What Engineers Need to Know about HVLS Fans

Asia AMCA Webinar
India

1 June 2023

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1

Michael Ivanovich, webinar moderator

Sr. Director, Global Affairs
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- Joined AMCA July 2011
- Coordinates advocacy in N. America, Asia, Europe, and Middle East
- Leads AMCA energy efficiency initiatives involving codes, standards and regulations
- M.Sc. Civil Engineering (Building Systems)

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2

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Participation Guidelines:

- Audience will be muted during the webinar.
- Questions can be submitted anytime via the GoToWebinar platform and will be addressed at the end of the presentation.
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- A post-webinar survey link will be shared within 1 hour of the conclusion of today's program and your feedback is greatly appreciated.
- PDH credits are not available for today's webinar.

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3

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To submit questions:

- From the attendee panel on the side of the screen, select the "Questions" drop down option.
- Type your question in the box. If possible, please indicate which speaker your question is for.
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- Questions will be answered at the end of the program.

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4

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5

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6

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7

7

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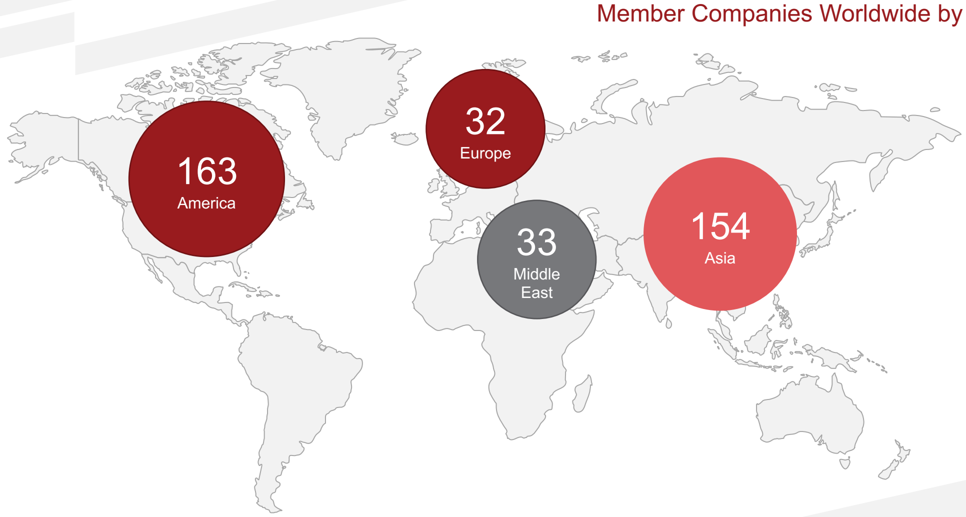
Member Companies Worldwide by Region



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8

8

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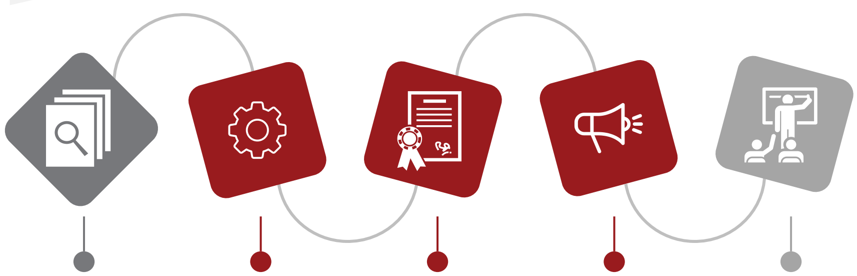
9

AMCA's Value Chain



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10

10

AMCA's Value Chain

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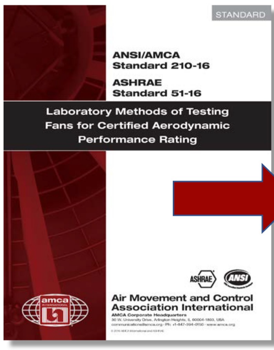

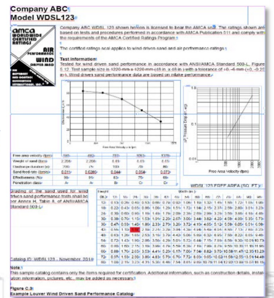

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11

11

Outline

- Introductions
- Part 1: Application & Design Guidance
- Part 2: Specification Guidance
- Part 3: Quality Assurance – Guidance
- Additional Resources
- Questions & Answers – Panel Discussion

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12

Mr. Pallab Kar

National Sales Manager
Greenheck India Private Ltd.

- Approximately 30-years industry experience
- Bachelor of Engineering: BITS Pilani
  – Birla Institute of Technology and Science
- MBA in Manufacturing Management
- President, ASHRAE East India Chapter for SY 2023

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13

Mr. Christian Taber

Principal Engineer, Codes and Standards
Big Ass Fans (AMCA Member Company)

- MSc in mechanical engineering & biosystems engineering; BSc in chemical engineering
- ASHRAE certified High-Performance Building Design Professional and Certified Energy Manager
- Chair, North America Air Movement Advocacy Committee
- Member, AMCA North America Region Steering Committee
- Vice Chair, AMCA Air Movement Division, AMCA 230-23
- ASHRAE – Standards Committee, SSPC 90.1

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14

Mr. Aaron Gunzner, P.E.

