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ACRONYMS

BSC	Bechtel SAIC Company, LLC
CHF	Canister Handling Facility
HVAC	heating, ventilation, and air-conditioning
SA	Supply Air
SC	Safety Category
VR	Ventilation Air
WP	waste package

ABBREVIATIONS

ACH	Air Change per hour
cfm	Cubic feet per minute
DF	Diversity Factor
sq. ft.	Square Feet

1. PURPOSE AND SCOPE

The purpose of this calculation is to calculate the necessary airflow distribution used to size the HVAC equipment for the Canister Handling Facility. These results will be compared to the Heating and Cooling Load Calculation in detailed design.

The calculations contained in this document were developed by D&E/Mechanical HVAC and are intended solely for the use of the D&E/Mechanical HVAC department in its work regarding the HVAC system for the Canister Handling Facility. Yucca Mountain Project personnel from the D&E/Mechanical HVAC department should be consulted before use of the calculations for purposes other than those stated herein or used by individuals other than authorized personnel in D&E/Mechanical HVAC department.

2. QUALITY ASSURANCE

This calculation was prepared in accordance with AP-3.12Q, *Design Calculations and Analyses*. Surface Nuclear and Industrial HVAC systems for the CHF are classified as Non-SC according to the *Q-List* (BSC 2005b), therefore per procedure AP-3.13Q, *Design Control*, this calculation is not subject to the *Quality Assurance Requirements and Description* document (DOE 2004).

3. USE OF SOFTWARE

The commercial off-the-shelf software Microsoft Excel 2000 was used in this calculation to produce the calculations in Section 6. It is listed under Section 2.1, Software Not Subject To This Procedure, of LP-SI.11Q-BSC, *Software Management*. The calculation process and equations are documented in Section 6 of this document for checking by manual calculation.

4. INPUTS

4.1 CRITERIA AND PARAMETERS

4.1.1 Tertiary Confinement Areas Air Change Rates

Tertiary Confinement areas are designed for 4 air changes per hour. Although, PDC (BSC 2004b, 4.8.2.2.13), states that the HVAC system shall be designed such that the confinement areas are provided with an air change frequency of 4 to 8 air changes per hour, the 4 air changes per hour for tertiary is adequate. However, actual number of air changes shall be determined during the detailed design phase.

4.1.2 Battery Rooms Ventilation Rates

The ventilation rate for Battery Rooms shall be 2 - 4 air changes per hour in accordance with the 2003 ASHRAE Handbook of Applications (ASHRAE 2003, page 25.8)

5. ASSUMPTIONS

5.1 BOUNDING ASSUMPTIONS

5.1.1 Tertiary Confinement HVAC Equipment Rooms Ventilation Rate

Tertiary confinement zones HVAC equipment rooms are designed for 4 air changes per hour. This is within the requirement of 4 to 8 air changes per hour for confinement areas in accordance with the Project Design Criteria (BSC 2004b), Section 4.8.2.2.13. However, it will be assumed that the room volume diversity factor due to the HVAC equipment volume is 50%.

Rationale – The HVAC equipment and duct volumes occupy a large portion of the room volume. This room volume diversity factor is based on industry practice in similar applications.

Where used: Table 1.

5.1.2 Non-Confinement Areas Ventilation Rate

The non-confinement areas (Electrical Rooms, Support Areas, HVAC Equipment Rooms, Elevator Equipment Rooms, Control System Rooms, Communication Rooms, Corridors, Vestibules etc.) will be designed for 1.0 cfm/sq. ft to 2.2 cfm/sq. ft or greater. The ventilation rate for the areas are as noted below:

- Areas with exterior wall and/or exterior ceiling will be designed for 1.6 cfm/sq. ft
- Interior areas will be designed for 1.0 cfm/sq. ft.
- Electrical Rooms and Areas with Equipment will be designed for 2.0 cfm/sq. ft.
- HVAC Equipment Rooms will be designed for 1.6 cfm/sq. ft.
- Communication Rooms and Control Systems Rooms will be designed for 3.0 cfm/sq. ft.

Rationale – Normally, the airflow rate is based on cooling load calculation. However, in absence of final building layout and internal equipment, the cooling load check figures from ASHRAE Pocket Guide (ASHRAE 2001, page 140 & 141) will be used. The recommended flow rate used is the minimum and the maximum values (internal and external rooms) tabulated for occupied offices to ensure bounding values. The ventilation rate specified for the rooms as noted above is within the range or exceeds the maximum ventilation rate. The actual airflow required will be calculated based on heat load during the detail design.

