

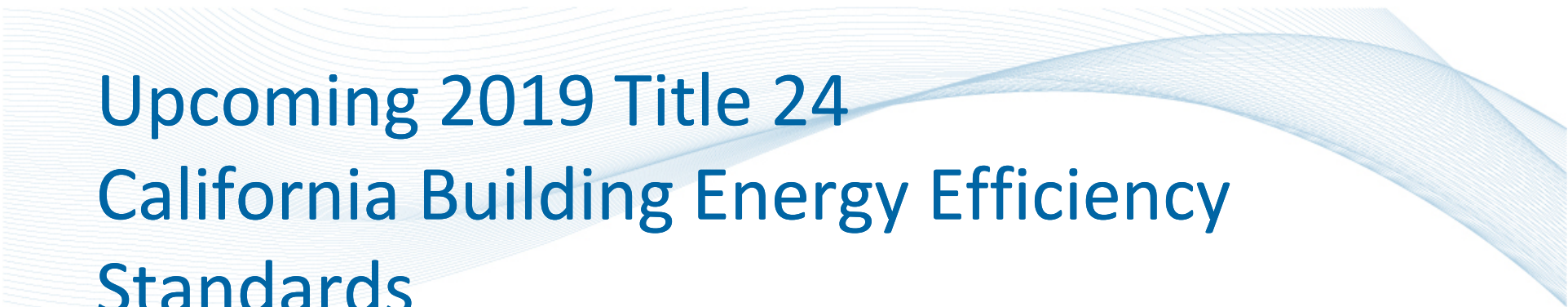


WIND ENGINEERING &
AIR QUALITY CONSULTANTS

Designing Safe and Energy Efficient Laboratory Exhaust Systems

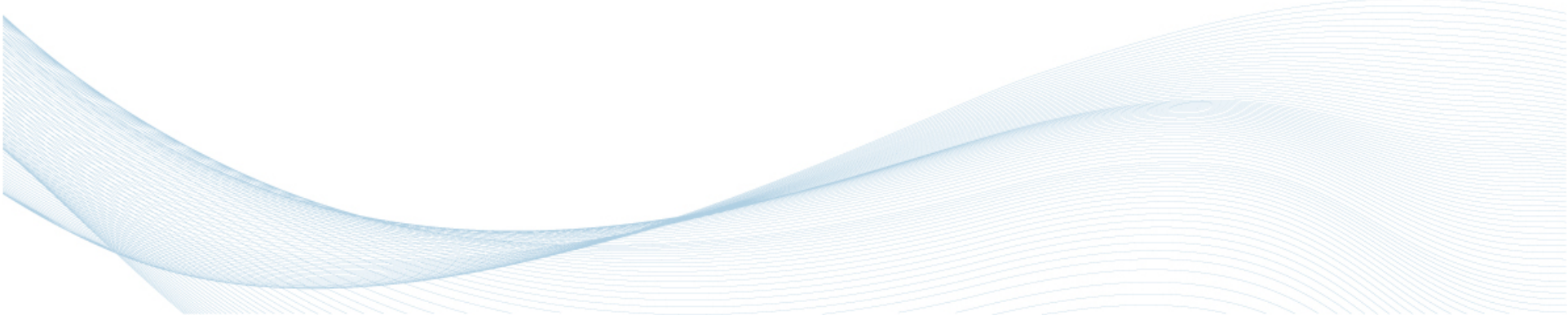
Under the 2019 California Title 24

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Quality Services
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Upcoming 2019 Title 24 California Building Energy Efficiency Standards

SUBCHAPTER 5 NONRESIDENTIAL, HIGH-RISE RESIDENTIAL, AND HOTEL/MOTEL OCCUPANCIES—PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR ACHIEVING ENERGY EFFICIENCY



Section 140.9 (c) - 1

Fan System Power Consumption

3. Fan System Power Consumption. All newly installed fan exhaust systems serving a laboratory or factory greater than 10,000 CFM, shall meet subsection A and either B, C, or D.

- A. System shall meet all discharge requirement in ANSI Z9.5 - 2012.

Section 140.9 (c) - 1

Fan System Power Consumption

ANSI Z9.5 - 2012

Section 5.4.6 Exhaust Stack Discharge

The exhaust stack discharge shall be in accordance with the current version of ASHRAE Handbook – HVAC Applications, and the chapter or section dealing with Building Air Intake and Exhaust Design.

In any event the discharge shall be a minimum of 10 ft (3 m) above adjacent roof lines and air intakes and in a vertical up direction.

Section 140.9 (c) - 1

Fan System Power Consumption

ANSI Z9.5 - 2012

Section 5.4.6 Exhaust Stack Discharge

Exhaust stack discharge velocity shall be at least 3000 fpm
(15.2 m/s) is required ...

Section 140.9 (c) - 1

Fan System Power Consumption

ANSI Z9.5 - 2012

Section 5.4.6 Exhaust Stack Discharge

Exhaust stack discharge velocity shall be at least 3000 fpm (15.2 m/s) is required **unless it can be demonstrated that a specific design meets the dilution criteria necessary to reduce the concentration of hazardous materials in the exhaust to safe levels at all potential receptors.**



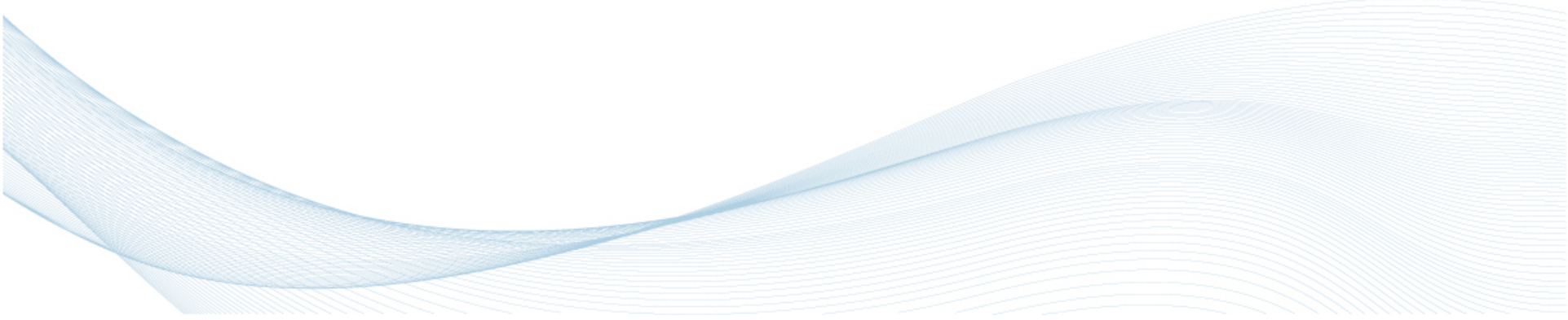
Section 140.9 (c) - 1

Fan System Power Consumption

ANSI Z9.5 - 2012

Section 5.4.6 Exhaust Stack Discharge

Aesthetic conditions concerning external appearance shall not supersede the requirements of Sections 5.4.5 and 5.4.6.



Section 140.9 (c) - 1

Fan System Power Consumption

ANSI Z9.5 - 2012

Section 5.4.6 Exhaust Stack Discharge

Aesthetic conditions concerning external appearance shall not supersede the requirements of Sections 5.4.5 and 5.4.6.

Any architectural structure that protrudes to a height close to the stack-top elevation (i.e., architectural structure to mask unwanted appearance of stack, penthouses, mechanical equipment, nearby buildings, trees or other structures) shall be evaluated for its effects on re-entrainment.

Section 140.9 (c) - 1

Fan System Power Consumption

ANSI Z9.5 - 2012

Section 5.4.6 Exhaust Stack Discharge

Aesthetic conditions concerning external appearance shall not supersede the requirements of Sections 5.4.5 and 5.4.6.

Any architectural structure that protrudes to a height close to the stack-top elevation (i.e., architectural structure to mask unwanted appearance of stack, penthouses, mechanical equipment, nearby buildings, trees or other structures) shall be evaluated for its effects on re-entrainment.

The air intake or exhaust grilles shall not be located within the architectural screen or mask unless it is demonstrated to be acceptable.

Section 140.9 (c) - 1

Fan System Power Consumption

ANSI Z9.5 - 2012

Appendix 3 Selecting Laboratory Stack Design

Necessary measures must be taken to protect the laboratory building and adjacent buildings from reingestion of toxic laboratory chemical hood exhaust back into a building air supply system.

Section 140.9 (c) - 1

Fan System Power Consumption

ANSI Z9.5 - 2012

Appendix 3 Selecting Laboratory Stack Design

Necessary measures must be taken to protect the laboratory building and adjacent buildings from reingestion of toxic laboratory chemical hood exhaust back into a building air supply system. **The 10 ft (3.05 m)**

minimum stack height called for in the body of this standard is primarily intended to protect maintenance workers from direct contamination from the top of the stack. However, the minimum height of 10 ft is not enough by itself to guarantee that harmful contaminants would not be reingested.

Section 140.9 (c) - 1

Fan System Power Consumption

ANSI Z9.5 - 2012

Appendix 3 Selecting Laboratory Stack Design

Necessary measures must be taken to protect the laboratory building and adjacent buildings from reingestion of toxic laboratory chemical hood exhaust back into a building air supply system. The 10 ft (3.05 m) minimum stack height called for in the body of this standard is primarily intended to protect maintenance workers from direct contamination from the top of the stack. However, the minimum height of 10 ft is not enough by itself to guarantee that harmful contaminants would not be reingested.

Similarly, a minimum 3000 fpm (15.3 m/s) exit velocity is specified in the body of this standard, but this exit velocity does not guarantee that reingestion will not occur.

DRAFT Z9.5 Laboratory Ventilation Standard

ASSE Z9.5 – 20?? DRAFT

Section 5.4.6 Exhaust Stack Discharge

Exhaust stack discharge height and exit velocity shall be sufficient, as defined by the methodology described in Appendix 3, to reduce the concentration of hazardous materials in the exhaust to safe levels at all potential receptor locations, as described in Section 5.4.5 and Appendix 3.

DRAFT Z9.5 Laboratory Ventilation Standard

ASSE Z9.5 – 20?? DRAFT

Appendix 3 Selecting Laboratory Stack Design

Necessary measures must be taken to protect the laboratory building and adjacent buildings from re-ingestion of toxic laboratory chemical hood exhaust back into a building air supply system and other areas of potential exposure (operable windows, roof top worker locations, outdoor plazas, doorways, etc.). . .

DRAFT Z9.5 Laboratory Ventilation Standard

ASSE Z9.5 – 20?? DRAFT

Appendix 3 Selecting Laboratory Stack Design

Necessary measures must be taken to protect the laboratory building and adjacent buildings from re-ingestion of toxic laboratory chemical hood exhaust back into a building air supply system and other areas of potential exposure (operable windows, roof top worker locations, outdoor plazas, doorways, etc.). . .

This appendix describes general stack design guidelines and analysis methods for determining an adequate stack design. The appendix also includes a methodology for developing a design criterion to judge the acceptability of the predicted dilutions/concentrations in defining an adequate exhaust designs.

DRAFT Z9.5 Laboratory Ventilation Standard

ASSE Z9.5 – 20?? DRAFT

Appendix 3 Selecting Laboratory Stack Design

Acceptable Methods to Evaluate Stack Performance*:

- 1) ASHRAE Graphical Method – for Preliminary Assessment Only
- 2) ASHRAE Dilution Equations – for Simple Building Geometries
- 3) EPA Dispersion Model – for Simple Building Geometries
- 4) CFD – Steady state solutions (RANS) NOT Recommended
Transient solutions (LES, etc.) only w/ project specific validation
- 5) Physical Modeling – for Complex Building geometries and environments. And, when defining minimum flow rates vs. wind speed and wind direction.

* - As described in ASHRAE Handbook HVAC Applications Chapter 45

Section 140.9 (c) - 1

Fan System Power Consumption

3. Fan System Power Consumption. All newly installed fan exhaust systems serving a laboratory or factory greater than 10,000 CFM, shall meet subsection A and either B, C, or D.