Senior Manager, Advocacy, AMCA International

- Primary Voting Member, ASHRAE 90.1 Mechanical Subcommittee
- Member, IAPMO UMC TC
- Corresponding Member, ASHRAE Technical Committees 5.1, 5.2 and 5.6
- Staff liaison for AMCA's primary advocacy committees
- BSc, MSc Mechanical Engineering, Colorado School of Mines

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15

Mr. Pallab Kar

Part 1: Application/Design Guidance

How to size and locate HVLS fans for typical applications

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16

Definitions

- High-Volume Low-Speed (HVLS) Fan
  - No formal definition with performance benchmarks
  - Designed to circulate high volumes of air at low rotational speed
- Large Diameter Ceiling Fan (LDCF)
  - Defined by U.S. Department of Energy in U.S. Code of Federal Regulations
  - Ceiling fan with diameter larger than 7 ft (2.1 m)
  - Some LDCF have residential-fan performance, so not HVLS
- AMCA tends to use LDCF because it is defined in U.S. regulations
  - But we generally mean HVLS …

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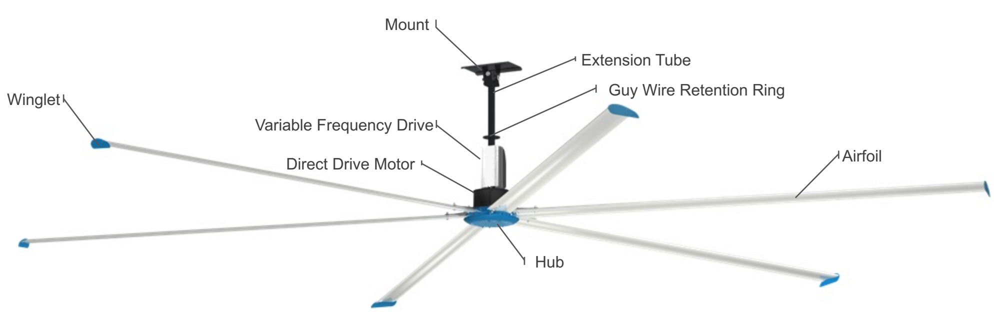
17

Example HVLS Fan (or LDCF)



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18

HVLS – Primary Applications

- Occupant comfort
  - Summer cooling & heat recovery
- Building cost reduction
  - Contribute to first-cost savings via reduction in HVAC equipment
  - Improve building efficiency via cooling setpoint changes and destratification
- Improve occupant health & safety
  - Improve measured & perceived indoor air quality

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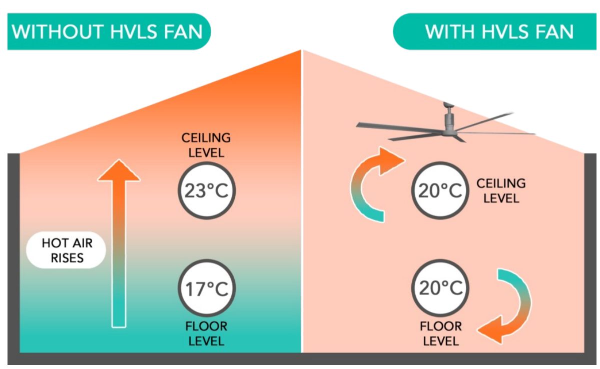
19

Occupant Comfort

- HVLS fans increase occupant comfort via two mechanisms
  - Provide elevated air speed for occupant cooling
    - Most common application of HVLS
  - Evenly distribute air for uniform temperatures; floor to ceiling
    - Recovers trapped warm air and circulates to occupant level



Smith, J. (2022). Destratification HVLS [Digital image]. Retrieved from https://nordicco.eu/wp-content/uploads/2022/10/Destratification-HVLS-1024x617.png

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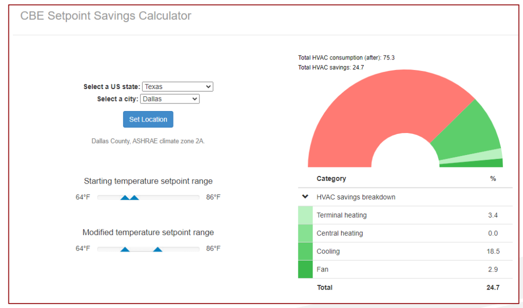
20

Building Cost Reduction

- Downsize HVAC Equipment
  - Increased occupant comfort allows an increase in temperature setpoint
  - Provides ability to downsize tonnage requirement
- Reduce or eliminate ductwork and air distribution devices
  - HVLS fans increase air distribution in large, open zones reducing material & labor
- Improve building efficiency
  - Summer Cooling: Setpoint offset reduces runtime on existing AC system (ex. From CBE calculator for US cities)
  - Heat Recovery: Destratification pushes warm air out of ceiling and circulates to occupant level

