.

The time delay arising from the changeover to the standby train may lead to a pressure increase in the containment due mainly to the thermal expansion of the air.

With the start-up of the standby CERS train, the pressure within the containment will return to a value equal to or slightly below that existing prior to the initial failure. This will depend on the temperature range of the control loops that modulate the power of the heaters.

Because the valve will be fully open, the air from the CERS cooling coil will be at a lower temperature than normal and, as a consequence, the heater control loops will react to increase the powers to the heaters to meet the temperature set point values. Relative humidity will decrease within the containment.

A failure of the fan is detected by low differential pressure switches placed in the air supply duct.

The failure of the chilled water pump (or interruption of the chilled water flow to the operating CERS cooling coil) or the failure of the operating chiller units is detected through high temperature signals in the main air supply duct.

Use of the heat exchanger interface between the two trains to pre-cool the water circuit of the standby CERS train ensures that any pressure peak in containment will not exceed 1000 Pa.

7.8.6.5 Failure of the Heaters Temperature Control

A failure within the heaters or the associated temperature control loop that results in the heating up of the containment environment is detected by the FRPS and the heaters isolated by the FRPS.

Failure of room temperature control loops could result in increased heat generation by the respective heaters and, consequently, a temperature rise within the containment.

The temperature rise would be detected by high temperature signals installed on the returning air duct to the CERS cooling coil, sending a signal to the RPS. The FRPS would then isolate the heaters.

Subsequently, the temperature within the containment would drop until the heat generated in the containment balances the heat removed by the CERS.

With the reactor in operation, this will lead to a drop in temperature and a rise in relative humidity within the containment areas.

7.8.7 Design Evaluation

7.8.7.1 General

As shown by the analysis presented in Chapter 16, Sections 16.7 to 16.18, the design of the reactor is very robust and it can cope with Design Basis Accidents (DBA) with no damage to the core or rigs and without release of radioactivity taking place. Nevertheless, for emergency planning purposes, a Beyond Design Basis Accident (BDBA) has been postulated that leads to the release of fission products to the Reactor Pool and the Reactor Hall. In this hypothetical event, the containment minimises the releases into the environment.

The BDBA Postulated Initiating Event (PIE) considered is the loss of flow in the RSPCS with failure to shutdown the reactor. This implies that cooling to the irradiation rigs is lost and the uranium metal foil targets' cladding is breached. The main contributors to dose outside the reactor building are the noble gases that generate as fission products in the uranium metal foil targets. For further details on the BDBA description, see Chapter 16.

The RCS adequately manages this accident containing the fission products inside the building and thus keeping the doses to the environment well below applicable limits and regulations.

7.8.7.2 Containment Isolation Transient

The system performance has been analysed for a range of events and conditions. Conceptual design of the system was based on previous INVAP experience in ventilation for research reactors. The ASHRAE code was applied in the design. Software based in the Fortran language was used for the analysis of energy balance and to model the Containment humidity, temperature and pressure transients following Containment Isolation.

7.8.7.2.1 Computational Model

The computer model used control volumes or compartments, each having a mixture of water vapour and air, and where appropriate, liquid water.

A FORTRAN code computer model of the CERS air and water systems was prepared. The model uses conservation of mass and energy in each of the volumes and structures for heat exchange. It consists of an air circuit and a water circuit, both coupled by means of a fin tube heat exchanger.

7.8.7.2.1.1 Containment Air Model

The air model rooms include two volumes; “Reactor Hall” comprising the upper containment levels and “Process” comprising the lower containment levels.

Four structures are modelled using the finite difference method. The external boundary condition is constant temperature. Circulating air from the return ventilation ducts passes through a modelled fin tube heat exchanger where it releases heat.

No volumetric variation of the circulating air is calculated.

The ideal gas law is used to calculate the containment pressure. Humidity is also added as an ideal gas, while the released mass is calculated.

7.8.7.2.1.2 Chilled Water Model

The long pipes that convey the chilled water from the chiller units to the cooling coils are modelled as pipes (outlet and return) connected to the modelled fin tube heat exchanger. The delay and holdup that the pipes introduce into the system was modelled by dividing the pipes into discrete sections. The temperature in each section is determined according to the time it takes a fluid particle to transverse a section.

The heat exchanger model was also divided into sections. A convection balance of heat and mass is performed for each section. A two section model was used for the chiller unit.