- A. System shall meet all discharge requirement in ANSI Z9.5-2012
- B. The **exhaust fan system power** shall not exceed **0.85 watts per cfm** of exhaust air for systems with air filtration, scrubbers, or other air treatment devices. For all other exhaust fan systems the system power shall not exceed **0.65 watts per cfm** of exhaust air.

Section 140.9 (c) - 1

Fan System Power Consumption

3. Fan System Power Consumption. All newly installed fan exhaust systems serving a laboratory or factory greater than 10,000 CFM, shall meet subsection A and either B, C, or D.

A. System shall meet all discharge requirement in ANSI Z9.5-2012.

B. The **exhaust fan system power** shall not exceed 0.85 watts per cfm of exhaust air for systems with air filtration, scrubbers, or other air treatment devices. For all other exhaust fan systems the system power shall not exceed 0.65 watts per cfm of exhaust air. Exhaust fan system power equals the sum of the power of all fans in the exhaust system that are required to operate at normal occupied design conditions in order to exhaust air from the conditioned space to the outdoors. Exhaust air does not include entrained air, but does include all exhaust air from fume hoods, hazardous exhaust flows, or other manifolded exhaust streams.

Section 140.9 (c) - 1

Fan System Power Consumption

10,000 cfm Centrifugal Fan

Power Limit = 10,000 cfm x 0.65W/cfm = 6.5kW = 8.7 BHp

Model Name	Best Value Rank	Relative Cost	Operating Cost / Yr (USD)	Actual Volume (CFM)	Total External SP (in. wg)	Drive Type	Fan Class	Fan Speed (RPM)	Max Fan Speed (RPM)	Drive Loss (%)	Operating Power (hp)
CSW-33-AF	8	1.52	1,274	10,000	3	Belt	0	906	935	3.8	6.23
CSW-30-AF	2	1.36	1,305	10,000	3	Belt	I	1060	1329	3.8	6.38
CSW-36-AF	14	1.77	1,334	10,000	3	Belt	0	792	846	3.8	6.52
CSW-33-BI	7	1.43	1,388	10,000	3	Belt	0	879	900	3.7	6.79
CSW-30-BI	4	1.28	1,400	10,000	3	Belt	I	1010	1279	3.7	6.85
CSW-36-BI	13	1.65	1,442	10,000	3	Belt	0	773	814	3.7	7.05
CSW-27-AF	3	1.20	1,453	10,000	3	Belt	I	1330	1537	3.7	7.1
CSW-27-BI	1	1.11	1,498	10,000	3	Belt	I	1224	1425	3.7	7.32
CSW-30-AF-90	10	1.46	1,530	10,594	3.367	Direct	I	1170	1376	-	7.54
CSW-24-AF	6	1.10	1,622	10,000	3	Belt	I	1636	1694	3.6	7.99
CSW-24-BI	5	1.05	1,643	10,000	3	Belt	I	1489	1570	3.6	8.09
CSW-24-AF-90	9	1.14	1,755	10,122	3.074	Direct	II	1770	2287	-	8.65
CSW-30-BI-85	16	1.44	1,830	10,942	3.592	Direct	I	1170	1350	-	9.01
CSW-22-AF	11	1.02	1,960	10,000	3	Belt	II	2066	2459	3.6	9.66
CSW-22-BI	12	1.00	2,001	10,000	3	Belt	II	1843	2246	3.6	9.86
CSW-24-BI-80	15	1.07	2,068	10,330	3.201	Direct	II	1770	2206	-	10.33
CSW-20-AF	17	1.02	2,394	10,000	3	Belt	II	2688	2734	3.5	11.96
CSW-20-BI	18	1.00	2,488	10,000	3	Belt	II	2395	2498	3.5	12.43
CSW-18-AF	20	1.59	2,984	10,000	3	Belt	III	3409	3781	3.4	14.91
CSW-18-AF-100	19	1.28	3,119	10,267	3.162	Direct	III	3500	3781	-	15.58
CSW-18-BI	21	1.64	3,151	10,000	3	Belt	III	3040	3450	3.4	15.74
CSW-20-AF-75	22	1.38	3,639	10,306	3.187	Direct	III	3500	3791	-	18.18
CSW-18-BI-85	23	1.15	3,868	10,019	3.011	Direct	III	3500	3642	-	19.33
CSW-20-BI-65	24	1.26	4,604	10,185	3.112	Direct	III	3500	3632	-	23.15

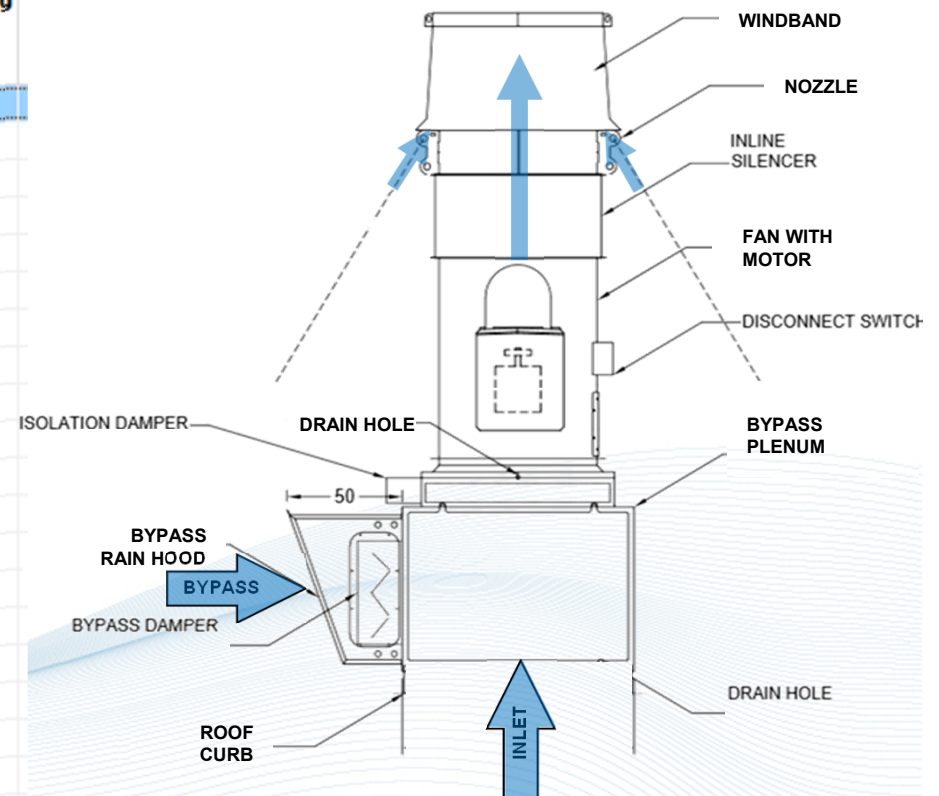
Section 140.9 (c) - 1

Fan System Power Consumption

30,000 cfm Induced Flow Fan

Power Limit = 30,000 cfm x 0.65W/cfm = 19.5kW = 26.1 BHp

Model Name	Drive Type	Relative Cost	Operating Cost / Yr (USD)	Total External SP (in. wg)	Actual Volume (CFM)	Operating Power (hp)
VK-MD-44-100-LV-HPW	Belt	1.37	5,991	3.55	30,000	30.29
VK-MD-44-85-LV-HPW	Belt	1.37	6,063	3.55	30,000	30.65
VK-MD-44-70-LV-HPW	Belt	1.44	6,109	3.55	30,000	30.89
VK-MD-54-70-MV-HPW	Belt	1.74	6,406	3.55	30,000	32.39
VK-MD-40-100-LV-HPW	Belt	1.10	6,503	3.55	30,000	32.88
VK-MD-40-85-LV-HPW	Belt	1.10	6,681	3.55	30,000	33.78
VK-MD-54-85-MV-HPW	Belt	1.65	6,714	3.55	30,000	33.94
VK-MD-49-70-MV-HPW	Belt	1.61	6,760	3.55	30,000	34.17
VK-MD-40-70-LV-HPW	Belt	1.16	6,884	3.55	30,000	34.8
VK-MD-49-85-MV-HPW	Belt	1.52	6,944	3.55	30,000	35.11
VK-MD-49-100-MV-HPW	Belt	1.52	7,015	3.55	30,000	35.47
VK-MD-44-100-MV-HPW	Belt	1.37	7,544	3.55	30,000	38.14
VK-MD-44-70-MV-HPW	Belt	1.44	7,553	3.55	30,000	38.19
VK-MD-44-85-MV-HPW	Belt	1.37	7,563	3.55	30,000	38.24
VK-MD-54-70-HV-HPW	Belt	1.74	7,590	3.55	30,000	38.37
VK-MD-40-70-LV-HPW	Direct	1.09	7,631	3.55	32,308	38.58
VK-MD-36-85-LV-HPW	Belt	1.00	7,703	3.55	30,000	38.94
VK-MD-54-85-HV-HPW	Belt	1.67	7,988	3.55	30,000	40.56
VK-MD-36-70-LV-HPW	Belt	1.07	8,168	3.55	30,000	41.47



Section 140.9 (c) - 1

Fan System Power Consumption

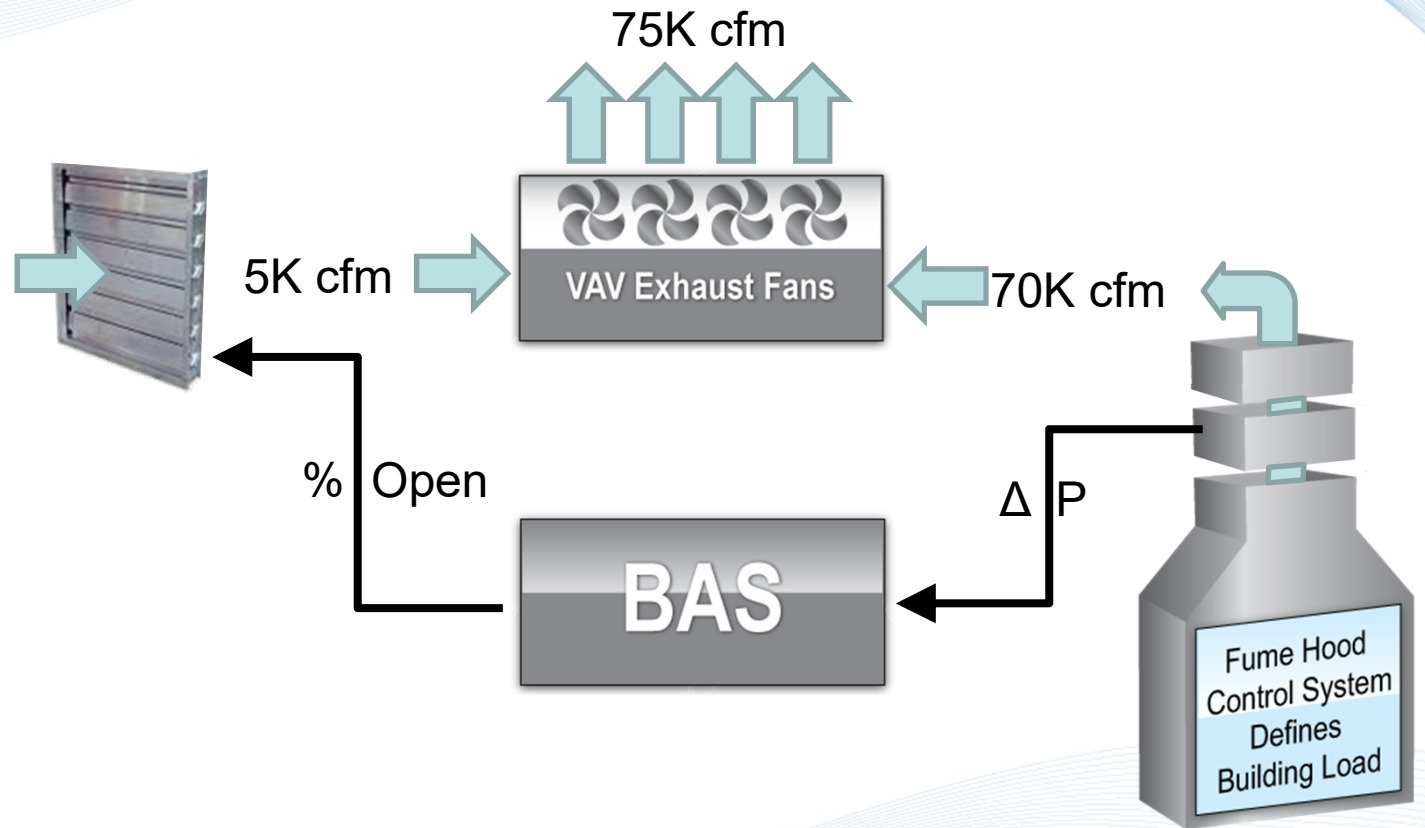
3. Fan System Power Consumption. All newly installed fan exhaust systems serving a laboratory or factory greater than 10,000 CFM, shall meet subsection A and either B, C, or D.

