6.2.3 Secondary Containment Functional Design

The Reactor Shield Building (RSB) completely encloses the Reactor Containment Building (RCB) and provides a second containment barrier to the release of airborne radioactive material. The space between the RSB and RCB forms an annulus, which is maintained at a subatmospheric pressure and is filtered by the annulus ventilation system (AVS).

6.2.3.1 Design Bases

The RSB functions as a secondary containment to prevent the uncontrolled release of radioactivity to the environment following a postulated accident.

The RSB and AVS provide the secondary containment function under the environmental conditions of normal operation, maintenance, testing, and postulated accidents, including protection against dynamic effects resulting from equipment failures (GDC 4).

The AVS maintains the annulus at a subatmospheric pressure during normal operations and following postulated accidents, establishing a barrier against uncontrolled release of radioactivity to the environment (GDC 16).

The AVS filters leakage from the primary containment electrical penetrations that terminate in the annulus following a postulated accident before releasing it to the environment.

The AVS maintains the ambient air temperature in the annulus to avoid significant boron precipitation in piping that traverses the annulus.

The AVS is designed to permit periodic inspection and functional testing to confirm barrier integrity and the operability of the secondary containment ventilation system (GDC 43). RSB inspection is addressed in Section 3.8.4. Containment leakage testing in accordance with 10 CFR 50, Appendix J is described in Section 6.2.6.

6.2.3.2 System Description

6.2.3.2.1 General Description

The RSB is a reinforced concrete shell structure consisting of an upright cylinder capped with a spherical dome. The RSB is concentric with, and completely encloses the RCB, creating an annular region approximately six feet in width. The RSB is surrounded by the Safeguard Buildings and the Fuel Building. Section 3.8.1 contains plan and elevation views of the Reactor Building.

The primary function of the RSB is to protect the RCB from damage due to external events. The RSB also functions as a secondary containment to prevent the uncontrolled release of radioactivity to the environment. The design description and performance criteria of the RSB are presented in Section 3.8.4.

The annulus ventilation system collects and filters airborne radioactive material that may leak from the primary containment by maintaining a subatmospheric pressure in the annulus.

By maintaining a subatmospheric pressure in the Fuel Building and Safeguard Building controlled-area, the fuel building ventilation system (FBVS) and safeguard building controlled-area ventilation system (SBVS) collect and filter airborne radioactive material that may leak from the primary containment. A description of the FBVS and SBVS is given in Sections 9.4.2 and 9.4.5, respectively.

6.2.3.2.2 Annulus Ventilation System

The AVS is designed to contain leakage from the primary containment by maintaining a subatmospheric pressure in the annulus. The AVS consists of three trains: one train is used during normal plant operation; two trains are used to mitigate potential accidents. AVS design and performance parameters are presented in Table 6.2.3-1.

Table 3.2.2-1 provides the seismic and other design classifications of the components in the AVS.

Refer to Section 12.3.6.5.6 for ventilation system design features which demonstrate compliance with the requirements of 10 CFR 20.1406.

6.2.3.2.2.1 AVS Normal Operation Train

The normal operation filtration train is shown in Figure 6.2.3-1. The full capacity normal operation filtration train is designed to maintain a subatmospheric pressure in the annulus, to maintain the annulus temperature above 45°F to prevent boron precipitation in the extra borating system piping, and to provide conditioned air in the annulus for personnel accessibility.

During normal operation, the conditioned air is drawn from the Nuclear Auxiliary Building ventilation supply shaft (See Section 9.4.3) through a fire damper, a motor-operated control damper, and two motor-operated isolation dampers. The supply air is distributed in the bottom of the annulus to four different locations. A subatmospheric pressure of less than or equal to -0.8 inches water gauge is maintained in the annulus during normal operation by regulating the control damper with two redundant pressure sensors located in the annulus.

The exhaust air is drawn from the top of annulus by the Nuclear Auxiliary Building ventilation system exhaust fans through two motor-operated isolation dampers and a fire damper. The exhaust air is filtered by the Nuclear Auxiliary Building filtration trains and discharged through the vent stack.

The normal operation filtration train is in service during normal plant operation and plant shutdown conditions. The two accident trains are available as backup if the normal operation train is not able to maintain the subatmospheric pressure in the annulus.