Where used: Table 1 and 2

5.2 ASSUMPTIONS REQUIRING VERIFICATION

5.2.1 Confinement Zoning (TBV 7183)

Confinement classifications for the rooms are as noted in Table 1 and 2.

Rationale - The Confinement classifications designations are derived from the Canister Handling Facility – Ventilation Confinement Zoning Analysis, 190-M1C-VN00-00100-000-00C (BSC 2005a), Section 7.1.

Where used: Table 1 and 2.

5.2.2 Room Designation and Dimensions (TBV 7182)

Room designations and dimensions for the rooms are as noted in Table 1 and 2.

Rationale - The room designations and dimensions are derived from the Canister Handling Facility – General Arrangement Drawings (BSC 2004a).

Where used: Table 1 and 2.

5.2.3 Site-Specific Cask/WP Loading Pits and Cask Preparation Pits Supply Air Flow (TBV 7181)

The required design supply airflow is 4,000 cfm for each of the three transfer pits.

Rationale – This value is based on the results of the preliminary calculation, Thermal Analysis of Canister Pits and Staging Area (BSC 2004c, Section 9.2.1).

Where used: Table 1.

5.2.4 Canister Staging Area Supply Air Flow (TBV 7181)

The required design supply airflow is 5,000 cfm.

Rationale – This value is based on the results of the preliminary calculation, Thermal Analysis of Canister Pits and Staging Area (BSC 2004c, Section 9.2.2).

Where used: Table 2.

5.2.5 Air Lock ventilation Rate (TBV 7181)

Assumption – The Ventilation Rate for the air locks serving the tertiary zones will be the greater of 1 air change per hour or 500 cfm.

Rationale –The estimated airflow rate based on 1 ACH is provided to maintain negative differential pressure in the Air Lock relative to the Tertiary. The rate of 500 cfm comes from Air Lock Design Criteria in *Heating, Ventilating, and Air-Conditioning Design Guide for Department of Energy Nuclear Facilities* (ASHRAE DG-1-93 1993, p. 9).

6. CALCULATION

6.1 CALCULATION PROCEDURE

1. Determine the Ventilation Confinement Zone classification for each room(s) from *Canister Handling Facility - Ventilation Confinement Zoning Analysis* (BSC 2005a).
2. Determine room number, room name and dimensions of the rooms using *Canister Handling Facility – General Arrangement Drawings* (BSC 2004a).
3. Use the dimensions to calculate the floor area of the rooms.
4. Calculate the minimum supply airflow rate for the rooms using the applicable equation in Section 6.2.1.
5. Sum the minimum required supply airflow rates on an HVAC zone/system basis.

6.2 CALCULATION EQUATIONS

6.2.1 Supply Airflow Rate

The supply airflow rate is calculated using either an air change rate basis or a ventilation rate basis. The equations are as follows:

$$SA = \frac{A \times H \times ACH}{60} \times DF \quad \text{Equation 1}$$

$$SA = A \times VR \quad \text{Equation 2}$$

where

SA = Supply Airflow rate (cfm)
A = Area of space (ft²)
H = Height of space (ft)
ACH = Air Change per hour (1/hr)
DF = Diversity Factor
VR = Ventilation Rate (cfm/sq. ft.)
60 = min/hr

7. CONCLUSIONS

The minimum required supply airflow rates are presented on a room-by-room basis in Table 1 and Table 2. Table 1 shows the calculated minimum supply airflow rates for rooms/areas serving tertiary confinement zone and airlock (serves tertiary confinement zone). Table 2 shows the calculated minimum supply airflow rates for rooms/areas serving non-confinement zone. All values are preliminary and should only be used to determine the relative amount of air being supplied to and returned from each room/area.

The rooms/areas in Table 1 and Table 2 are grouped into HVAC zones whereupon the airflow rates are subtotaled to obtain the minimum required supply air for that zone. Table 3, Table 4, and Table 5 present the minimum supply air required for each zone. A factor of safety is applied to the supply air value and the result is rounded to obtain a "rounded supply air" value for each zone.

Table 3 which contains the ventilation air summary for the tertiary confinement zones shows the quantity of supply air that can be cascaded from Operating Galleries and Airlocks through directly communicating openings. Subtracting the "cascaded supply air" from the "rounded supply air" value gives the amount of air that must be supplied directly from the HVAC system.

Table 4 presents a summary of the ventilation air required for the Canister Handling Facility Site-Specific Cask/WP Loading Pits and Cask Preparation Pits and Cask Preparation Pit.

Table 5 contains the ventilation air summary for the non-confinement zones.

The results of this calculation are reasonable compared to the inputs and can be used for the intended use of HVAC equipment sizing and selection.