A. System shall meet all discharge requirement in ANSI Z9.5

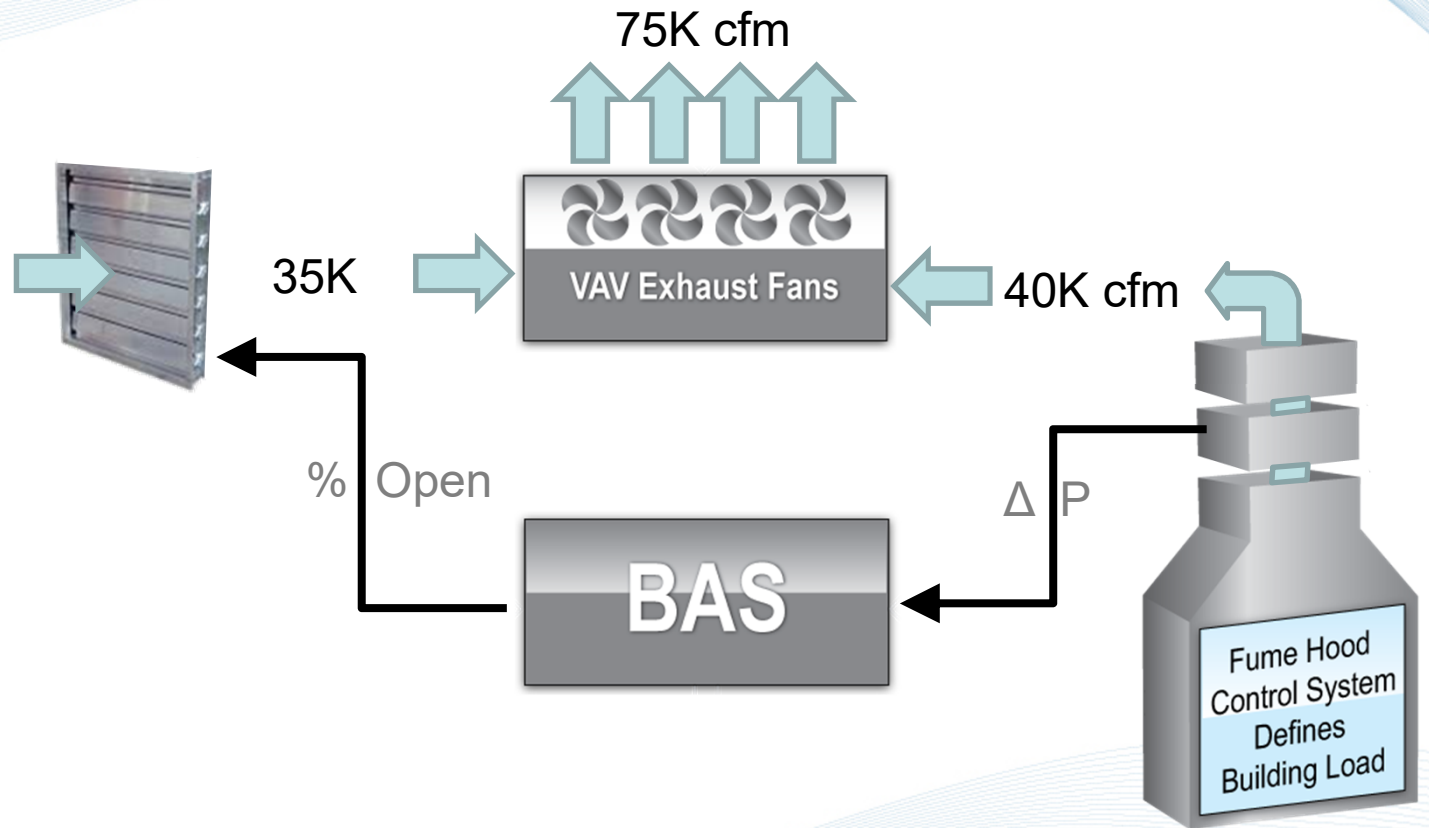
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C. The volume flow rate at the stack shall vary based on the measured 5-minute averaged wind speed and wind direction obtained from a calibrated local anemometer.

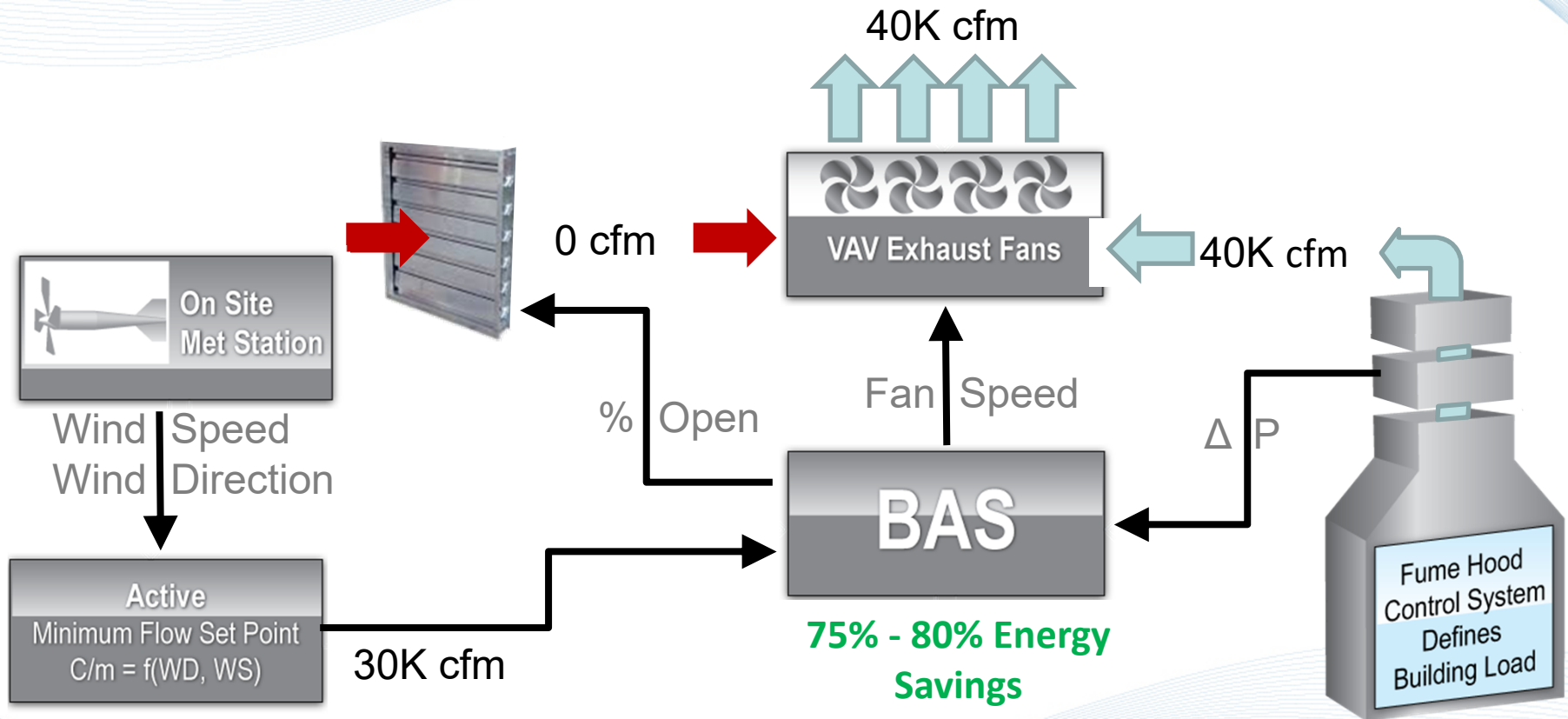
Constant Volume Manifolded Extract System



Constant Volume Manifolded Extract System w/ Nighttime Turndown



WIND RESPONSIVE Variable Volume Manifolded Extract System w/ Nighttime Turndown



Section 140.9 (c) - 1

Fan System Power Consumption

3. Fan System Power Consumption. All newly installed fan exhaust systems serving a laboratory or factory greater than 10,000 CFM, shall meet subsection A and either B, C, or D.

A. System shall meet all discharge requirement in ANSI Z9.5 - 2012

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C. The volume flow rate at the stack shall vary based on the measured 5-minute averaged wind speed and wind direction obtained from a calibrated local anemometer.

- i. At least two anemometers shall be installed in a location that experiences similar wind conditions to the free stream environment above the exhaust stacks and be at a height that is outside of the wake region of nearby structures.

Sonic Anemometer



Sonic Anemometer – View from Street



Section 140.9 (c) - 1

Fan System Power Consumption

3. Fan System Power Consumption. All newly installed fan exhaust systems serving a laboratory or factory greater than 10,000 CFM, shall meet subsection A and either B, C, or D.

A. System shall meet all discharge requirement in ANSI Z9.5

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C. The volume flow rate at the stack shall vary based on the measured 5-minute averaged wind speed and wind direction obtained from a calibrated local anemometer.

- ii. Look-up tables shall be used to define the required exhaust volume flow rate, as a function of at least eight wind speeds and eight wind directions to maintain downwind concentrations below health and odor limits

Wind Responsive Look-up Table

Minimum Volume Flow Rate vs. Wind Speed and Wind Direction

Wind Direction		Minimum Volume Flow Rate (cfm) Anemometer Wind Speed (m/s)														
Min	Max	<1	1	2	3	4	5	7	9	11	13	15	18	21	24	27
350	10	12,983	12,700	14,908	17,254	19,679	22,130	26,935	31,385	35,296	38,554	41,135	43,797	45,258	45,914	46,203
10	30	12,983	12,184	17,580	22,205	25,155	29,519	34,806	38,629	41,439	43,593	45,356	47,667	49,880	56,408	56,408
30	50	12,983	10,765	16,115	21,151	25,892	30,353	38,497	45,699	52,063	56,408	56,408	56,408	56,408	56,408	56,408
50	70	12,983	10,163	15,554	20,581	25,270	29,644	37,537	44,244	55,742	55,742	55,742	56,408	56,408	56,408	56,408
70	90	12,983	10,067	15,376	20,332	24,595	29,281	37,093	43,925	55,186	55,186	55,186	56,408	56,408	56,408	56,408
90	110	12,983	9,070	16,052	22,182	27,543	32,212	39,595	45,337	52,137	52,317	52,317	56,408	56,408	56,408	56,408
110	130	12,983	11,815	15,658	19,516	23,350	27,142	34,369	41,044	52,096	52,096	56,300	56,408	56,408	56,408	56,408
130	150	12,983	12,983	16,539	20,114	23,674	27,188	33,972	40,280	50,932	50,932	55,108	56,408	56,408	56,408	56,408
150	170	12,983	12,422	16,189	19,414	22,143	24,422	27,793	29,834	30,989	30,989	30,550	29,133	27,232	25,208	56,408
170	190	12,983	10,358	8,082	7,545	6,550	5,780	4,794	4,357	4,279	4,403	4,607	4,866	4,893	4,599	23,314
190	210	12,983	10,268	8,633	7,321	6,290	5,501	4,515	4,114	4,091	4,278	4,541	4,870	4,935	4,643	3,982
210	230	12,983	11,677	10,638	9,714	8,895	8,174	6,988	6,095	5,440	4,974	4,657	4,383	4,265	4,231	3,999
230	250	12,983	11,005	9,610	8,447	7,485	6,700	5,566	4,878	4,501	4,326	4,269	4,276	4,285	4,243	4,229
250	270	12,983	8,067	8,157	8,062	7,826	7,491	6,651	5,760	4,968	4,367	3,997	3,859	4,093	4,465	4,148
270	290	12,983	6,758	5,904	5,204	4,637	4,185	3,563	3,223	3,073	3,037	3,059	3,118	3,137	3,089	4,707
290	310	12,983	3,999	3,686	5,204	3,277	3,155	3,023	2,986	2,994	3,014	3,026	3,010	2,962	2,913	2,904
310	330	12,983	3,372	3,520	3,450	3,156	3,098	2,985	2,650	2,564	5,286	5,252	5,274	5,326	5,344	5,279
330	350	12,983	12,334	15,201	16,728	17,216	16,932	14,820	12,116	9,460	9,460	6,418	6,318	7,095	7,814	7,123

