HVLS FANS

ASHRAE Philadelphia & New Jersey

April 21, 2021

GREENHECK

Housekeeping Guidelines

- Audience members are muted during the presentation.
- Questions can be submitted using the chat function during the presentation. They will be answered via chat or by the presenter at the end of the presentation.

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HVLS Fan Design, Application, & Specification

Learning Objectives

- Identify the function and application of HVLS fans
- Describe the primary fan design considerations for specifying HVLS fans
- Understand HVLS fan performance testing, data, and industry standards
- Explain the criteria and processes used to make appropriate HVLS fan selections

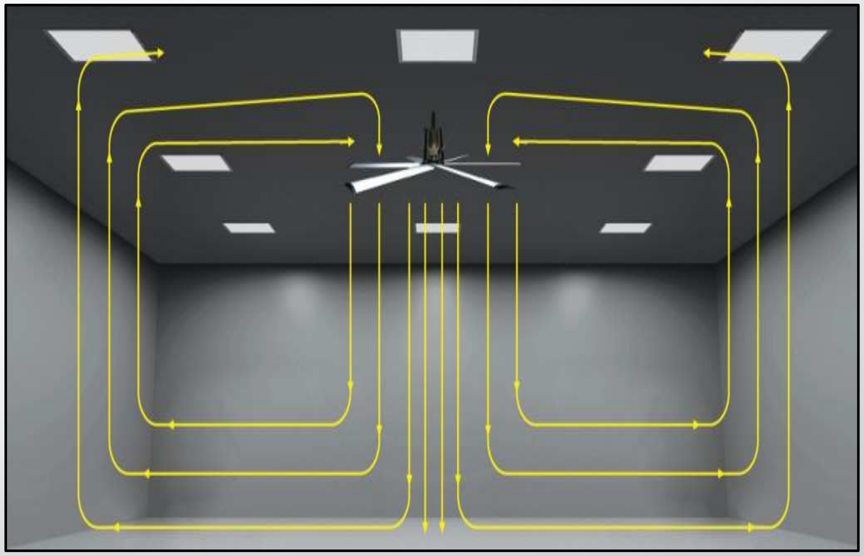
What is an HVLS Fan?

HVLS = High Volume Low Speed

Large diameter ceiling fans designed to circulate high volumes of air using low operational speeds

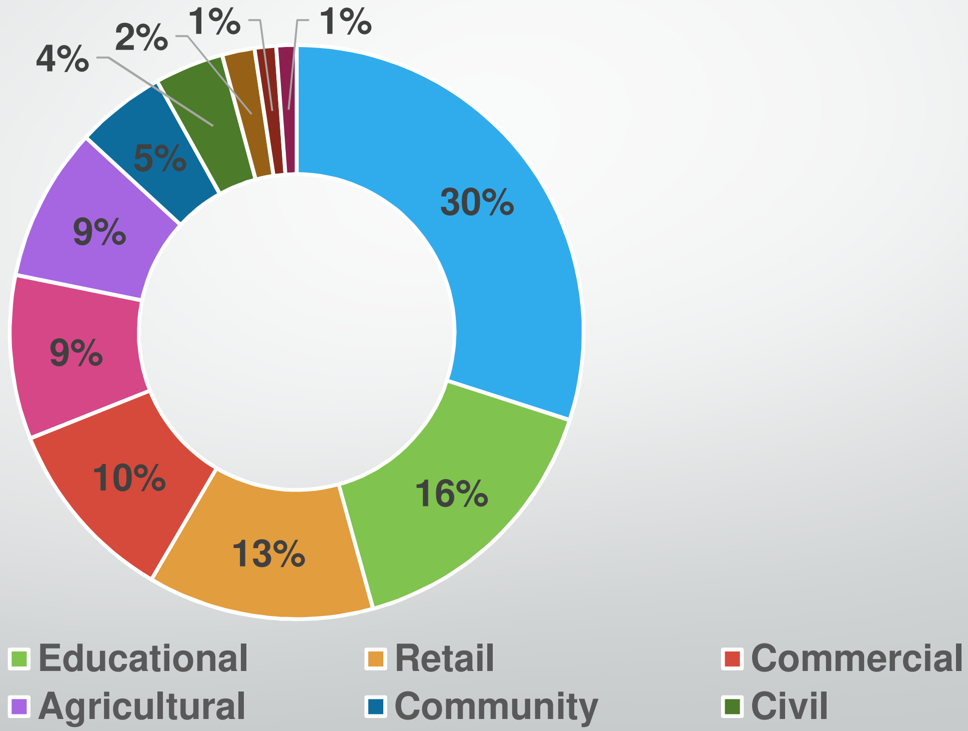
HVLS Fan Operating Principles

- High volume air movement
  - Large diameter results in large column of air being displaced
- Low operational speeds
  - Gentle air movement with minimal turbulence
  - Low sound levels
  - Less horsepower required to operate fan
- Large area of effect
  - Coanda effect causes air to cling to surfaces and entrain surrounding air
  - Large air mass capable of traveling long distances



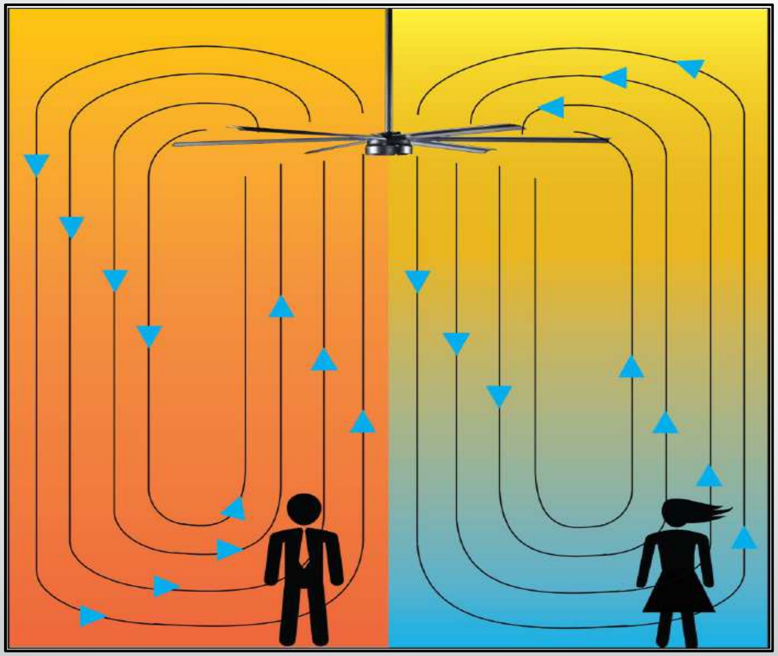
HVLS Fan Market & Applications

Construction Market Distribution



Applications

Thermal Comfort & Energy Efficiency



Winter

- Destratification
- Reduce heat loss through roof
- Save up to 25% on heating costs

