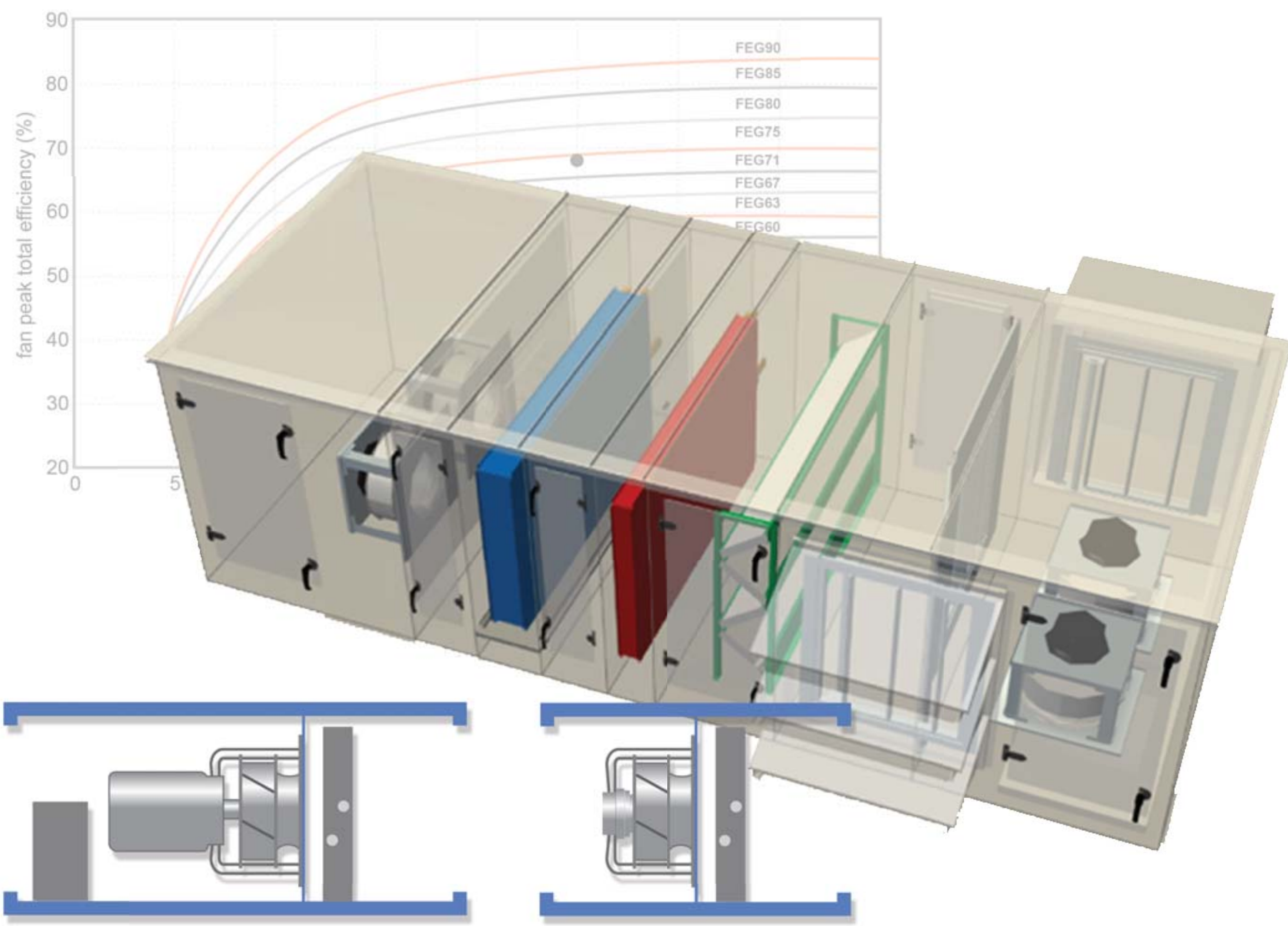
Trane Engineers Newsletter Live

Fan Efficiency Regulations and Technology Advances

Presenters: John Murphy, Dustin Meredith and Jeanne Harshaw (host)



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TRANE

Agenda

Trane *Engineers Newsletter Live* Series

Fan Efficiency Regulations and Technology Advances

Abstract

The Air Movement and Control Association (AMCA) estimates that fans consume between 30 and 40 percent of commercial HVAC energy. Improving fan efficiency is an important step towards reducing overall building energy use. This ENL will discuss common fan efficiency metrics, and explain the requirements of new regulations and industry energy standards. It will also discuss recent fan technology advances, including motorized impellers, direct-drive plenum fans, and fan arrays.

Presenters: Trane engineers John Murphy and Dustin Meredith

After viewing attendees will be able to:

1. Summarize the most recent regulations and industry energy standards related to fan efficiency
2. Summarize how the ASHRAE Standard 90.1 fan power limitation applies to various air system configurations
3. Understand the best applications for housed versus plenum fans
4. Identify recent fan technologies that can help reduce energy use, improve acoustics, or minimize space

Agenda

- Latest fan efficiency requirements
- Recent fan technology advances
  - Direct-drive plenum fans & fan arrays
  - Optimized motor selection
  - Motorized impellers
  - Impact of variable aspect ratio
  - Vibration isolation methods
- Summary

Ingersoll Rand

Presenter biographies

Fan Efficiency Regulations and Technology Advances

Dustin Meredith | applications engineer | Trane

Dustin has been with Trane since 2000. As an applications engineer, he specializes in airside products. His main areas of expertise include fan, pressure, and acoustic selection and optimization. He develops and analyzes research and leads development projects for new air-handling options.

Dustin has authored various technical engineering bulletins, white papers, Trane *Engineers Newsletter* articles and Trane *Engineers Newsletter LIVE* programs. He is an ASHRAE Section Head and serves on the "Fans" and "Sound and Vibration" technical committees, including as past Chair of the latter. He is the primary Trane contact for Air Movement and Control Association International, Inc. (AMCA) and serves on a number of AMCA committees.

John Murphy | applications engineer | Trane

John has been with Trane since 1993. His primary responsibility as an applications engineer is to aid design engineers and Trane sales personnel in the proper design and application of HVAC systems. His main areas of expertise include energy efficiency, dehumidification, dedicated outdoor-air systems, air-to-air energy recovery, psychrometry, airside system control and ventilation. He is also a LEED Accredited Professional.

John is the author of numerous Trane application manuals and Engineers Newsletters, and is a frequent presenter on Trane's Engineers Newsletter Live series. He has authored several articles for the ASHRAE Journal, and was twice awarded "Article of the Year" award. He is an ASHRAE Fellow and has served on the "Moisture Management in Buildings" and "Mechanical Dehumidifiers" technical committees. John was a contributing author of the Advanced Energy Design Guide for K-12 Schools and the Advanced Energy Design Guide for Small Hospitals and Health Care Facilities, a technical reviewer for the ASHRAE Guide for Buildings in Hot and Humid Climates, and a presenter on the 2012 ASHRAE "Dedicated Outdoor Air Systems" webcast.

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Fan Efficiency Regulations and Technology Advances

Trane Engineers Newsletter Live Series

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Learning Objectives

1. Understand the most recent regulations and industry energy standards related to fan efficiency
2. Learn how the ASHRAE Standard 90.1 fan power limitation applies to various air system configurations
3. Understand the best applications for housed versus plenum fans
4. Identify recent fan technologies that can help reduce energy use, improve acoustics, or minimize space

AGENDA

- Latest fan efficiency requirements
- Recent fan technology advances
  - Direct-drive plenum fans & fan arrays
  - Optimized motor selection
  - Motorized impellers
  - Impact of variable aspect ratio
  - Vibration isolation methods

Today's Presenters

Dustin Meredith
Applications Engineer

John Murphy
Applications Engineer

ASHRAE Standard 90.1-2013

Fan System Power Limitation

*"**6.5.3 Air System Design and Control.** Each HVAC system having a total fan system motor nameplate hp exceeding 5 hp shall meet the provisions of Sections 6.5.3.1 through 6.5.3.5."*

> *"**6.5.3.1.1** Each HVAC system at fan system design conditions shall not exceed the allowable fan system motor nameplate hp (Option 1) or the fan system bhp (Option 2) as shown in Table 6.5.3.1-1."*

ASHRAE Standard 90.1-2013

Fan System Power Limitation

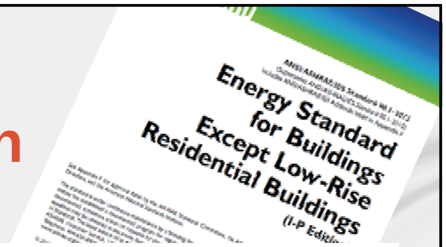

TABLE 6.5.3.1-1 Fan Power Limitation[a]

	Limit	Constant Volume	Variable Volume
Option 1: Fan system motor nameplate hp	Allowable nameplate motor hp	$hp \leq cfm_S \cdot 0.0011$	$hp \leq cfm_S \cdot 0.0015$
Option 2: Fan system bhp	Allowable fan system bhp	$bhp \leq cfm_S \cdot 0.00094 + A$	$bhp \leq cfm_S \cdot 0.0013 + A$

a. where
cfm_S = maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute
hp = maximum combined motor nameplate horsepower
hp = maximum combined fanbrake horsepower
A = sum of $(PD \times cfm_D/4131)$
where
PD = each applicable pressure drop adjustment from Table 6.5.3.1-2 in in. wc
cfm_D = the design airflow through each applicable device from Table 6.5.3.1-2 in cubic feet per minute

ASHRAE Standard 90.1-2013

Fan System Power Limitation

*"**6.5.3.1.1** Each HVAC system at fan system design conditions shall not exceed the allowable fan system motor nameplate hp (Option 1) or the fan system bhp (Option 2) as shown in Table 6.5.3.1-1. Single zone VAV systems shall comply with the constant volume fan power limitation."*

Exceptions:

a. Hospital, vivarium, and laboratory systems that use flow control devices on exhaust and/or return air to maintain space-to-space pressurization may use the limit for variable volume systems
b. Individual exhaust fans ≤ 1 nameplate hp

ASHRAE 90.1-2013: Fan System Power Limitation

Option 1: Motor Nameplate Horsepower

TABLE 6.5.3.1-1 Fan Power Limitation[a]

	Limit	Constant Volume	Variable Volume
Option 1: Fan system motor nameplate hp	Allowable nameplate motor hp	hp ≤ $cfm_S \cdot 0.0011$	hp ≤ $cfm_S \cdot 0.0015$
Option 2: Fan system bhp	Allowable fan system bhp	bhp ≤ $cfm_S \cdot 0.00094 + A$	bhp ≤ $cfm_S \cdot 0.0013 + A$

a. where
cfm_S = maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute
hp = maximum combined motor nameplate horsepower
hp = maximum combined fanbrake horsepower
A = sum of (PD × cfm_D/4131)
where
PD = each applicable pressure drop adjustment from Table 6.5.3.1-2 in in. wc
cfm_D = the design airflow through each applicable device from Table 6.5.3.1-2 in cubic feet per minute

example: 30,000 cfm VAV system
allowable nameplate motor hp ≤ 45 (30,000 × 0.0015)

ASHRAE 90.1-2013: Fan System Power Limitation

Option 2: Fan System Brake Horsepower

TABLE 6.5.3.1-1 Fan Power Limitation[a]

	Limit	Constant Volume	Variable Volume
Option 1: Fan system motor nameplate hp	Allowable nameplate motor hp	hp ≤ $cfm_S \cdot 0.0011$	hp ≤ $cfm_S \cdot 0.0015$
Option 2: Fan system bhp	Allowable fan system bhp	bhp ≤ $cfm_S \cdot 0.00094 + A$	bhp ≤ $cfm_S \cdot 0.0013 + A$

a. where
cfm_S = maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute
hp = maximum combined motor nameplate horsepower
hp = maximum combined fanbrake horsepower
A = sum of (PD × cfm_D/4131)
where
PD = each applicable pressure drop adjustment from Table 6.5.3.1-2 in in. wc
cfm_D = the design airflow through each applicable device from Table 6.5.3.1-2 in cubic feet per minute

example: 30,000 cfm VAV system
allowable fan system bhp ≤ 39 (30,000 × 0.0013)

ASHRAE 90.1-2013: Fan System Power Limitation

Option 2: Pressure Drop Adjustments

TABLE 6.5.3.1-2 Fan Power Limitation Pressure Drop Adjustment

Device	Adjustment
Credits	
Fully ducted return and/or exhaust air systems	0.5 in. wc (2.15 in. wc for laboratory and vivarium systems)
Return and/or exhaust airflow control devices	0.5 in. wc
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. wc
Particulate Filtration Credit: MERV 13 through 15	0.9 in. wc
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 loop	(2.2 × Energy Recovery Effectiveness) – 0.5 in. wc for each airstream
Coil runaround loop	0.6 in. wc for each airstream
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design condition
Sound attenuation section (fans serving spaces with design background noise goals below NC35)	0.15 in. wc
Exhaust system serving fume hoods	0.35 in. wc
Laboratory and vivarium exhaust systems in high-rise buildings	0.25 in. wc/100 ft of vertical duct exceeding 75 ft