Wind Responsive Look-up Table

Minimum Fan Motor Frequency, Hz vs. Wind Speed and Wind Direction

Wind Direction		Minimum Fan Motor Frequency (Hz)														
		Anemometer Wind Speed (m/s)														
Min	Max	<1	1	2	3	4	5	7	9	11	13	15	18	21	24	27
350	10	25.4	25.1	26.9	28.8	30.7	32.7	36.5	40.0	43.2	45.8	47.8	49.9	51.1	51.6	51.9
10	30	25.4	24.7	29.0	32.7	35.1	38.5	42.8	45.8	48.1	49.8	51.2	53.0	54.8	60.0	60.0
30	50	25.4	23.6	27.9	31.9	35.7	39.2	45.7	51.5	56.5	60.0	60.0	60.0	60.0	60.0	60.0
50	70	25.4	23.1	27.4	31.4	35.2	38.6	44.9	50.3	59.5	59.5	59.5	60.0	60.0	60.0	60.0
70	90	25.4	23.0	27.3	31.2	34.6	38.4	44.6	50.0	59.0	59.0	59.0	60.0	60.0	60.0	60.0
90	110	25.4	22.2	27.8	32.7	37.0	40.7	46.6	51.2	56.6	56.7	56.7	60.0	60.0	60.0	60.0
110	130	25.4	24.4	27.5	30.6	33.6	36.7	42.4	47.7	56.6	56.6	59.9	60.0	60.0	60.0	60.0
130	150	25.4	25.4	28.2	31.0	33.9	36.7	42.1	47.1	55.6	55.6	59.0	60.0	60.0	60.0	60.0
150	170	25.4	24.9	27.9	30.5	32.7	34.5	37.2	38.8	39.7	39.7	39.4	38.2	36.7	35.1	60.0
170	190	25.4	23.3	21.4	21.0	20.2	19.6	18.8	18.5	18.4	18.5	18.7	18.9	18.9	18.7	33.6
190	210	25.4	23.2	21.9	20.8	20.0	19.4	18.6	18.3	18.3	18.4	18.6	18.9	18.9	18.7	18.2
210	230	25.4	24.3	23.5	22.7	22.1	21.5	20.6	19.9	19.3	19.0	18.7	18.5	18.4	18.4	18.2
230	250	25.4	23.8	22.7	21.7	21.0	20.3	19.4	18.9	18.6	18.5	18.4	18.4	18.4	18.4	18.4
250	270	25.4	21.4	21.5	21.4	21.2	21.0	20.3	19.6	19.0	18.5	18.2	18.1	18.3	18.6	18.3
270	290	25.4	20.4	19.7	19.2	18.7	18.3	17.8	17.6	17.5	17.4	17.4	17.5	17.5	17.5	18.8
290	310	25.4	18.2	17.9	19.2	17.6	17.5	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.3	17.3
310	330	25.4	17.7	17.8	17.8	17.5	17.5	17.4	17.1	17.0	19.2	19.2	19.2	19.2	19.3	19.2
330	350	25.4	24.8	27.1	28.3	28.7	28.5	26.8	24.7	22.5	22.5	20.1	20.0	20.7	21.2	20.7

Minimum Volume Flow Rate vs. Fan Motor Frequency, Hz w/ Minimum Fan Speed to Meet Building Load

Minimum Volume Flow Rate vs. Fan Motor Frequency, Hz w/ Minimum Fan Speed to Meet Building Load

[illegible]

Wind Responsive Look-up Table

Minimum Volume Flow Rate vs. Wind Speed and Wind Direction
Increased Stack Height

Wind Direction		Minimum Volume Flow Rate (cfm) Anemometer Wind Speed (m/s)														
Min	Max	<1	1	2	3	4	5	7	9	11	13	15	18	21	24	27
350	10	11,803	12,700	13,553	14,260	14,785	15,115	15,997	16,209	15,851	15,740	15,267	14,778	13,882	12,803	11,713
10	30	11,803	12,184	15,982	18,351	18,899	20,162	20,672	19,950	18,610	17,798	16,834	16,083	15,300	15,729	14,299
30	50	11,803	10,765	14,650	17,480	19,453	20,732	22,864	23,602	23,381	23,029	20,936	19,033	17,302	15,729	14,299
50	70	11,803	10,163	14,140	17,009	18,986	20,247	22,294	22,850	25,033	22,758	20,689	19,033	17,302	15,729	14,299
70	90	11,803	10,067	13,978	16,803	18,479	19,999	22,030	22,685	24,784	22,531	20,482	19,033	17,302	15,729	14,299
90	110	11,803	9,070	14,593	18,332	20,693	22,001	23,516	23,415	23,414	21,359	19,417	19,033	17,302	15,729	14,299
110	130	11,803	11,815	14,235	16,129	17,543	18,538	20,413	21,197	23,396	21,269	20,896	19,033	17,302	15,729	14,299
130	150	11,803	12,983	15,035	16,623	17,787	18,570	20,177	20,803	22,873	20,794	20,453	19,033	17,302	15,729	14,299
150	170	11,803	12,422	14,717	16,045	16,636	16,681	16,507	15,408	13,917	12,652	11,339	9,830	8,353	7,029	14,299
170	190	11,803	10,358	7,347	6,236	4,921	3,948	2,847	2,250	1,922	1,798	1,710	1,642	1,501	1,282	5,910
190	210	11,803	10,268	7,848	6,050	4,726	3,757	2,682	2,125	1,837	1,747	1,685	1,643	1,514	1,295	1,009
210	230	11,803	11,677	9,671	8,028	6,683	5,583	4,150	3,148	2,443	2,031	1,728	1,479	1,308	1,180	1,014
230	250	11,803	11,005	8,736	6,981	5,624	4,576	3,306	2,519	2,021	1,766	1,584	1,443	1,314	1,183	1,072
250	270	11,803	8,067	7,415	6,663	5,880	5,116	3,950	2,975	2,231	1,783	1,483	1,302	1,255	1,245	1,052
270	290	11,803	6,758	5,367	4,301	3,484	2,858	2,116	1,665	1,380	1,240	1,135	1,052	962	861	1,193
290	310	11,803	3,999	3,351	4,301	2,462	2,155	1,795	1,542	1,345	1,231	1,123	1,016	909	812	736
310	330	11,803	3,372	3,200	2,851	2,371	2,116	1,773	1,369	1,151	2,158	1,949	1,779	1,634	1,490	1,338
330	350	11,803	12,334	13,819	13,825	12,935	11,565	8,802	6,257	4,248	3,862	2,382	2,132	2,176	2,179	1,806

Wind Responsive Look-up Table

Minimum Volume Flow Rate vs. Fan Motor Frequency, Hz
w/ Minimum Fan Speed to Meet Building Load

Wind Direction		Minimum Fan Motor Frequency (Hz) Anemometer Wind Speed (m/s)														
Min	Max	<1	1	2	3	4	5	7	9	11	13	15	18	21	24	27
350	10	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
10	30	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
30	50	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
50	70	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
70	90	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
90	110	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
110	130	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
130	150	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
150	170	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
170	190	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
190	210	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
210	230	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
230	250	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
250	270	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
270	290	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
290	310	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
310	330	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
330	350	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0

**Simple Turndown – No Look-up Table Needed
– No Anemometer Required**

Section 140.9 (c) - 1

Fan System Power Consumption

3. Fan System Power Consumption. All newly installed fan exhaust systems serving a laboratory or factory greater than 10,000 CFM, shall meet subsection A and either B, C, or D.

A. System shall meet all discharge requirement in ANSI Z9.5

.
.

C. The volume flow rate at the stack shall vary based on the measured 5-minute averaged wind speed and wind direction obtained from a calibrated local anemometer.

iii. Wind speed/direction sensors shall be certified by the manufacturer to be accurate within plus or minus 40 fpm (0.2 m/s) and 5.0 degrees when measured at sea level and 25°C, factory calibrated and certified by the manufacturer to require calibration no more frequently than once every 5 years.