The cold tank was modelled as a complete mixture system.

7.8.7.2.1.3 Atmospheric Pressure Variations

In terms of providing a driving force for leakage from the Containment, a decrease in atmospheric pressure has the same effect as an increase in Containment internal pressure. The maximum expected daily change in barometric pressure has been estimated from historic data series. The maximum pressure drop observed in a single day at the reactor facility site in the period assessed was 1860 Pa and occurred on 10^{th} March 1998. The length of the assessment period was three years (data for 1998, 1999 and 2000 was used). This maximum pressure drop was used for modelling.

7.8.7.2.2 Simulation Results

The performance of the containment system, has been analysed for several conditions.

a) CASE A: Summer Containment Isolation

   In this event it is postulated that the Containment changes to Isolation Mode on a summer day.

   Because fresh inlet air coming from the Air Supply System air handling units is lost due to the closure of the containment isolating valves, sensible load in the building is increased. The temperature will increase, and, as a result, the modulating valve (that controls chilled water inlet flow) of the CERS unit will automatically be opened, to take account of the extra load.

   Simulations carried out showed that the positive differential pressure in this event does not exceed 100 Pa, and in some minutes the pressure inside the containment is in equilibrium with respect to atmospheric pressure outside the containment.

   The volume of containment air released in this case is lower than (bounded by) the volumes indicated for the event where Containment Isolation occurs with simultaneous failure of a CERS unit (please refer to discussion in following sections), and/or atmospheric pressure variations. See CASES C1 and C2.

b) CASE B: Loss of Normal Electric Power Supply

   In this event the failure of the Off-site electric power supply on a summer day is postulated.

   The reactor is automatically tripped and the PCS, RCPS and RSPCS pumps lose their power supply. Due to their design configuration, the Containment isolation valves will close as a consequence of the loss of electric power supply (fail safe characteristics).

In this condition, the sensible thermal load from the Containment equipment will decay with time, while external loads (e.g. solar irradiation) remain unchanged.

The Safety Category 1 Diesel Generators will be started automatically and will provide power to the CERS as well as to the essential power loads of the facility.

The volume of containment air released in this case is lower than (bounded by) the volumes indicated for the event where Containment Isolation occurs with simultaneous failure of a CERS unit (refer to discussion in following sections), and/or atmospheric pressure variations. See CASES C1 and C2.

c) CASE C: Containment Isolation with failure of one CERS unit

In this event it is postulated that the Containment Isolation is tripped on a summer day. Also it is postulated that simultaneously the operating CERS unit fails instantaneously and in a complete way (therefore bounding other partial failures modes). As a consequence, air that is cooled in the operating coil increases in temperature, which is measured at the coil outlet.

The thermal loads in this event will be the ones corresponding to the Reactor in Power State.

The FRPS will automatically detect the failure of the duty CERS train (due to high coil air outlet temperature) and will start the standby CERS train. Once initiated, the standby CERS train does not reach full power for another 10 minutes.

Two possible scenarios are analysed:

(i) CASE C1: Containment isolation with failure of one CERS unit and no atmospheric pressure variation

The differential pressure variations inside the containment as a function of time show that, after an initial pressure peak, some depressurisation could be attained inside the containment as a consequence of the contraction of the air mass due to temperature drop. This effect will be compensated by air infiltration from the outside. Therefore if atmospheric pressure drops do not occur, no further release of air towards the environment can occur following this initial period of time.

The assumptions used for the simultaneous failure on the CERS start time with the containment isolation are conservative and maximise the pressure peak, thus these results bound other CERS failure conditions (in terms of time and partial degradation of the CERS duty).

Even for containment permeability as high as 5.0E-3 [m^3/Pa.s] the volume of air released does not exceed 1% in a single day.

(ii) CASE C2: Containment Isolation with failure of one CERS unit and maximum atmospheric pressure drop.

As indicated previously this case is similar to C1 except that a simultaneous drop in the atmospheric pressure is postulated.

A review of historic atmospheric pressure records at the reactor facility site has indicated the maximum one–day barometric drop. This change corresponds to 1860 Pa over the 24 hour period.