The motor-operated air-tight dampers—located on the normal operation filtration train supply and exhaust ducts—isolate the secondary containment in case of a postulated accident. The redundant dampers in the supply and exhaust trains are powered by different electrical divisions backed by separate emergency diesel generators. The dampers can be operated automatically or manually from the main control room (MCR). In the event of a station blackout (SBO), these dampers are automatically closed by batteries.

The fire dampers on both supply and exhaust trains are located at the wall penetration between the Fuel Building and the annulus. These dampers are equipped with thermal sensors for automatic closing.

6.2.3.2.2.2 AVS Accident Trains

The AVS accident filtration trains are shown on Figure 6.2.3-2. The filtration trains are engineered safety feature (ESF) filters and are used during postulated accidents to contain leakage from the primary containment by maintaining a subatmospheric pressure in the annulus. The exhaust air from the annulus is filtered before release to the environment via the vent stack.

There are two full capacity ESF trains, each consists of an air-tight motor-controlled damper, moisture separator, two stage electrical heater, pre-filter, HEPA filter, iodine absorber, post filter, air-tight motor controlled damper, fan, and backdraft damper. The filter system components are designed in accordance with Regulatory Guide 1.52, and are described in Section 6.5.1.

During a postulated accident, the ESF filtration trains collect the containment leakage from the annulus, remove airborne radioactivity through the filtration train, and release the filtered air to the vent stack. The AVS accident trains reduce the pressure in the annulus to less than or equal -0.25 inches water gauge or less and maintain the lower subatmospheric pressure. The system is capable of maintaining a uniform negative pressure throughout the secondary containment structure following the design basis loss of coolant accident (LOCA).

The exhaust air is monitored and sampled for radiation levels before release to the vent stack, as described in Section 11.5.3.1.10 and Table 11.5-1, Monitors R-27 and R-28.

The two ESF trains are physically separated by being installed in separate rooms of the Fuel Building, which are also in separate fire areas. The two ESF trains are powered by different electrical divisions backed by separate emergency diesel generators.

6.2.3.2.2.3 System Operation

The normal operation filtration train is in service during normal plant operation, including cold shutdown and outages. During normal operation, the isolation dampers are in the open position and the annulus is continuously vented. The subatmospheric pressure inside the annulus is maintained by regulating the control damper located on the supply side of the normal operation filtration train. The supply air from the AVS maintains the annulus temperature between 45°F and 113°F.

A failure of the normal operation filtration train leads to the loss of supply and exhaust air to the annulus. In this case, one of the accident filtration trains is started, and the two isolation dampers on the supply and exhaust side of the normal filtration train are closed to isolate the normal operation filtration train and maintain the leak tightness of the annulus.

In case of a postulated accident, a containment isolation signal causes the normal filtration train to automatically stop. The normal filtration train supply air isolation dampers close immediately and the exhaust isolation dampers close with a delay, to maintain the annulus negative pressure during the switchover to the accident filtration trains. Both accident filtration trains start on receipt of a containment isolation signal and an alarm is issued in the MCR.

At the start of an accident, full power of the two stage electric heater is switched on when the fans start and filter bank isolation dampers open. As the negative pressure is drawn down in the annulus, and when the temperature downstream of the heater increases to 158°F, the first step of heater power is switched off automatically. As the temperature downstream of the heater reaches 176°F, the second step of the heater is also switched off automatically.

6.2.3.2.3 Bypass Leakage

Certain containment penetrations introduce the potential for primary containment leakage to bypass the filtered annulus and escape directly to the environment. Potential bypass leakage paths exist through the double resilient seals of the equipment hatch, personnel airlocks, fuel transfer tube, and containment purge isolation valves. These potential bypass leakage paths terminate in either the fuel building or the anteroom of Safeguards Buildings 2 and 3 in areas equipped with filtered ventilation and monitoring prior to being discharged out the vent stack.

Three basic categories of leakage paths are evaluated:

1. Electrical penetrations and seals that terminate within the secondary containment volume. Potential bypass leakage from electrical penetrations are captured within the annulus. The annulus provides a volume to capture containment leakage that may occur during accident conditions. The AVS provides a sub-atmospheric pressure in relationship to the containment during normal and accident conditions. Leakage through penetrations and seals that terminate in the secondary containment do not become bypass leakage during normal or accident operation modes.