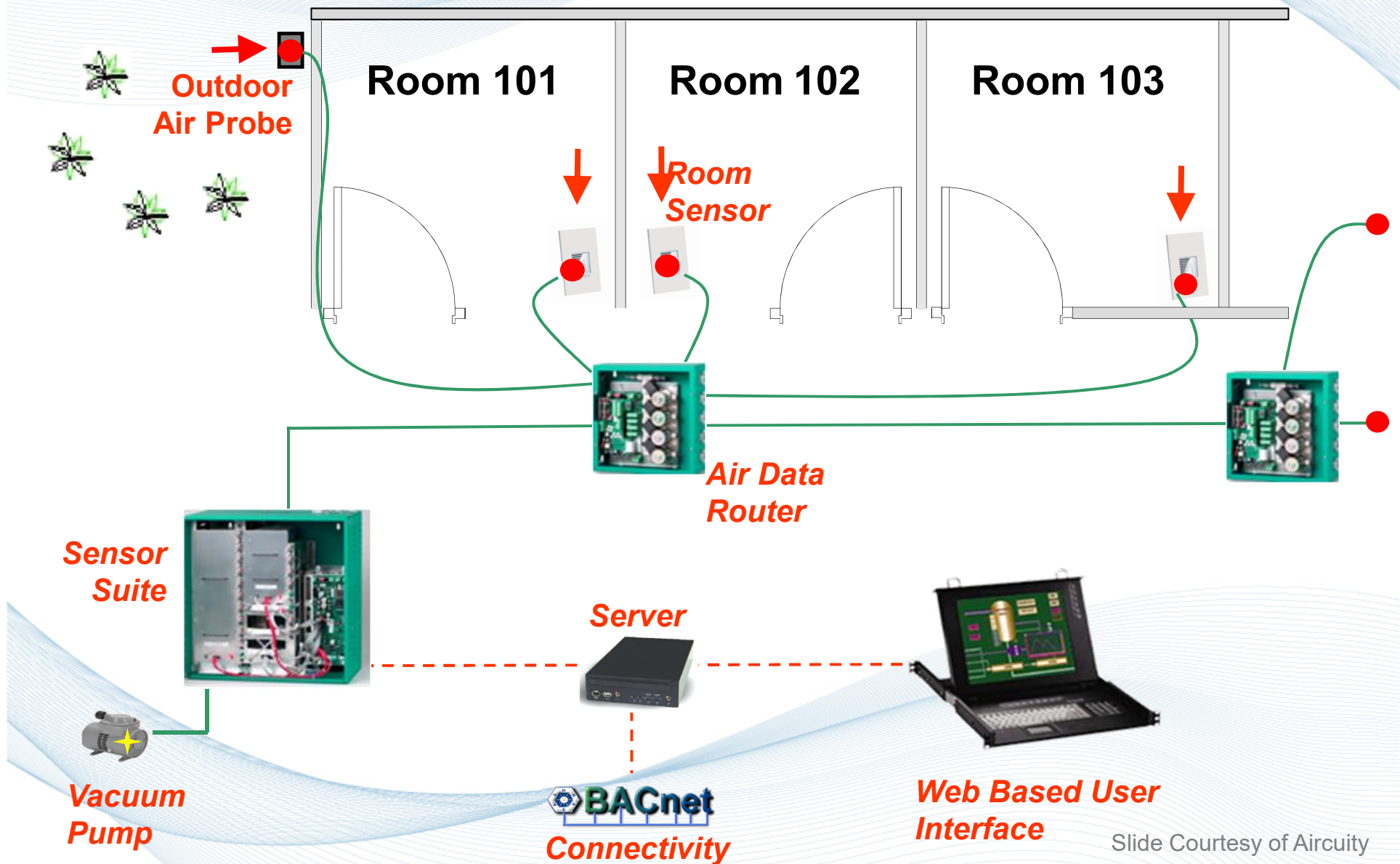
Section 140.9 (c) - 1

Fan System Power Consumption

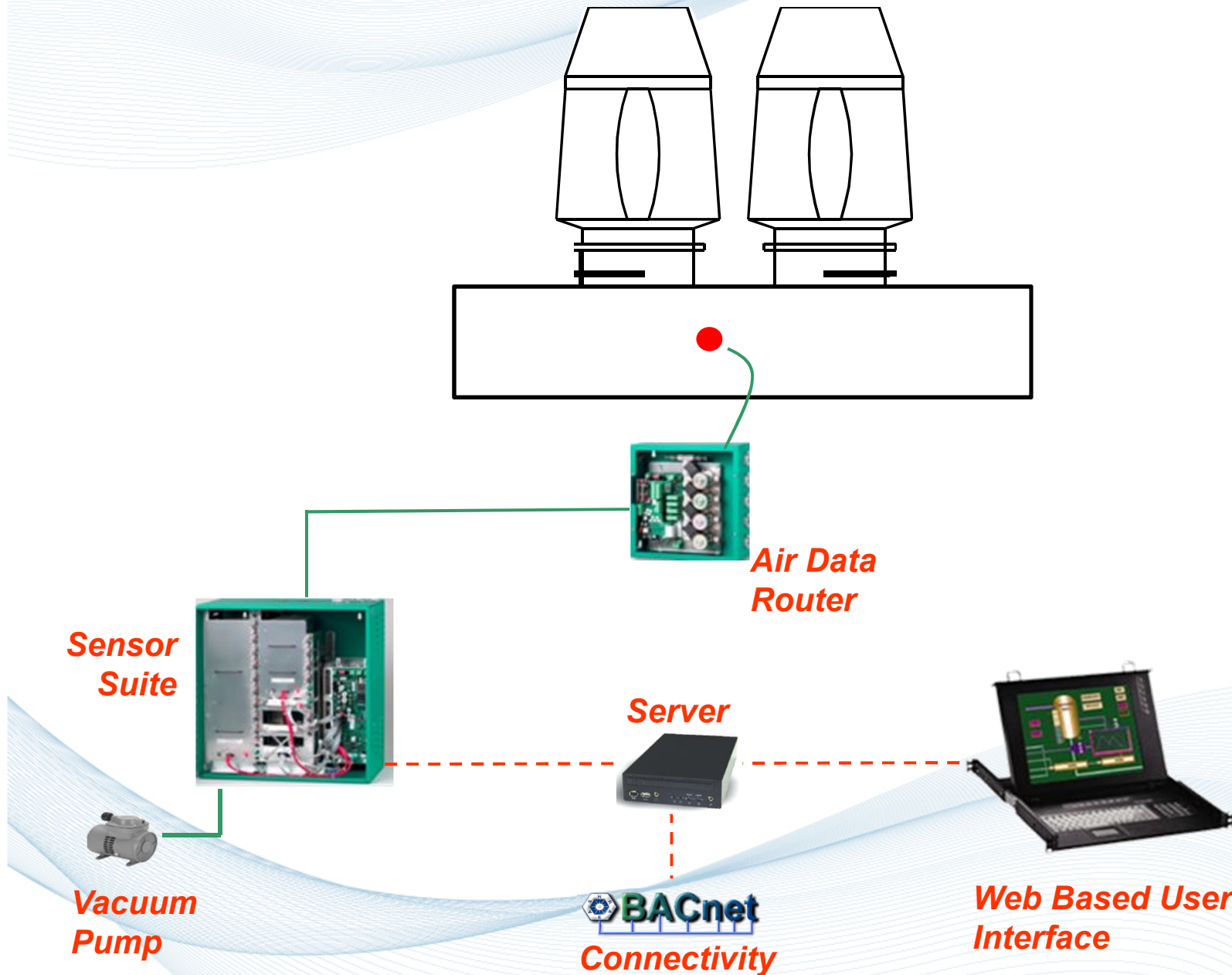
Fan System Power Consumption. All newly installed fan exhaust systems serving a laboratory or factory greater than 10,000 CFM, shall meet subsection A and either B, C, or D.

- A. System shall meet all discharge requirement in ANSI Z9.5 - 2012
 - .
 - .
- D. The volume flow rate at the stack shall vary based on the measured contaminant concentration in the exhaust plenum from a calibrated contaminant sensor installed within each exhaust plenum.

Chemical Monitoring – In the Lab



Chemical Monitoring – ^{w/in} the Exhaust Manifold



Section 140.9 (c) - 1

Fan System Power Consumption

Fan System Power Consumption. All newly installed fan exhaust systems serving a laboratory or factory greater than 10,000 CFM, shall meet subsection A and either B, C, or D.

A. System shall meet all discharge requirement in ANSI Z9.5 - 2012

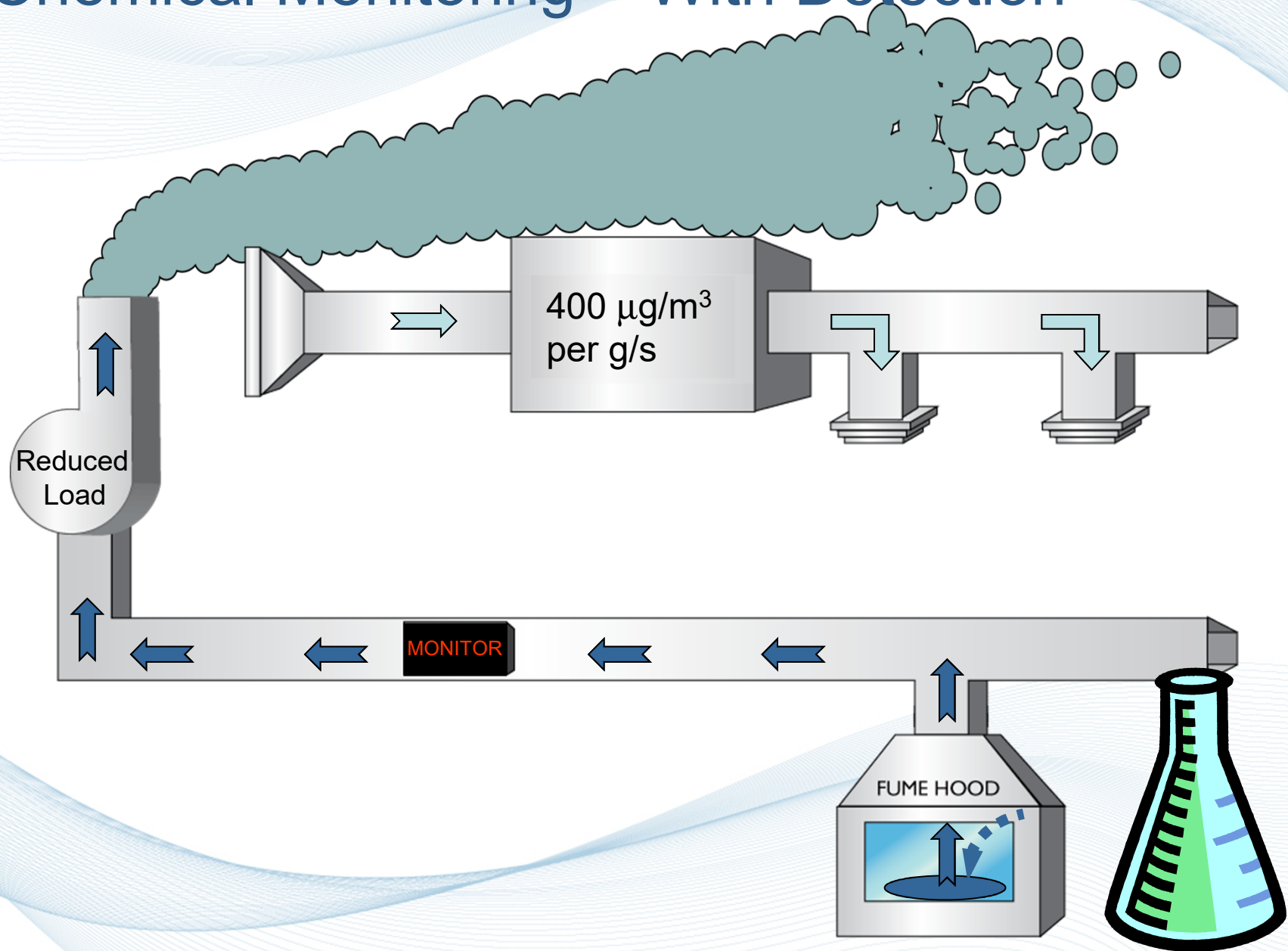
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D. The volume flow rate at the stack shall vary based on the measured contaminant concentration in the exhaust plenum from a calibrated contaminant sensor installed within each exhaust plenum.

- i. A contaminant-event threshold shall be established based on maintaining downwind concentrations below health and odor limits for all detectable chemicals at worst-case wind conditions.

Chemical Monitoring – With Detection

The diagram illustrates a chemical monitoring system with detection. A large cloud of green gas is shown entering a duct from the left. The duct is labeled "Reduced Load" and has a blue arrow pointing upwards. The gas flows through a section of the duct where the concentration is indicated as $400 \mu\text{g}/\text{m}^3$ per g/s. The duct then splits into two paths, each leading to a stack. A blue arrow points to the right, indicating the flow direction. Below the main duct, a horizontal duct is shown with a blue arrow pointing to the left. A black box labeled "MONITOR" is positioned on this lower duct. A blue arrow points upwards from the lower duct to a "FUME HOOD". To the right of the fume hood is a beaker containing a green liquid.



Section 140.9 (c) - 1

Fan System Power Consumption

Fan System Power Consumption. All newly installed fan exhaust systems serving a laboratory or factory greater than 10,000 CFM, shall meet subsection A and either B, C, or D.

A. System shall meet all discharge requirement in ANSI Z9.5 - 2012

.
.

D. The volume flow rate at the stack shall vary based on the measured contaminant concentration in the exhaust plenum from a calibrated contaminant sensor installed within each exhaust plenum.

- ii. At least two contaminant concentration sensors shall be Photo Ionization Detectors (PID). Certified by the manufacturer to be accurate within +/-5%, when measured at sea level and 25°C, factory calibrated, and certified by the manufacturer to require calibration no more than once every 6 months.

Sensor Suite

Typical Set of Sensors

- Carbon Dioxide
- Dewpoint / Temperature / Relative Humidity
- Airborne Particulates
- Carbon Monoxide
- Total Volatile Organic Compounds (VOC's)

Photoionization Detector (PID)

- A PID uses UV light to break down VOC's into (+) and (-) ions. It then measures the charge of the ionized gas.
- Only detects organic (carbon containing) chemicals.
- Response depends upon the ionization potential and the concentration.

Issues:

- Doesn't identify the chemical, just the ionization potential.
- A toxic chemical with a low response factor can easily be swamped by the signal from a non-toxic (or low toxic) chemical with a high response factor.