Summer

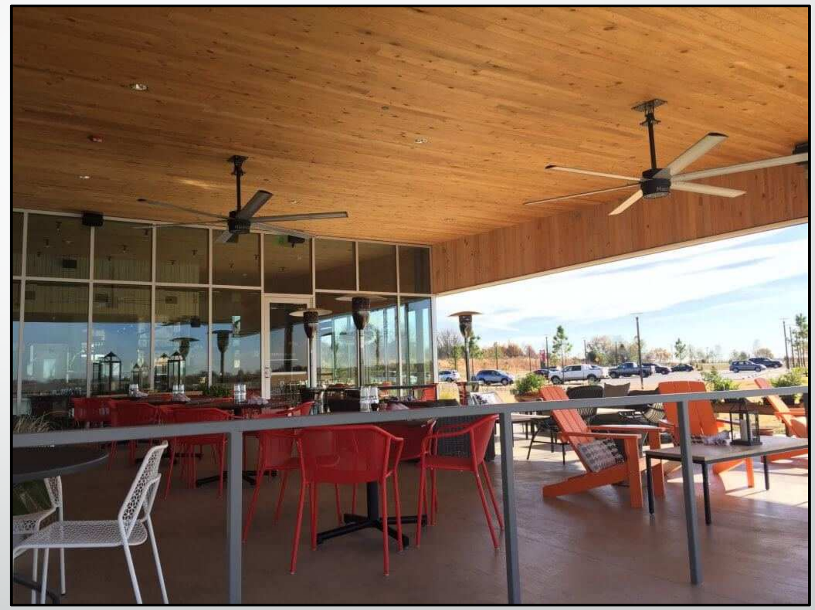
- Air circulation & evaporative cooling
- Improve occupant efficiency
- Save up to 30% on cooling costs

Applications

Safety & Inventory Integrity

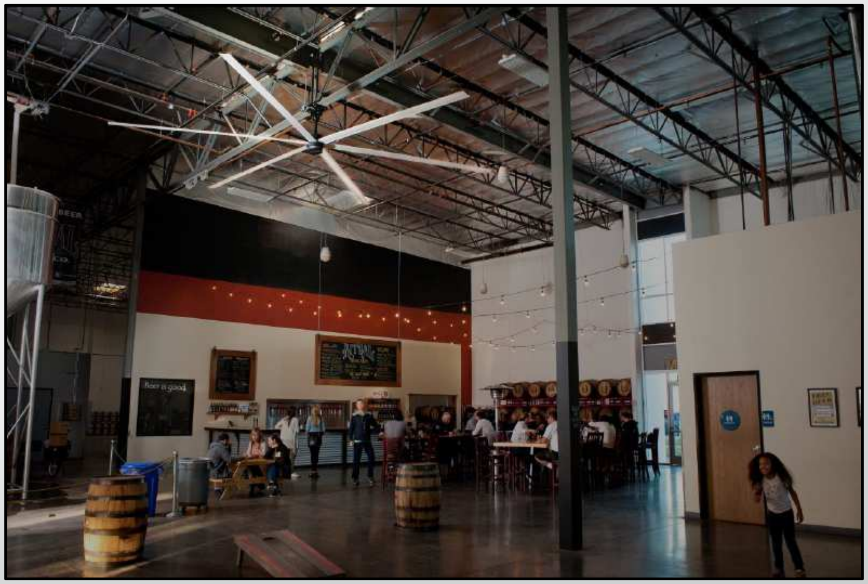
Applications

Pest Deterrence



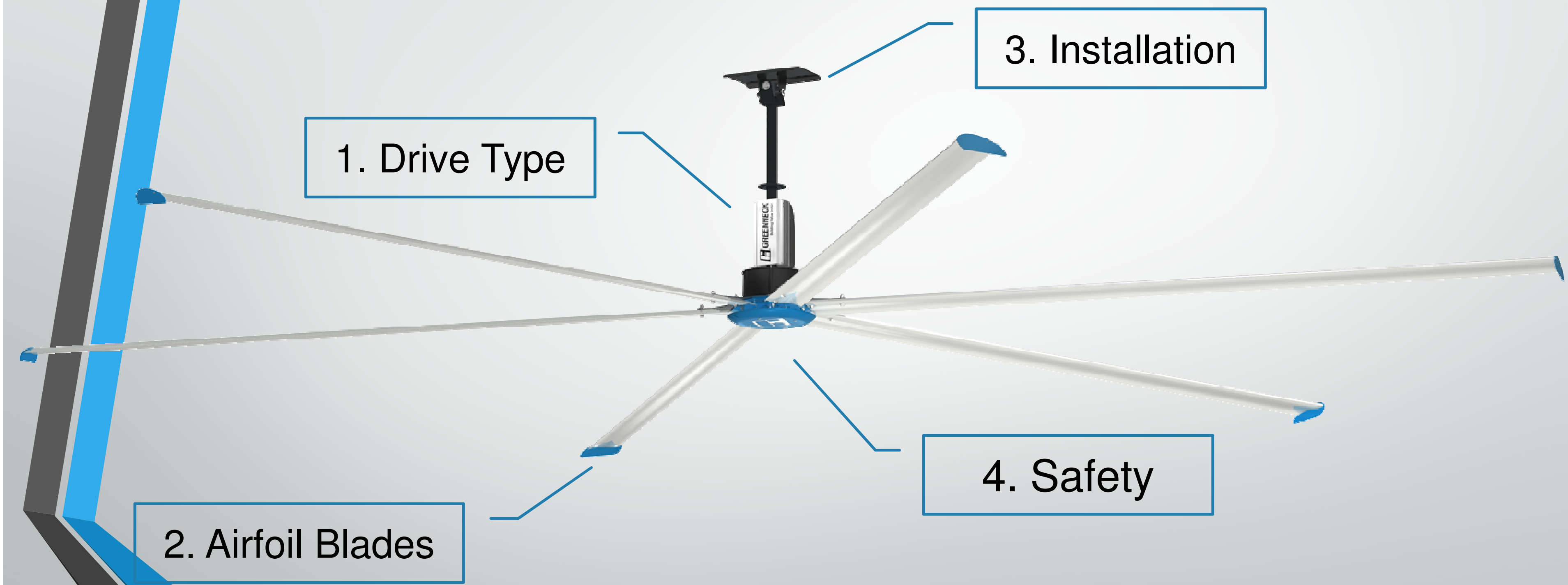
Applications

Architectural Design



HVLS Fan Design Considerations

Fan Design Considerations



Drive Type

	Description	Pros	Cons
Gearbox 	High RPM motor with gear system that reduces speed to maximize torque $(P = \tau * RPM)$	• Motors more readily available • Lower first-cost • Easily applied to any diameter	• More maintenance (oil changes) • Physically larger/heavier • Efficiency losses • Can be noisy
Direct Drive 	Low RPM motor designed for high continuous torque	• Little to no maintenance • Compact design • High efficiency • Quiet	• Limited motor availability • Higher first-cost • Not always available for large diameters