Temp. Setpoint (°C)	Req'd Cooling Capacity (tons)	Min. Unit Capacity (tons)
22	15.2	16
23.8	13.9	14



https://energy-calc-2wmigiatpa-uc.a.run.app/

1. Tyler Hoyt, Edward Arens, Hui Zhang, Extending air temperature setpoints: Simulated energy savings and design considerations for new and retrofit buildings, Building and Environment, Volume 88, 2015, Pages 89-96, ISSN 0360-1323, https://doi.org/10.1016/j.buildenv.2014.09.010.

Occupant Health & Safety

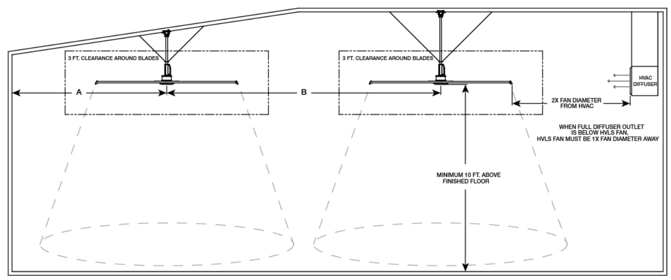
- Improve measured & perceived indoor air quality[1]
  - Dispel pockets of stagnant and contaminated air
- Reduce condensation on floors and surfaces
  - Circulation minimizes temperature differential
  - Elevated air speeds increase evaporation rate
- Eliminate trip hazards from traditional circulators
  - Slips and falls are leading cause of workers comp. claims in US[2]

1. *Yang B, Sekhar SC, Melikov AK. Ceiling-mounted personalized ventilation system integrated with a secondary air distribution system--a human response study in hot and humid climate. Indoor Air. 2010 Aug;20(4):309-19. doi: 10.1111/j.1600-0668.2010.00655.x. Epub 2010 Mar 19. PMID: 20546035.*

2. *Slip & fall quick facts.* NFSI. (n.d.). Retrieved November 1, 2022, from https://nfsi.org/nfsi-research/quick-facts/

Selection Considerations

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



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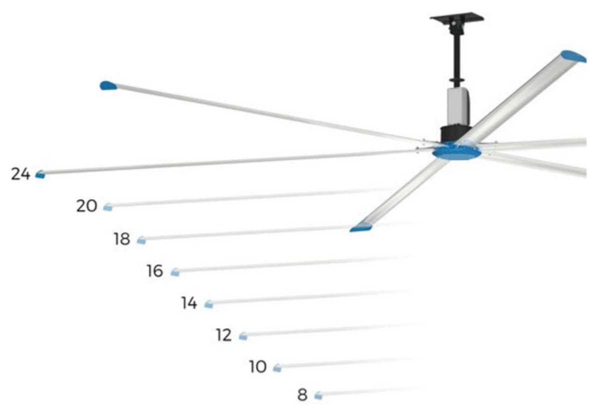
23

Selection Process

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



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24

Size-Based Selection

- Process
  - Utilize published maximum coverage areas or fan spacing values to identify quantity and size of fans that physically fit space
- Pros
  - Easy and fast
  - Generally "safe" design in open areas
- Cons
  - No performance considerations
  - No data to support design decisions
  - Can lead to "under-designed" systems

AIRFOIL DIAMETER	8ft	10ft
Airfoil Style		
Number of Airfoils		
PERFORMANCE		
Max Speed	214 RPM	163 RPM
Recommended Spacing*	60 ft [18.3 m]	65 ft [19.8 m]
Max Affected Area	4,000 ft^2 [372 m^2]	6,600 ft^2 [613 m^2]

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.

1. *AVDX Fan Specifications*, macroair.s3.amazonaws.com/documents/Fan_Specifications_AVDX_210528.pdf. Accessed 31 May 2023.
2. *Revolution Application Guidelines*, www.ritehite.com/en/eu/resource-center/literature/b1fd654971fc46fabe52062d9f405ed5/fanplanner. Accessed 31 May 2023.