2. Mechanical penetrations and seals that terminate outside the secondary containment volume in areas that are filtered and exhausted to the vent stack, which is a monitored release path. These mechanical penetrations are a potential source of bypass leakage for which a reasonable and acceptable design leak rate must be established and periodically verified to remain within acceptable operational limits.

   Penetrations that terminate outside the secondary containment (outside the annulus) exit the reactor shield building structure into either the fuel building or one of the four safeguard buildings. The ventilation systems for the fuel building and safeguard buildings are provided with filtering systems to capture radiological contaminants that may occur from a DBA. The ESF filters and ducts that capture potential bypass leakage are located in the fuel building, safeguard buildings and annulus. Therefore, any potential bypass leakage is processed by engineered safety features (ESF) filter systems before release. The ESF filters are described in Section 6.5.1. The fuel building ventilation system and the safeguard building controlled-area ventilation system are described in Section 9.4.2 and Section 9.4.5, respectively.

   A special sub-category of penetrations are those penetrations with elastomer seals. These seals are leakage rate tested in accordance with 10 CFR 50, Appendix J. Test connections are provided on these penetrations to facilitate leakage rate testing.

3. Mechanical penetrations that terminate outside the secondary containment volume in areas that are not filtered or released via the vent stack. These mechanical penetrations consist of closed loop secondary systems:

   A. Main steam (4 penetrations).

   B. Main feedwater (4 penetrations).

   C. Steam generator blowdown flashed steam (1 penetration with two bellows seal isolation valves located outside of the shield building penetration).

   D. Condensate to and from steam generator blowdown coolers (2 penetrations with two bellows seal isolation valves located outside of the shield building penetration on each line).

   These closed systems meet the requirements of SRP 3.6.2, SRP 6.2.4, RG 1.29 and GDC 57.

6.2.3.3 Safety Evaluation

The AVS system components are located inside the Fuel Building, which is a Seismic Category I structure. The two AVS accident filtration trains are designed to withstand the safe shutdown earthquake and are classified as Seismic Category I.

The safety-related components of the AVS system remain functional and perform their intended function following a postulated internal hazard (e.g., fire, flood, internal missiles, pipe breaks). The two accident filtration trains are physically separated from each other to prevent common mode failures. Since the accident filtration trains are completely redundant and are both full capacity, one train alone can collect and process radioactive material that may leak from the primary containment following an accident. The supply and exhaust trains of the normal filtration train can be isolated with two redundant dampers in series.

Guard pipes surround high energy lines passing through the annulus to protect against pipe failures that could compromise the integrity of the secondary containment. Design criteria for guard pipes are presented in Section 3.6.2.2. Containment penetrations are listed in Section 6.2.4. Doors and hatches leading to the annulus are maintained under administrative control.

If a fire is detected in the annulus during normal operation, the continuous ventilation of the annulus is stopped manually from the MCR by closing the isolation dampers to reduce the possibility for fire propagation.

Analyses have demonstrated the ability of the AVS to depressurize and maintain a subatmospheric pressure in the annulus during normal operation and following a design basis LOCA. The LOCA is assumed to occur concurrent with a loss of off-site power, and a loss of one of the accident trains. The total thermal and pressure expansion of the primary containment structure is assumed to occur prior to the start of the remaining accident train, resulting in a starting pressure of 14.712 psia. The drawdown of the annulus is started 60 seconds after the start of the postulated accident. Analytical results indicate that the pressure in the annulus reaches a subatmospheric pressure sufficient for the AVS to perform its safety function with substantial margin. Analytical specifications and results are presented in Table 6.2.3-2.

The components that make up the FBVS and SBVS are located inside the annulus, Fuel Building and Safeguard Buildings, which are classified Seismic Category I structures.

Analyses have demonstrated the ability of the SBVS to depressurize and maintain a subatmospheric pressure in the Fuel Building and controlled-area of the Safeguard Building following a design basis LOCA. The LOCA is assumed to occur concurrent with a loss of off-site power and a loss of one of the accident trains. The drawdown of the Fuel Building (FB) and controlled-area of the Safeguard Building (SB) is started 60 seconds after the start of the postulated accident. Analytical results indicate that the pressure in the FB and SB reaches a subatmospheric pressure sufficient for the SBVS to perform its safety function. Analytical specifications and results are presented in Table 6.2.3-2.