Airfoil Blades

$$P = \tau * RPM$$

- Factors to consider
  - Blade count
    - More blades not necessarily better
    - 5 or 6 blades = best balance of airflow & efficiency

	3-Blade Fan	6-Blade Fan
Motor Power	500 W	500 W
Max RPM	86	69
Max CFM	124,500	128,100

Airfoil Blades

- Factors to consider
  - Blade count
    - More blades not necessarily better
    - 5 or 6 blades = best balance of airflow & efficiency
  - Blade deflection
    - Blade structure and materials vary
    - Critical for preventing unsafe operation

24 ft. Diameter	Static Blade Deflection
Manufacturer A	3.7 in.
Manufacturer B	9.0 in.

Fan Installation

- Factors to consider
  - Installation location
    - Accessibility, clearance, structure, etc.

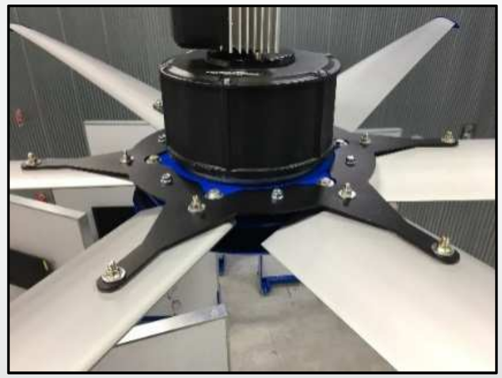
Fan Installation

- Factors to consider
  - Installation location
    - Accessibility, clearance, structure, etc.
  - Fan weight
    - Lighter weight = lower installed costs

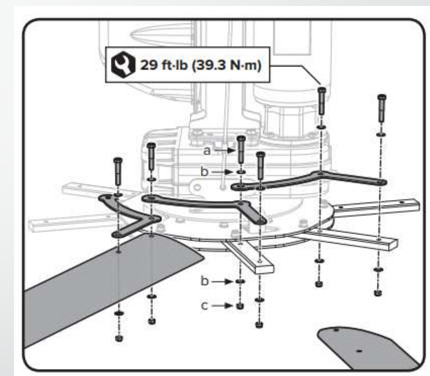
24 ft. Diameter	Weight (lbs.)
Manufacturer A	214
Manufacturer B	231
Manufacturer C	239
Manufacturer D	300
Manufacturer E	347

Product Safety

- Factors to consider
  - Mechanical safety systems
    - Factory-installed systems prevent installation problems

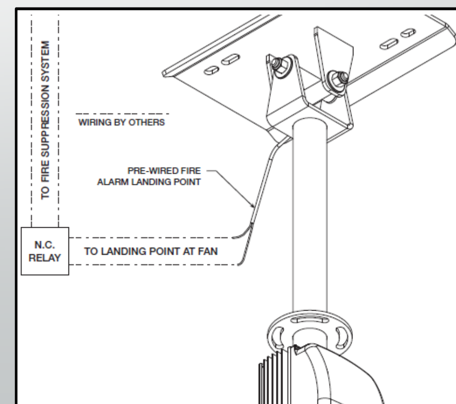


VS.



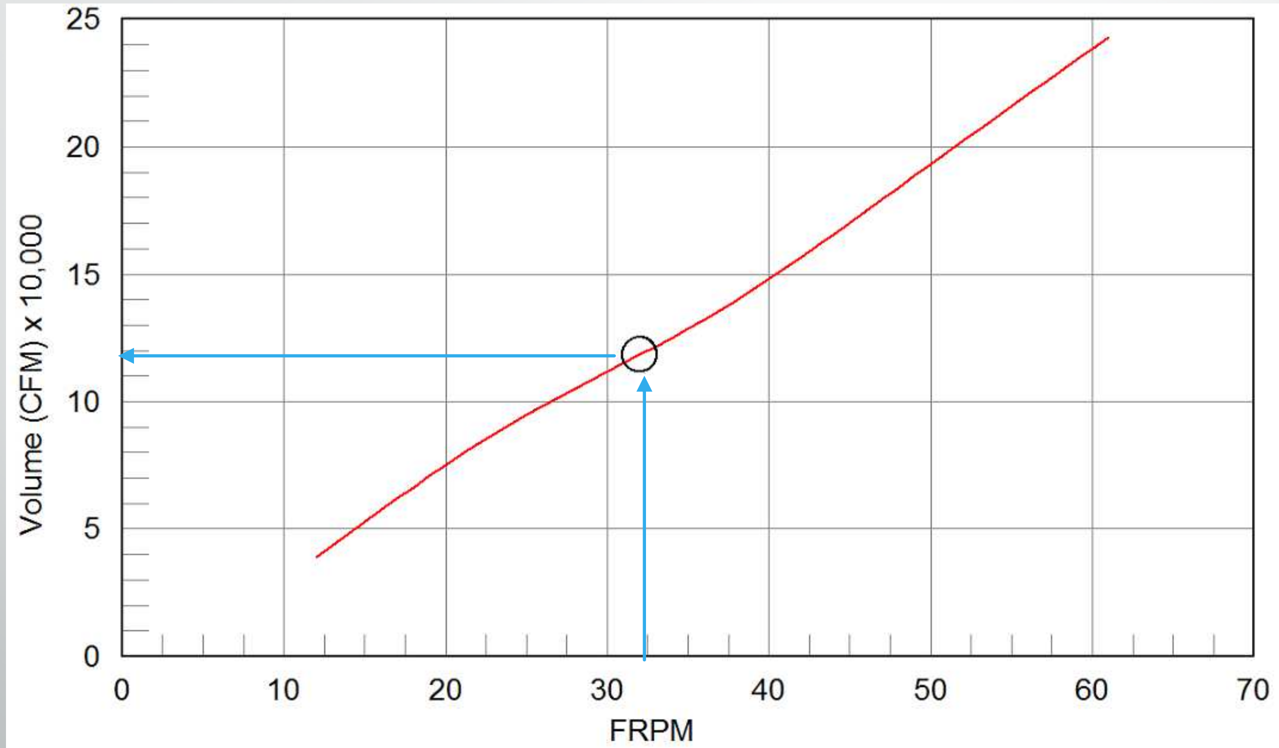
Product Safety

- Factors to consider
  - Mechanical safety systems
    - Factory-installed systems prevent installation problems
  - Fire system integration
    - NFPA 13 requires:
      1. Maximum fan diameter shall be 24 ft.
      2. Fan shall be centered between 4 sprinklers
      3. Vertical clearance to sprinkler deflector shall be minimum of 3 ft.
      4. Fans shall be interlocked to shut down upon receiving fire alarm
    - Factory-supplied parts simplify installation