Option 2 Example

TABLE 6.5.3.1-2 Fan Power Limitation Pressure Drop Adjustment

Device	Adjustment
Credits	
Fully ducted return and/or exhaust air systems	0.5 in. wc (2.15 in. wc for laboratory and vivarium systems)
Return and/or exhaust airflow control devices	0.5 in. wc
Exhaust filters, scrubbers, or other exhaust treatment	The pressure drop of device calculated at fan system design condition
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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 loop	(2.2 × Energy Recovery Effectiveness) – 0.5 in. wc for each airstream
Coil runaround loop	0.6 in. wc for each airstream
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design condition
Sound attenuation section (fans serving spaces with design background noise goals below NC35)	0.15 in. wc
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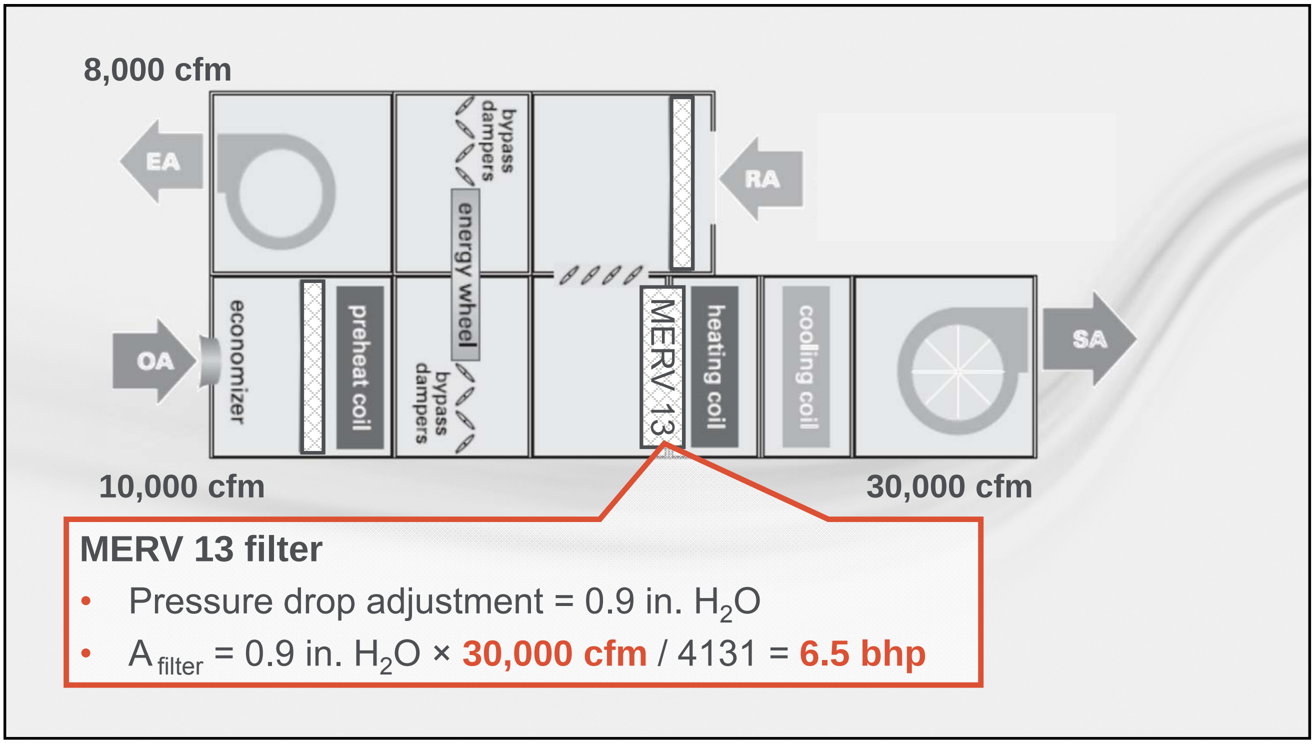
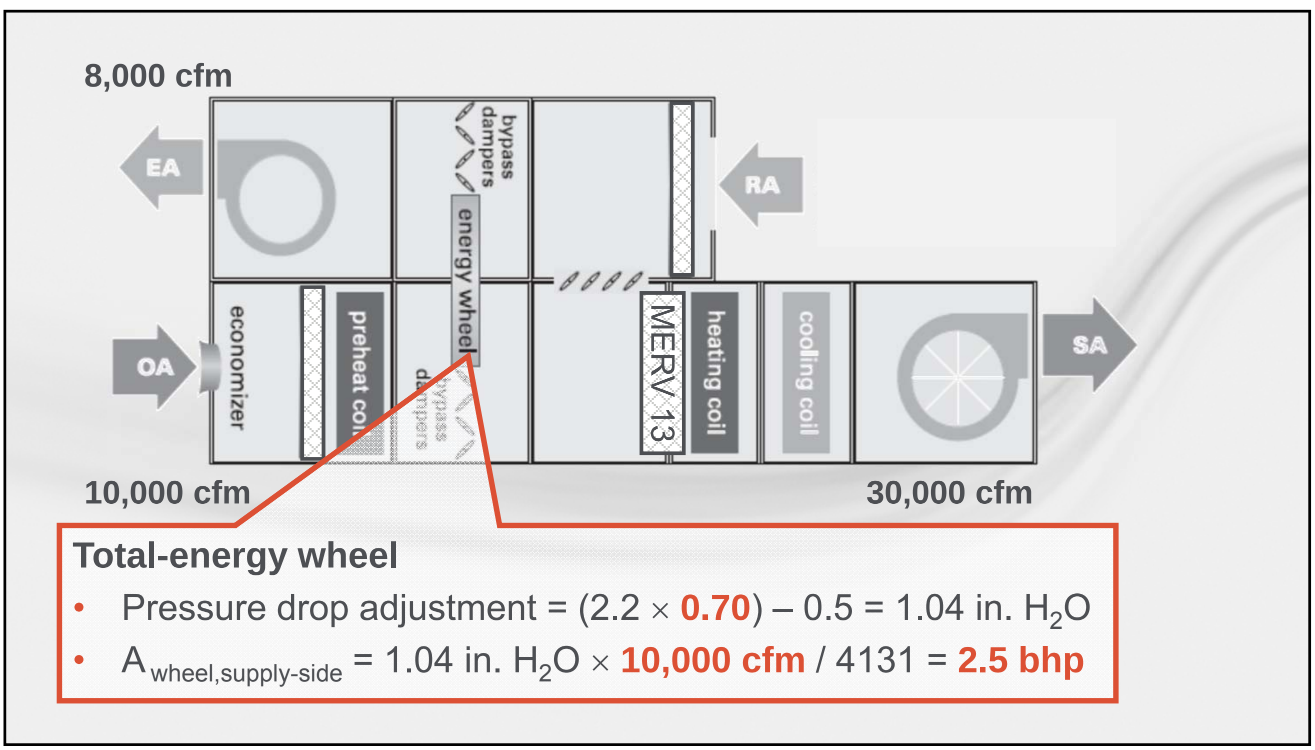
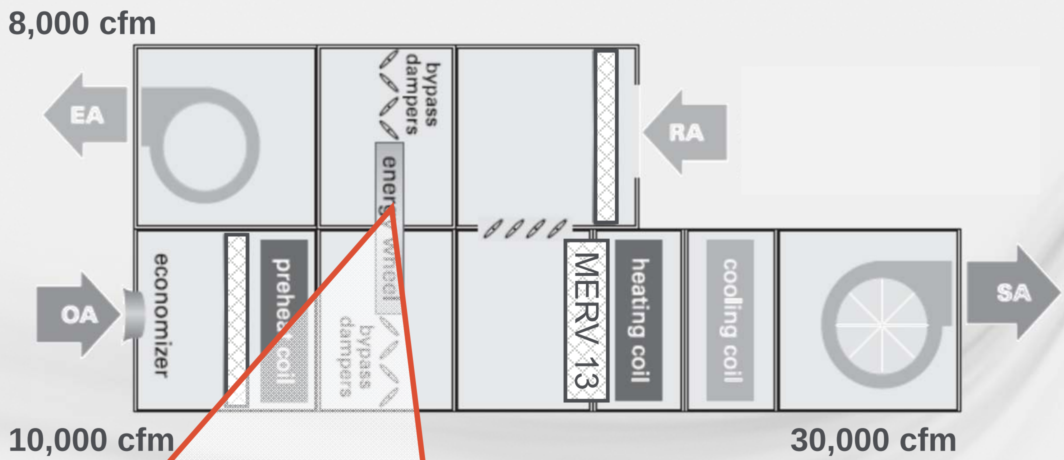
Laboratory and vivarium exhaust systems in high-rise buildings	0.25 in. wc/100 ft of vertical duct exceeding 75 ft


8,000 cfm
EA
bypass dampers
energy wheel
RA
OA
economizer
preheat coil
bypass dampers
MERV 13
heating coil
cooling coil
SA
10,000 cfm
30,000 cfm
MERV 13 filter
• Pressure drop adjustment = 0.9 in. H_2O
• A_{filter} = 0.9 in. H_2O × 30,000 cfm / 4131 = 6.5 bhp


8,000 cfm
EA
bypass dampers
energy wheel
RA
OA
economizer
MERV 13
heating coil
cooling coil
SA
10,000 cfm
30,000 cfm
Total-energy wheel
• Pressure drop adjustment = (2.2 × 0.70) – 0.5 = 1.04 in. H_2O
• $A_{wheel,supply\text{-}side}$ = 1.04 in. H_2O × 10,000 cfm / 4131 = 2.5 bhp



Total-energy wheel

- Pressure drop adjustment = (2.2 × **0.70**) – 0.5 = 1.04 in. H_2O
- $A_{wheel,exhaust\text{-}side}$ = 1.04 in. H_2O × **8,000 cfm** / 4131 = **2.0 bhp**

Option 2 Example

$A_{MERV\ 13\ filter}$	6.5 bhp
$A_{wheel,\ supply\text{-}side}$	2.5 bhp
$A_{wheel,\ exhaust\text{-}side}$	2.0 bhp
A_{total}	11.0 bhp

fan system bhp ≤ 30,000 cfm × 0.0013 + 11.0

≤ 50 bhp

ASHRAE Standard 90.1-2013

Fan System Power Limitation

*"**6.5.3 Air System Design and Control.** Each HVAC system having a total fan system motor nameplate hp exceeding 5 hp shall meet the provisions of Sections 6.5.3.1 through 6.5.3.5."*

> *"**6.5.3.1.1** Each HVAC system at fan system design conditions shall not exceed the allowable fan system motor nameplate hp (Option 1) or the fan system bhp (Option 2) as shown in Table 6.5.3.1-1."*

ASHRAE Standard 90.1-2013, Section 3.2

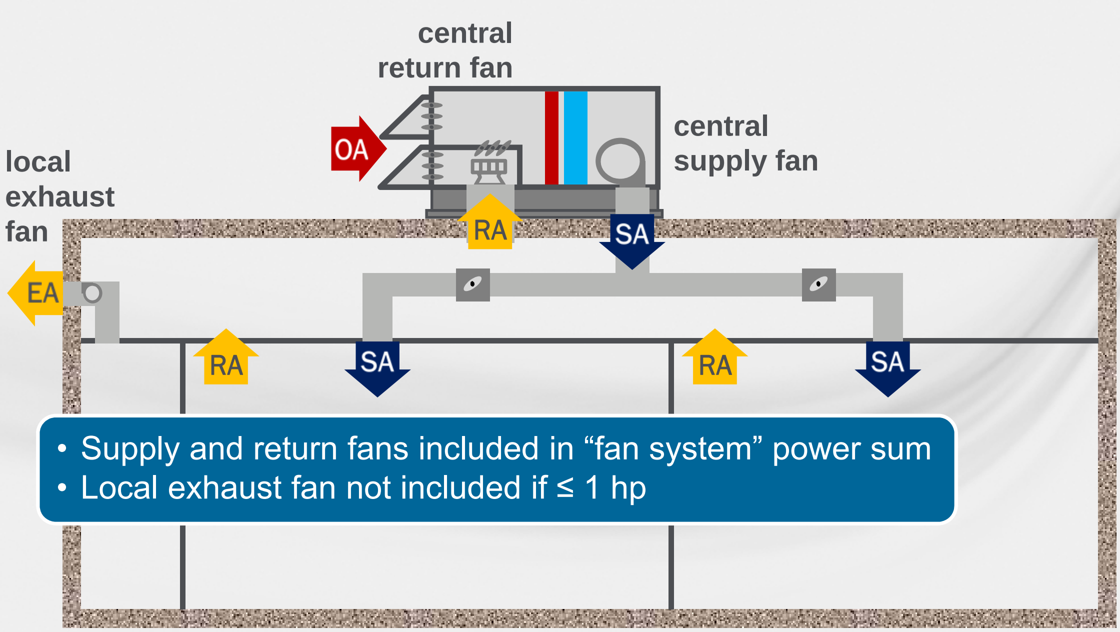
Definitions

*"**fan system bhp:** the sum of the fan brake horsepower of all fans that are required to operate at fan system design conditions to supply air from the heating or cooling source to the conditioned space(s) and return it to the source or exhaust it to the outdoors."*