All results and calculations are preliminary and they are based on conceptual and preliminary design activities, which are subject to change. This calculation should not be used to support drawings and specifications for fabrication, procurement, or construction.

Table 1 Tertiary Confinement Ventilation Air Calculation

Confinement Classification	Room No.	Room/Area Description	Area sq. ft.	Height ft	Input Ventilation Rate		Min. Required Supply Air cfm	Remarks	
					ACH	cfm/sq. ft.			
									Note 3
Note 1	Note 2	Note 2	Note 2	Note 2	Note 3	Note 4	Note 5		
	1011	WP Positioning Cell A	1,240	26	4		2,149		
	1032	WP Tool Storage Room	2300	31	4		4,753		
	1033	Canister Transfer Cell	13,280	61	4		54,005		
	1035	Tools / Parts Storage Room	2,000	31	4		4,133		
	1042	WP Positioning Cell B	1,220	26	4		2,115		
	1034	Corridor	440	31	4		909		
	2009	Closure Maintenance Cell A	700	35	4		1,633		
	2010	Closure Cell A	840	35	4		1,960		
	2023	WP and Canister Handling Crane Maintenance Area	2,400	30	4		4,800		
	2036	Cask Handling Crane Maintenance Area	2,700	30	4		5,400		
	2032	Closure Cell B	1,170	35	4		2,730		
	2031	Closure Maintenance Cell B	700	35	4		1,633		
	3011	Crane Maintenance Room B	3,220	35	4		7,513		
	3006	Crane Maintenance Room A	3,220	35	4		7,513		
		Tertiary Zones Subtotal	35,430				101,249		
		1005	Closure Support Room A	1,450	26	4		2,513	Buffer Zone
		1009	Trolley Recovery Equipment Room A	600	26	4		1,040	Buffer Zone
		1017	WP Loadout Operating Gallery	2,620	30	4		5,240	Buffer Zone
		1019	Door Recovery Room A	390	30	4		780	Buffer Zone
		1021	Canister Transfer Operating Gallery	1,120	30	4		2,240	Buffer Zone
		1024	Gas Sampling Room	370	26	4		641	Buffer Zone
		1039	WP Loadout Operating Gallery & Door Recovery Room B	720	26	4		1,248	Buffer Zone
		1040	Closure Support Room B	1,480	25	4		2,467	Buffer Zone
		1043	Trolley Recovery Equipment Room B	590	26	4		1,023	Buffer Zone
		1045	Canister Transfer Cell Operating Gallery B	390	26	4		676	Buffer Zone
		2007	Closure Support A	2,230	36	4		5,352	Buffer Zone
		2011	Closure Operating Gallery A	1,300	36	4		3,120	Buffer Zone
		2029	Closure Support B	2,240	36	4		5,376	Buffer Zone
		2033	Closure Operating Gallery B	1,300	36	4		3,120	Buffer Zone
		3002, 3003	Closure Maintenance Room A	4,860	36	4		11,664	Buffer Zone. Includes Vacuum Pump Room A (Room # 3003)
		3008, 3009	Closure Maintenance Room B	4,860	36	4		11,664	Buffer Zone. Includes Vacuum Pump Room A (Room # 3009)
		Operating Galleries Subtotal	26,520				58,164		