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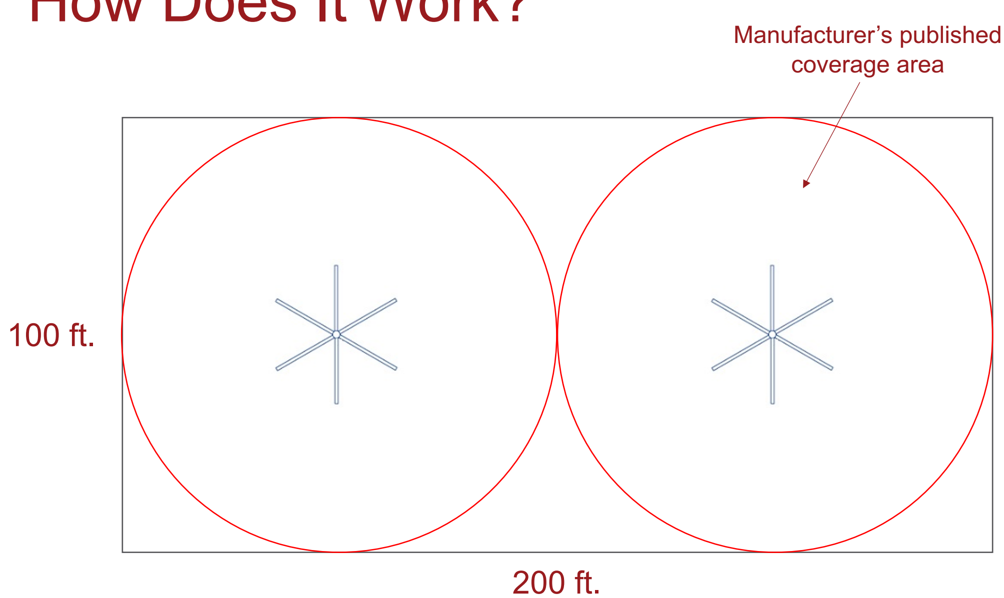
25

How Does It Work?



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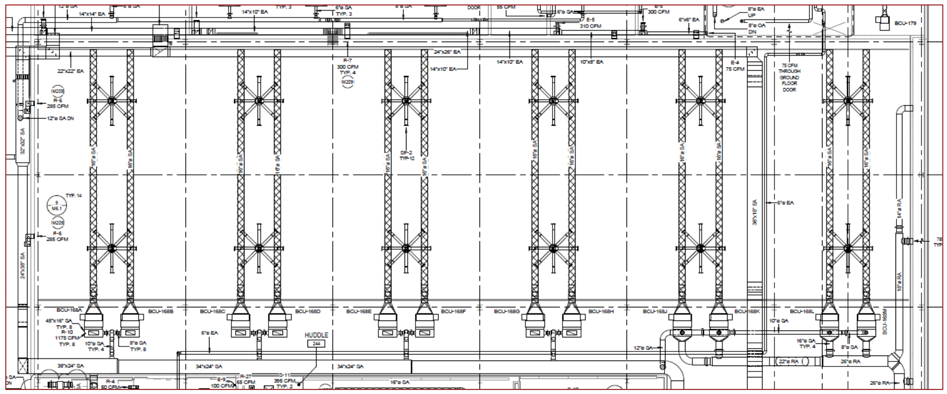
26

Example - Size-Based Selection

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

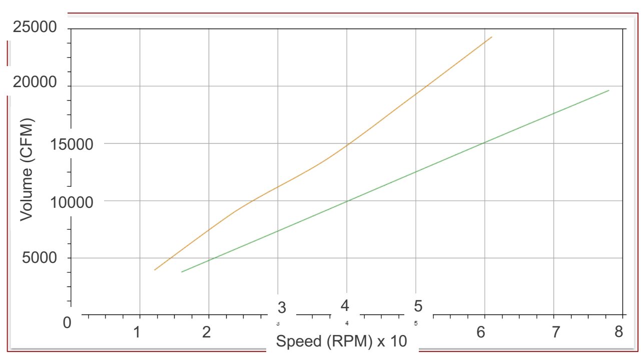


FAN SCHEDULE

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

- Process
  - Utilize performance data to identify size and quantity of fans that deliver desired performance
  - Based on industry standards (AMCA, ASHRAE, etc.)
- Pros
  - Better system design that accounts for performance needs of the building
  - Data to support design decisions
- Cons
  - Few manufacturers that publish data
  - Data not always certified
  - Software not always public
  - Can be more time-consuming



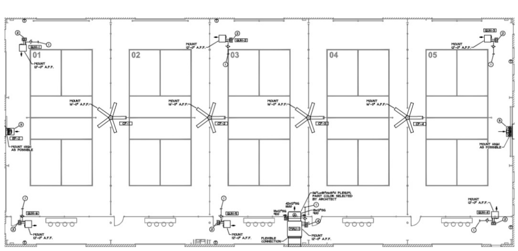
How Does It Work?