Photoionization Detector (PID)

Chemicals ^{w/} normalized health/odor limits < 1500 µg/m³ per g/s

- | | | |
|-----------------------------|-------------------------|-------------------------|
| ✓ Arsinine | ✓ Isopropyl Ether | ✓ Butadiene |
| ✓ Methyl Mercaptan | ✗ Methyl Isocyanate | ✓ Butylamine |
| ✓ Ethyl Mercaptan | ✓ Diethylamine | ✓ Bromine |
| ✓ Ethyl Acrylate | ✗ Phosgene | ✓ Dimethylamine |
| ✓ Hydrogen Sulfide | ✓ Amyl Acetate | ✓ Ethyl Ether |
| ✓ Nickel Carbonyl | ✗ Tungston Hexafluoride | ✓ Acrolein |
| ✗ Perchloromethyl Mercaptan | ✓ Dimethylhydrazine | ✗ Morpholine |
| ✗ Sulfur Pentafluoride | ✓ Isopropylamine | ✓ Diisopropylamine |
| ✗ Chromyl chloride | ✓ Cresol | ✗ Tetranitromethane |
| ✗ Chlorine Triflouride | ✗ Diborane | ✓ Mesityl Oxide |
| ✓ Butyl Mercaptan | ✓ Phosphine | ✗ Flourine |
| ✗ Osmium Tetroxide | ✓ Nitrogen Dioxide | ✗ Hydrogen Bromide |
| ✗ Picric Acid | ✓ Ethylamine | ✗ Sulfur Dioxide |
| ✓ Pentaborane | ✗ Carbon Disulfide | ✓ Nitric Oxide |
| ✗ Chlorine | ✓ Methyl Hydrazine | ✗ Boron Trifluoride |
| ✓ Acetaldehyde | ✗ Bromine Pentafluoride | ✓ Germane Tetrahydride |
| ✓ Hydrogen Selenide | ✗ Tetramethyl lead | ✓ Hydrazine |
| ✗ Chloromethyl Ether | | ✓ Methyl Methracrylate |
| ✗ Hydrogen Fluoride | | ✗ Dibromo Chloropropane |
| ✗ Dibromo-3-chloropropane | | ✗ Hydrogen Chloride |
| | | ✓ Iron carbonyl |

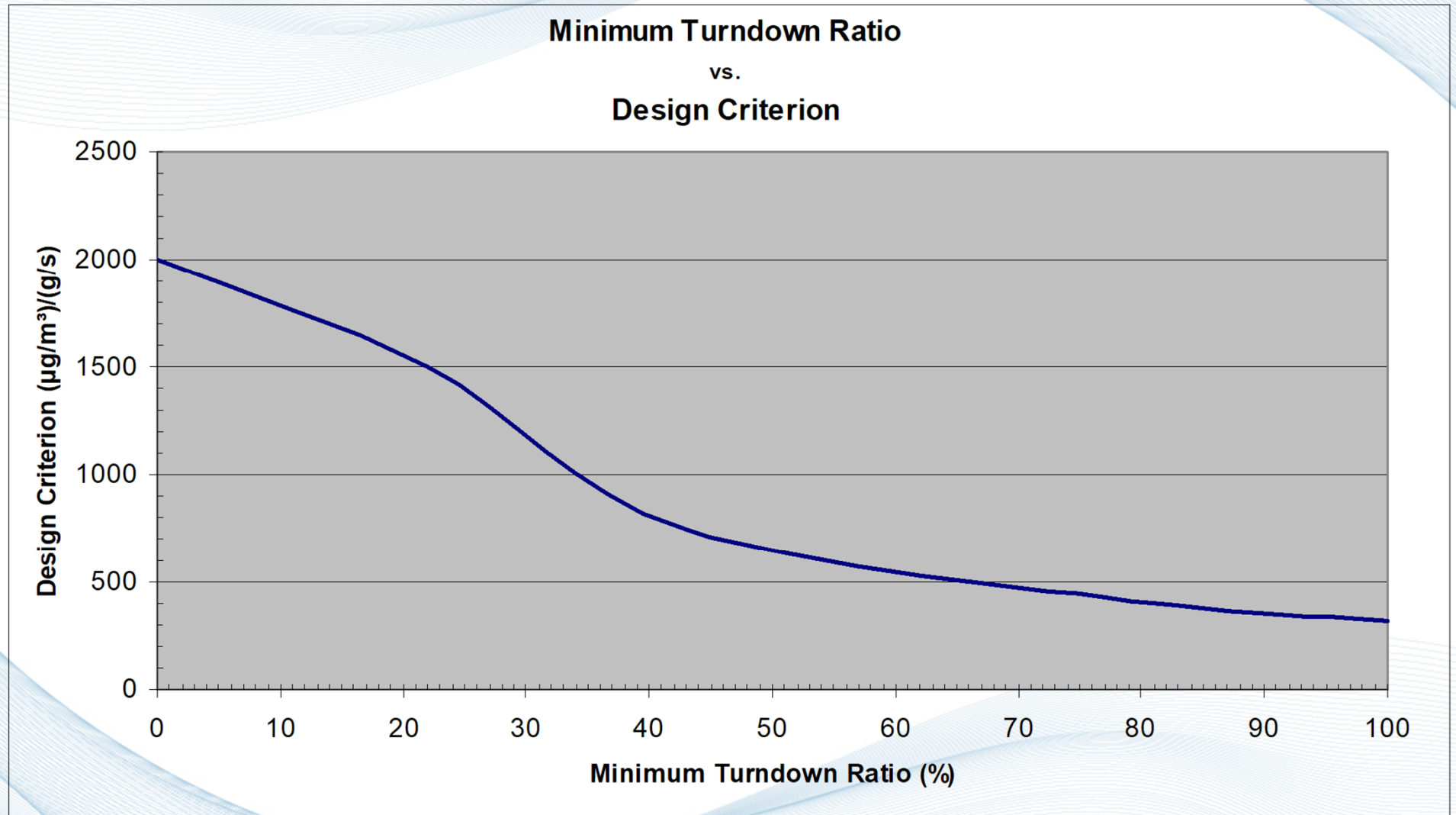
Develop an Acceptance Criterion

Detection Limits vs. Health Limits (HL) or Odor Thresholds (OT)

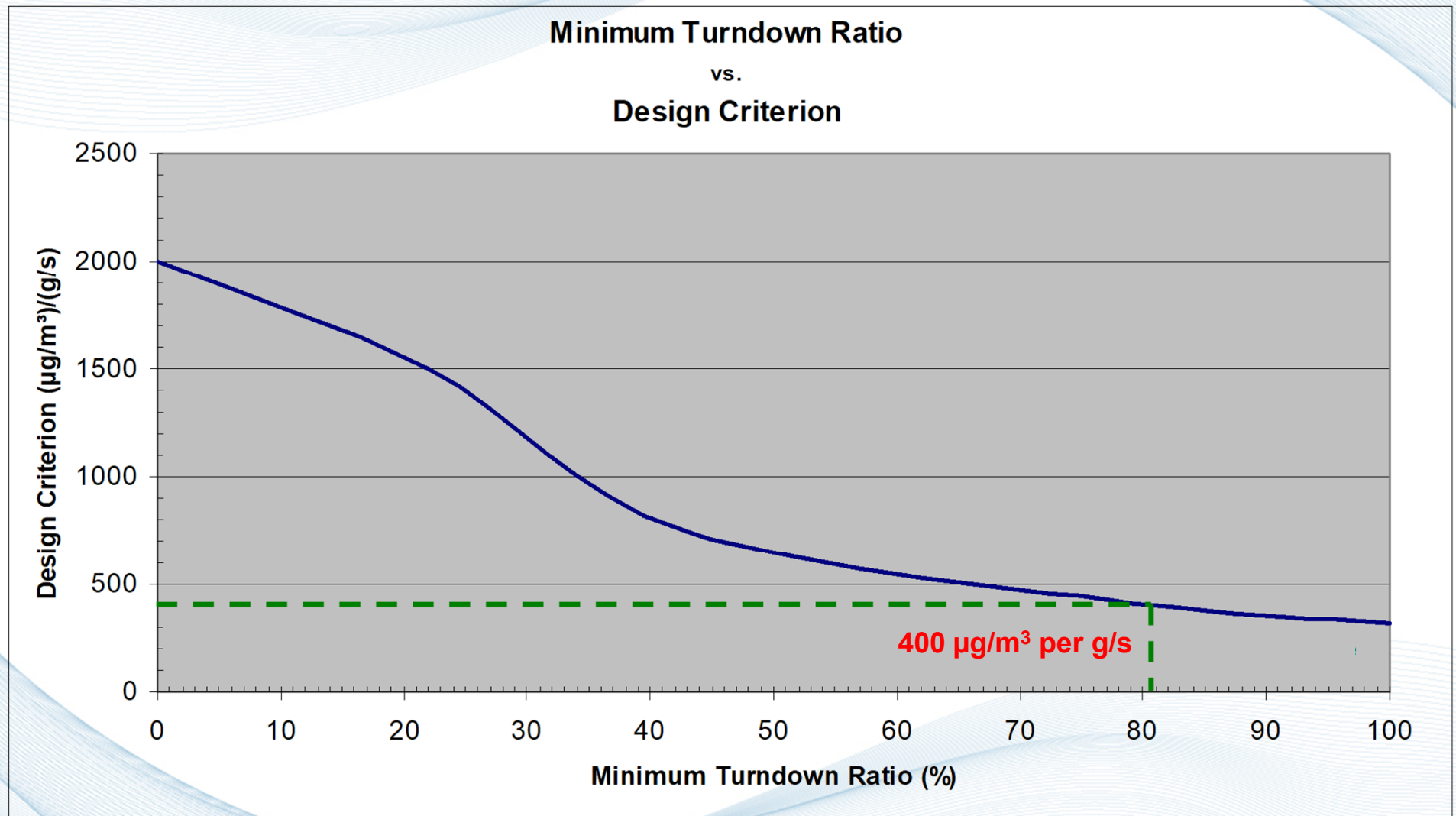
1:130
Dilution

		TVOC PID Limit (ppm):		Volume Flow Rate (cfm):					
		2		10,000					
Substance	CAS#	Detectable with PID	Normalized Concentration Limit ($\mu\text{g}/\text{m}^3$)/(g/s)	Sensor Response Factor (RF)	Min. HL / OT ($\mu\text{g}/\text{m}^3$)	Detection Limit (ppm)	Detection Limit ($\mu\text{g}/\text{m}^3$)	Detectable at Min. HL/OT Value	Max. Allowable Emission Rate Gas (g/s) Liquid (ml)
Arsine	7784-42-1	Yes	0.3	2.5	2.0	$\times 130$	15941	No	Emission Limit Based on 1500 $\mu\text{g}/\text{m}^3$ per g/s
Methyl mercaptan	74-93-1	Yes	0.3	0.7	1.1	1.4	2755	No	
Ethyl mercaptan	75-08-1	Yes	0.3	0.7	0.4	1.4	3458	No	
Ethyl acrylate	140-88-5	Yes	3.1	2	1.0	4	16376	No	
Hydrogen sulfide	7783-06-4	Yes	3.5	4	13	8	11151	No	
Nickel carbonyl (as Ni)	13463-39-3	Yes	3.6	1	21	2.0	13963	No	
Perchloromethyl mercaptan	594-42-3	No	5.7		8			No	
Sulfur pentafluoride	5714-22-7	No	6.5		100			No	
Chromyl chloride	14977-61-8	No	6.9		3			No	
Butyl mercaptan (n-)	109-79-5	Yes	10.8	0.5	4	1	3689	No	
Osmium tetroxide	20816-12-0	No	15.5		5			No	Emission Limit Based on 400 $\mu\text{g}/\text{m}^3$ per g/s
Picric acid	88-89-1	No	20.1		1			No	
Pentaborane	19624-22-7	No	21.9		30			No	
Bromine	7726-95-6	No	436.6		1300			No	
Dimethylamine	124-40-3	Yes	479.8	1.4	1457	2.8	5163	Yes	
Ethyl ether	60-29-7	Yes	487.9	0.9	1723	1.8	5457	Yes	
Morpholine	110-91-8	No	690.8		39			No	
Diisopropylamine	108-18-9	Yes	699.7	0.7	537	1.4	5795	Yes	
Tetranitromethane	509-14-8	No	706.5		120			No	
Mesityl oxide	141-79-7	Yes	711.7	0.7	68	1.4	5619	Yes	

