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Fan Power

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Acknowledgements

California Statewide Codes and Standards Team

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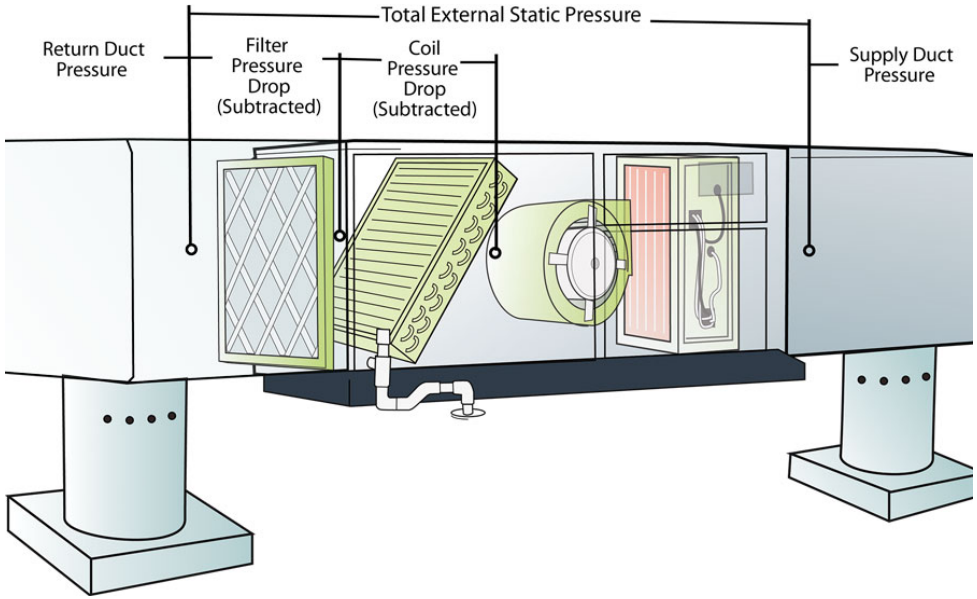
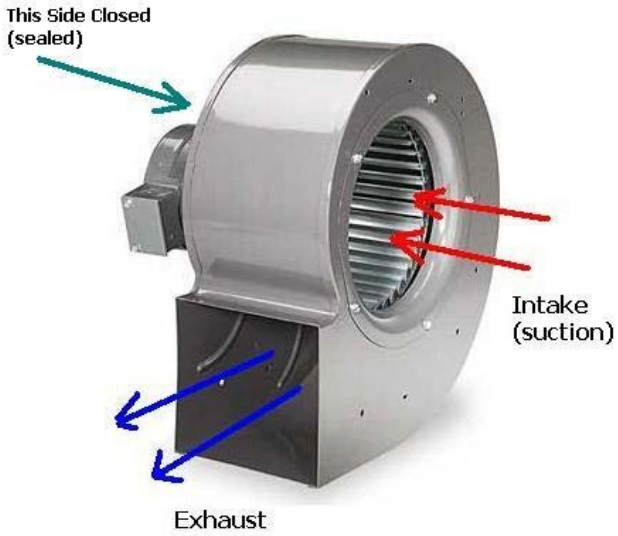
Background

HVAC system fans power





Background

Power Consumption of Fans – Section 140.4(c)

- First introduced in the 1992 version of Title 24, Part 6
- Efficiency Metric - Watts/CFM
- No limit to added static pressure due to filters

Background

Since its introduction into Part 6, DOE Standard for motor efficiency has been updated several times

Part 6 has not updated the fan power allowance in response to DOE updates

Background

2013 Title 24, Part 6

- Change in simulation engine from DOE-2 to EnergyPlus
- Shift in reference fan energy calculation
  - Brake horsepower
  - Fan efficiency
  - Air flow
  - HVAC system type
  - Fan motor efficiency
  - Fan efficiency
  - Air flow
  - HVAC system type
  - Static Pressure
  - Part load curve by building, HVAC and fan type

Allowed Total Static Pressure		
	Constant Volume	**Variable Volume**
Title 24 Part 6	3.96”	6.18”
Proposed (NR ACM)	3.50”	4.50”

Proposed Code Change

1. Adopt ASHRAE calculation methodology for allowed fan power
2. Align the prescriptive and performance requirements for fan power
3. Limit the total allowed static pressure based on current ACM

Allowed Total Static Pressure		
	Constant Volume	**Variable Volume**
Title 24 Part 6	3.96”	6.18”
ASHRAE 90.1	3.85”	5.35”
Proposed (NR ACM)	3.50”	4.50”