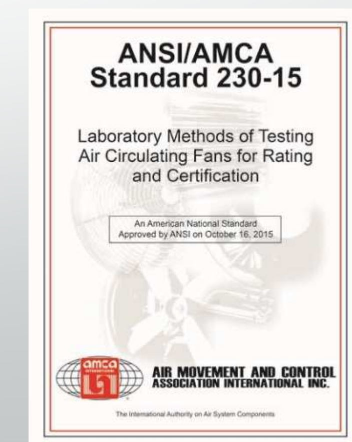
HVLS Fan Performance

Fan Curves



AMCA International

- Air Movement and Control Association
  - Independent third party verification
  - International Certified Ratings Program
  - Guaranteed performance as stated with AMCA seal


ANSI/AMCA Standard 230-15

Laboratory Methods of Testing Air Circulating Fans for Rating and Certification

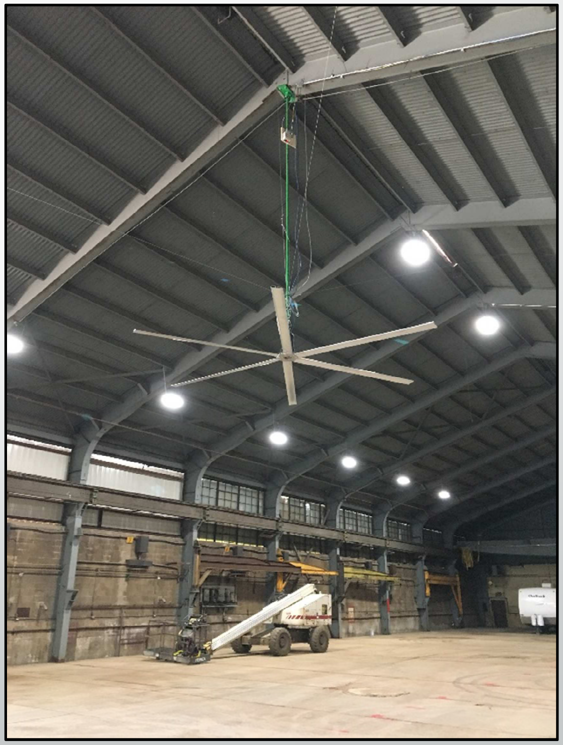
An American National Standard Approved by ANSI on October 16, 2015

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL INC.

The International Authority on Air System Components

HVLS Fan Testing

- Cannot be tested using traditional air chamber
  - Requires large open area with high ceilings
- Airflow is not measured directly
  - Measure thrust generated by fan using a load cell
- Power determined in two ways
  - Measure torque and RPM to calculate mechanical power
  - Measure input electrical power using power meter



Importance of AMCA Certification

- Guaranteed performance as stated with AMCA seal
- History of inaccurate performance data in HVLS industry
  - Previous performance calculations incorrectly included √2 correction factor resulting in ~30% higher CFM values
  - Many manufacturers continue to publish data calculated using these equations
  - No driving force for correcting published data until recently

Previous Calcs.

$$Q_0 = 340.3\sqrt{\frac{2AF_t}{\rho_{std}}}$$

$$F_t = 37.0$$

$$A = 113\ ft^2$$

$$Q_0 = 113{,}664\ CFM$$

AMCA 230-15

$$Q_0 = 340.3\sqrt{\frac{AF_t}{\rho_{std}}}$$

$$F_t = 37.0$$

$$A = 113\ ft^2$$

$$Q_0 = 80{,}365\ CFM$$

DOE Efficiency Legislation

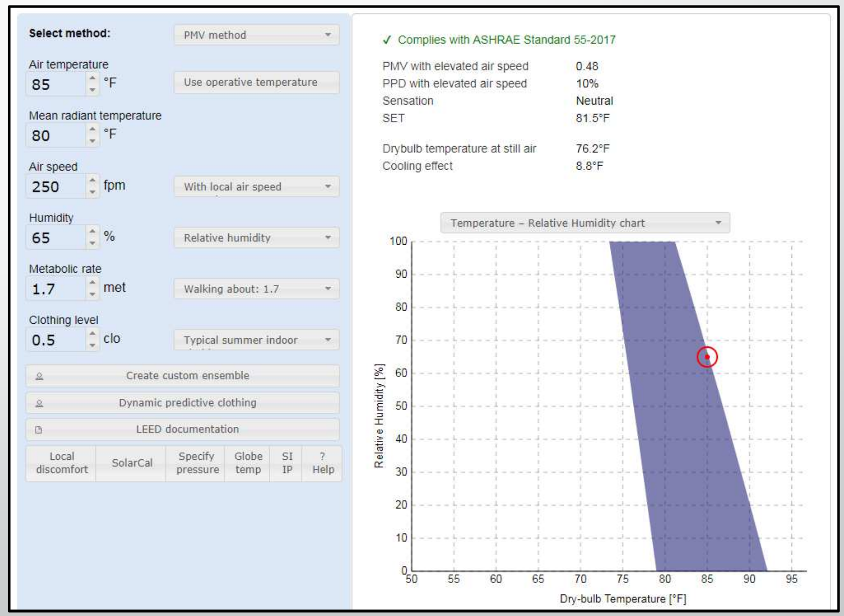
- Department of Energy (DOE) developed minimum efficiency standards for ceiling fans
- Adopted into national law and enforceable starting 2020
- DOE rule is in sync with AMCA 230!
  - Will require manufacturers to correct published performance data
- Efficiency minimums intended to obsolete least efficient products (~10%)

Therefore, DOE requires all large-diameter ceiling fans to be tested according to AMCA 230–15, but with the modification that the number of speeds to be tested is as set forth in Table 2.