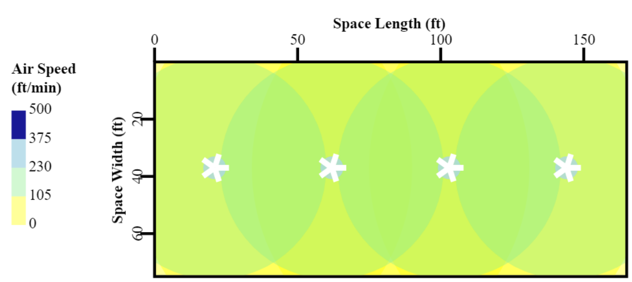
- Software uses manufacturer's test data to compare selections based on key application criteria:
  - Dimensions and geometry of the space
  - Airflow (cfm, m^3/s)
  - Min, max, and average air speeds at occupant level (ft/min, m/s)
  - Cooling effect (°F, °C)
  - Cooling coverage fraction (%)
  - Predicted occupant comfort based on ASHRAE 55
  - Electrical energy consumption (watts)
  - Sound (dBA)
- May include computational fluid dynamics (CFD) modeling to account for airflow obstructions

Example - Performance-Based Selection

- Qty. (4) 10 ft. fans specified using manufacturer performance data
- Engineer targeted average air speed of ~200 ft/min (1.01 m/s) to achieve desired cooling effect for this application

EQUIP. TAG NUMBER	LOCATION	MAX. CFM	FAN SIZE	SOUND (dBA)	ELECTRICAL			APPROX. WEIGHT (POUNDS)
					MAX RPM	MOTOR HP	VOLTS/PH	
CF-1	SEE DRAWINGS	41,200	10 FT.	55	160	0.25	120/1	77
CF-2	SEE DRAWINGS	41,200	10 FT.	55	160	0.25	120/1	77
CF-3	SEE DRAWINGS	41,200	10 FT.	55	160	0.25	120/1	77
CF-4	SEE DRAWINGS	41,200	10 FT.	55	160	0.25	120/1	77





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Part 2: Specification Guidance

How to compare products across different manufacturers by analyzing airflow performance ratings

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31

Engineering - More Than Just Mathematics

Average Starting Salary for a B.S. in US Dollars:

Mechanical Engineering = $X

Mathematics = $X - $10k

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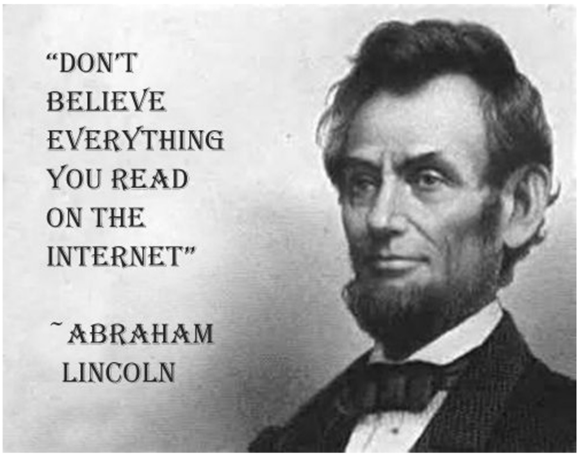
32

Critical Thinking



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33

Fundamental Concept 1 - Fan Laws

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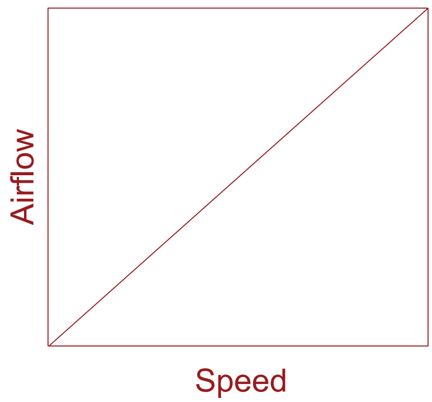
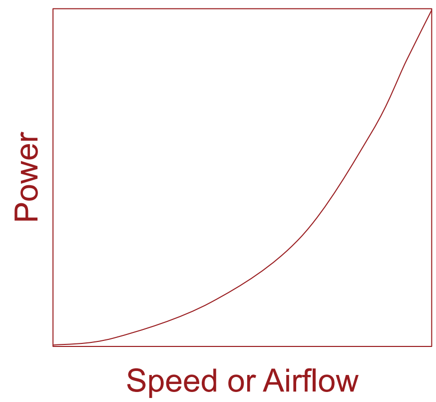
34





$$\frac{\text{Airflow}_1}{\text{Airflow}_2} = \frac{\text{Speed}_1}{\text{Speed}_2}$$

$$\frac{\text{Airflow}_1}{\text{Airflow}_2} = \left(\frac{\text{Speed}_1}{\text{Speed}_2}\right)^3$$

Airflow and Speed = Linear

Power and Speed = Nonlinear

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Fundamental Concept 2 - Fan Efficiency

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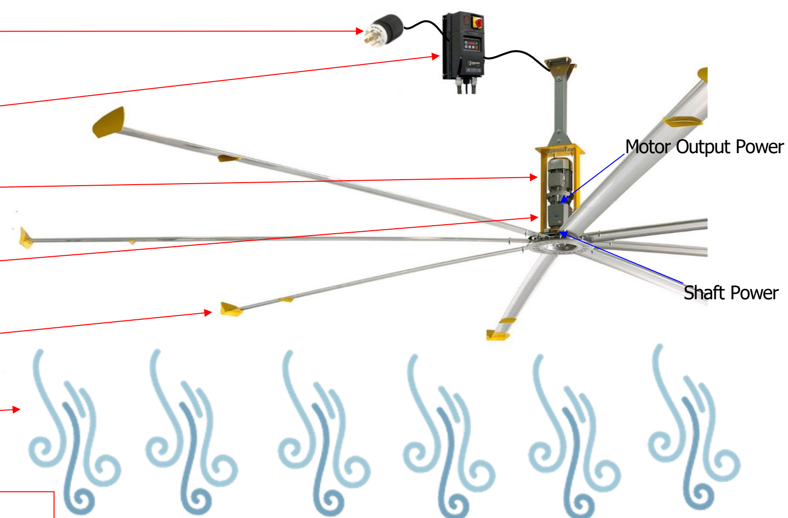
36