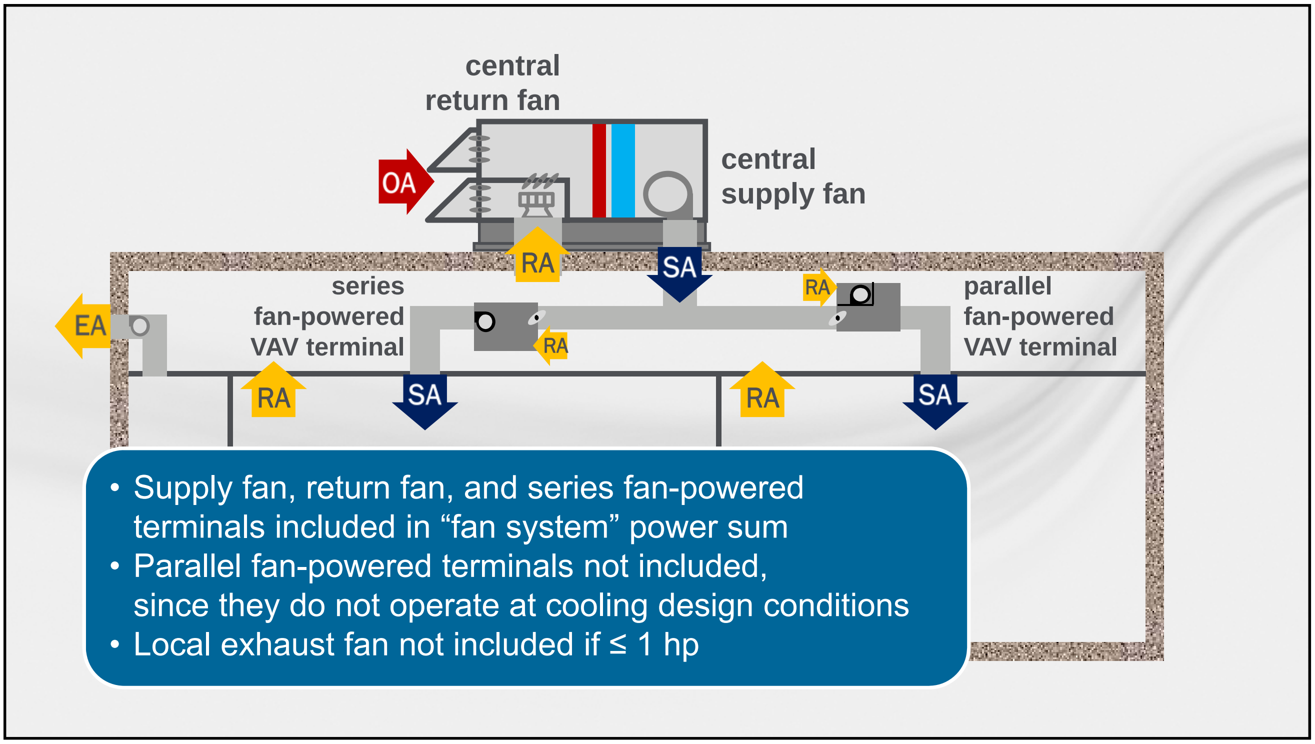
ASHRAE Standard 90.1-2013, Section 3.2

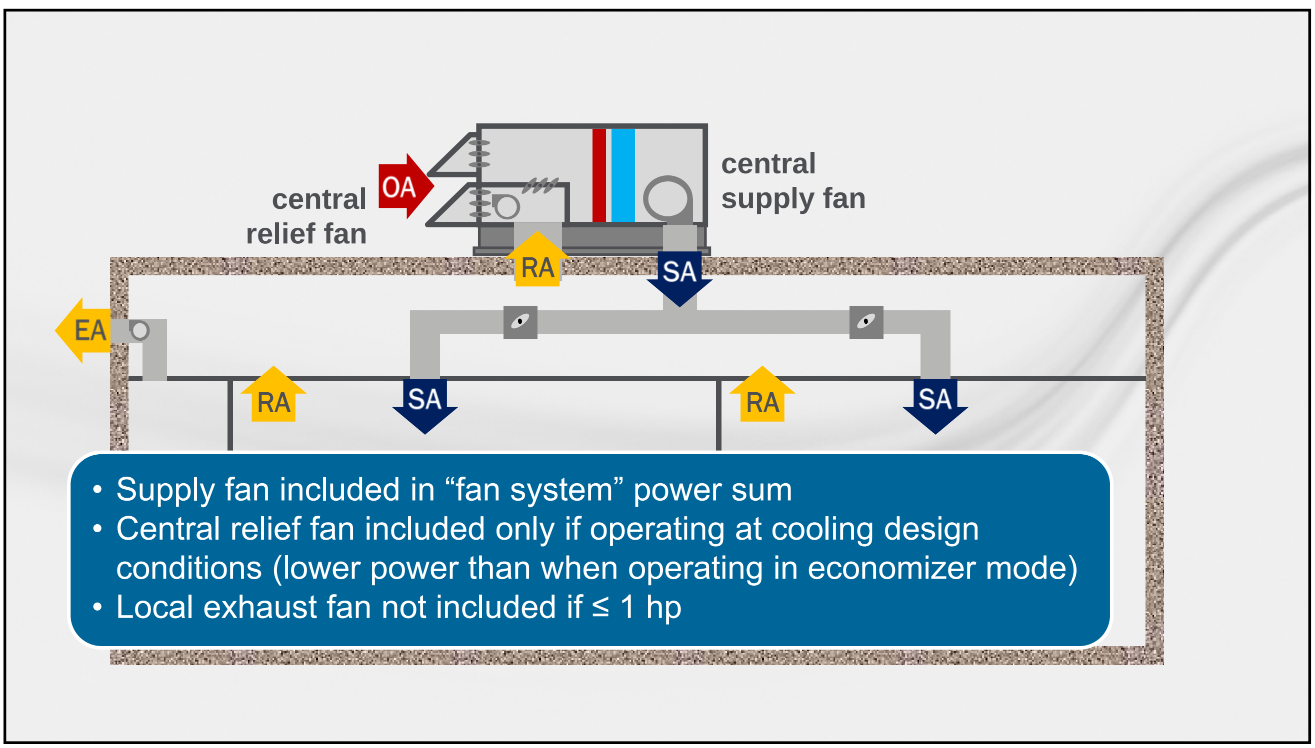
Definitions

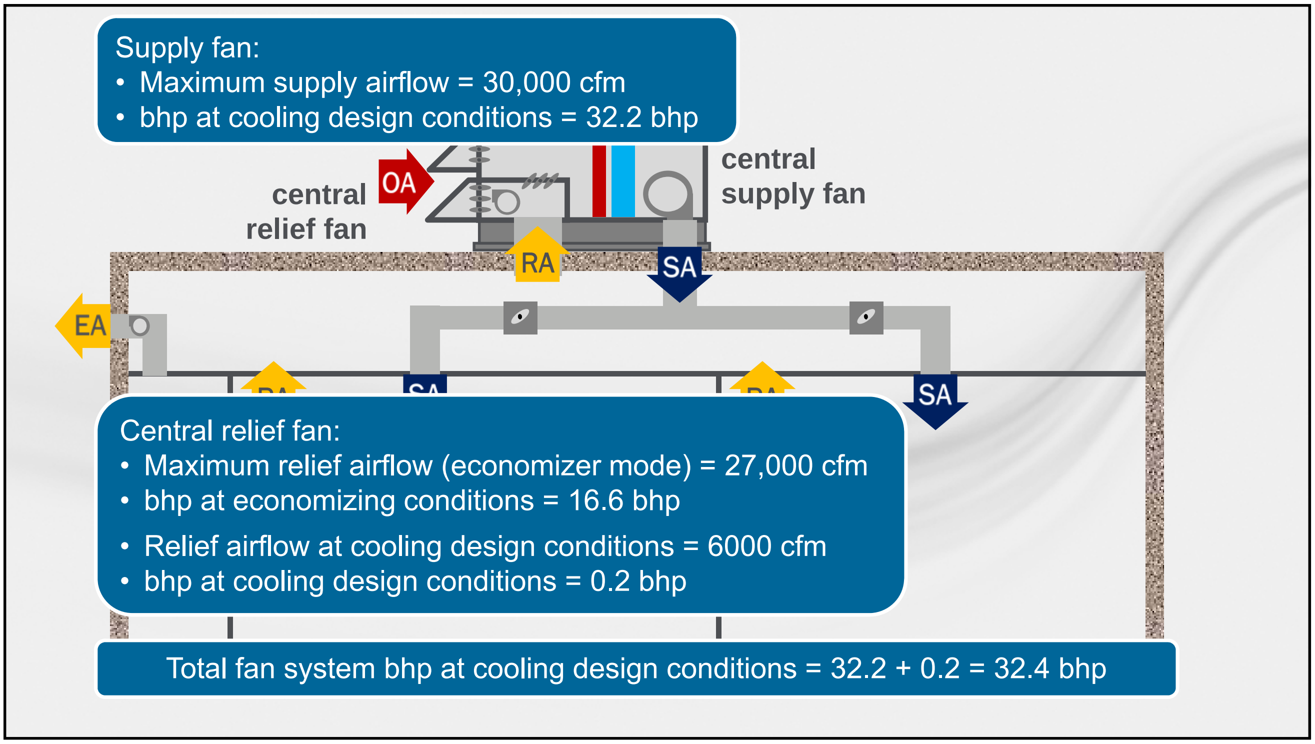
*"**fan system design conditions:** operating conditions that can be expected to occur during normal system operation that result in the highest supply airflow rate to conditioned spaces served by the system."*

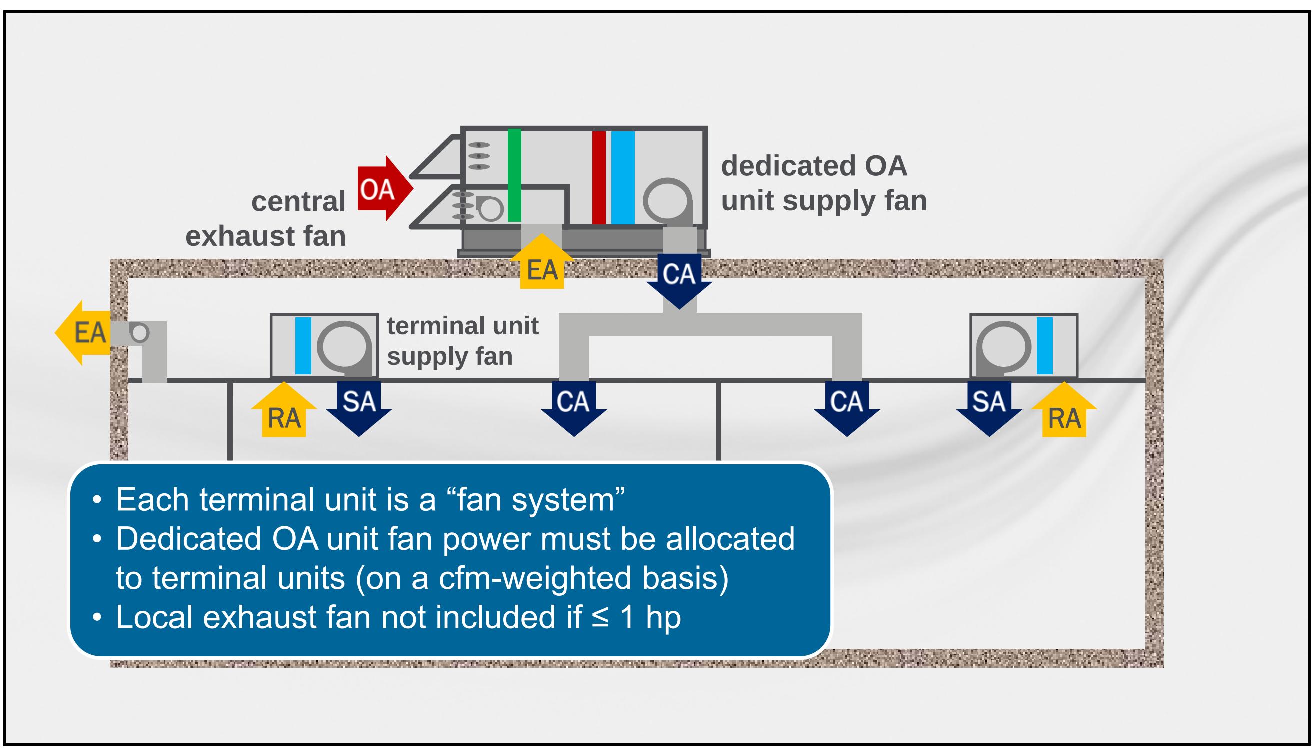


- Supply and return fans included in "fan system" power sum
- Local exhaust fan not included if ≤ 1 hp


central
return fan
OA
central
supply fan
RA
SA
series
fan-powered
VAV terminal
RA
parallel
fan-powered
VAV terminal
EA
RA
SA
RA
SA
• Supply fan, return fan, and series fan-powered terminals included in “fan system” power sum
• Parallel fan-powered terminals not included, since they do not operate at cooling design conditions
• Local exhaust fan not included if ≤ 1 hp


OA
central
supply fan
central
relief fan
RA
SA
EA
RA
SA
RA
SA
• Supply fan included in “fan system” power sum
• Central relief fan included only if operating at cooling design conditions (lower power than when operating in economizer mode)
• Local exhaust fan not included if ≤ 1 hp