The explanation is as follows:

a) At (t=0), the Containment is isolated, the operating CERS fails, and starting of the standby CERS is initiated.

b) The pressure inside Containment increases up to where the cooling power of the standby CERS unit exceeds the sensible heat loads and pressure begins to decrease.

c) The minimum pressure is reached which is caused by the contraction of air inside the containment as a consequence of temperature drop due to CERS cooling.

d) The pressure in the Containment trends towards atmospheric pressure in the longer term due to in-leakage to the Containment.

The greater the containment permeability factor, the closer the pressure inside of Containment will follow external atmospheric pressure.

In the long term the CERS unit takes the heat loads from the facility. Therefore the released volume will only depend on the fluctuations in atmospheric pressure. Taking into account the historic data and a very high permeability value, the released volume will not be larger than 3% of the containment volume in a day due to this effect.

7.8.7.3 Doses to the Public

The Reactor Containment System constitutes an adequate barrier to fission products minimising the impact to the environment in case of a radiological accident. In all cases the doses to the public for accidents analysed in Chapter 16 are acceptably low. The Reactor Containment provides a satisfactory means of controlling the radiological consequences. For a more detailed analysis see Chapter 16.

7.8.7.4 Conformance Analysis

7.8.7.4.1 Containment Building

The Containment Building is capable of withstanding the initial peak and long-term pressure and temperature resulting from a beyond design-basis event while providing a barrier against radioactivity products released from the reactor core, reactor coolant boundary, or reactor irradiation facilities. As shown by the analysis, pressure transients are limited by the removal of heat, thus ensuring it is able to withstand foreseen conditions. The Containment area is designed with special doors and hatches and special wall surfaces to ensure leak tightness.

The total volume that can be lost from the Containment in any given accidental sequence in any given day, taking into account the correct functioning of the CERS, will not exceed 3% of the Containment volume.

7.8.7.4.2 Containment Isolation Valves

The CIS isolates the Containment area of the Reactor Building when required to do so. Each of the ventilation pipelines that penetrate the Containment boundary has two Category 1 isolation valves, one at each side of the boundary. Through-wall penetrations to the Containment boundary are properly sealed and tested ensuring they will properly isolate the Containment area. The Containment isolation valves close automatically by command of the FRPS when activity in the ventilation stack surpasses the established limit, thus ensuring the availability of the system when required.

7.8.7.4.3 Containment Energy Removal System

The CERS provides a satisfactory means of controlling the initial peak and long term pressure inside the Containment during the period of Containment Isolation and of minimising leakage to the environment.

CERS is a Safety Category 1 system the performance of which will be demonstrated. To ensure a high availability, the CERS has two independent, 100% capacity trains. An additional 100% capacity spare chiller unit is also provided that may be re-aligned to either train (but not both simultaneously) to replace an on-line chiller unit that is unavailable. CERS components are fed by the standby power supply.

7.8.7.4.4 Containment Pressure Relief and Filtered Vent System

The pressure relief system provides a passive means of preventing pressure transients from compromising the structural integrity of the Containment. The simplicity and passive nature of the system ensures a high availability when required.

The filtered vent system provides adequate operational flexibility for the management of accident situations.

7.8.7.4.5 Containment Vacuum Relief System

The vacuum relief system provides a passive means of preventing pressure transients from compromising the structural integrity of the Containment. The simplicity and passive nature of the system ensures a high availability when required.

7.8.8 Seismic Evaluation

Seismic Evaluation of the containment comprises the evaluation of its components. Evaluation of the seismic response of the building can be found in Chapter 4.

7.8.8.1 Containment Isolation Valves

Seismic evaluation of the containment isolation valves has been undertaken as part of the analysis of the systems in which the valves are located.

7.8.8.2 CERS

The CERS is required to maintain its structural integrity during the SL-2 event and be capable of carrying out its safety function following the SL-2 event.

An evaluation of the stresses imposed on the CERS as a result of the SL-2 event has been carried out. The evaluation utilised the design criteria recommended by IAEA and USNRC (see Chapter 2, section 2.6.1).

The analysis was directed towards the stress evaluation in piping, components and fixing points and took into account:

a) The acceleration spectra for the building positions where the system components are located,

b) the fixing characteristics of the components, and

c) the mass of water contained within the various components.

The analysis comprised the water pipelines of the CERS chilled air unit cooling system and its purpose was to verify that the design of the CERS Chilled Water System pipelines meets the stress requirements set by Code ASME B31.1.