Ceiling Fan Efficiency - Wire-to-Air

Wire → To → Air

- Input Power
- Drive Efficiency
- Motor Efficiency
- Gearbox Efficiency
- Airfoil Efficiency
- Output Air Power

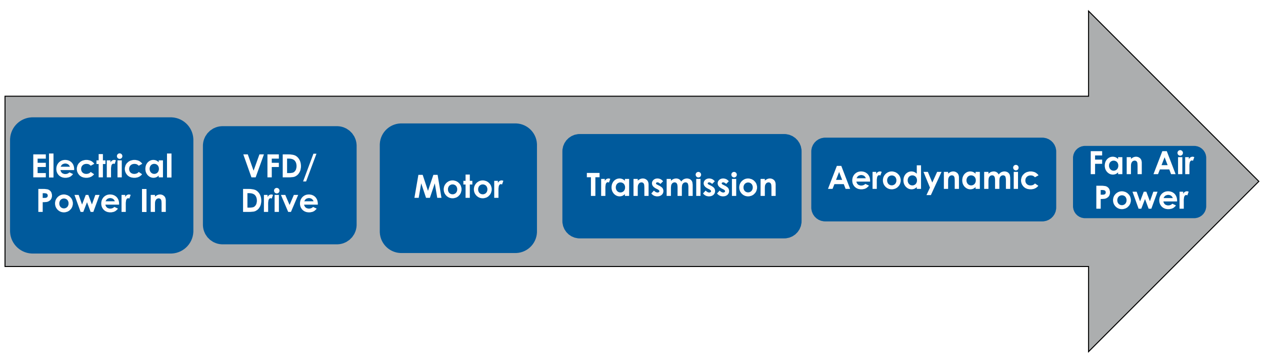


Overall Efficiency =
Output Air Power / Input Electric Power

37

37

Elements of Fan Power

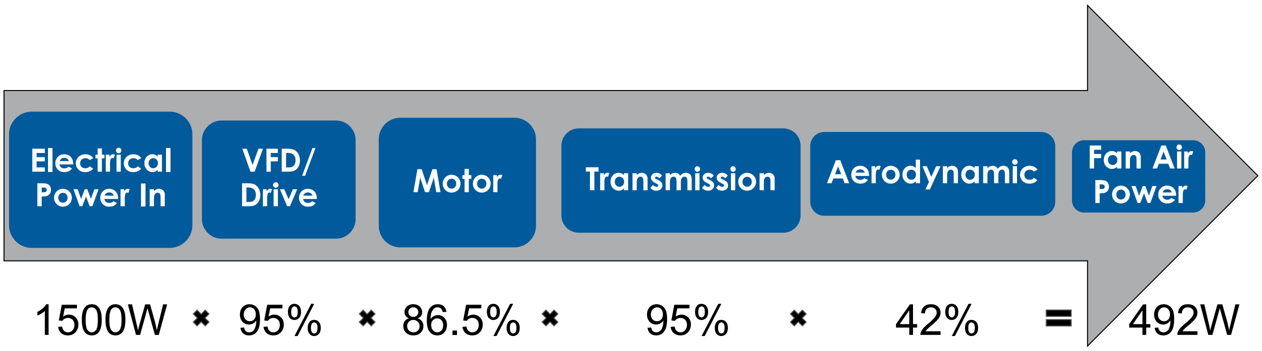


Wire → Air

38

38

Elements of Fan Power - 7.3m (24ft) Fan Example



492W of Air Power = 6785 cmm (239,600 cfm) for a 7.3m fan

492W / 1500W = 33% Efficient

Wire → Air

39

39

Relative Efficiency - Airflow Vs Power (Side Note)

Fan Type	Approximate Efficacy (CFM / W)
HVLS Fan 6.1m (20ft) @100%	143
HVLS Fan 6.1m (20ft) @20% RPM)	344
HVLS Fan 3.7m (12ft) @100%	101
HVLS Fan 3.7m (12ft) @ 20%	297
Ceiling fan with AC motor - 52”	75
Axial panel - 36”	26
Upblast roof exhaust fan - 42” (0” s.p.)	22
Cylindrical air circulating fan - small thermal destratifciation - 12”	16
Box fan - 31”	15
Unhoused air circulating fan head - 24”	13
Cylindrical air circulating fan - barrel/tube - 24”	12
Rooftop HVAC supply fan (5 ton)	3