Supply fan:
• Maximum supply airflow = 30,000 cfm
• bhp at cooling design conditions = 32.2 bhp
central relief fan
OA
central supply fan
RA
SA
EA
SA
Central relief fan:
• Maximum relief airflow (economizer mode) = 27,000 cfm
• bhp at economizing conditions = 16.6 bhp
• Relief airflow at cooling design conditions = 6000 cfm
• bhp at cooling design conditions = 0.2 bhp
Total fan system bhp at cooling design conditions = 32.2 + 0.2 = 32.4 bhp


central exhaust fan
OA
dedicated OA unit supply fan
EA
CA
EA
terminal unit supply fan
RA
SA
CA
CA
SA
RA
• Each terminal unit is a “fan system”
• Dedicated OA unit fan power must be allocated to terminal units (on a cfm-weighted basis)
• Local exhaust fan not included if ≤ 1 hp

Standard 90.1-2013 User's Manual (example 6-CCC)

DOAS with Local Terminal Units

- Each classroom is served by a WSHP with a ¾ hp fan
- DOAS delivers 500 cfm to each classroom (4000 cfm total), and is equipped with a 5 hp supply fan and a 3 hp exhaust fan

  ⅛ of DOAS fan power is added to fan power of each WSHP:

  (500 cfm / 4000 cfm) × (5 hp + 3 hp) = 1.0 hp

  0.75 (WSHP fan) + 1.0 (allocated DOAS fan power) = **1.75 hp**

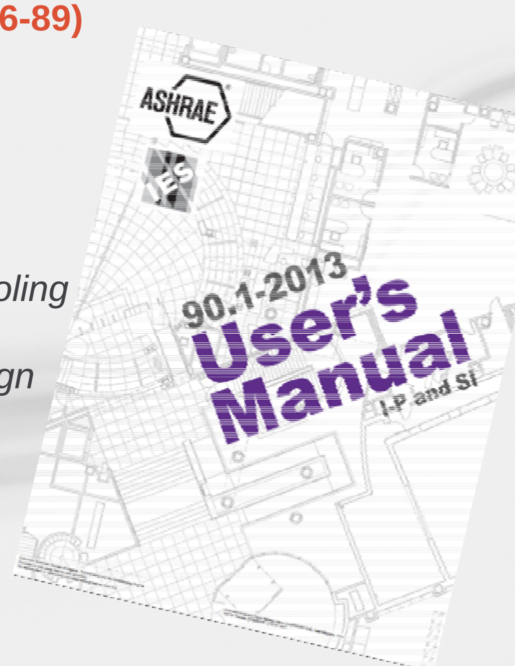
Even with DOAS fan power allocated, each WSHP "fan system" is smaller than the 5 hp threshold, so the system does not need to comply with the fan power requirements of Section 6.5.3.

Standard 90.1-2013 User's Manual (page 6-89)

Further Clarification…

"Only fans that operate at design conditions need to be included."

"For systems that have both heating and cooling capability, the system would be rated by the higher of the power required at heating design conditions or cooling design conditions."



Standard 90.1-2013 User's Manual (pages 6-98 and 6-99)

"First, determine which fans to include in the fan power calculation:

- *The supply and return fans are clearly included.*
- *The economizer relief fans are not included because they will not operate at peak cooling design conditions.*
- *The toilet exhaust fans are not included since they [have a] nameplate horsepower of 1 hp or less.*
- *The series fan-powered VAV boxes are included since they assist in supplying air to the conditioned space and operate at cooling design conditions.*
- *The parallel fan-powered VAV boxes are not included in the fan power calculation since they operate in heating mode when the supply fan is not operating at cooling design conditions."*

Standard 90.1-2013 User's Manual (pages 6-100 and 6-101)

"Each WSHP is a separate fan system because each has a separate cooling and heating source. The power of the DOAS fan must be allocated to each heat pump on a cfm-weighted basis."

ASHRAE Standard 90.1-2013, Section 6.5.3.1.2

Fan Motor Nameplate Horsepower

"For each fan, the selected fan motor shall be no larger than the first available motor size greater than the bhp. The fan bhp must be indicated on the design documents to allow for compliance verification."

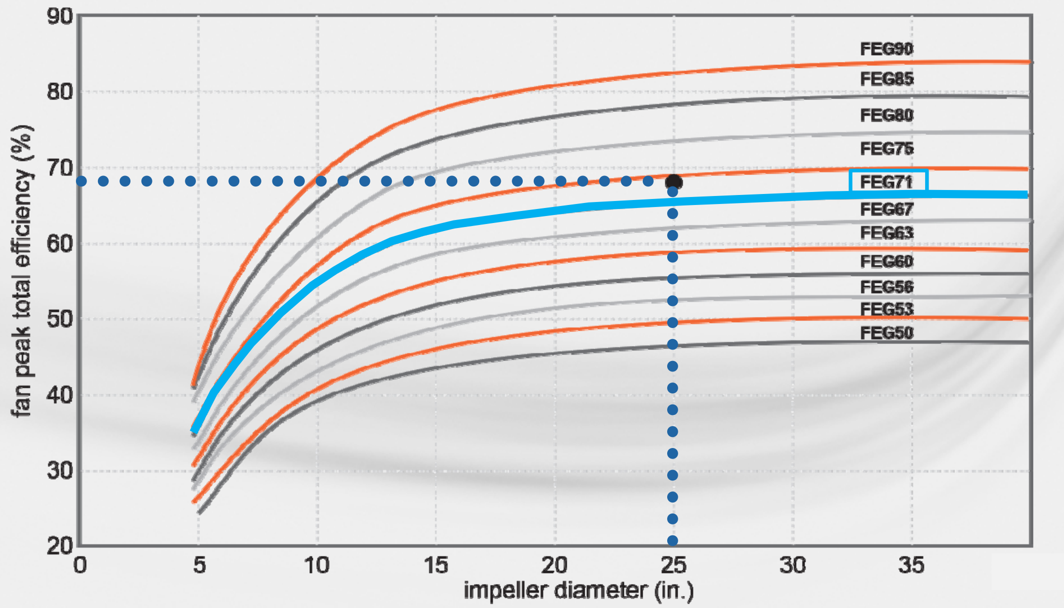
Exceptions:

1. Fans < 6 bhp: next larger motor size may be selected if the first available motor has a nameplate rating within 50% of bhp
2. Fans ≥ 6 bhp: next larger motor size may be selected if the first available motor has a nameplate rating within 30% of the bhp
3. Systems complying with Section 6.5.3.1.1, Option 1.

ASHRAE Standard 90.1-2013, Section 6.5.3.1.3

Fan Efficiency

"Fans shall have a fan efficiency grade (FEG) of 67 or higher based on manufacturers' certified data, as defined by AMCA 205. The total efficiency of the fan at the design point of operation shall be within 15 percentage points of the maximum total efficiency of the fan."



ASHRAE Standard 90.1-2013, Section 6.5.3.1.3

Fan Efficiency

"Fans shall have a fan efficiency grade (FEG) of 67 or higher based on manufacturers' certified data, as defined by AMCA 205. The total efficiency of the fan at the design point of operation shall be within 15 percentage points of the maximum total efficiency of the fan."

example:

- Maximum total efficiency of selected fan = 68%
- Required total efficiency at selected design operating point ≥ 53%

Exceptions (Section 6.5.3.1.3):

1. Single fans with a motor nameplate horsepower of 5 hp or less
2. Multiple fans in series or parallel (e.g., fan arrays) that have a combined motor nameplate horsepower of 5 hp or less and are operated as the functional equivalent of a single fan
3. Fans that are part of equipment listed under Section 6.4.1.1
4. Fans included in equipment bearing a third party-certified seal for air or energy performance of the equipment package
5. Powered wall/roof ventilators (PRV)
6. Fans outside the scope of AMCA 205
7. Fans intended to only operate during emergency conditions

exempt from Section 6.5.3.1.3 (FEG)

Equipment Included in Section 6.4.1.1

- Packaged rooftop units
- DX split systems
- Self-contained units
- Air-cooled condensing units
- Water-source heat pumps
- Air-cooled chillers
- PTACs
- Furnaces
- Cooling towers
- VRF systems

Exceptions (Section 6.5.3.1.3):

1. Single fans with a motor nameplate horsepower of 5 hp or less
2. Multiple fans in series or parallel (e.g., fan arrays) that have a combined motor nameplate horsepower of 5 hp or less and are operated as the functional equivalent of a single fan
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4. Fans included in equipment bearing a third party-certified seal for air or energy performance of the equipment package
5. Powered wall/roof ventilators (PRV)
6. Fans outside the scope of AMCA 205
7. Fans intended to only operate during emergency conditions

exempt from Section 6.5.3.1.3 (FEG)

Equipment with a Third-Party Seal

- Catalogued air-handling units AHRI Standard 430
- Blower coils AHRI Standard 430
- Fan-coils AHRI Standard 440
- Unit ventilators AHRI Standard 440

AHRI CERTIFIED™
www.ahridirectory.org
Central Station Air-Handlers
AHRI Standard 430


TRANE
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A Closer Look At Fan Efficiency Metrics
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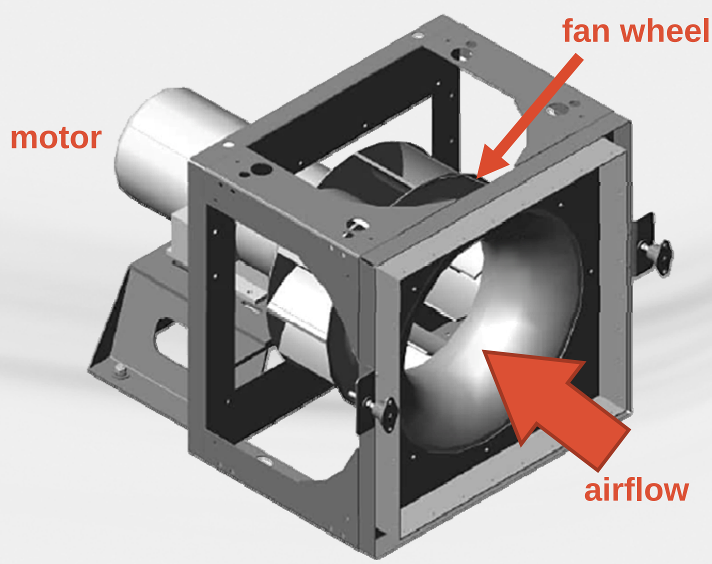
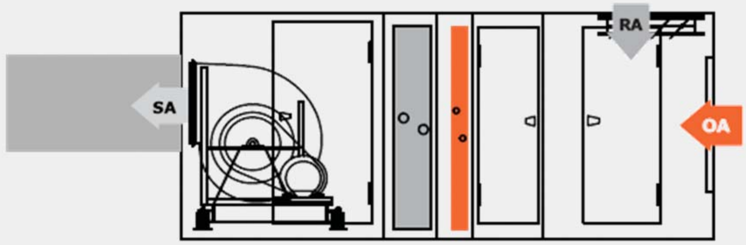
AGENDA
• Fan efficiency requirements
• Fan technology advances
• Summary

Fan Technology Advances

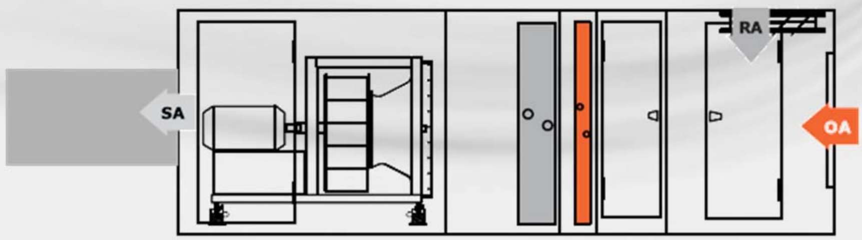
- Direct-drive plenum fans
- Fan arrays
- Optimized motor selection
- Motorized impellers
- Impact of variable aspect ratio
- Vibration isolation methods

Direct-Drive Plenum Fan





AHU with a housed centrifugal fan
(single front discharge opening)