Proposed Code Change

- ASHRAE calculation methodology for allowed fan power
  - Applicable to supply, return fans; exhaust fans at the system level; vav boxes; zonal exhaust
  - Greater than 5 horsepower
  - Pressure drop adjustment factors
    - Particulate Filtration, exhaust filters, energy recovery devices, etc

Energy Analysis

CBECC-Com Standard Design (VAV)

- 4.5 inches of total static
- Resulting in 0.911 W/cfm

CBECC-Com Proposed Design (VAV)

- Modified to reflect current prescriptive maximum 1.25 W/cfm
- 6.231 inches of total static

Prototype ID	Occupancy Type (Residential, Retail, Office, etc.)	Area (ft2)	Number of Stories	Statewide Area (million ft2)
Prototype 1	Large Office	498,589	13	42.358
Prototype 2	Medium Retail	24,563	1	35.881

Energy Analysis – First Year Impact per ft^2

Large Office Climate Zone	Electricity Savings (kWh/ft2-yr)	Peak Electricity Demand Reductions (kW/ft2)	Natural Gas Savings (therms/ft2-yr)	TDV Energy Savings (TDV kBtu/ft2-yr)
1	0.19	2.48E-05	-2.71E-03	4.66
2	0.22	3.35E-05	-1.91E-03	6.25
3	0.21	2.93E-05	-1.58E-03	5.49
4	0.23	3.36E-05	-1.32E-03	6.37
5	0.22	2.82E-05	-1.90E-03	5.67
6	0.24	3.13E-05	-0.74E-03	7.22
7	0.24	3.13E-05	-0.28E-03	7.23
8	0.24	3.20E-05	-0.63E-03	7.58
9	0.25	3.54E-05	-0.74E-03	7.84
10	0.24	3.51E-05	-0.84E-03	7.54
11	0.24	3.78E-05	-1.50E-03	6.89
12	0.23	3.63E-05	-1.47E-03	6.48
13	0.24	3.58E-05	-1.40E-03	6.56
14	0.27	3.81E-05	-1.34E-03	7.99
15	0.28	3.88E-05	-0.30E-03	8.43
16	0.25	3.69E-05	-2.61E-03	6.44

Energy Analysis – First Year Impact per ft^2

Medium Retail Climate Zone	Electricity Savings (kWh/ft2-yr)	Peak Electricity Demand Reductions (kW/ft2)	Natural Gas Savings (therms/ft2-yr)	TDV Energy Savings (TDV kBtu/ft2-yr)
1	0.25	5.31E-05	-10.66E-03	5.47
2	0.26	6.39E-05	-3.05E-03	7.80
3	0.25	5.63E-05	-2.61E-03	6.95
4	0.26	5.24E-05	-1.95E-03	7.95
5	0.25	5.42E-05	-2.72E-03	6.91
6	0.30	6.53E-05	-0.96E-03	8.98
7	0.30	6.53E-05	-0.49E-03	9.12
8	0.31	7.02E-05	-1.01E-03	9.79
9	0.31	7.78E-05	-1.41E-03	9.89
10	0.33	8.08E-05	-1.32E-03	10.54
11	0.32	9.44E-05	-2.35E-03	10.66
12	0.29	8.07E-05	-2.64E-03	9.09
13	0.33	9.32E-05	-2.57E-03	10.43
14	0.35	9.63E-05	-2.35E-03	11.38
15	0.43	11.03E-05	-0.68E-03	13.99
16	0.30	7.46E-05	-4.82E-03	8.02

Energy Analysis – 15 Year Costs per ft^2

Large Office Climate Zone	15-Year TDV Electricity Cost Savings (2020 PV$)	15-Year TDV Natural Gas Cost Savings (2020 PV$)	Total 15-Year TDV Energy Cost Savings (2020 PV$)
1	$0.46	-$0.04	$0.41
2	$0.59	-$0.03	$0.56
3	$0.52	-$0.03	$0.49
4	$0.59	-$0.02	$0.57
5	$0.54	-$0.03	$0.50
6	$0.66	-$0.01	$0.64
7	$0.65	-$0.01	$0.64
8	$0.69	-$0.01	$0.67
9	$0.71	-$0.01	$0.70
10	$0.69	-$0.02	$0.67
11	$0.64	-$0.03	$0.61
12	$0.60	-$0.03	$0.58
13	$0.61	-$0.03	$0.58
14	$0.73	-$0.02	$0.71
15	$0.76	-$0.01	$0.75
16	$0.62	-$0.05	$0.57