The analysis was carried out with the CAESAR II stress analysis program.

7.8.8.2.1 Hypotheses of the Analysis

The main hypotheses for the analysis are as follows:

a) The calculation model simulates the configuration of the pipelines and supports.

b) Pipeline reductions are modelled as pipeline sections of equal. The diameter adopted is the average of the two diameters, the same applying to thickness.

c) The joints between the Water Chillers and the pipeline are designed using flexible connections, then the piping loads are not transmitted to the Water chillers.

7.8.8.2.2 Input Data

The basic input data used in this analysis consists of:

a) Dimensions, geometry and design characteristics of piping and equipment corresponding to the detailed engineering stage and when appropriate/available provided by the manufacturer.

b) Process data

c) Materials characteristic extracted from ASME Boiler & Pressure Vessel Code.

   (i) Seismic Spectra for seismic class SL-2 for the relevant levels obtained from the Seismic Design Floor Response Spectra defined for the Reactor Building, which corresponds to 0.37 PGA.

7.8.8.2.3 Model Description

The system has been divided into 3 parts to produce the finite element models.:

CERS 1

CERS 2

CERS 3

7.8.8.2.4 Definition of Dynamic Cases

The following list includes the dynamic cases analysed and their definitions:

CASE No.	CASE	Description
DY1	(OCC) SHOCK + ST1	Seismic event combination
DY2	(OCC) SHOCK + ST8	Seismic event combination verified through ANSI B31.1

Where:

a) OCC (Occasional loads): The stress produced in the load cases considered shall be contrasted with the maximum allowable stress given by the ASME code.

b) SHOCK Shock Case: This load case is generated by the software to evaluate the stresses on the pipeline due to the Seismic Event. This case is combined with the sustained and operation load cases. The stresses calculated on the pipelines for this isolated case is not evaluated by the applicable code.

c) ST1 Normal Operation 1 (OPE) W+T1+P1, where

(i) OPE: These load cases are calculated for the purpose of determining the maximum loads withstood by the equipment. The stress calculated on the pipelines for these cases are not evaluated in the applicable code
(ii) W: Generic name of the loads by the pipeline's own weight and the fluid it contains
(iii) T1: Operating temperature
(iv) P1: Operating pressure

d) ST8 Design combination (SUS) W+P3, where:

(i) SUS Sustained loads: The stresses produced in the load states considered tol be contrasted with the maximum stresses allowed by the applicable Code
(ii) P3: Design pressure

7.8.8.2.5 Summary of Results

7.8.8.2.5.1 CERS 1

Both cases were within allowable limits.

7.8.8.2.5.2 CERS 2

Both cases were within allowable limits.

7.8.8.2.5.3 CERS 3

Both cases were within allowable limits.

7.8.8.2.6 Conclusions

The summary of results show the stresses were within the allowable limits.

7.8.8.3 Containment Pressure Relief and Vacuum Relief Systems

The Containment Pressure Relief and Vacuum Relief systems are classified as Seismic Category 1. Thus, the components of the systems must maintain their structural or safety function during and after the SL-2 earthquake, independent of whether they remain operational or out of service for the rest of their useful life. This last condition depends on the type of component under study.

The seismic stress evaluation performed followed the recommendations of IAEA and USNRC about design criteria for the resistance against seismic hazard (see Chapter 2, section 2.6.1).

The analysis was based on the information available at the detailed engineering design stage and considered:

a) The acceleration spectra for the building positions where systems are fixed
b) consideration of the fixing characteristics
c) consideration of the mass of water contained within the system
d) stress evaluation in piping, components and fixing points

The present analysis comprises the pipelines from the Containment Pressure & Vacuum Relief Systems.

The applicable code is ASME.

The analysis was carried out with the CAESAR II pipeline stress analysis program.

7.8.8.3.1 Hypotheses of the Analysis

The main hypotheses for the analysis are as follows:

a) The calculation model simulates the configuration of the pipelines, with the adequate support configuration to meet the stability conditions in static and dynamic rates.

b) Pipeline reductions are modeled as pipeline sections of length equal to that of a standard reduction. The diameter adopted is the average of the two diameters, the same applying to thickness.

7.8.8.3.2 Input Data

The basic input data used in this analysis consists of:

a) Dimensions, geometry and design characteristics of piping and equipment corresponding to the detailed engineering stage and when appropriate/available provided by the manufacturer.

b) Process data

c) Materials characteristic extracted from ASME Boiler & Pressure Vessel Code.

