



Ventilation of Reactor Buildings in Indian PHWR Nuclear Power Plants

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Nuclear ventilation in Indian Pressurised Heavy Water Reactors (PHWRs) comprises of systems which enhance habitability, minimize occupational dose during normal conditions and those which are engineered to minimize radiological consequences in the event of various postulated off-normal conditions.

Pressurized Heavy Water Reactor employs natural uranium fuel cooled by heavy water. In the process of producing heat, the reactor generates radioactive fission fragments and induced radionuclides. Nuclear ventilation system aims at limiting these releases within the plant and to the public domain within acceptable limits arrived at by application of guidelines laid down by International Commission on Radiological Protection and Atomic Energy Regulatory Body (AERB). It may be noted here that these limits are two orders of magnitude lower than the threshold limit value for most of the toxic chemical agents. Special techniques are employed for containing and/or dispersing

the gaseous radioactivity. At the same time, nuclear ventilation is designed as an engineered safety feature (ESF) which supports the containment in mitigating the consequences of release of radioactivity to public domain both under normal and accident conditions. The importance to safety of a ventilation system determines its safety and seismic classification.

The regulatory requirements on air borne activities as stipulated by Atomic Energy Regulatory Board (AERB) form a basis for functional design of ventilation systems. Mandatory in-service inspection aspects of components are built into the station technical specification. QA in design is ensured by detailing to appropriate standards such as ERDA-76-21 and ANSI-N-509. Detailed equipment specifications which incorporate the requirements of ANSI-N-509 and 510, AMCA, ARI, UL, MIL and IEEE Standards ensure that the design intent is met.

This article gives an overview of Reactor Building (RB) ventilation with the

sole aim of highlighting special features which make it an important safety system at a nuclear power station.

Reactor Building (RB) Ventilation

The Reactor building in the current design of Indian PHWRs is of double containment type namely, Primary Containment (PC) and Secondary Containment (SC) with suppression pool for pressure suppression. Primary containment is a cylindrical building of prestressed concrete with a dome. PC houses the nuclear reactor and associated steam generating equipment. Primary containment forms the barrier in

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controlling releases of radioactivity to the environment, both at the ground level, and at stack level. It is designed to withstand an accident pressure of 1.44 kg/cm² (g) and temperature of around 125°C.

Primary Containment

The primary containment is further divided into two areas namely V1 & V2:

V1 areas are where high enthalpy systems are located and not accessible during normal reactor operation. The main equipment which handles high enthalpy fluids are primary heat transport (PHT) pumps, heat exchangers, steam generator and fuelling machine, etc.

V2 areas are normally accessible, comprising of the rest of the reactor building (within the primary containment). However, some of the areas of this volume are shut down accessible areas which can be accessed during reactor shutdown.

Secondary Containment

The primary containment is surrounded by a secondary envelope. The only cause of pressure rise in the inter space between the two structures is leakage from the primary containment and compressed air in leakages. The secondary containment helps in practically eliminating the ground level releases.

RB Ventilation Systems

The RB ventilation system comprises of seven sub-systems as shown in Figure 1. Three of these are for normal operation and the remaining four systems designated as Engineered Safety Feature (ESF). These ESF systems are for energy and radionuclide management after Design Basis Accident (DBA):

Systems for Normal Operation

- Primary containment ventilation system
- Secondary containment ventilation system
- Heavy water vapour recovery system

Systems for Post DBA Management

- Primary containment (V1 areas) cooling system
- Primary containment clean-up system
- Primary containment controlled discharge system
- Secondary containment recirculation and purge system
- These systems function within the framework of containment philosophy and operational safety to meet the following criteria:
 - To maintain a negative pressure gradient in the direction of increasing radioactivity levels (during normal operation). This concept applies at every level of division of volume.
 - To provide the cooling for human occupancy.
 - To limit ground level and stack releases of activity during normal and accident conditions to meet the stipulated dose limits.
 - To maintain low tritium activity levels in occupancy areas.
 - To remove heat rejected to building atmosphere and maintain temperatures in various areas, well below levels that would affect performance of process and safety instrumentation.
 - Prevention of spread of fire and smoke