AHU with an unhoused centrifugal (plenum) fan
(single front discharge opening)

example #1

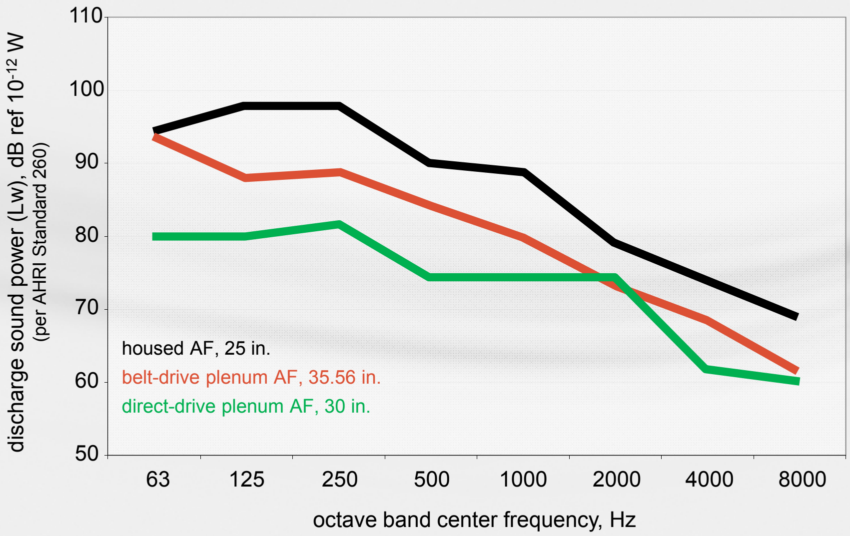
Single Outlet Into Straight Duct

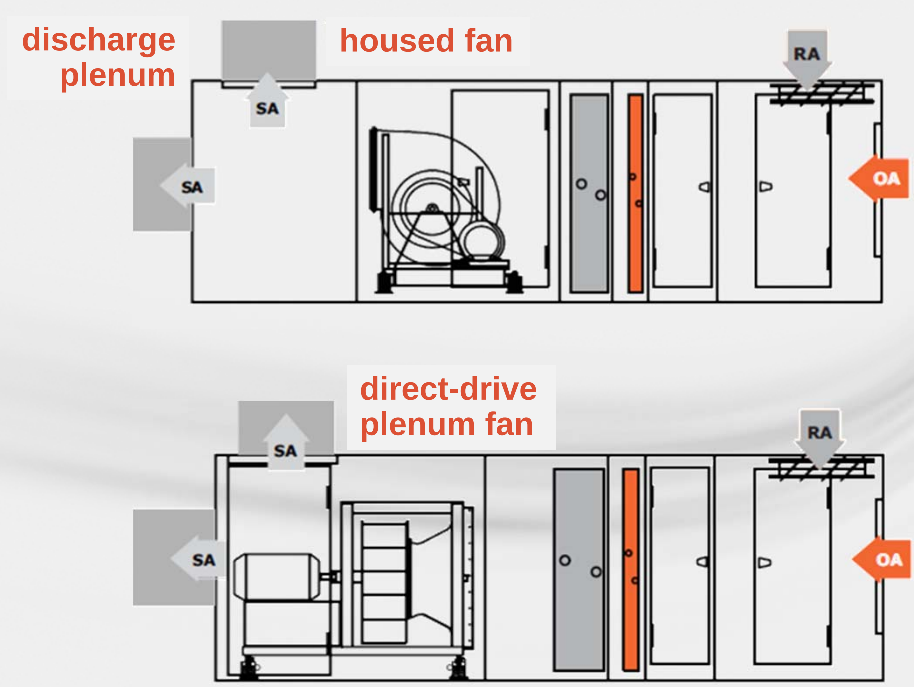
Fan type and wheel diameter	Input power, bhp	Rotational speed, rpm
Housed AF (25 in.)	11.8	1320
Belt-drive plenum AF (35.56 in.)	14.0	1050
Direct-drive plenum AF (30 in.)	12.8	1320

Based on a typical VAV air-handling unit configuration (OA/RA mixing box, high-efficiency filter, hot-water heating coil, chilled-water cooling coil, and draw-thru supply fan with a single discharge opening off fan section) operating at 13,000 cfm and 2 in. H_2O of external static pressure drop.

example #1

Single Outlet Into Straight Duct





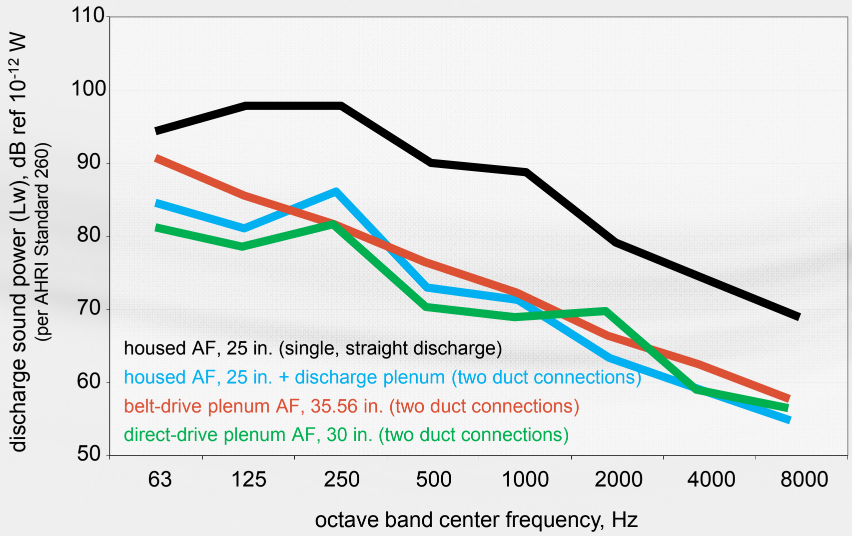
example #2

Discharge Plenum with Multiple Outlets

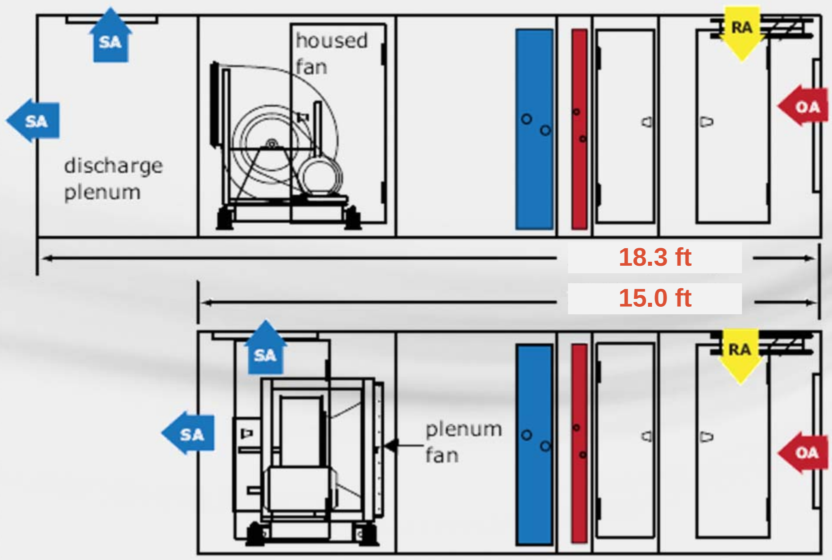
Fan type and wheel diameter	Input power, bhp	Rotational speed, rpm
Housed AF (25 in.) + plenum	13.2	1380
Belt-drive plenum AF (35.56 in.)	14.0	1050
Direct-drive plenum AF (30 in.)	12.8	1320

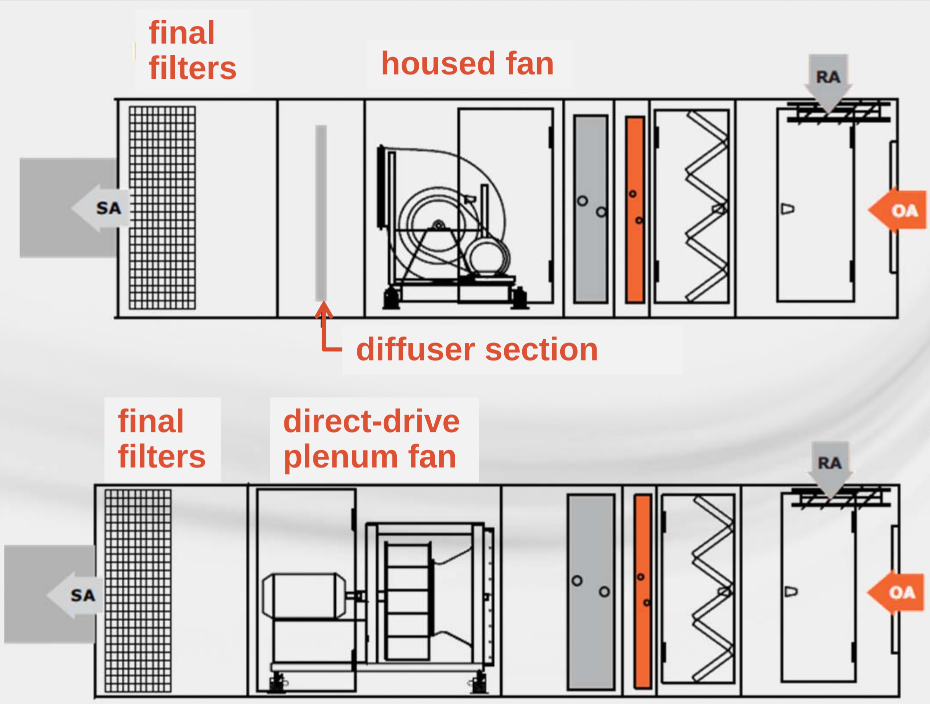
example #2

Discharge Plenum with Multiple Outlets



Plenum Fan Can Reduce Overall Length





example #3

Final Filters

Fan type and wheel diameter	Input power, bhp	Rotational speed, rpm
Housed AF (25 in.) + diffuser	15.0	1450
Belt-drive plenum AF (35.56 in.)	15.4	1090
Direct-drive plenum AF (30 in.)	14.1	1370

summary

Housed vs. Plenum Fans

- Single discharge into a long, straight section of duct
  - Housed fan likely to require less power, but a plenum fan will likely have lower discharge sound levels
- Downstream discharge plenum
  - Plenum fan will likely require less power with similar discharge sound levels, and likely result in a shorter AHU
- Downstream components (e.g., final filters)
  - Plenum fan will likely require less power

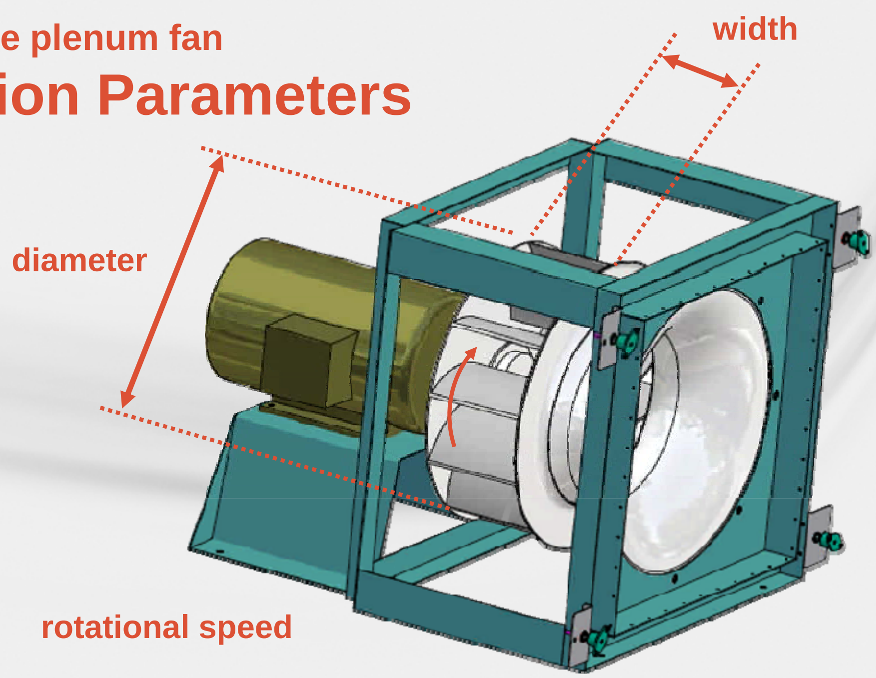
summary

Housed vs. Plenum Fans

- When discharging into a single, sufficiently-long, straight section of duct that is about the same size as the fan outlet, a housed fan will likely require less power than a plenum fan, but a plenum fan will likely have lower discharge sound levels.
- If a discharge plenum is added downstream of a housed fan to reduce sound levels or to allow for discharge flexibility, a direct-drive plenum fan will likely require less power than a housed airfoil fan, with similar discharge sound levels. And the plenum fan will likely result in a shorter air-handling unit.
- With downstream sections (such as a discharge plenum, final filter, gas heater, or even a blow-thru cooling coil), a direct-drive plenum fan will likely require less power than either a housed or belt-driven plenum fan.

direct-drive plenum fan

Selection Parameters



direct-drive plenum fan

Flexible-Speed Selection

Synchronous speed

- Fan speed (rpm) is held constant
- Wheel diameter and width are varied

Flexible speed

- Fan wheel width is held constant
- Wheel diameter and speed are varied (Trane VFDs and motors max out at 90 to 120 Hz)

Flexible-speed DDP fan selections are typically more efficient and quieter than synchronous-speed selections

Multiple Fans (Fan Array)

upstream (inlet) side

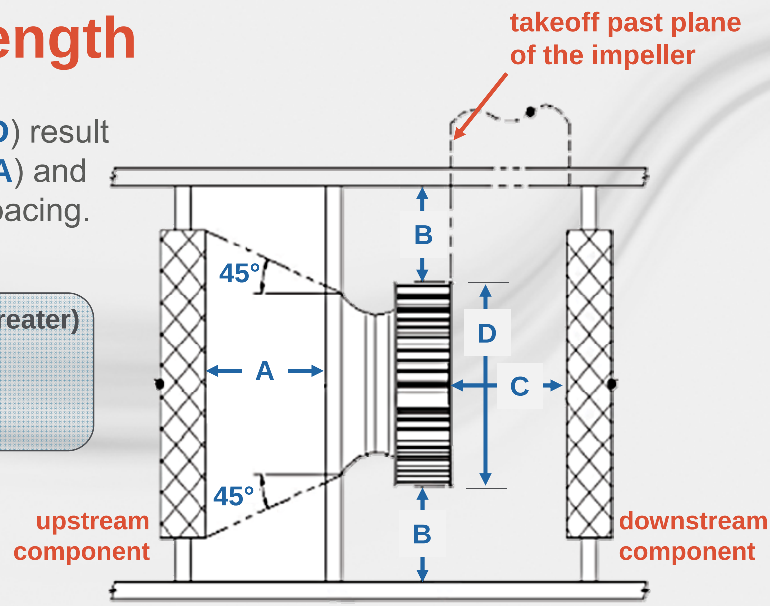
downstream (outlet) side

fan array

Reduced Unit Length

Smaller fan wheel diameters (**D**) result in shorter component-to-inlet (**A**) and discharge-to-component (**C**) spacing.