6.2.3.4 Inspection and Testing Requirements

The AVS major components, such as dampers, motors, fans, filters, heaters, and ducts are located to provide access for initial and periodic testing to verify their integrity.

Initial in-place acceptance testing of the AVS is performed as described in Section 14.2 (test abstracts #077 and #203), Initial Plant Test Program, to verify the system is built in accordance with applicable programs and specifications.

The AVS is designed with adequate instrumentation for differential pressure, temperature, and flow indicating devices to enable testing and verification of equipment function, heat transfer capability and air flow monitoring.

During normal plant operation, periodic testing of AVS is performed to demonstrate system and component operability and integrity.

Isolation dampers are periodically inspected and damper seats replaced as required.

Per IEEE 334 (Reference 17), type tests of continuous duty class 1E motors for AVS are conducted to confirm ESF system operation and availability.

Fans are tested by manufacturer in accordance with Air Movement and Control Association (AMCA) standards (References 18, 19, and 20). Air filters are tested in accordance with the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards (Reference 21).

Housings and ductwork are leak-tested in accordance with the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) technical manual “HVAC Air Duct Leakage Test Manual” (Reference 22), ANSI/ASME N510 (Reference 23), ASME AG-1 (Reference 24), and RG 1.52 (Reference 25).

Heaters are tested in accordance with ASME AG-1, Section CA (Reference 24).

Emergency filtration units are tested by manufacturer for housing leakage, filter bypass leakage and airflow performance. Periodically and subsequent to each filter or adsorber material replacement, the unit is inspected and tested in-place in accordance with the requirements of RG 1.52 (Reference 25), ANSI/ASME N510 (Reference 23) and ASME AG-1 (Reference 24). The charcoal adsorber samples are tested for efficiency in accordance with RG 1.52 (Reference 25) and ASTM D3803

(Reference 26). Air filtration and adsorption unit heaters are tested in accordance with ANSI/ASME N510 (Reference 23).

Periodic testing and inspections identify systems and components requiring corrective maintenance, and plant maintenance programs correct deficiencies.

In-service test program and test frequency requirements are described in Section 16, "Technical Specification" Subsections 3.6.6, 3.6.7 and per Ventilation Filter Test Program (VFTP) described in Section 16, "Technical Specification" Subsection 5.5.10.

6.2.3.5 Instrumentation Requirements

Indication of the operational status of the AVS equipment, position of dampers, instrument indications and alarms are provided in the MCR. Fans, motor-operated dampers, and heaters are operable from the MCR. Local instruments are provided to measure differential pressure across filters, flow, temperature and pressure. The fire detection and sensors information is delivered to the fire detection system. The radiation instrumentation requirements for controlling airborne radioactivity releases via the vent stack are addressed in Section 11.5.

The minimum instrumentation, indications, and alarms for the AVS ESF filter systems is provided in Table 6.2.3-3 per the requirements of ANSI/ASME N509 (Reference 27).

Table 6.2.3-1—Design and Performance of Annulus Ventilation System

Design Feature	Value
Maximum annulus pressure during normal operation [2]	≤ -0.8 inches water gauge
Maximum annulus pressure during postulated accidents [2]	≤ -0.25 inches water gauge
Minimum annulus temperature (all modes)	45°F
Maximum relative humidity at iodine filters (postulated accident)	70%
Design pressure	2.77 inches water gauge
Design temperature	212°F
Electrical heater power (each train)	6 kW
Minimum rated efficiency – Pre-filter	55-65%
Minimum rated efficiency – HEPA filters	99.95%
Minimum rated efficiency – Iodine adsorbers [1]	99%
Fan design air flow	60 – 1177 cfm

Note:

1. Laboratory test results for both elemental iodine and organic iodine, based on four (4) inch deep bed of carbon.

2. The subatmospheric pressure in the annulus will be equal to or lower than the value listed.

Table 6.2.3-2—Secondary Containment Response Analysis
Sheet 1 of 2

Design Feature [3]	Value	
Annulus Analysis		
Annulus temperature	Initial	86.5°F
	After 24 hours	< 92°F
Annulus pressure	Start of drawdown	0.44 inches water gauge
	At 305 seconds	≤ -0.25 inches water gauge
	After 565 seconds	≤ -0.25 inches water gauge
Annulus volume	Initial	706,293 ft^3
	After compression and at start of drawdown analysis	704,737 ft^3
Heat transfer coefficients [1, 2]	N/A [4]	
Conductive heat transfer [1]	N/A [4]	
Radiant heat transfer [1]	N/A [4]	
Compressive effect of primary containment [1]	Volume reduction of 1556 ft^3	
Secondary containment in-leakage assumed [1]	0.25% of containment free volume per day	
Secondary containment out-leakage assumed [1]	Zero leakage out of the secondary containment	
Heat loads generated within annulus [1]	Negligible	
Safeguard Building Controlled Area and Fuel Building Analysis		
Safeguard Building temperature	Normal Operation	65°F to 86°F
	Initial [5]	113°F
Safeguard Building pressure	Start of drawdown	0.4 inches water gauge
	At 265 seconds	≤ -0.25 inches water gauge
	After 400 seconds	≤ -0.25 inches water gauge
Safeguard Building volume [6]	5.28×10^5 ft^3 (all four divisions)	
Secondary Containment in-leakage assumed from primary containment[1]	9.8 cfm	
Secondary Containment in-leakage assumed from the environment[1]	6 cfm per division	
Heat loads generated within the Safeguard Building	49.8 Btu/sec	
Fuel Building temperature	Normal Operation	65°F to 86°F
	Initial [5]	113°F

Table 6.2.3-2—Secondary Containment Response Analysis
Sheet 2 of 2

Design Feature [3]	Value	
Fuel Building pressure	Start of drawdown	0.6 inches water gauge
	At 289 seconds	≤ -0.25 inches water gauge
	After 400 seconds	≤ -0.25 inches water gauge
Fuel Building volume[6]	$1.13x10^6$ ft^3	
Secondary Containment in-leakage assumed from primary containment[1]	9.8 cfm	
Secondary Containment in-leakage assumed from the environment[1]	30 cfm	
Heat loads generated within the Fuel Building	120.3 Btu/sec	
Heat transfer coefficients (Safeguard Building and Fuel Building)	N/A	
Conductive heat transfer (Safeguard Building and Fuel Building)	N/A	
Radiant heat transfer (Safeguard Building and Fuel Building)	N/A	
Compressive effect of primary containment (Safeguard Building and Fuel Building)	N/A [6]	

Notes:

1. During postulated accident in primary containment.
2. Heat transfer calculated by methods provided in BTP 6-2.
3. Secondary containment response analysis based on worst single failure.
4. An infinite heat transfer coefficient was assumed such that the surface temperature in contact with primary containment is at the design maximum value from time zero.
5. Analysis of drawdown of the Fuel Building and controlled-area of the Safeguard Buildings was run for 1000 seconds.
6. The Fuel Building and Safeguard Buildings are not adjacent to the primary containment; therefore, they are not subject to compression from the expansion of the primary containment.

Table 6.2.3-3—Instrumentation, Indication, and Alarm Features for AVS (Accident Filtration Trains)

Sensing Location	Local Indication / Alarm	MCR Indication / Alarm
Electric Heater Inlet	Temperature Indication	
Electric Heater	Status Indication	Status Indication
Electric Heater Outlet	Temperature Indication	Temperature Indication / High Temperature Alarm
Prefilter	Pressure Drop Indication / High Alarm	
HEPA	Pressure Drop Indication / High Alarm	
Adsorber	Pressure Drop Indication / High Alarm	
Adsorber Outlet	Temperature Indication	Temperature Indication / High Temperature Alarm
Post filter	Pressure Drop Indication / High Alarm	
System Filters Inlet to Outlet		Summation of pressure drop across entire filtration train (Indication / High Pressure Drop Alarm)
Fan	Pressure Drop Indication	Handswitch / Status Indication
Damper / Operator	Position Indication	Position Indication
Unit Outlet	Flow Rate Indication	Flow Rate (recorded indication, high alarm signal)
Unit Outlet	Radiation Indication	Radiation Indication / High Radiation Alarm

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