Systems for Normal Operation

Primary Containment Ventilation

As mentioned earlier, primary containment is divided into

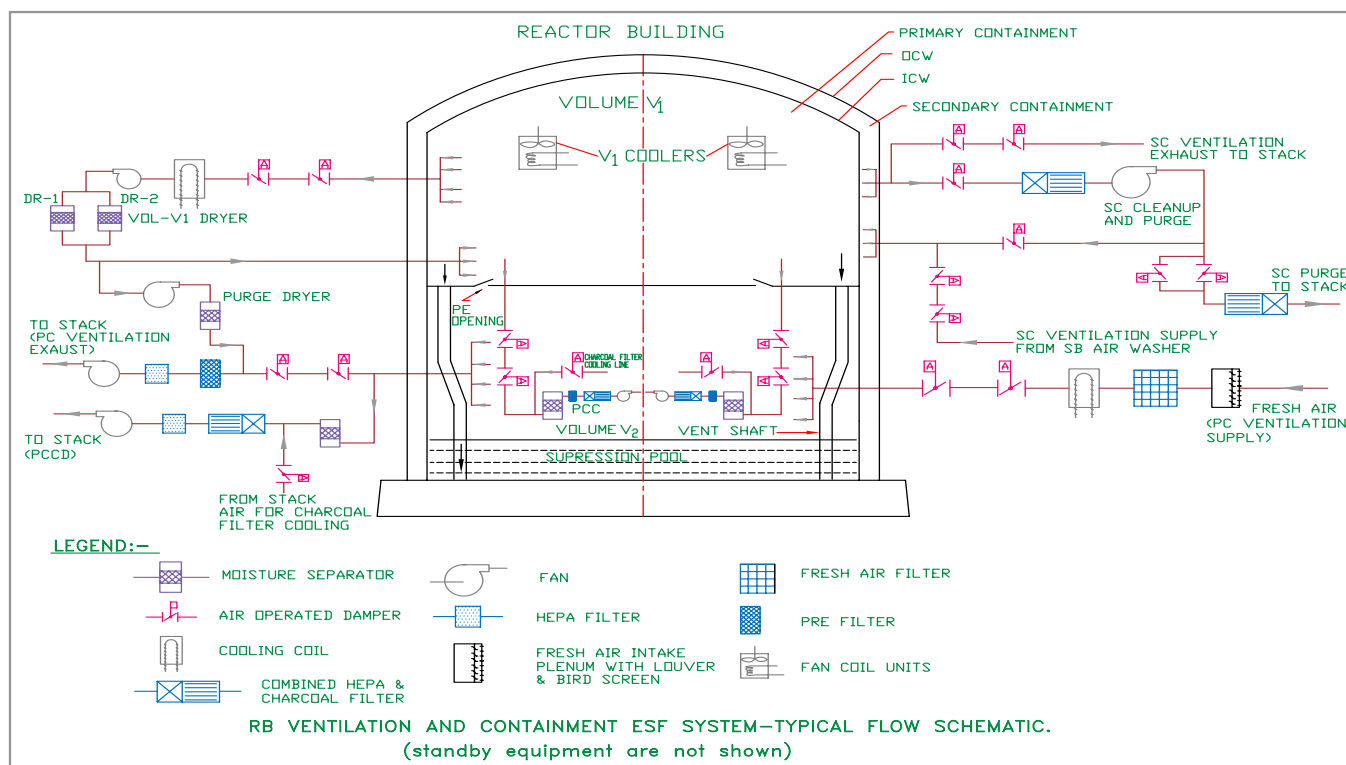


Figure 1: The Reactor Building ventilation system

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two volumes, namely volume V1 and volume V2. Volume V1 is provided with a closed loop system for recovery of expensive and radioactive heavy water vapours. Dew point of 0°C is maintained to keep tritium within allowable limits. The area temperature is kept around 45°C by fan coil units cooled by process water which is at 35°C

Volume V2 is provided with a once-through ventilation system of pull type so as to maintain PC at a slightly negative pressure with respect to the environment. This helps in preventing leakages of containment air. Filtered and conditioned air at 21°C and 95% relative humidity is supplied to the V2 areas. The filtration helps in reducing dust load which would otherwise settle on electronic components thus impairing their performance. Dust particles can also become radioactive while passing through the nuclear environment. Dust particles if not removed at inlet can load HEPA filters (high efficiency particulate air filters) in the exhaust system thus requiring frequent replacements which may be costly in nature. Local air handling units cooled by chilled water keep the area temperatures at 30°C – 35°C and RH of less than 60%.

Human occupancy inside the primary containment is at a low level during normal operation and hence a small number of air changes are provided. This also indirectly helps in reducing heavy water vapour losses which is an important objective to be achieved.

Zoning is an important concept in nuclear ventilation. Air flow direction is maintained from areas of low radioactivity to the areas of high radioactivity from where it is exhausted to the stack. Small quantity of air is therefore continuously purged from V1 areas. Clean air therefore moves from surrounding V2 areas towards V1 areas.

Air from V2 areas is exhausted by one of 2x100% fans located in the service building through a network of ducting on various floors of primary containment and passed through disposable type prefilters and HEPA filters to remove dust before exhausting to the stack.

Under accident conditions, primary containment is boxed up by closing fast acting automatic isolation dampers on supply and exhaust ducts. Two dampers in series are provided on each of these ducts for improving the reliability of containment isolation. Ventilation ducts outside the containment are of welded construction to withstand containment pressure under accident conditions.