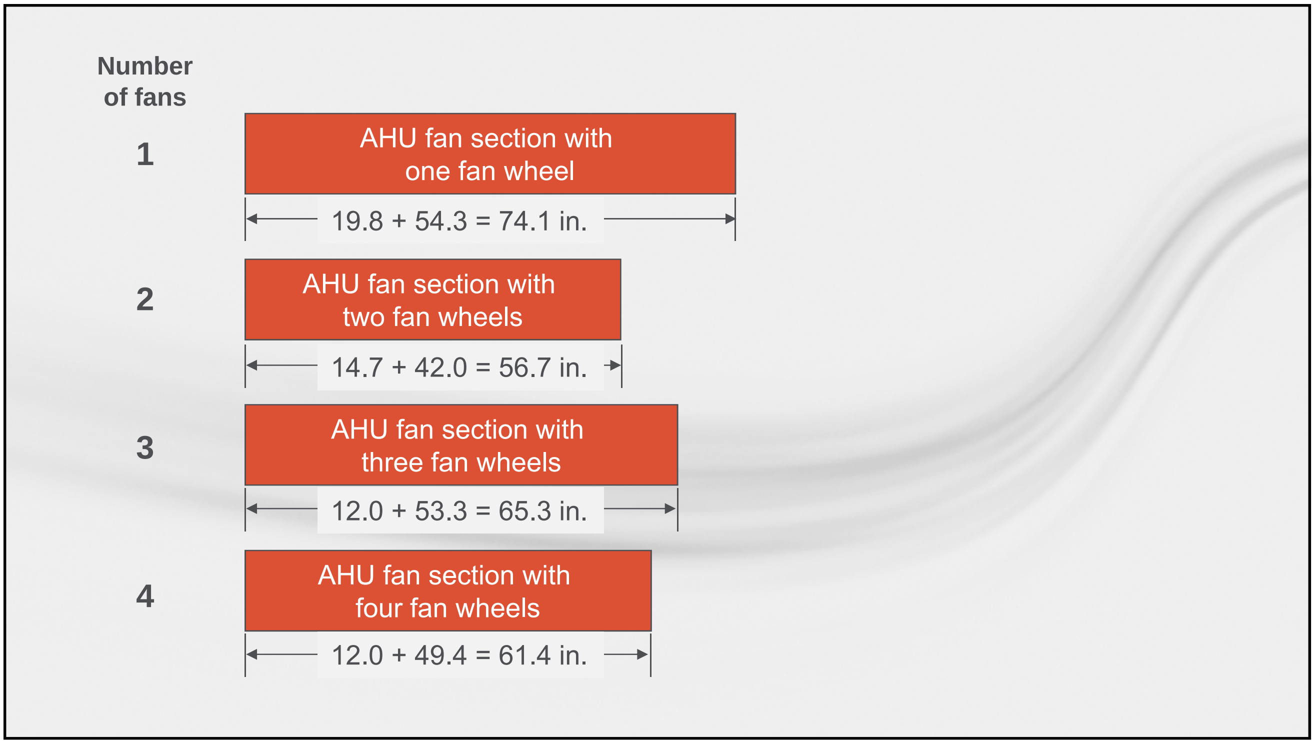
A = 45° or 1 × D (whichever is greater)
B = ½ × D minimum
C = 1 × D
D = fan wheel diameter



example length reduction

Single Fan Versus Fan Array

Number of fans	Fan diameter, in.	Upstream spacing required, in.	Upstream service clearance, in.	Upstream total, in.
1	33	**19.8**	~~12~~	19.8
2	24.5	**14.7**	~~12~~	14.7
3	20	**12.0**	~~12~~	12.0
4	18.75	11.0	**12**	**12.0**



example

Providing Redundancy with a Fan Array

Number of fans operating	Fan diameter, in.	Level of redundancy	Airflow, cfm (each fan)	Power, bhp (each fan)	Power, bhp (total)	Motor hp (each fan)
2	24.5	Design	7500	6.55	13.10	7.5
1	24.5	100%	15000	16.13	16.13	**20***

* 100% redundancy requires changing both motors from 7.5 to 20 hp

example

Providing Redundancy with a Fan Array

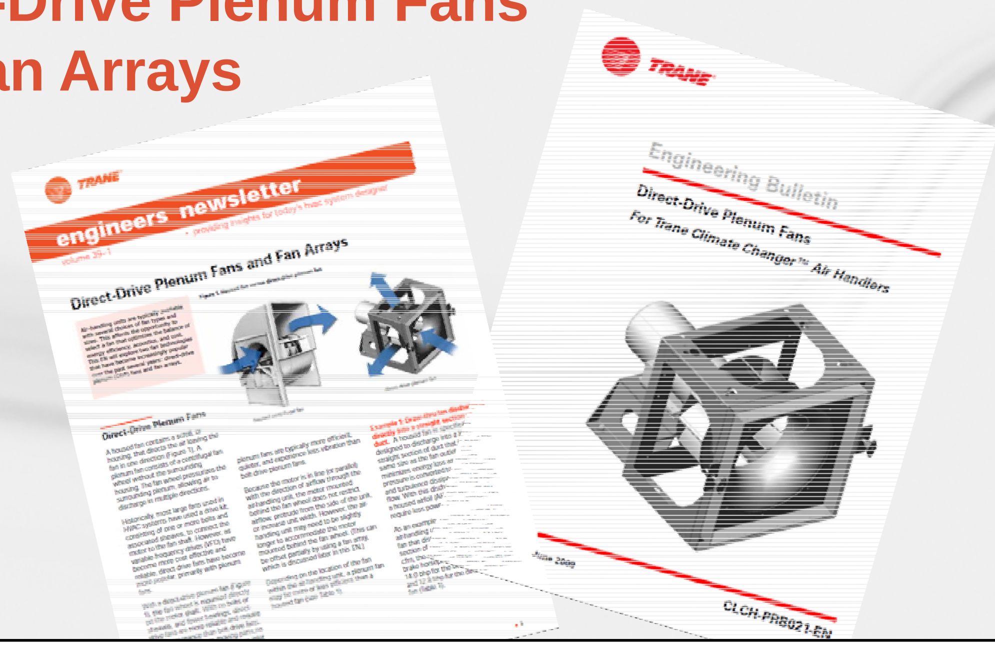
Number of fans operating	Fan diameter, in.	Level of redundancy	Airflow, cfm (each fan)	Power, bhp (each fan)	Power, bhp (total)	Motor hp (each fan)
3	20	Design	5000	4.68	14.04	7.5
2	20	100%	7500	7.43	14.86	7.5

Number of fans operating	Fan diameter, in.	Level of redundancy	Airflow, cfm (each fan)	Power, bhp (each fan)	Power, bhp (total)	Motor hp (each fan)
4	18.25	Design	3750	3.53	14.12	5
3	18.25	100%	5000	4.71	14.13	5

Single Fan Versus a Fan Array

Factor for Consideration	Single Fan	Multiple Fans	
		Fewer Fans	More Fans
Unit Footprint	✔	✔✔	✔✔✔
Installed Cost	✔✔✔	✔✔	✔
Redundancy	None	✔✔✔	✔✔✔
Energy Efficiency	✔✔✔	✔✔	✔
Unit Acoustics	✔✔	✔✔	✔✔
Serviceability	✔	✔✔	✔✔✔
Fan Reliability	✔✔✔	✔✔	✔

Direct-Drive Plenum Fans and Fan Arrays



Fan Technology Advances

- Direct-drive plenum fans
- Fan arrays
- Optimized motor selection
- Motorized impellers
- Impact of variable aspect ratio
- Vibration isolation methods

Optimized Motor Selection

5.85 bhp → 5

NEMA motor HP increments: 1, 1.5, 2, 3, 5, 7.5, 10, 15, 20, 25, 30, 40, 50, 60, 75, 100

Example:

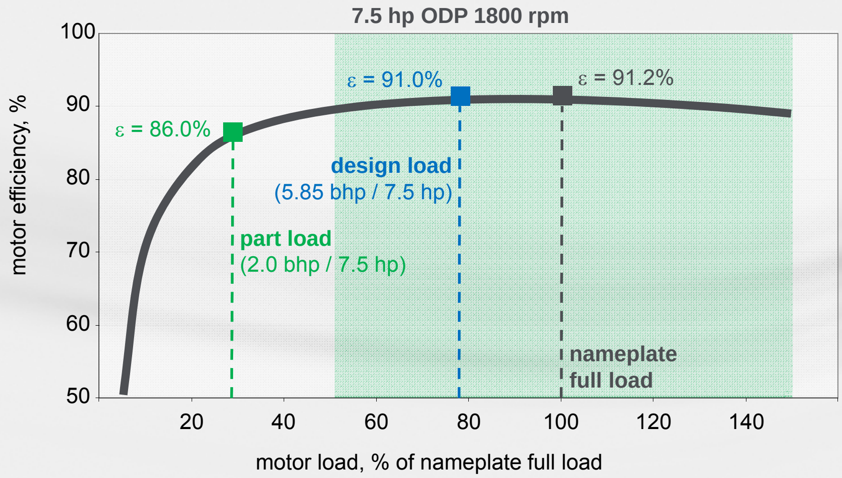
- Fan input power = 5.85 bhp
- Traditional motor selection = 7.5 hp
- Optimized motor selection = 6.5 hp

Principle of Optimized Motor Selection

- Considers the motor's specific application (located in a conditioned space, variable torque load)
- Allows operation beyond the motor's nameplate power
- Enables incremental motor sizes (e.g., 6.5 hp motor)

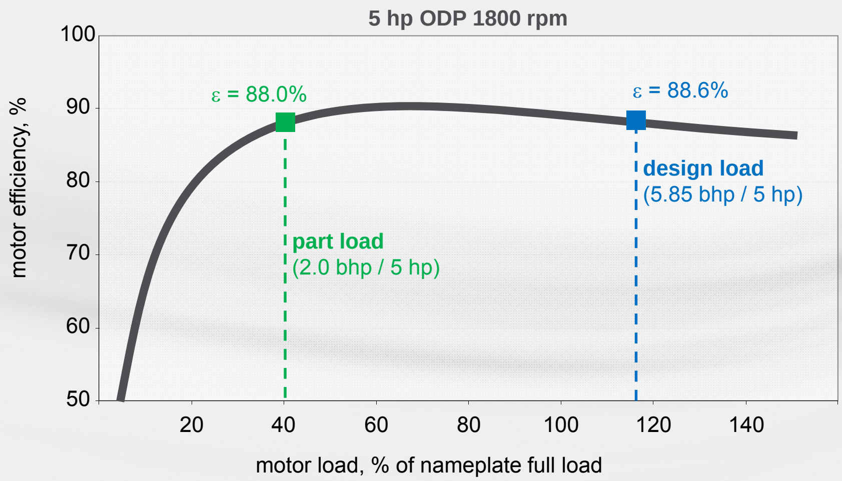
example

Traditional Motor Selection



example

Optimized Motor Selection



Benefits of Optimized Motor Selection

- Minimize connected load costs
- Improve serviceability
- Optimize part-load efficiency

optimized motor selection

Impact on ASHRAE Standard 90.1

Option 1 (nameplate horsepower)

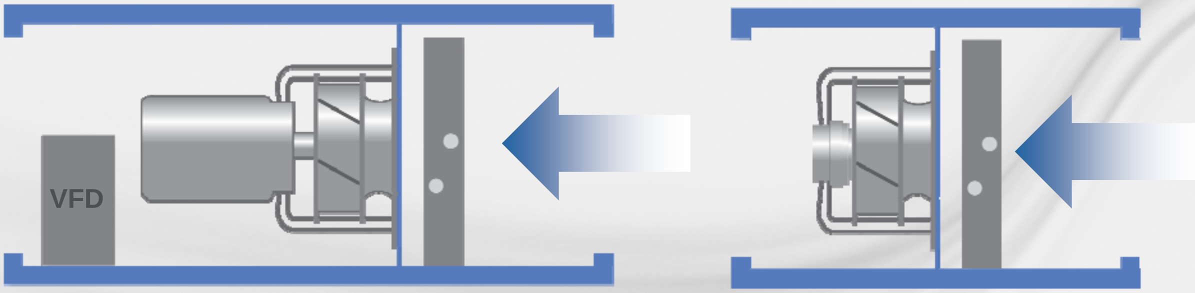
- Optimized motor selection makes it easier to comply

Option 2 (brake horsepower)