Confinement Classification	Room No.	Room/Area Description	Area sq. ft.	Height ft	Input Ventilation Rate		Min. Required Supply Air cfm	Remarks
					ACH	cfm/sq. ft.		
Note 1	Note 2	Note 2	Note 2	Note 2	Note 3	Note 4	Note 5	
Tertiary Confinement Zone	1037	Tertiary Recirculating HVAC Equipment Room A	2,820	31	4		2,914	Buffer Zone, See Section 5.1.1
	1038	Tertiary Recirculating HVAC Equipment Room B	4,320	31	4		4,464	Buffer Zone, See Section 5.1.1
	1046	Tertiary Recirculating HVAC Equipment Room C	3,730	31	4		3,854	Buffer Zone, See Section 5.1.1
	1048	Transfer Pits Supply/Recirculating HVAC Equipment Room	3,400	31	4		3,513	Buffer Zone, See Section 5.1.1
	2027	Tertiary Recirculating HVAC Equipment Room D	5,630	31	4		5,818	Buffer Zone, See Section 5.1.1
Serves Tertiary Confinement Zone	2034	Tertiary Exhaust HVAC Equipment Room	1,510	16	4		805	Space above Vestibule 2024, Decon 2025, and Corridor 2026. Buffer Zone. See Section 5.1.1.
	2035	Tertiary Pits Exhaust HVAC Equipment Room	5,600	31	4		5,787	Buffer Zone, See Section 5.1.1
			710	16	4		379	Space above Corridor 2037. Buffer Zone. See Section 5.1.1.
			2,630	31	4		2,718	Buffer Zone, See Section 5.1.1
			1,100	16	4		587	Space above Corridor 2037. Buffer Zone. See Section 5.1.1.
		HVAC Equipment Rooms Subtotal	31,450				30,838	
	1025	Corridor	200	15	1		500	See Section 5.2.5
	1027	Corridor	180	15	1		500	See Section 5.2.5
	1031	Exit Vestibule	4,740	31	1		2,449	See Section 5.2.5
	1036	Entrance Vestibule	5,700	53	1		5,035	See Section 5.2.5
Tertiary Confinement Zone	2002/2003	Vestibule / Decon. Room	220	10	1		500	See Section 5.2.5
	2018/2019	Vestibule / Decon. Room	220	10	1		500	See Section 5.2.5
	2024/2025	Vestibule / Decon. Room	220	10	1		500	See Section 5.2.5
		Airlock Subtotal	11,480				9,984	
	P002	Cask Preparation Pit	225	23			4,000	See Section 5.2.3
Tertiary Confinement Zone	P003	Site-Specific Cask/WP Loading Pit	225	23			4,000	See Section 5.2.3
	P004	Site-Specific Cask/WP Loading Pit	225	23			4,000	See Section 5.2.3
		Transfer Pits Subtotal	675				12,000	

Notes:

1. See Section 5.2.1
2. See Section 5.2.2
3. See Section 4.1.1 and 5.1.1
4. See Section 5.1.2
5. See Section 6.2.1

Table 2 Non-Confinement Ventilation Air Calculation

Confinement Classification	Room No.	Room/Area Description	Area sq. ft.	Height ft	Input Ventilation Rate		Min. Required Supply Air cfm	Remarks
					ACH Note 3	cfm/sq. ft. Note 4		
Non-Confinement Zone	Note 2	Note 2	Note 2	Note 2	Note 3	Note 4	Note 5	
	1004	Elevator Vestibule A	650	10		1.6	1,040	
	1008	Corridor	1,190	10		1.0	1,190	Includes Storage Room (South of Room # 1012)
	1014	Support Area	5,880	10		1.6	9,408	
	1015	Elevator Vestibule	64	10		1.0	64	
	1016	Radiation Protection Lab	240	10		1.0	240	
	1026	Radiation Protection Control Point	490	15		1.0	490	
	1041	Elevator Vestibule B	670	25		1.6	1,072	
	1044	Corridor	1,870	25		1.6	2,992	
	1047	Staging Exhaust HVAC Equipment Room	2,440	31		1.6	3,904	
	1057	Stack Monitoring Room	150	10		1.6	240	
	M102	Support Area	3,480	10		1.6	5,568	
	M104	Safeguards & Security Rm	950	10		1.6	1,520	
	M105	Break Room	420	10		2.0	840	
	M106	Vestibule	300	10		1.0	300	
	M101	Corridor	1,580	10		1.0	1,580	
	M015	Elevator Vestibule	55	10		1.0	55	
	2013	Control Systems and Support Area Supply HVAC Equipment Room	5,370	31		1.6	8,592	Space above Corridor 2012
			790	16		1.6	1,264	
			1,150	10		1.6	1,840	
	2005	Corridor	1,510	31		1.6	2,416	
	2004	Freight Elevator A Vestibule	638	10		1.6	1,021	
	2006	Corridor	280	31		1.6	448	
	2008	Unassigned	790	10		1.6	1,264	
	2012	Corridor	1,690	31		1.6	2,704	
	2014	Support Areas Supply HVAC Equipment Room	530	10		1.6	848	
	2017	Corridor	1,290	10		1.6	2,064	
	2026	Corridor	410	31		1.6	656	
	2030	Unassigned	100	31		1.6	160	
	2040	Freight Elevator B Vestibule	1,210	31		1.6	1,936	
	2028	Corridor	1,810	10		1.6	2,896	
	2037	Corridor	750	12		1.6	1,200	
	2022	Corridor	60	10		1.6	96	
	2015	Elevator Vestibule	1,420	36		1.6	2,272	
	3001	Exit Corridor	2,460	10		1.6	3,936	
	3004, 3005	Corridor	50	10		1.6	80	
	3015	Elevator Vestibule	1,420	36		1.6	2,272	
	3007	Exit Corridor	1,150	10		1.6	1,840	
	3010	Corridor	225	10		2.0	450	
	3012	Elevator Equipment Room A	225	10		2.0	450	
	3013	Elevator Equipment Room B						
		Support Areas Subtotal	45,757				71,208	