Fan Diameter	Min. Efficiency (CFM/W)
8	57
10	79
12	101
14	123
16	145
18	167
20	188
24	232

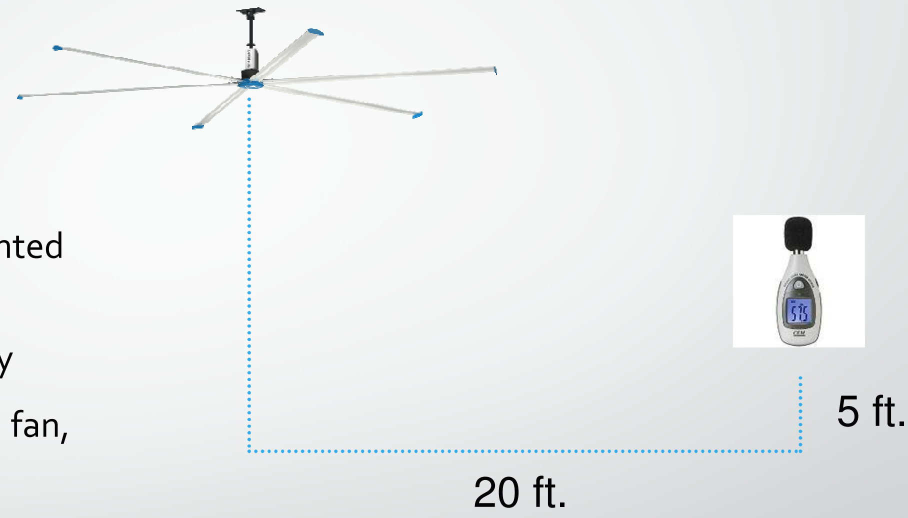
Other Performance Considerations

- Air velocity in occupied zone
  - Studies have shown employee efficiency and comfort benefits of higher air velocity when temperature/humidity are high
  - ASHRAE 55 establishes methodology for quantifying effect of air velocity on thermal comfort



Other Performance Considerations

- Sound
  - Typically published as total dBA (A-weighted sound pressure including fan & air noise)
  - No test standards so test procedures vary
  - Commonly shown at distance 20 ft. from fan, measured 5 ft. above floor



Performance is Critical!

"Aren't all 24 ft. fans the same?"

	Manufacturer A	Manufacturer B	Difference
AMCA Certified	✓	-	-
Max CFM	243,000	217,000	+12%
Efficiency (CFM/W)	249	217	+15%
dBA at Max RPM	50	55	-9%
Coverage Area (Sq. Ft.)	23,700	20,736	+14%

Not all HVLS fans are created equal!

Performance Specification Language

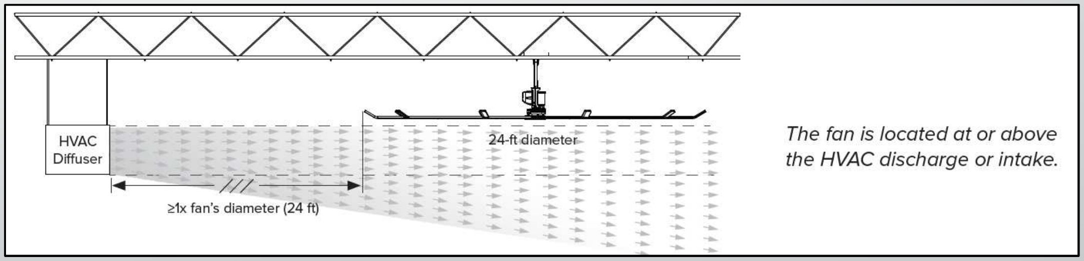
Ensure accurate performance on HVLS fans by specifying AMCA!

"Performance ratings for HVLS fans shall conform to AMCA standard 211. Fans must be tested in accordance with ANSI/AMCA Standard 230-15 in an AMCA accredited laboratory. Fans shall be certified to bear the AMCA Seal for Circulating Fan Performance."

HVLS Fan Selection & Specification

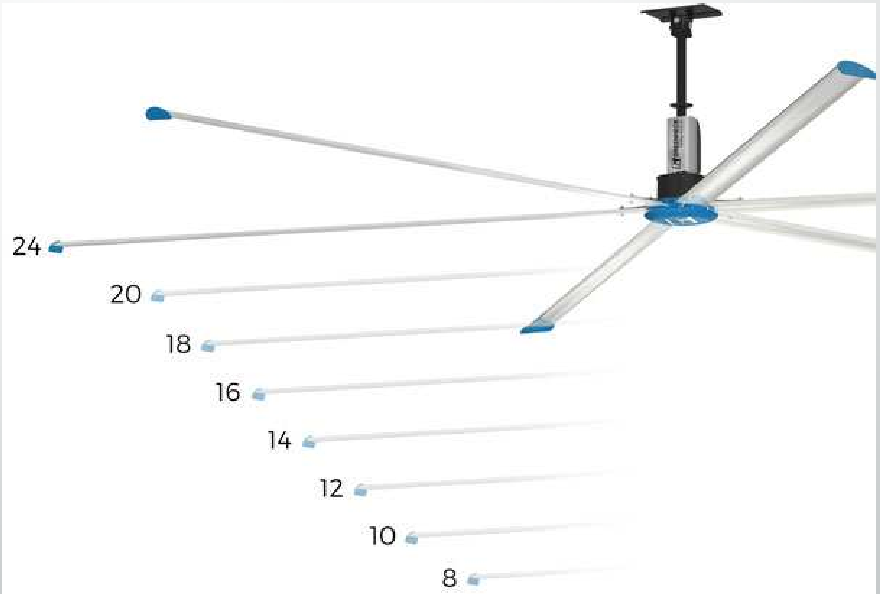
Selection Considerations

- Building type & application
- Fan design
- Fan performance (airflow, efficiency, sound, air velocity)
- Installation location
  - Accessibility, structural support, etc.
- Airflow obstructions
  - Anything that disrupts air movement
  - Walls, furniture, equipment, racking, etc.
- Clearance requirements
  - Clearance to physical obstructions
  - Clearance to HVAC inlets/outlets



Selection Process

- Processes vary among design professionals
- Two primary methods
  - Size-based selection
  - Performance-based selection
- Size-based method is most commonly used today



Size-Based Selection

- Process
  - Utilize published coverage area or fan spacing values to identify quantity and size of fans that <u>physically fit space</u>
- Pros
  - Easy and fast
  - Generally a "safe" design
- Cons
  - No performance considerations
  - No data to support design decisions
  - Typically over-designs systems leading to higher first-cost

- Space the fans at a center-to-center distance that is at least 2.5x the fan diameter.