   (iii) Seismic Spectra for seismic class SL-2 for the relevant levels obtained from the Seismic Design Floor Response Spectra defined for the Reactor Building, which corresponds to 0.37 PGA.

7.8.8.3.3 Model Description

The system under analysis modelled complete with the stack. The stack was modelled assuming that it is built with Carbon Steel.

7.8.8.3.4 Definition of Dynamic Cases

The following list includes the dynamic cases analysed and their definitions:

CASE No.	CASE	Description
DY1	SHOCK + ST3	Seismic event combination verified through ANSI

Where:

a) ST3 Design combination(SUS) W+P2, with

   (i) SUS Sustained loads: The stress produced in the load states considered to be contrasted with the maximum stress allowed by the applicable Code
   (ii) W: Generic name of the loads by the pipeline's own weight and the fluid it contains
   (iii) P2: Operating pressure

b) SHOCK Shock Case: This load case is generated by the software to evaluate the stresses on the pipeline due to the Seismic Event. This case is combined with the sustained and operation load cases. The stresses calculated on the pipelines for this isolated case is not evaluated by the applicable code.

7.8.8.3.5 Summary of Results

The results show the stresses were within the allowable limits.

7.8.8.3.6 Conclusions

The analysis shows that the stress produced by a seismic event is within the limits set by the applicable code.