Energy Analysis – 15 Year Costs per ft^2

Medium Retail Climate Zone	15-Year TDV Electricity Cost Savings (2020 PV$)	15-Year TDV Natural Gas Cost Savings (2020 PV$)	Total 15-Year TDV Energy Cost Savings (2020 PV$)
1	$0.67	-$0.18	$0.49
2	$0.75	-$0.05	$0.69
3	$0.67	-$0.05	$0.62
4	$0.74	-$0.03	$0.71
5	$0.66	-$0.05	$0.61
6	$0.82	-$0.02	$0.80
7	$0.82	-$0.01	$0.81
8	$0.89	-$0.02	$0.87
9	$0.91	-$0.03	$0.88
10	$0.96	-$0.02	$0.94
11	$0.99	-$0.04	$0.95
12	$0.86	-$0.05	$0.81
13	$0.98	-$0.05	$0.93
14	$1.06	-$0.04	$1.01
15	$1.26	-$0.01	$1.25
16	$0.80	-$0.08	$0.71

Lifecycle Cost-Effectiveness per ft^2

Large Office Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings1 (2020 PV$)	Costs Total Incremental PV Costs2 (2020 PV$)	Benefit-to- Cost Ratio
1	$0.41	$0.36	1.15
2	$0.56	$0.38	1.45
3	$0.49	$0.38	1.29
4	$0.57	$0.39	1.45
5	$0.50	$0.38	1.33
6	$0.64	$0.39	1.66
7	$0.64	$0.38	1.68
8	$0.67	$0.39	1.72
9	$0.70	$0.40	1.76
10	$0.67	$0.43	1.55
11	$0.61	$0.40	1.53
12	$0.58	$0.39	1.50
13	$0.58	$0.40	1.46
14	$0.71	$0.42	1.69
15	$0.75	$0.42	1.81
16	$0.57	$0.48	1.18

Lifecycle Cost-Effectiveness per ft^2

Medium Retail Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings1 (2020 PV$)	Costs Total Incremental PV Costs2 (2020 PV$)	Benefit-to- Cost Ratio
1	$0.49	$0.30	1.22
2	$0.69	$0.32	1.64
3	$0.62	$0.31	1.49
4	$0.71	$0.33	1.59
5	$0.61	$0.30	1.56
6	$0.80	$0.32	1.85
7	$0.81	$0.31	1.93
8	$0.87	$0.34	1.94
9	$0.88	$0.33	1.98
10	$0.94	$0.36	1.93
11	$0.95	$0.35	2.03
12	$0.81	$0.33	1.84
13	$0.93	$0.35	1.99
14	$1.01	$0.35	2.15
15	$1.25	$0.36	2.60
16	$0.71	$0.36	1.47

Statewide Energy and Cost Impacts

Climate Zone	Statewide Construction in 2020 (million ft2)	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	Lifecycle2 Present Valued Energy Cost Savings (PV$ million)
1	0.1336	0.029	0.005	-0.001	0.060
2	1.092	0.263	0.053	-0.003	0.683
3	5.5209	1.254	0.236	-0.012	3.056
4	2.5118	0.616	0.108	-0.004	1.601
5	0.4877	0.113	0.020	-0.001	0.273
6	3.9203	1.050	0.189	-0.003	2.826
7	2.5713	0.690	0.124	-0.001	1.871
8	5.6605	1.555	0.289	-0.005	4.375
9	6.5567	1.821	0.371	-0.007	5.173
10	4.1947	1.202	0.243	-0.005	3.375
11	0.9991	0.279	0.066	-0.002	0.780
12	5.4712	1.402	0.320	-0.011	3.791
13	2.1175	0.606	0.137	-0.004	1.601
14	0.8302	0.254	0.056	-0.002	0.716
15	0.7574	0.270	0.056	0.000	0.756
16	1.1653	0.325	0.065	-0.004	0.750
Total	**43.9899**	**11.728**	**2.340**	**-0.065**	**31.686**

Proposed Code Language

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

Subsection 140.4(C) – Power Consumption of Fans. Each fan system used for space conditioning shall meet the requirements of Items 1, 2, ~~3 and 4~~ below. ~~Total fan system power demand equals the sum of the power demand of all fans in the system that are required to operate at design conditions in order to supply air from the heating or cooling source to the conditioned space, and to return it back to the source or to exhaust it to the outdoors; however, total fan system power demand need not include (i) the additional power demand caused solely by air treatment or filtering systems with final pressure drops more than 245 pascals or one-inch water column (only the energy accounted for by the amount of pressure drop that is over 1 inch may be excluded), or (ii) fan system power caused solely by exempt process loads.~~

1. ~~Constant volume fan systems. The total fan power index at design conditions of each fan system with total horsepower over 25 hp shall not exceed 0.8 watts per cfm of supply air~~.