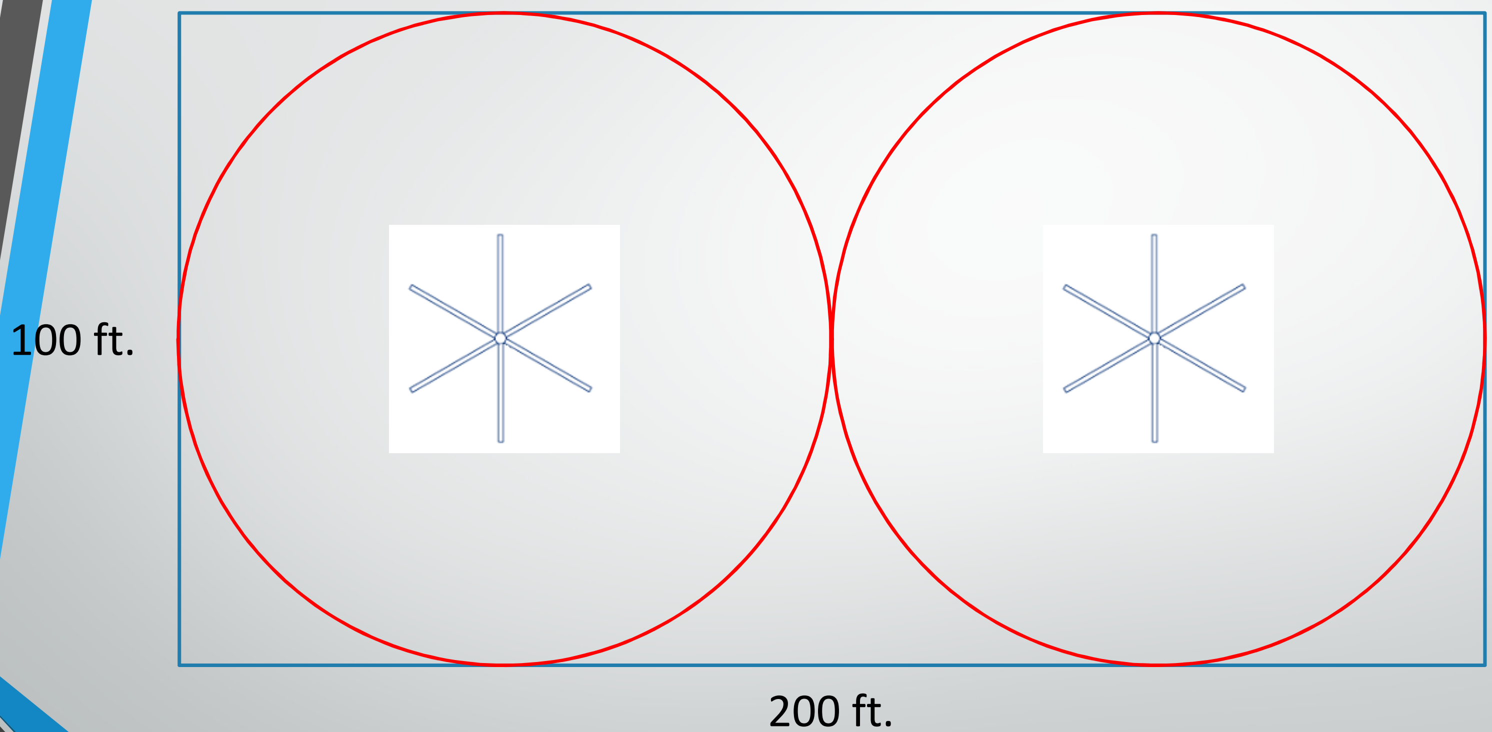
PERFORMANCE	
Max Speed	75 RPM
Recommended Spacing*	105 ft [32 m]
Max Affected Area	20,000 ft² [1,858 m²]

Open Area Fan Requirements*

Length \ Width	100'	200'	300'	400'	500'
100'	1	1 or 2	2	2 or 3	3
200'	1 or 2	2	2 or 3	3 or 4	4 or 5
300'	2	2 or 3	4 or 5		
400'	2 or 3	3 or 4			
500'	3	4 or 5			

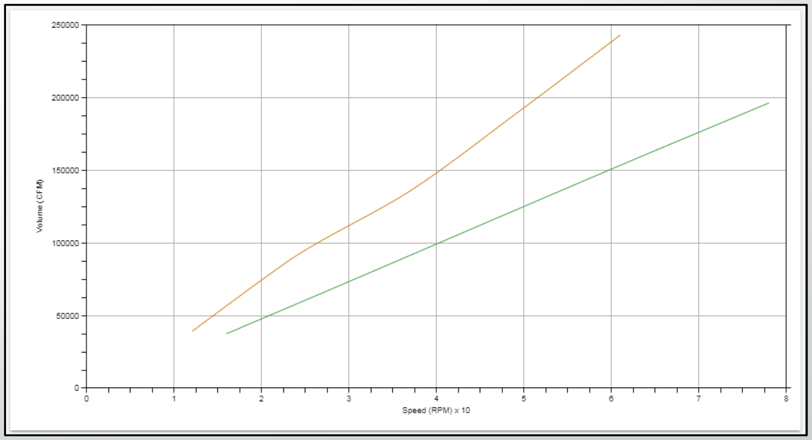
*Grid and chart based on 30' ceiling heights and 24' diameter fans. Fans in open areas may cover up to 85 feet from the fan's center in all directions.

Size-Based Selection



Performance-Based Selection

- Process
  - Utilize performance data to identify size and quantity of fans that <u>deliver correct performance</u>
  - Based on industry standards (AMCA, ASHRAE, etc.)
- Pros
  - Better system design that balances cost & performance
  - Data to support design decisions
- Cons
  - Few manufacturers that publish data
  - Software not always public
  - Can be more time-consuming



Performance-Based Selection

Selection Method: By Performanc | Space Length (ft): 100 | Space Height (ft): 20 | Available Sizes: Recommended

Sizing Method: Comfort Coolin | Space Width (ft): 200 | Minutes / Air Rotation: 3