End of Section

Figure 7.8/1 Schematic of the Reactor Containment

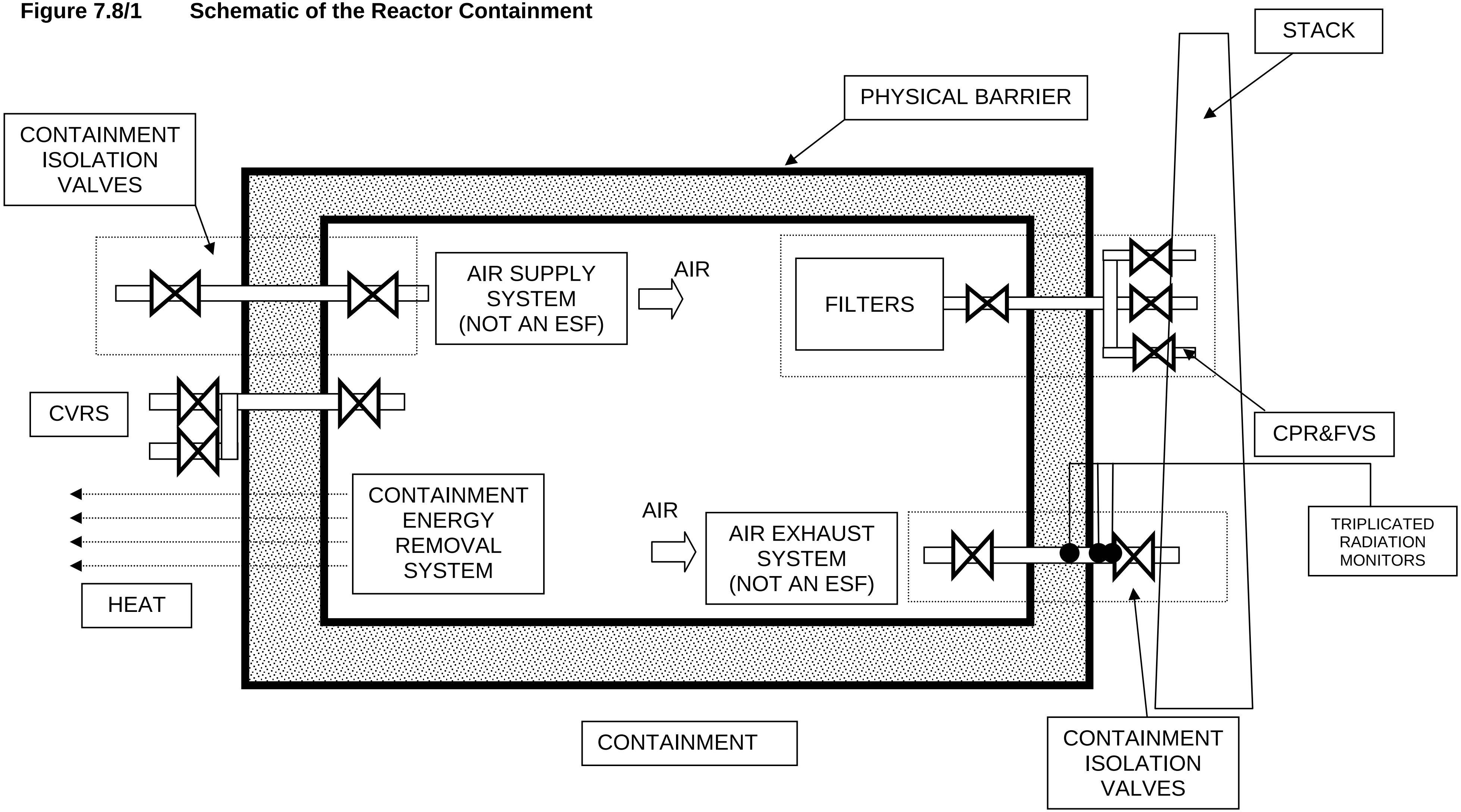


Figure 7.8/2 Containment Energy Balance

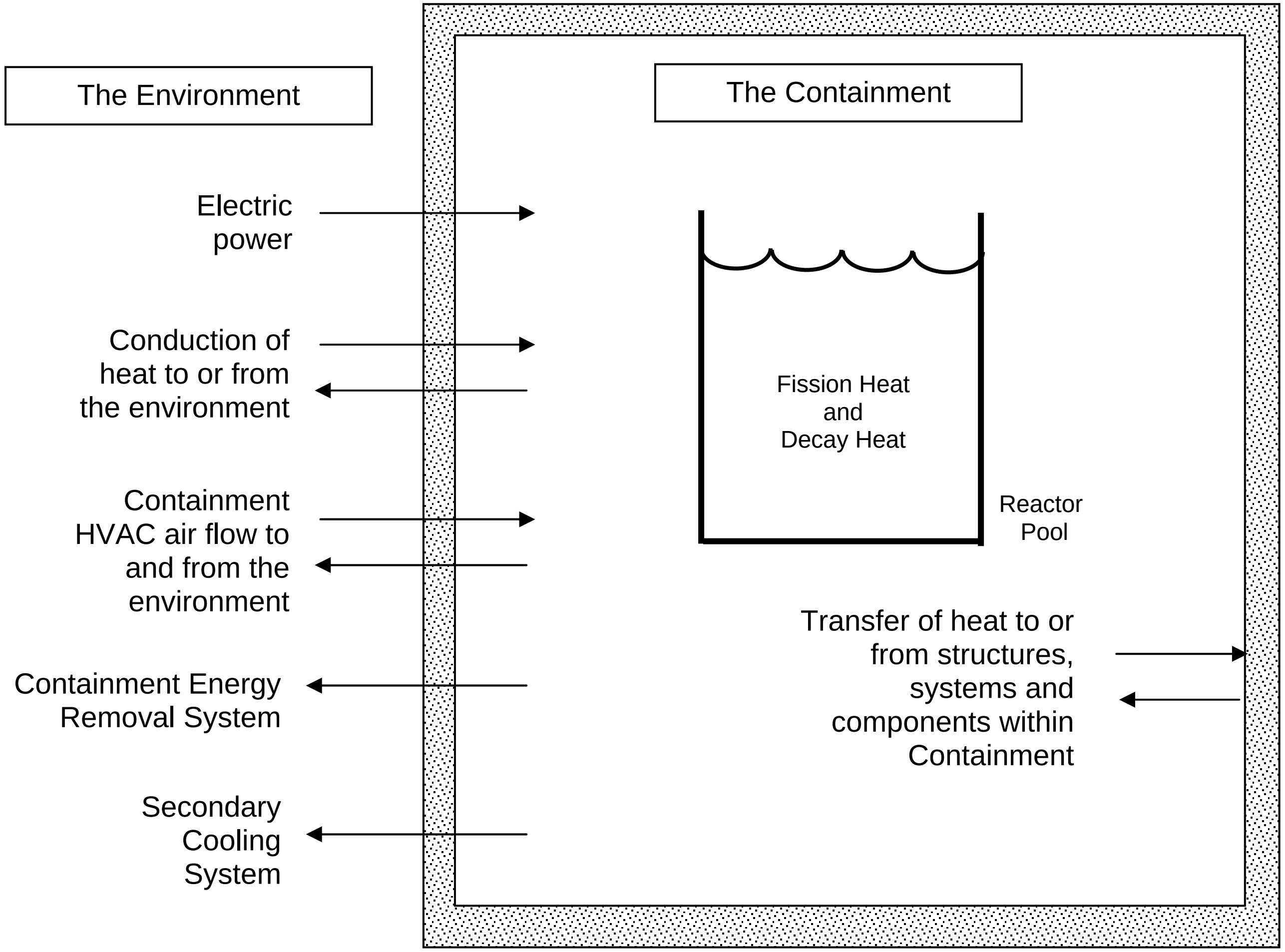