Table 2 (Continued)

Confinement Classification	Room No.	Room/Area Description	Area sq. ft.	Height ft	Input Ventilation Rate		Min. Required Supply Air cfm	Remarks
					ACH	cfm/sq. ft.		
Note 1	Note 2	Note 2	Note 2	Note 2	Note 3	Note 4	Note 5	
Non-Confinement Zone	P001	Canister Staging Pit	420	23			5,000	See Section 5.2.4
		Staging Pit Subtotal	420				5,000	
Non-Confinement Zone	1001	Electrical Rm (Normal Power)	1,380	30		2.0	2,760	
	1001A	UPS Room	170	14		1.0	170	
		Battery Area	60	14	6		84	
	1001B	UPS Room	170	14		1.0	170	
		Battery Area	60	14	6		84	
	1002	Electrical Room Train "A"	1,110	30		2.0	2,220	
	1002A	UPS Room	375	14		1.0	375	
		Battery Area	125	14	6		175	
	1003	Electrical Room Train "B"	1,110	30		2.0	2,220	
	1003A	UPS Room	375	14		1.0	375	
		Battery Area	125	14	6		175	
	2001	HVAC Supply Equipment Room	5,950	31		1.6	9,520	
			1,370	16		1.6	2,192	Space above Corridor 2005, Vestibule 2002, and Decon 2003
		Electrical Equipment Rooms Subtotal	12,380				20,520	
	1013	Communications Room	266	15		3.0	798	
	1022	Control Systems Room	240	15		3.0	720	
	1023	Control Systems Room	515	15		3.0	1,545	
		Control Systems and Communication Rooms Subtotal	1,021				3,063	

Notes:

1. See Section 5.2.1
2. See Section 5.2.2
3. See Section 4.1.1 and 5.1.1
4. See Section 5.1.2
5. See Section 6.2.1

Table 3 Tertiary Confinement Zones Ventilation Air Summary

Confinement Classification	HVAC Zone Description	Minimum Required Supply Air (cfm)	Factor of Safety (%)	Calculated Supply Air (cfm)	Rounded Supply Air (cfm)	Cascaded Supply Air (cfm)	Direct Supply air (cfm)
Note 1	Note 1	Note 1	Note 2	Note 3	Note 4	Note 5	Note 6
Tertiary Confinement Zone	Tertiary Zones	101,249	10	111,374	111,500	75,000	36,500
Tertiary Confinement Zone	Operating Galleries	58,164	10	63,980	64,000	0	64,000
Serves Tertiary Zones	Airlocks	9,984	10	10,982	11,000	0	11,000
Tertiary Confinement Zone	HVAC Equipment Rooms	30,838	10	33,922	34,000	0	34,000
Totals							145,500

Notes:

1. From Table 1.
2. Based on industry practice.
3. Value obtained by multiplying "Minimum Required Supply Air" by $(1 + (\text{"Factor of Safety"}/100))$.
4. Value obtained by rounding "Calculated Supply Air" up to next 500th.
5. Value obtained by adding the "Rounded Supply Air" values for the Operating galleries and the Airlocks.
6. Value obtained by subtracting "Cascaded Supply Air" from "Rounded Supply Air."

Table 4 Transfer Pits and Staging Area Ventilation Air Summary

Confinement Classification	HVAC Zone Description	Minimum Required Supply Air (cfm)
Note 1	Note 1	Note 1
Tertiary Confinement Zone	Transfer Pits	12,000
Non-confinement Zone	Staging Pit	5,000

NOTES:

1. From Table 1 and Table 2.

Table 5 Non-confinement Zones Ventilation Air Summary

Confinement Classification	HVAC Zone Description	Minimum Required Supply Air (cfm)	Factor of Safety (%)	Calculated Supply Air (cfm)	Use Rounded Supply Air (cfm)
Note 1	Note 1	Note 1	Note 2	Note 3	
Non-confinement Zone	Electrical Equipment Rooms	20,520	10	22,572	24,000
Non-confinement Zone	Control Systems and Communication Rooms	3,063	10	3,369	4,000
Non-confinement Zone	Support Areas	71,208	20	85,449	96,000
Totals					124,000

NOTES: 1. From Table 2.

2. Based on industry practice 10% factor of safety is provided. However, additional 10% is provided for Support Areas to account for Unassigned Areas.

3. Value obtained by multiplying "Minimum Required Supply Air" by $(1 + (\text{"Factor of Safety"}/100))$.

8. REFERENCES

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