Name	Rank	Relative Cost	Quantity	Total Operating Cost/Year (USD)	Impeller Diameter (in.)	Actual Volume Per Fan (CFM)	Affected Area Per Fan (ft2)	Min. Fan Spacing (ft)	Fan Spacing (ft)	Avg. Air Speed (ft/min)	Max Avg. Air Speed (ft/min)	Direction of Operation	Fan Speed (RPM)	Max Fan Speed (RPM)	Motor Size (W)	Standby Power Per Fan (W)	208/60/3 Input Watts Per Fan	Integrated Efficiency Per Fan (CFM/W)	Total dBA Per Fan	Base Fan Weight Per Fan (lb)	Best Lead Time
	1	2.00	2	17	288	69,367	10,000	72	113	119	321	Forward	19	61	1,100	11	67	249	30	214	Standard
	2	1.96	2	22	240	68,100	10,000	60	113	97	368	Forward	28	78	1,100	11	87	224	33	196	Standard
	3	1.96	2	118	240	132,740	10,000	60	113	219	368	Forward	53	78	1,100	11	474	224	44	196	Standard
	4	2.00	2	79	288	132,462	10,000	72	113	214	321	Forward	36	61	1,100	11	315	249	39	214	Standard
	5	2.52	3	81	144	48,950	6,667	36	92	207	291	Forward	89	119	500	11	326	148	42	160	Standard
	6	2.52	3	69	144	45,500	6,667	36	92	190	291	Forward	83	119	500	11	275	148	40	160	Standard
	7	2.59	3	79	168	64,070	6,667	42	92	195	280	Forward	72	97	500	11	316	190	41	169	Standard
	8	2.59	3	53	168	57,725	6,667	42	92	164	280	Forward	63	97	500	11	213	190	38	169	Standard
	9	2.65	3	43	192	62,900	6,667	48	92	152	277	Forward	49	81	500	11	172	221	36	178	Standard
	10	2.65	3	50	192	65,450	6,667	48	92	160	277	Forward	51	81	500	11	200	221	37	178	Standard
	11	2.93	3	11	240	45,000	6,667	60	92	82	427	Forward	19	78	1,100	11	45	224	28	196	Standard
	12	3.45	4	19	168	34,684	5,000	42	80	100	300	Forward	40	97	500	11	75	190	28	169	Standard
	13	3.28	4	60	120	34,196	5,000	30	80	178	238	Forward	102	136	500	11	241	128	40	151	Standard
	14	3.54	4	17	192	43,512	5,000	48	80	105	319	Forward	33	81	500	11	70	221	28	178	Standard
	15	3.36	4	33	144	34,530	5,000	36	80	150	328	Forward	63	119	500	11	134	148	35	160	Standard
	16	4.42	5	10	192	26,944	4,000	48	71	77	349	Forward	23	81	500	11	40	221	27	178	Standard
	17	4.20	5	16	144	26,900	4,000	36	71	121	354	Forward	48	119	500	11	64	148	30	160	Standard
	18	4.31	5	14	168	27,075	4,000	42	71	87	314	Forward	34	97	500	11	58	190	28	169	Standard
	19	4.09	5	26	120	26,725	4,000	30	71	138	251	Forward	75	136	500	11	104	128	34	151	Standard

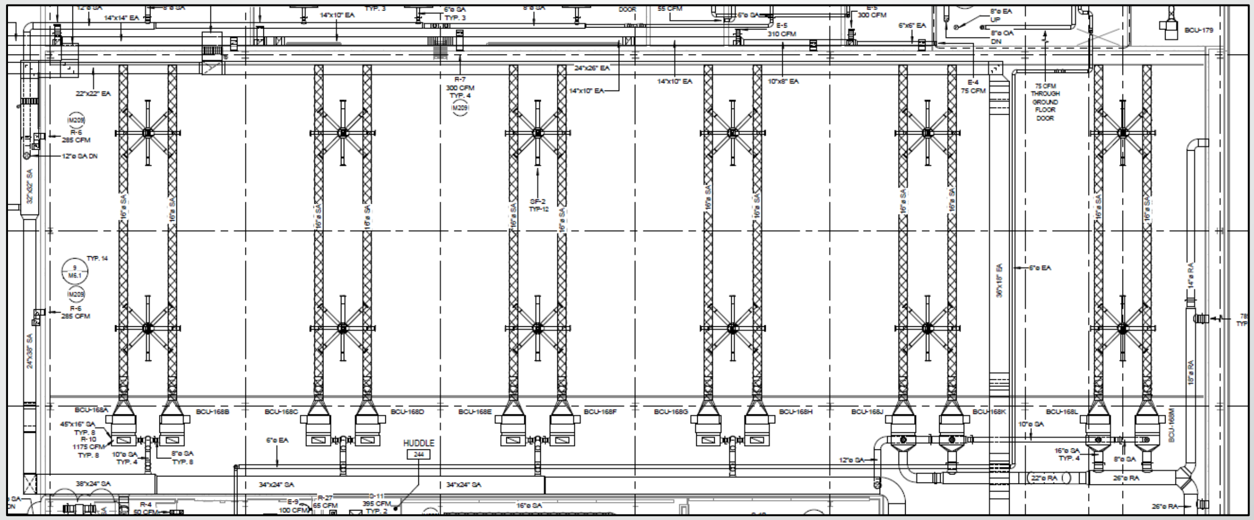
Selection Example

- Manufacturing facility in northern climate
- Fans needed for both destratification and cooling applications
- 185’ x 68’ open space with 25’ ceiling

DARE TO compare

Size-Based Selection

- Qty. (12) 10 ft. fans specified using manufacturer spacing data
- No performance data to populate schedule



FAN SCHEDULE

TYPE	AIR CAPACITY			MIN DIAMETER	TSP	ESP	FAN RPM	OCTAVE BANDS, MAX DUTY POINT, MAX PWL (DB RE 10^(-12)) W								MOTOR DATA				
	MIN	DESIGN	MAX					1 (63 HZ)	2 (125 HZ)	3 (250 HZ)	4 (500 HZ)	5 (1,000 HZ)	6 (2,000 HZ)	7 (4,000 HZ)	8 (8,000 HZ)	BHP	HP	MAX RPM	VOLTAGE	PHASE
AXIAL	11000	11000	11000	3' - 0"	1.28 in-wg	1.13 in-wg	1456	87	93	92	90	89	86	83	80	4.26	7.5	1760	460 V	3
PLENUM	11000	11000	11000	2' - 6"	4.87 in-wg	4.78 in-wg	1360	93	92	94	97	96	92	89	82	12.88	20	1760	460 V	3
AIRFOIL CEILING	0	0	0	10' - 0"	0.00 in-wg	0.00 in-wg	107	0	0	0	0	0	0	0	0		0	107	208 V	1

Performance-Based Selection

- Qty. (6) 10 ft. fans
  - Based on required airflow and air velocity to meet project requirements
  - Significant first-cost savings compared to size-based selection
- Other selection options available
  - (1) 20 ft. fan
  - (3) 14 ft. fans

- Data to populate schedule including:
  - CFM per fan
  - Affected area per fan
  - Required operating RPM
  - Power consumption per fan
  - Fan efficiency
  - Total dBA per fan

Relative Cost	Quantity	Total Operating Cost/Year (USD)	Impeller Diameter (in.)	Actual Volume Per Fan (CFM)	Affected Area Per Fan (ft2)	Min. Fan Spacing (ft)	Fan Spacing (ft)	Avg. Air Speed (ft/min)	Max Avg. Air Speed (ft/min)	Direction of Operation	Fan Speed (RPM)	Max Fan Speed (RPM)	Motor Size (W)	Standby Power Per Fan (W)	208/60/3 Input Watts Per Fan	Integrated Efficiency Per Fan (CFM/W)	Total dBA Per Fan
5.56	6	13	120	17,654	2,097	30	52	114	282	Forward	55	136	500	11	54	128	30