Figure 7.8/3 Schematic of Containment Pressure Relief and Filtered Vent Relief

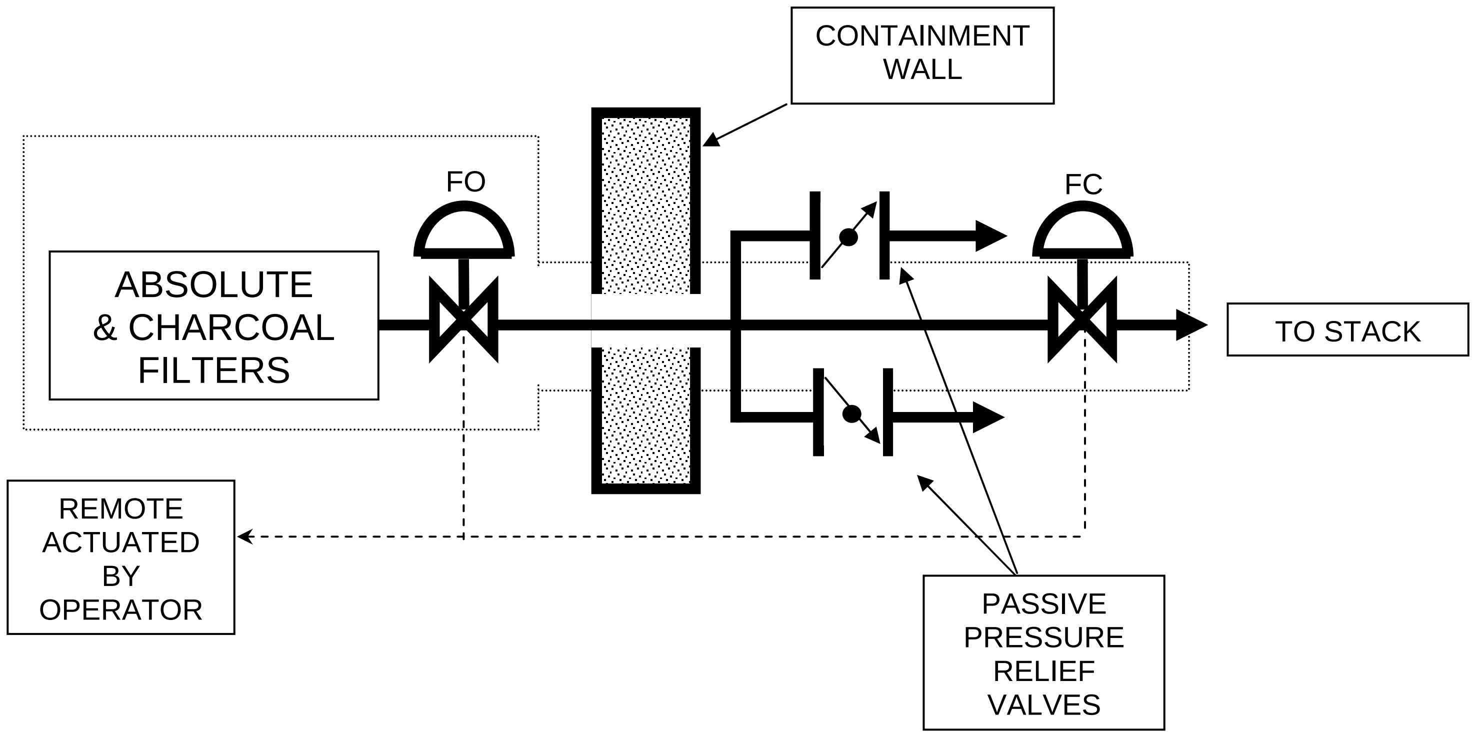
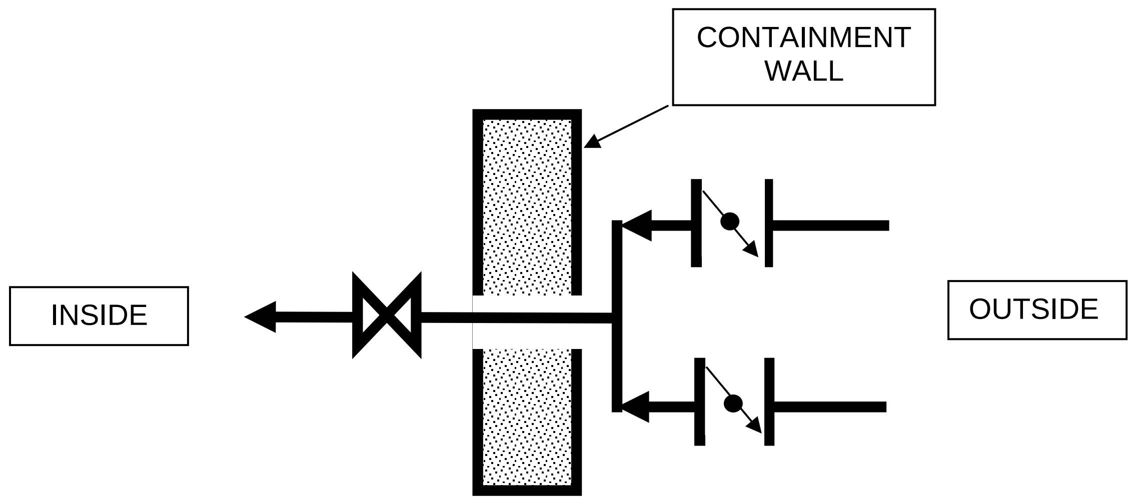