- Optimized motor selection has no impact

Do not select a motor any larger than the next available NEMA HP increment

DDP vs. Motorized Impeller



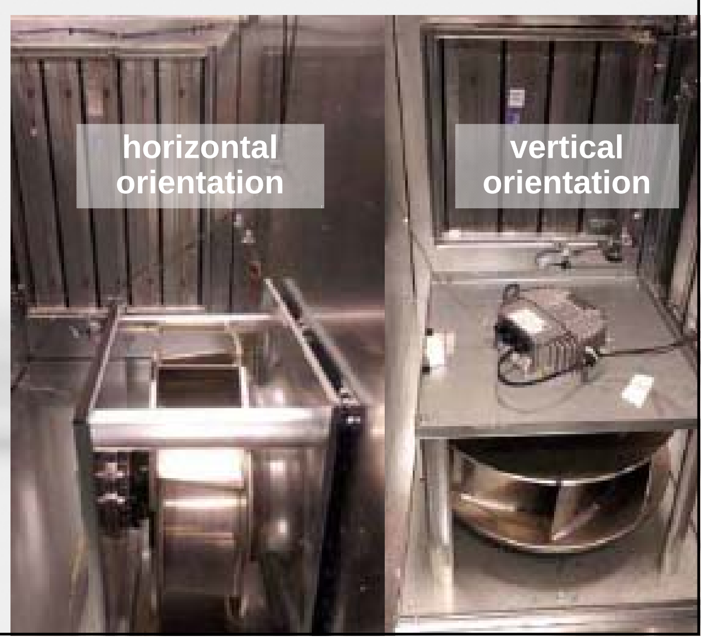
traditional direct-drive plenum fan

motorized impeller

Motorized Impeller

Benefits

- Reduced installed cost
- Smaller footprint
- Flexibility for horizontal or vertical orientation



Motorized Impeller

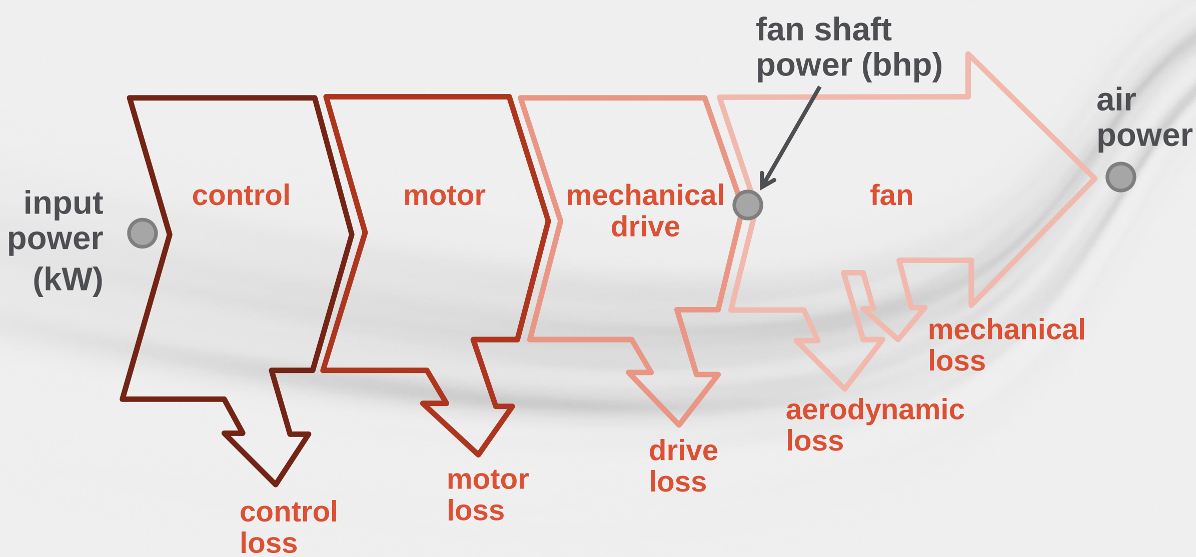
Benefits

- Reduced installed cost
- Smaller footprint
- Flexibility for horizontal or vertical orientation

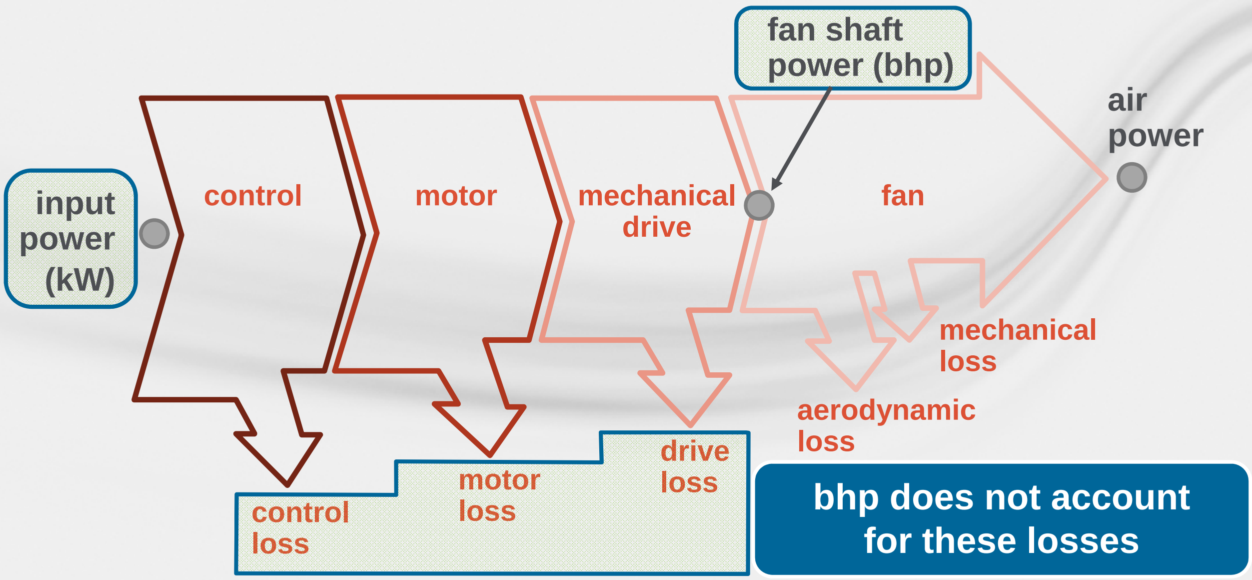
Considerations

- May not be suitable for higher-pressure applications
- Performance
- Higher replacement cost

Overall Fan System Efficiency



Input kW vs. Brake Horsepower (bhp)



Motor Impeller Electrical Sizing

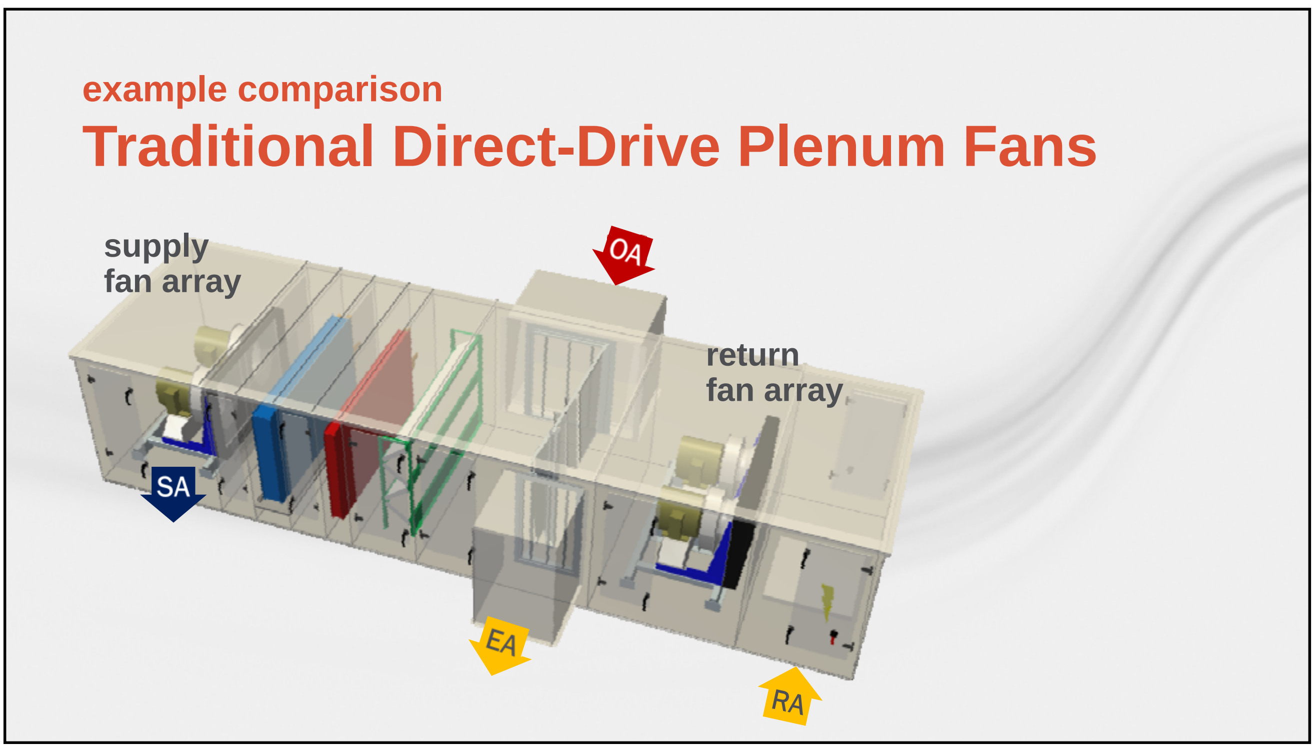
Traditional direct-drive plenum (DDP) fan

- Motor selected based on fan shaft power (bhp)
- VFD and wiring sized based on motor nameplate hp
- Upstream electrical sized based on VFD line input current

Motorized impeller (MI)

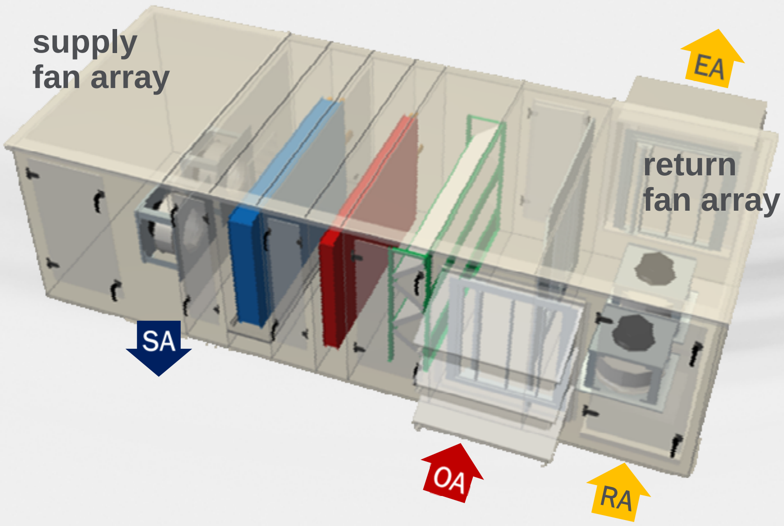
- Motor and variable-speed drive are integrated package
- Upstream electrical sized based on MI line input current


AMCA Publication 207
Clean Draft as of
2-17-2015
Fan System Efficiency and
Fan System Input Power Calculation
DRAFT
ANSI/AHRI Standard 1210 (I-P)
with Addenda 1 and 2
2011 Standard for
Performance Rating
of Variable Frequency
Drives


example comparison
Traditional Direct-Drive Plenum Fans
supply
fan array
OA
return
fan array
SA
EA
RA

example comparison

Motorized Impellers



example comparison

Traditional DDPs vs. Motorized Impellers

Fan type	supply fan power, bhp	return fan power, bhp	overall unit length, in.	unit cost, % of base
Traditional DDPs	10.2	6.9	277.75	base
Motorized impellers	10.1*	8.1*	198.25	base – 20%

*bhp estimated based on input power to motorized impellers motorized impellers

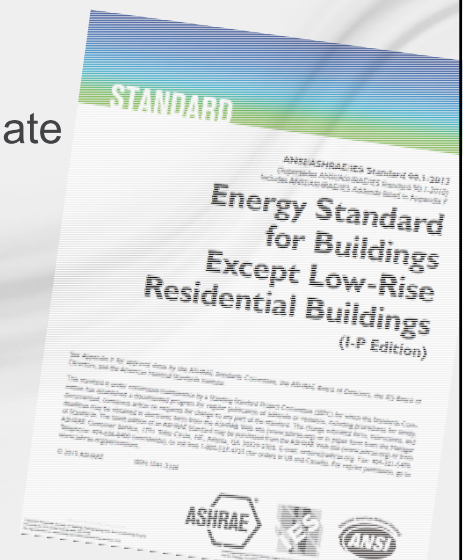
Impact on ASHRAE Standard 90.1

Option 1 (nameplate horsepower)

- Input kW is converted to hp for nameplate
  - Supply fan: 11.0 kW (14.8 hp)
  - Return fan: 11.0 kW (14.8 hp)

Option 2 (brake horsepower)