Secondary Containment Ventilation System

The annulus gap of around 1.8 meter between PC & SC is served by a once-through ventilation system of pull type to maintain negative pressure w.r.t. environment. This system serves fresh air for occasional occupancy and to prevent the atmosphere from becoming stale. The fresh air is drawn through an air washer and is supplied through suitably laid out ducting and grills. Exhaust (stale) air is drawn through exhaust air grills, by a centrifugal exhaust fan. Discharge from the fan is connected to common ventilation tunnel leading to the stack.

Under an accident condition, SC is boxed-up by closing fast acting automatic isolation dampers on supply and exhaust ducts. Two dampers in series are provided on each of these ducts for improving the reliability of containment isolation.

Vapour Recovery System

Recovery of traces of heavy water vapours from air in the reactor building is important from safety and economic considerations. An extensive system of recovering the heavy water vapours has been provided for this purpose. Molecular sieve based twin bed dryer systems have been chosen for their high efficiency at low humidity level. The dryer system is of regenerating type. Being of twin bed design, one bed is normally under adsorption with the other bed on closed loop regeneration by hot air heated with the help of electric air heaters to a temperature of about 250°C – 290°C. The heavy water vapours released by the bed are condensed in a chilled water cooler and recovered for further processing. (*See Editor's Note on the next page*)

Systems for Post DBA Management

Primary Containment (V1 Area) Cooling System

After a postulated design basis accident (DBA), peak pressure in the primary containment is limited to less than design pressure by quenching the steam air mixture in suppression pool water. It is important to bring down the pressure as fast as possible to minimize ground level releases through a painted prestressed concrete containment. To achieve this, fan coil units having redundant capacity (located in V1 areas) come into operation automatically. These cooler units are provided with reliable process water supply. These coolers (considering the operation of 50%) bring down the peak pressure to 0.045 Kg/cm²g in about 4 hours.

Primary Containment Clean-up System

This system starts by manual remote action from the control room. The system starts seven hours after the DBA when a large fraction of fission fragments are expected to have plated out on various surfaces available inside the containment. This system comprises of a demister for removing moisture, combined HEPA and charcoal filters for removing particulate activity and radioiodine and a fan to circulate air from V1 to V2 areas. This helps in trapping the radioactivity, thereby reducing its concentration in the air. Therefore, the ground level as well as stack releases from the containment via controlled discharge would be at lower concentration levels of radioactivity.

Primary Containment Controlled Discharge System

The fan cooler units bring down the containment pressure to about 0.045 Kg/cm²g at a fast rate. Further reduction in pressure by this method is very slow due to small temperature gradients available between the area temperature and the process water temperature. This is therefore achieved by controlled discharge to the stack via combined HEPA & charcoal and HEPA filters. Charcoal impregnated and activated filters have high affinity for trapping radioiodine which is one of the main radio-nuclides of concern from human safety point of view. The HEPA filter traps particulate activity.

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Secondary Containment Clean-up & Purge System

The annulus space between primary containment and secondary containment is maintained under negative pressure with respect to atmosphere for prevention of ground level release of radioactivity from the primary containment which goes under positive pressure under accident conditions. This is achieved by providing a closed loop ventilation system on secondary containment which recirculates the air via combined HEPA and charcoal filters. Part of this air is continuously purged to the stack to maintain the secondary containment under negative pressure.

Editor’s Note

Air Conditioning requirements of Nuclear Power Plants

Chilled water at 6.5°C both for process and comfort needs of Indian Nuclear Power plants of the PHWR type described in this article are generally provided by water-cooled centrifugal chillers with operating capacities of 1000 ton to 2000 ton along with a standby unit.

For example, at Kaiga 1&2 and Rajashtan 3&4 atomic power plants, four nos. 580 TR centrifugal chillers are provided at each site, with three working and one acting as standby.

Safety & Seismic Classifications

To ensure quality, selection of design standards commensurate with the importance of the system is very important. The process of safety and seismic classification for all systems at a nuclear power plant is carried out on the basis of AERB Safety Guide AERB/NPP-PHWR/SG/D-1.

Safety Classification

As per AERB guide, ventilation systems for normal operation are classified as Safety Class-4, the ventilation system of ESF category as Safety Class-3 and containment isolation dampers (CID) & ducting from ICW to last CID as Safety Class-2 which calls for mechanical design as per ASME section VIII Division-1 and Section-III ND/NC respectively for pressure retaining components.

Seismic Classification

Ducting between ICW and OCW, containment isolation dampers, ducting supports and all ESF systems are classified for severe earth quake condition.

In-service Inspection

To meet the safety requirements, HEPA and iodine filters and frame are tested insitu during commissioning, operation and on replacement. DOP (Dioctyle Phethalate) aerosols and size selective particle counter are used for HEPA filter testing. Iodine filters are tested using molecular or methyl iodide species as test agent using I-131. ESF operability is to be ensured by testing once in a quarter. Containment isolation dampers are also tested for operability once in a quarter and leak tested annually. Containment isolation logics are also tested periodically.

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