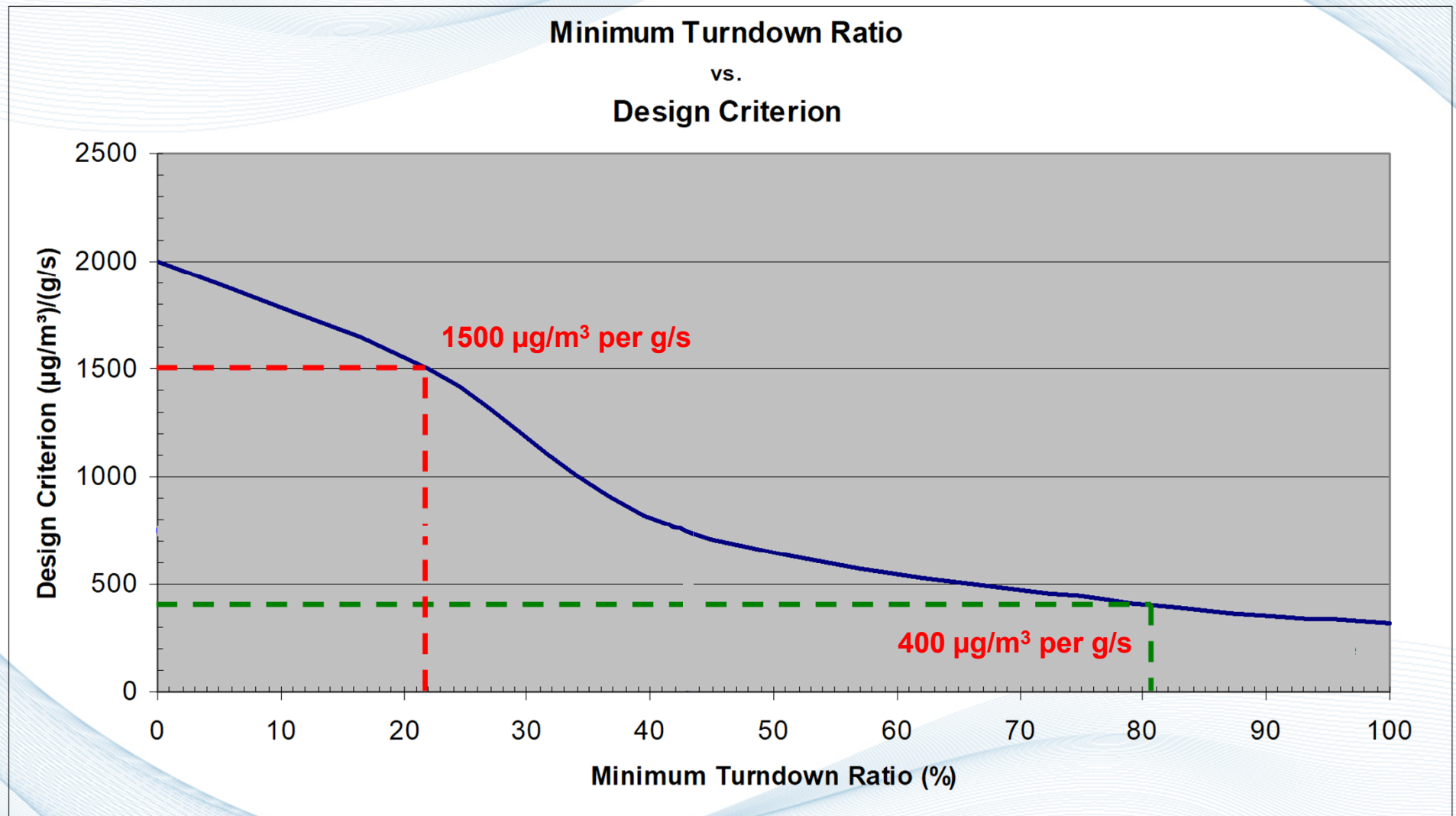
Turndown Ratio vs. Design Criterion



Turndown Ratio vs. Design Criterion



Turndown Ratio vs. Design Criterion



Chemical Monitoring - Summary

Just because you do not detect it,
doesn't mean it's not there.

Recommended Controls for Research Labs:

- Limit chemical emissions to achieve a $1500 \mu\text{g}/\text{m}^3$ per g/s design criterion for those chemicals that can not be detected, or for those chemicals with HL or OT below detection limits.
- When chemicals are detected at the trigger level, increase volume flow rate to achieve a $400 \mu\text{g}/\text{m}^3$ per g/s limit at all downwind receptor locations.

Case Study

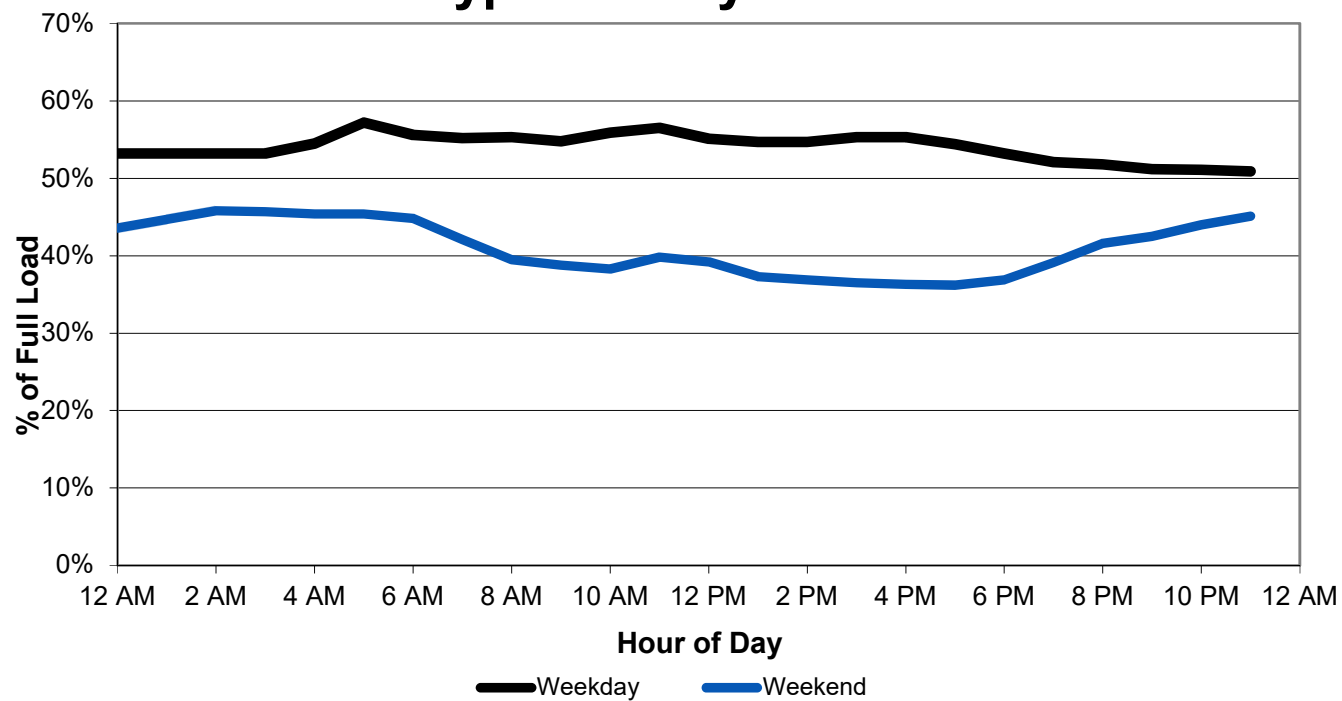
Constant Volume - Existing

- Existing Operating Conditions
 - 3 of 4 Operating
 - (n+1 Redundancy)
 - 58,500 cfm each
- 1,377 MW hrs/yr
- \$179,080 per year



Case Study

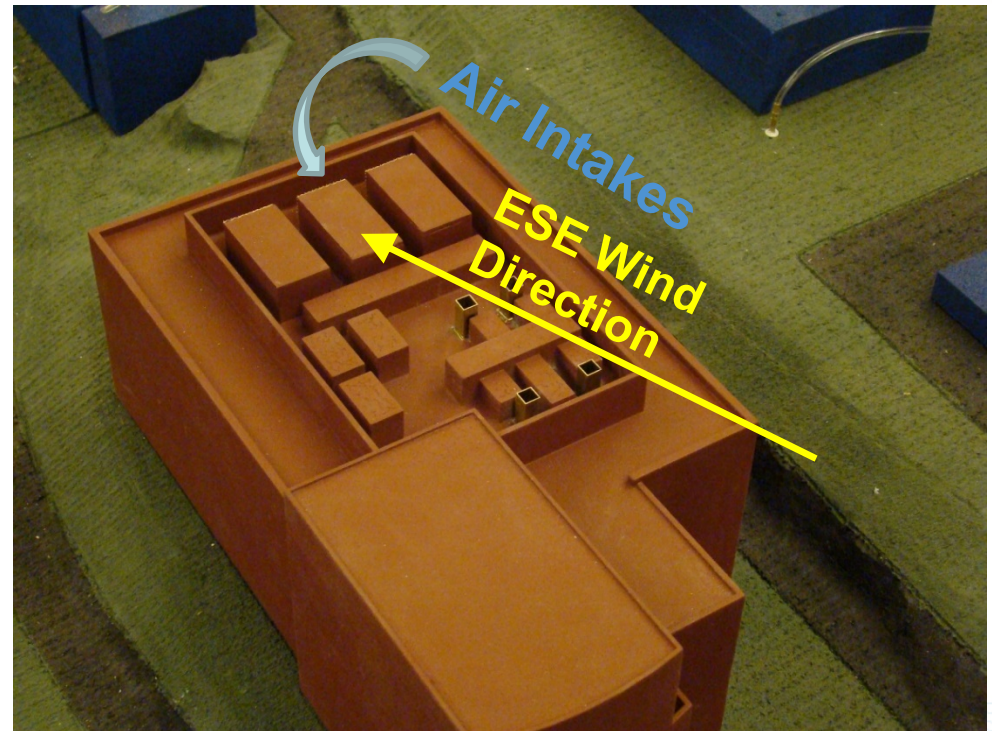
Typical Daily Load Profile



Case Study

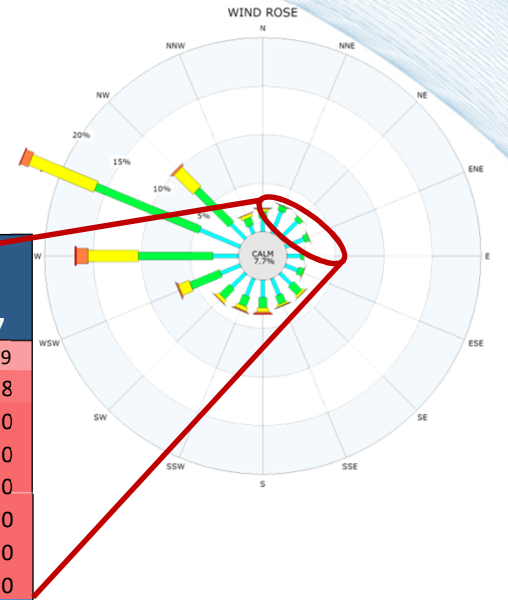
Simple Turndown VAV

- Maximum concentrations met design criteria for certain wind speeds and wind directions.
- Little or no turndown available – need the maximum volume flow rate under ESE wind conditions.
- **No Energy Savings Available w/ Simple VAV System**