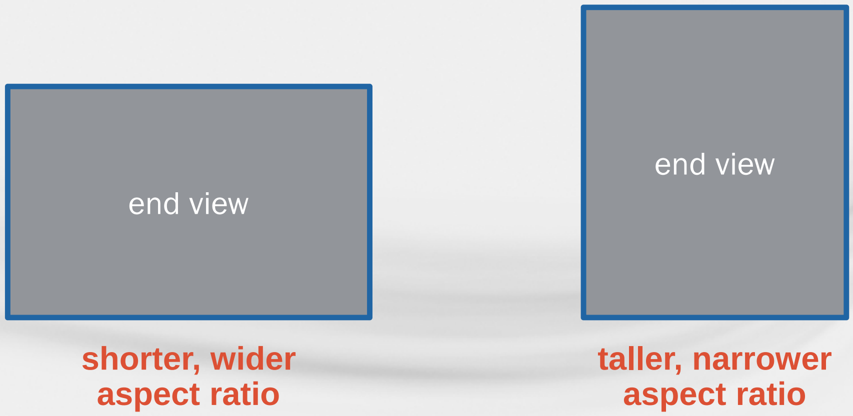
- Use estimated bhp
  - Supply fan: 10.1 bhp
  - Return fan: 8.1 bhp



Fan Technology Advances

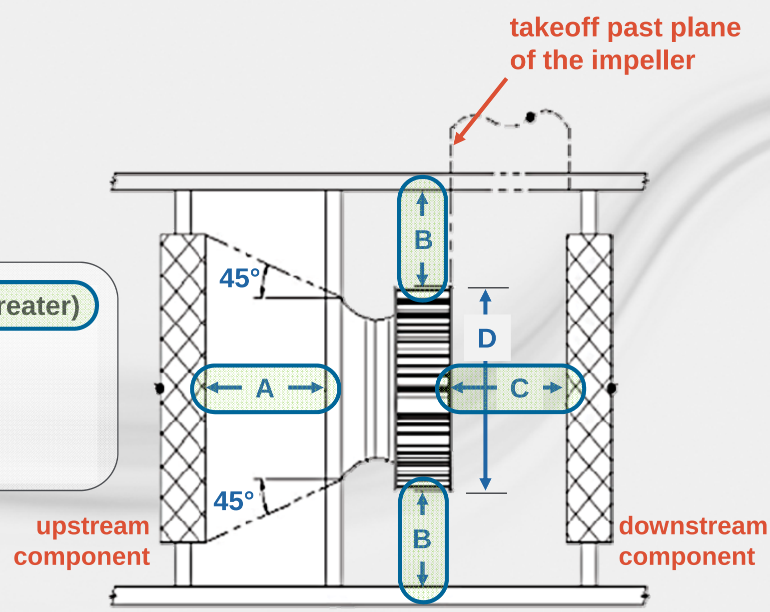
- Direct-drive plenum fans
- Fan arrays
- Optimized motor selection
- Motorized impellers
- Impact of variable aspect ratio air handlers
- Vibration isolation options

Cabinet Aspect Ratio

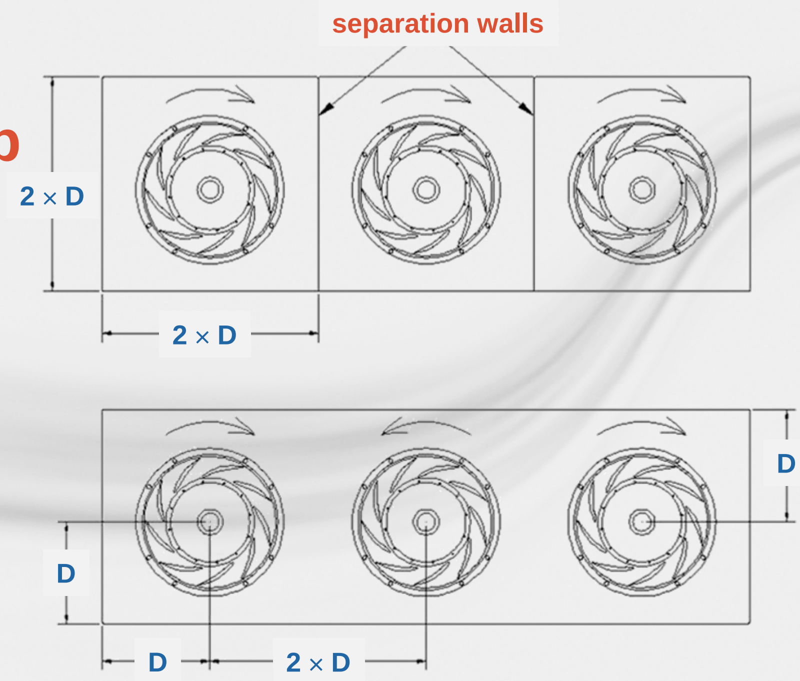


Common Rules of Thumb

- A = 45° or 1 × D (whichever is greater)
- B = ½ × D minimum
- C = 1 × D
- D = fan wheel diameter



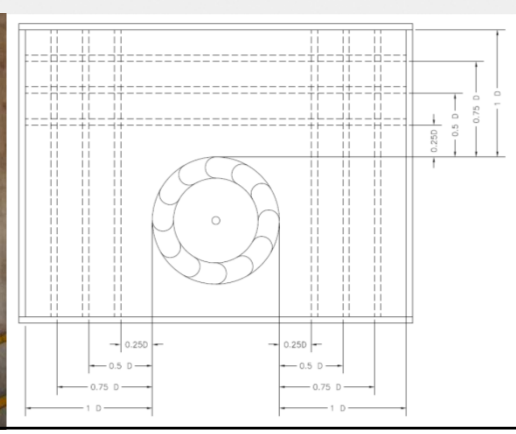
Common Rules of Thumb



D = fan wheel diameter

Variable Aspect Ratio Testing

- ASHRAE Research Project 1420
- AHRI Standard 260 and 430 testing



Vibration Isolation Methods

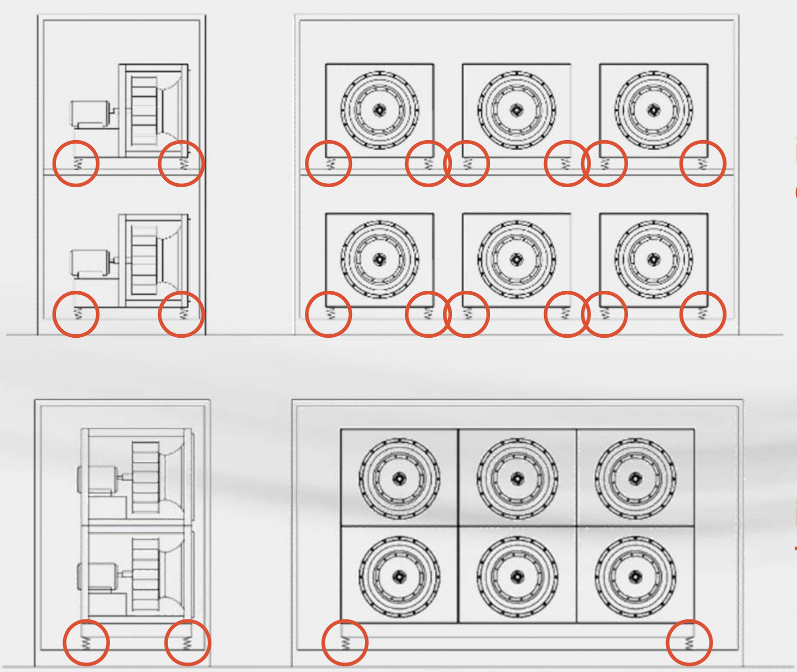
External isolation

- Reduces structure-borne sound and vibration
- Helps avoid *building* resonances
- Higher isolation efficiencies

Internal isolation

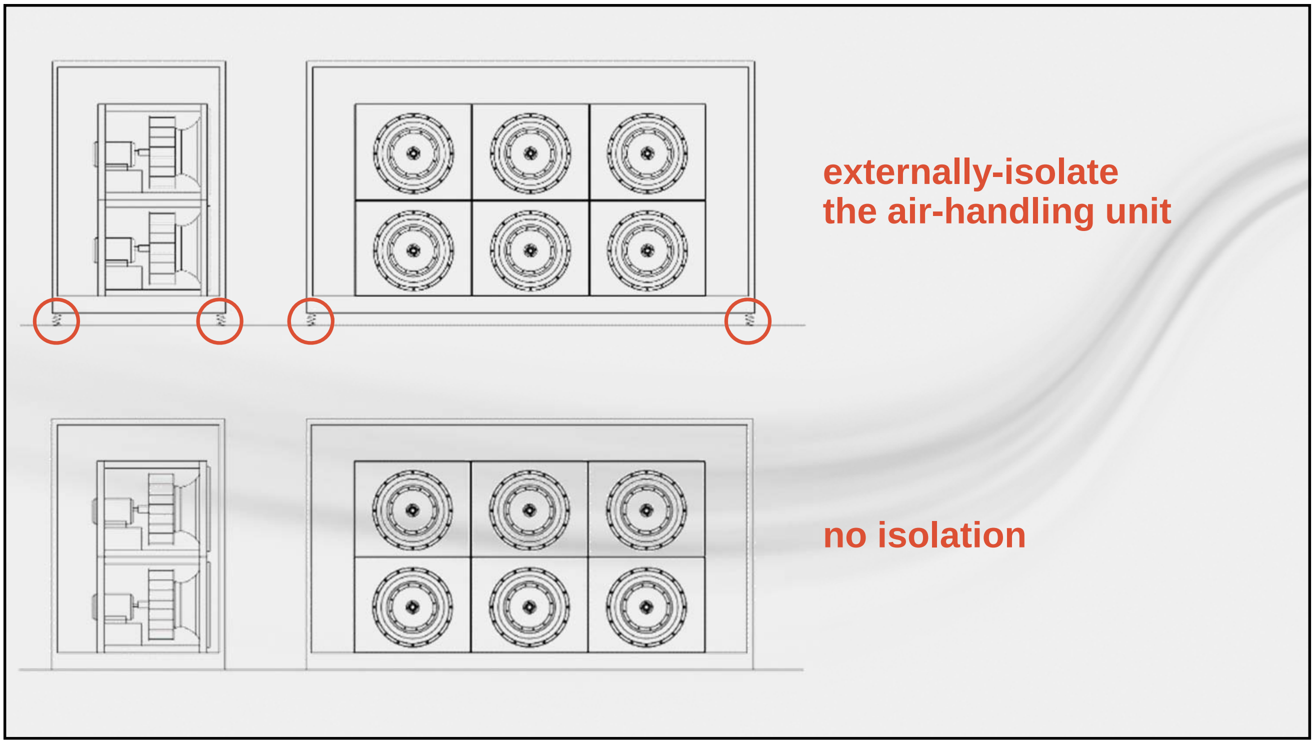
- Reduces structure-borne sound and vibration
- Helps avoid *building* resonances
- Reduces casing radiated sound
- Helps avoid *unit* resonances
- Easy installation

No isolation: minimized footprint, turnkey installation



internally-isolate each fan separately

internally-isolate fan array as a group



Vibration Isolation Considerations

Vibration isolation methods and options

"Considering the trend toward direct-drive and smaller fans, do I still need to specify internal or external isolation?"

Sound performance verification

"How do I specify performance to ensure my sound criteria can be met without costly witness testing?"

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Fan Efficiency Regulations and Technology Advances

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Trane *Engineers Newsletter LIVE: Fan Efficiency Regulations and Technology Advances*
APP-CMC059-EN QUIZ

1. Which industry standard prescribes a limit on fan system power?
    a. ASHRAE Standard 55
    b. ASHRAE Standard 90.1
    c. ASHRAE Standard 140
    d. AHRI Standard 885

2. True/False: Only those fans that operate at "fan system design conditions" need to be included in the sum to determine compliance with the fan power limitation in ASHRAE Standard 90.1.

3. True/False: Every fan in the building must comply with the minimum Fan Efficiency Grade (FEG) requirement of ASHRAE Standard 90.1-2013.

4. Which of the following are reasons why a direct-drive plenum fan is more efficient that a belt-drive plenum fan? (select all that apply)
    a. There are no belt-related drive losses
    b. The fan blades are more efficient
    c. The motor is mounted behind the fan wheel so it does not restrict airflow
    d. The fan housing reduces aerodynamic losses

5. True/False: When discharging into a single, sufficiently-long, straight section of duct that is about the same size as the fan outlet, a housed fan will likely require less power than a plenum fan, but a plenum fan will likely have lower discharge sound levels.

6. If a discharge plenum is added downstream of a housed fan, which of the following are true? (select all that apply)
    a. A direct-drive plenum fan would likely require less power than the housed fan
    b. A direct-drive plenum fan would require a diffuser section downstream
    c. Both a direct-drive plenum fan and a housed fan would likely have similar discharge sound levels
    d. A direct-drive plenum fan would likely allow for a shorter overall unit than a housed fan

7. Which of the following are potential benefits of using a fan array? (select all that apply)
    a. Reduced length of the air-handling unit
    b. Smaller fan motors are easier to handle, if motor replacement is needed
    c. Fewer moving parts
    d. Redundancy in the event that a fan or motor was to fail

8. Which of the following are potential benefits of using a motorized impeller rather than a traditional direct-drive plenum fan? (select all that apply)
    a. Reduced length of the air-handling unit
    b. Lower replacement cost
    c. Flexibility for use in a vertical orientation
    d. Suitable for higher-pressure applications

9. True/False: Brake horsepower does not account for power losses due to motor inefficiency or belt/drive losses.

10. True/False: A general-purpose motor is never able to operate above 100 percent of its rated motor load.

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Fan Efficiency Regulations and Technology Advances

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