Figure 7.8/4 Schematic of Containment Vacuum Relief System



7.9 EMERGENCY CONTROL CENTRE VENTILATION AND PRESSURISATION SYSTEM

The Emergency Control Centre (ECC) Ventilation and Pressurisation System is described in Chapter 10, Section 10.4, as part of the Auxiliary Systems description.

The ECC Ventilation and Pressurisation System provides fresh, filtered air to the ECC and maintains the pressure in the ECC above that in surrounding areas to prevent in-leakage of unfiltered air. The system has two independent trains.

In the event of an emergency situation, the operation of the ECC Ventilation and Pressurisation System is initiated manually from within the ECC. This will start the duty supply ventilation system. The operation of the ventilation system will be monitored at the point of air entry to the ECC to prove effective operation. Any loss of airflow will cause the standby fan to automatically operate as the duty fan. Power to the system is provided from the Standby Power System.

End of Section

7.10 STANDBY POWER SYSTEM

The Standby Power System (SPS) is described in Chapter 9, Section 9.3, as part of the Electric Power description.

The function of the Standby Power System is to provide electric power to essential loads when the Normal Power Supply is not available. During the Reactor Normal Operation, all interruptible electric loads (Category 1, Category 2 and Category 3) are fed by Normal Power Supply (Category 3), including the input of the Category 1 UPS units.

When the Normal Power Supply is not available, essential loads receive power from the Category 1 Diesel Generator Sets (the Standby Power Supply). Supply to Uninterruptible Category 1 loads is maintained by UPS units without interruption. Other loads are supplied by the Diesel Generator Sets following start-up. The Diesel Generator Sets are able to supply the total maximum demand of the essential loads, including in rush currents of UPS systems and motors. The arrangement of the SPS, comprising two independent Diesel Generator Sets, switchboards and UPS systems, ensures that a single failure cannot prevent supply of Standby Power to essential loads. The transfer from Normal Power supply to Standby Power is automatic (after a time delay for degraded voltage condition). Return to the Normal Power supply is a manual operation. A third diesel generator identical to the two on-line diesel generators, is provided as an installed spare.

The Safety Category 1 Essential Loads of the 415/240 VAC power distribution system are supplied via Safety Category 1 switchboards and, therefore, are capable of being supplied by either Normal Power or Standby Power.

End of Section