Summary

- HVLS fans are highly engineered products that can provide significant value to HVAC and ventilation system designs in any facility
- Not all HVLS fans are created equal, so it is critical to be informed about product and performance differences
- Design professionals need to account for a variety of factors to achieve cost-effective systems that meet customer performance requirements

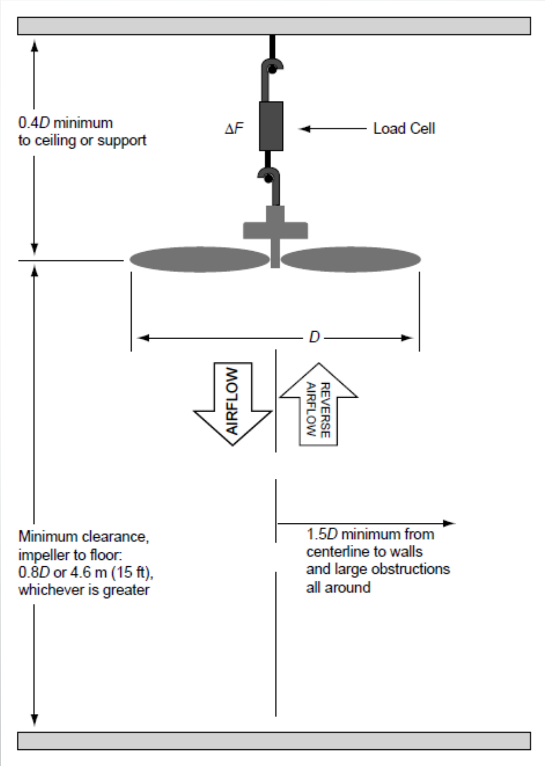
Appendix

History of

- Invented in the late 1990's
- Designed for agricultural applications
  - Livestock comfort & health
- Transitioned into commercial & industrial applications in the early 2000's
  - Similar benefits for building occupants!
  - Exponential growth rate over ~10 years

AMCA 230

- International test standard for consistent performance testing of circulating fans
  - Part of CRP program for AMCA certification of air performance data
- Test setup for 24 ft. HVLS fan:
  - Minimum 72′ x 72′ x 29′ space
  - Fan installed at least ~20′ above floor
  - Load cell installed between fan and ceiling mount
  - Power meter measuring input electrical power
  - Optical tachometer measuring RPM
  - Wet-bulb, dry-bulb, and barometric pressure measurements for calculating air density
  - No extraneous airflow (>50 FPM) in test area
- Test procedure
  - Performance data recorded at 5 test speeds (20, 40, 60, 80, 100%) and standby mode



AMCA

- Airflow calculation
  - Measure load differential
  - Calculate thrust force at standard air density (70°F at sea level)
  - Calculate airflow using thrust and area of the fan sweep (outlet area)

Thrust shall be calculated according to the following:
For Test Figures 1, 3A and 3B:

$$F_t = \Delta F \left(\frac{\rho_{std}}{\rho_0} \right) \quad \text{Eq. 9.4}$$

ΔF	= Load differential, N (lbf)
ρ_0	= Ambient air density, kg/m^3 (lbm/ft^3)
ρ_{std}	= Standard air density, 1.2 kg/m^3 (0.075 lbm/ft^3)

$$Q_0 = 340.3 \sqrt{\frac{AF_t}{\rho_{std}}} \quad \text{Eq. 9.6 I-P}$$

Q_0	= Airflow rate, m^3/s (cfm)
F_t	= Thrust, N (lb)
A	= $\pi(D/2)^2$, m^2 (ft^2)
ρ_{std}	= Standard air density, 1.2 kg/m^3 (0.075 lbm/ft^3)

AMCA 230

- Airflow calculation
  - Measure load differential
  - Calculate thrust force at standard air density (70°F at sea level)
  - Calculate airflow using thrust and area of the fan sweep (outlet area)
- Fan efficiency calculation
  - Calculate airflow
  - Measure input electrical power in watts
  - Calculate efficiency in terms of airflow / watt

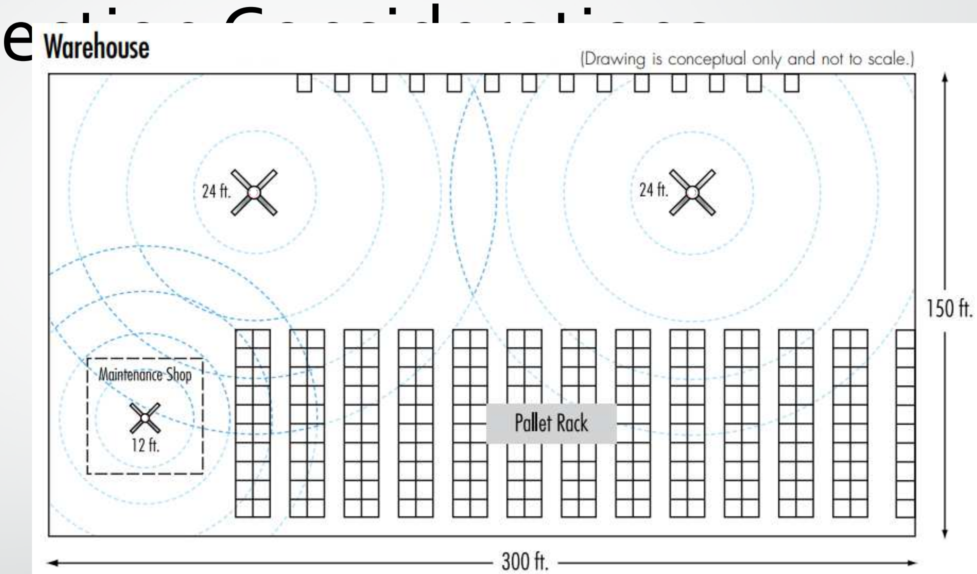
$$Eff_{circ} = \frac{Q_0}{W_E} \qquad \text{Eq. 9.8}$$

Where:

Q_0 = Fan airflow rate m^3/s (cfm)
W_E = Electrical input power, watt

Additional Sele

- Impact on heating & cooling loads
  - Should design conditions be changed?
- Controls
  - Quantity
  - Location
  - Functionality



Thank you for your time.

Questions?

GREENHECK®
Building Value in Air.

The mission of Greenheck is to be the market leader in the development, manufacture and worldwide sales of quality air moving, control and conditioning equipment with a total commitment to customer service.

2019
2016, 2012, 2004
WISCONSIN
MANUFACTURER
OF THE YEAR