1. Variable air volume (VAV) systems.

~~A. The total fan power index at design conditions of each fan system with total horsepower over 25 hp shall not exceed 1.25 watts per cfm of supply air; and~~

B. Static Pressure Sensor Location. Static pressure sensors used to control variable air volume fans shall be placed in a position such that the controller set point is no greater than one-third the total design fan static pressure, except for systems with zone reset control complying with Section140.4(c)2C. If this results in the sensor being located downstream of any major duct split, multiple sensors shall be installed in each major branch with fan capacity controlled to satisfy the sensor furthest below its setpoint; and

C. Setpoint Reset. For systems with direct digital control of individual zone boxes reporting to the central control panel, static pressure setpoints shall be reset based on the zone requiring the most pressure; i.e., the set point is reset lower until one zone damper is nearly wide open.

Proposed Code Language

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

Subsection 140.4(C) – Power Consumption of Fans. Each fan system used for space conditioning shall meet the requirements of Items 1, 2, ~~3 and 4~~ below. ~~Total fan system power demand equals the sum of the power demand of all fans in the system that are required to operate at design conditions in order to supply air from the heating or cooling source to the conditioned space, and to return it back to the source or to exhaust it to the outdoors; however, total fan system power demand need not include (i) the additional power demand caused solely by air treatment or filtering systems with final pressure drops more than 245 pascals or one-inch water column (only the energy accounted for by the amount of pressure drop that is over 1 inch may be excluded), or (ii) fan system power caused solely by exempt process loads.~~

1. […]
2. […]

~~3. Air-treatment or filtering systems. For systems with air-treatment or filtering systems, calculate the total adjusted fan power index using Equation 140.4-A:~~

~~EQUATION 140.4-A ADJUSTED TOTAL FAN POWER INDEX Adjusted total fan power index = Fan power index x Fan Adjustment Fan Adjustment~~

Proposed Code Language

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

Subsection 140.4(C) – Power Consumption of Fans. Each HVAC system having a total fan system motor nameplate horsepower exceeding 5 hp at fan system design conditions shall not exceed the allowable fan system motor nameplate horsepower (Option 1) or fan system bhp (Option 2) as shown in Table 140.4-A including supply fans, return/relief fans, exhaust fans, and fan-powered terminal units associated with systems providing heating or cooling capability that operate at fan system design conditions. Single-zone VAV systems shall comply with the constant-volume fan power limitation

EXCEPTION 1 TO 140.4(C): Hospital, vivarium, and laboratory systems that use flow control devices on exhaust and/or return to maintain space pressure relationships necessary for occupant health and safety or environmental control may use variable-volume fan power limitation.

EXCEPTION 1 TO 140.4(C): Individual exhaust fans with motor nameplate horsepower of 1 hp or less.

Proposed Code Language

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

Table 140.4-A Fan Power Limitation[1]

	Limit	**Constant Volume**	**Variable Volume**
Option 1: Fan *system* motor nameplate hp	Allowable *motor nameplate hp*	hp ≤ cfm*S* × 0.00095	hp ≤ cfm*S* × 0.0013
Option 2: Fan *system* bhp	Allowable fan *system* bhp	bhp ≤ cfm*S* × 0.00082 + *A*	bhp ≤ cfm*S* × 0.0011 + *A*

1 where:

cfmS = maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute

hp = maximum combined motor nameplate horsepower

bhp = maximum combined fan-brake horsepower

A = sum of (PD × cfmD/4131) where

PD = each applicable pressure drop adjustment from Table 140.4-A-2 in in. of water

cfmD = the design airflow through each applicable device from Table 140.4-A-2 in cubic feet per minute

Proposed Code Language

SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

Table 140.4-B Fan Power Limitation Pressure Drop Adjustment[2]

Device	**Adjustment**
Credits	
Return or exhaust systems required by code or accreditation standards to be fully ducted, or systems required to maintain air pressure differentials between adjacent rooms	0.5 in. of water
Return and/or exhaust airflow control devices	0.5 in. of water
Exhaust filters, scrubbers, or other exhaust treatment	The pressure drop of device calculated at *fan system design condition*
Particulate Filtration Credit: MERV 9 through 12	0.5 in. of water
Particulate Filtration Credit: MERV 13 through 15	0.9 in. of water
Particulate Filtration Credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at 2× clean filter pressure drop at *fan system design condition*
Carbon and other gas-phase air cleaners	Clean filter pressure drop at *fan system design condition*
Biosafety cabinet	Pressure drop of device at *fan system design condition*
Energy recovery device, other than coil runaround loop2	For each airstream [(2.2 × *Enthalpy Recovery Ratio*) – 0.5] in. of water
Coil runaround loop2	0.6 in. of water for each airstream
Exhaust *system* serving fume hoods	0.35 in. of water

2Credit to be taken only when required by code

Questions?

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