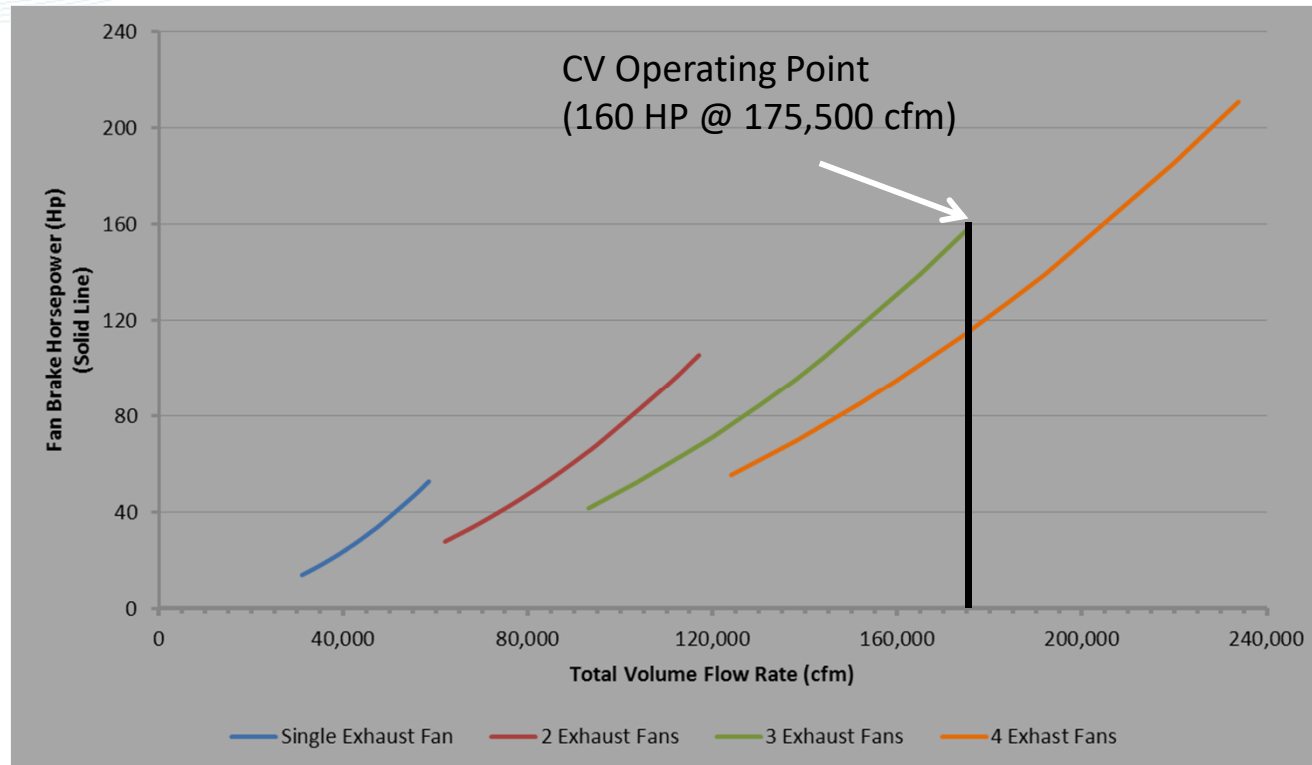
Case Study

Wind Direction		Minimum Motor Frequency Hz Anemometer Wind Speed*														
		< 1	1	2	3	4	5	7	9	11	13	15	18	21	24	27
350	10	43.2	43.2	43.2	43.2	43.2	43.2	43.2	45.0	47.4	49.3	50.9	52.5	53.4	53.7	53.9
10	30	43.2	43.2	43.2	43.2	43.2	43.9	47.1	49.4	51.1	52.4	53.4	54.8	56.1	57.5	58.8
30	50	43.2	43.2	43.2	43.2	43.2	44.4	49.3	53.6	57.4	60.0	60.0	60.0	60.0	60.0	60.0
50	70	43.2	43.2	43.2	43.2	43.2	44.0	48.7	52.9	56.5	59.6	60.0	60.0	60.0	60.0	60.0
70	90	43.2	43.2	43.2	43.2	43.2	43.8	48.5	52.6	56.1	59.3	60.0	60.0	60.0	60.0	60.0
90	110	43.2	43.2	43.2	43.2	43.2	45.5	50.1	53.4	55.8	57.6	58.8	60.0	60.0	60.0	60.0
110	130	43.2	43.2	43.2	43.2	43.2	43.2	46.8	50.8	54.4	57.5	60.0	60.0	60.0	60.0	60.0
130	150	43.2	43.2	43.2	43.2	43.2	43.2	46.6	50.4	53.8	56.8	59.3	60.0	60.0	60.0	60.0
150	170	43.2	43.2	43.2	43.2	43.2	43.2	43.2	44.1	44.7	44.8	44.5	43.7	43.2	43.2	43.2
170	190	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2
190	210	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2
210	230	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2
230	250	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2
250	270	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2
270	290	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2
290	310	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2
310	330	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2
330	350	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2



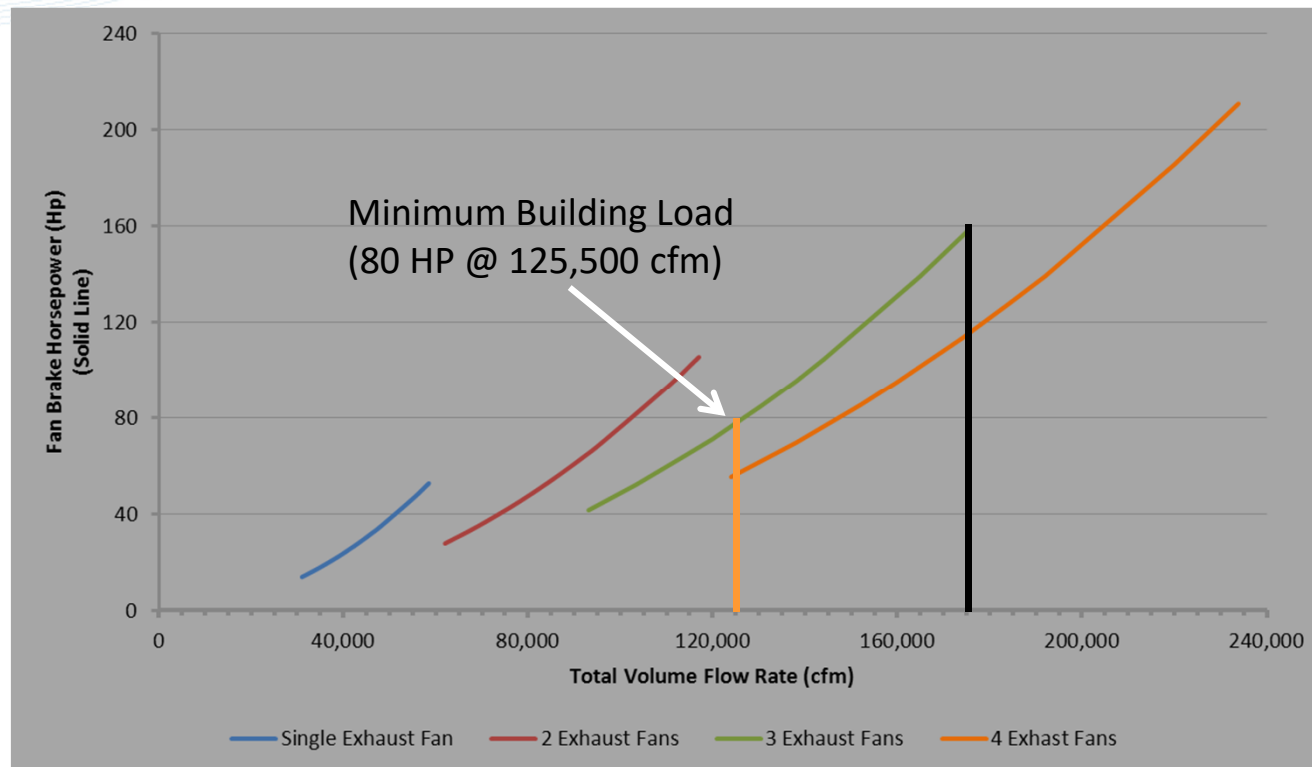
Case Study

Fan Characteristics at Reduced Air Flow



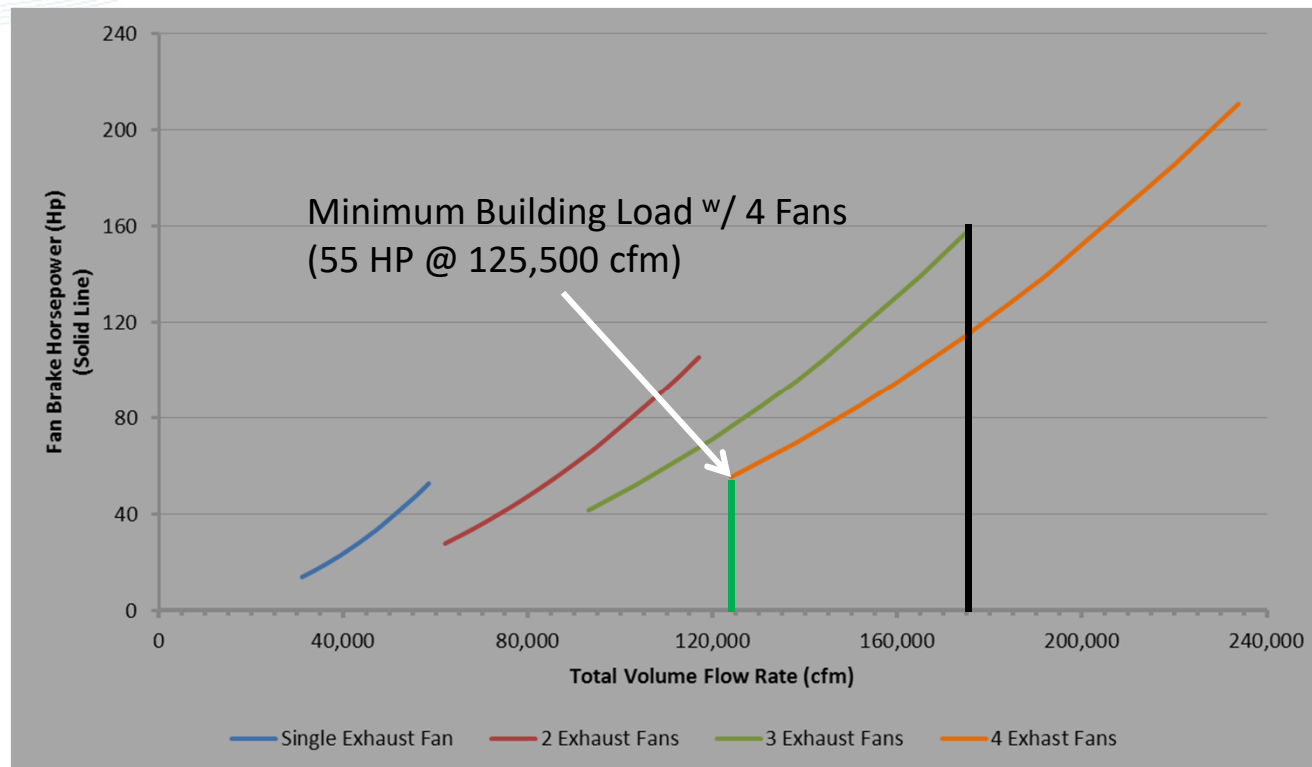
Case Study

Fan Characteristics at Reduced Air Flow



Case Study

Fan Characteristics at Reduced Air Flow



Case Study

	Annual Energy Consumption	Annual Savings vs. CV
Constant Volume	1,377 MW hrs/yr	(-)
Simple Turndown VAV	1,377 MW hrs/yr	(-)
Wind Responsive VAV	484 MW hrs/yr	\$116,168 / yr



QUESTIONS?

For More Information

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