1 CFM ~ 0.03 CMM

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40

Establishing A Baseline

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41

Rule of Thumb (RoT) Performance

Diameter	Input Power	Drive / Motor / Blade Efficiency	Airflow
7.3m (24ft)	1.5kW	92.2% / 86.8% / 42%	6456 cmm (228k cfm)
6.1m (20ft)	1.5kW	92.2% / 86.8% / 42%	5069 cmm (179k cfm)
4.9m (16ft)	1.1kW	91.3% / 85.2% / 42%	3299 cmm (117k cfm)
3.7m (12ft)	1.1kW	91.3% / 85.2% / 42%	2209 cmm (78k cfm)

Calculations based on equations from AMCA 214 & 230, $CFEI_{100}$ = 1.10

42

Applying Our Knowledge

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43

Publicly Available HVLS Fan Performance Data

Fan	Diameter	Motor kW	Airflow
A	7.3m (24ft)	1.37 kW	6456 cmm (228k cfm)
B	7.3m (24ft)	1.50 kW	10200 cmm (360k cfm)
C	7.3m (24ft)	1.80 kW	14800 cmm (523k cfm)
D	7.3m (24ft)	1.50 kW	783000 cmm (27651k cfm)

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44

Publicly Available HVLS Fan Performance Data Vs RoT

Fan	Diameter	Motor kW	Airflow	Airflow / RoT	Power - Fan Laws	Power / ROT
A	7.3m (24ft)	1.37 kW	6456 cmm (228k cfm)	1.00	1.00	0.91
B	7.3m (24ft)	1.50 kW	10200 cmm (360k cfm)	1.58	3.94	1.00
C	7.3m (24ft)	1.80 kW	14800 cmm (523k cfm)	2.29	12.00	1.20
D	7.3m (24ft)	1.50 kW	783000 cmm (27651k cfm)	121.28	1783888	1.00

Diameter	Input Power	Drive / Motor / Blade Efficiency	Airflow
7.3m (24ft)	1.5 kW	92.2% / 86.8% / 42%	6456 cmm (228k cfm)

45

Publicly Available HVLS Fan Performance Data

Fan	Diameter	Motor kW	Airflow	Airflow / RoT	Power - Fan Laws	Power / ROT	Claimed Efficiency
A	7.3m (24ft)	1.37 kW	6456 cmm (228k cfm)	1.00	1.00	0.91	31%
B	7.3m (24ft)	1.50 kW	10200 cmm (360k cfm)	1.58	3.94	1.00	112%
C	7.3m (24ft)	1.80 kW	14800 cmm (523k cfm)	2.29	12.00	1.20	284%
D	7.3m (24ft)	1.50 kW	783000 cmm (27651k cfm)	121.28	1783888	1.00	50384944%

46

Equations Used - For Reference

Input Data = Published by fan manufacturer

Discharge Area = Pi x (Fan Diameter / 2)^2

Thrust = (Airflow / 340.3)^2 x Std Air Density / Discharge Area

Output Air Power = 3.845 x √(Thrust^3 / (Area x Std Air Density))

Overall Efficiency = Output Power / Input Power

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47

Be On the Lookout…Other Claims

- XXX Years in the LDCF or HVLS fan industry
  - LDCF invented less than 25 years ago
- “Tested To AMCA 230-XX”
  - Is not the same as “AMCA Certified”
- Product Certification Claims
  - AMCA certifies LDCF airflow and power (no sound, yet)
  - NRTL’s (UL, TUV SUD, ETL, etc.) certify fan safety (UL 507)
  - ASHRAE, LEED, AIA, AHRI, etc. do not certify LDCF

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48

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49

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Part 3: Quality Assurance Guidance

How HVLS fans are tested, rated, and certified by AMCA International

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50

AMCA International

- Developed the test standard for HVLS fans; first published in 2012
- Test fans in laboratory at AMCA headquarters in USA
- Certify manufacturers' performance ratings
- Participate in advocacy shaping HVLS provisions in energy codes (like ASHRAE 90.1) and the U.S. Department of Energy fan regulations
  - HVLS fans in USA regulations use the term Large Diameter Ceiling Fan (LDCF)
    - Used interchangeably in this presentation

For USA Regulations: New Metric for U.S. LDCF Efficiency Regulations

- Ceiling Fan Energy Index (CFEI)
  - Calculated at two speeds – 100% and 40% of max RPM
  - Intended primarily as a regulatory metric
  - Engineers would still use conventional parameters for sizing/selecting
    - CFEI could help compare relative energy performance
  - Removes penalty for high utility (airflow) products
  - More difficult to "game" than cfm/W metrics
  - Very similar to AMCA 208's FEI, except different constants
  - Not covered in today's presentation – AMCA can cover this in a future webinar

Standards and Performance Ratings

- Test standard for performance rating:

  ANSI/AMCA 230-23, *Laboratory Methods of Testing Air Circulating Fans for Rating and Certification*

  – Useful for manufacturers performing tests

  – Useful for regulators needing to specify a test procedure as part of a code/regulation requirement

    - Building codes
    - Product regulations

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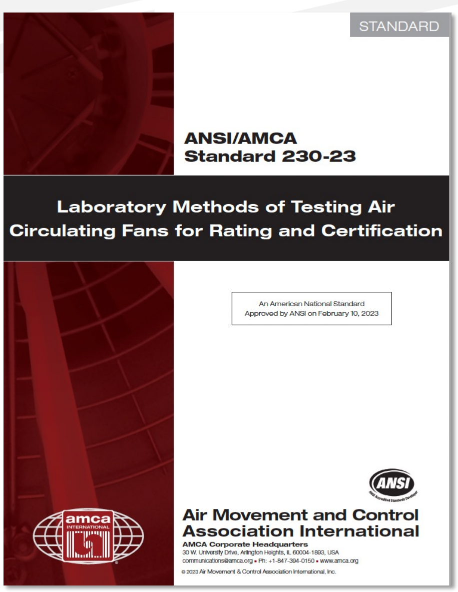
53

Standards and Performance Ratings



Available for purchase at
www.amca.org/store

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54

Standards and Performance Ratings

- AMCA 230 had problems in early editions, which has led to confusing ratings in the market because ratings to old standards persist, especially outside USA
  - Newer ratings will have corrected airflow ratings by a factor of approximately square-root of two (old airflows are about 40% over-rated)
  - Engineers need to be wary of manufacturer ratings for HVLS fans -- what version of AMCA 230 did they use?

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55

How to Check HVLS Ratings

Equations to check published ratings for thrust and overall efficiency!

Input/Published Data:

- Fan Diameter (ft)
- Fan Airflow (ft^3/min)
- Input Power (W)
- Fan Weight (lb)

Input Data = Published by fan manufacturer

Discharge Area = Pi x (Fan Diameter / 2)^2

Thrust = (Airflow / 340.3)^2 x Std Air Density / Discharge Area

Output Air Power = 3.845 x √(Thrust^3 / (Area x Std Air Density))

Overall Efficiency = Output Power / Input Power

Calculated Data:

- Discharge Area (ft^2)
- Thrust (lb-f)
- Output Air Power (W)
- Overall Efficiency (%)

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56

How to Check HVLS Ratings

Step 1

- Is the calculated thrust greater than the fan weight?
  - Yes - Published data is false. (Fan is a helicopter)
  - No - Published data might be true, move to step 2.

Step 2

- Compare calculated efficiency to ranges below:
  - Possible < 50%
  - Highly Unlikely ≥ 50% and ≤ 60%
  - Nearly Impossible > 60% and < 100%
  - Impossible ≥ 100%

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57

Why and How to Specify AMCA-Certified HVLS Fans

- AMCA Certified Ratings Program certifies product ratings
  - Including large diameter ceiling fans (HVLS)
- Product certification status
  - 6 licensees (companies)
  - 15 certified product lines
  - More HVLS fans are in the process of becoming certified
  - Most are USA-based companies
- Find certified products at www.amca.org/certify
- Outside USA, compare HVLS ratings to ratings of AMCA-certified products – results should not be way out of proportion

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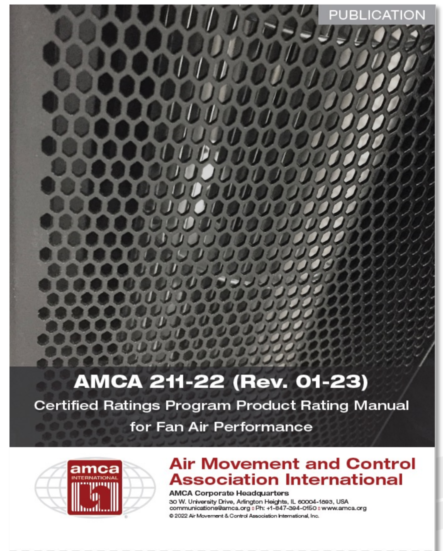
58

How to Know Fan is AMCA-Certified?

- Licensee must obtain license from AMCA to use CRP seal
  - Follow procedures;
  - Agree to binding agreement to follow rules after obtaining license
- AMCA CRP seal shall be placed in catalogs, and in software outputs
- Licensee *optionally* may affix AMCA CRP seal on certified product



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59

How to Know Fan is AMCA-Certified?

- Certified products have this information in catalogs:

ABC Company certifies that the model XXXX shown herein is licensed to bear the AMCA Seal. The ratings shown are based on tests and procedures performed in accordance with AMCA Publication 211 and comply with the requirements of the AMCA Certified Ratings Program. The AMCA Certified Ratings Seals applies to air performance ratings only. The AMCA Certified Ratings Seal applies at free delivery only. Performance ratings do not include the effects of appurtenances (accessories).

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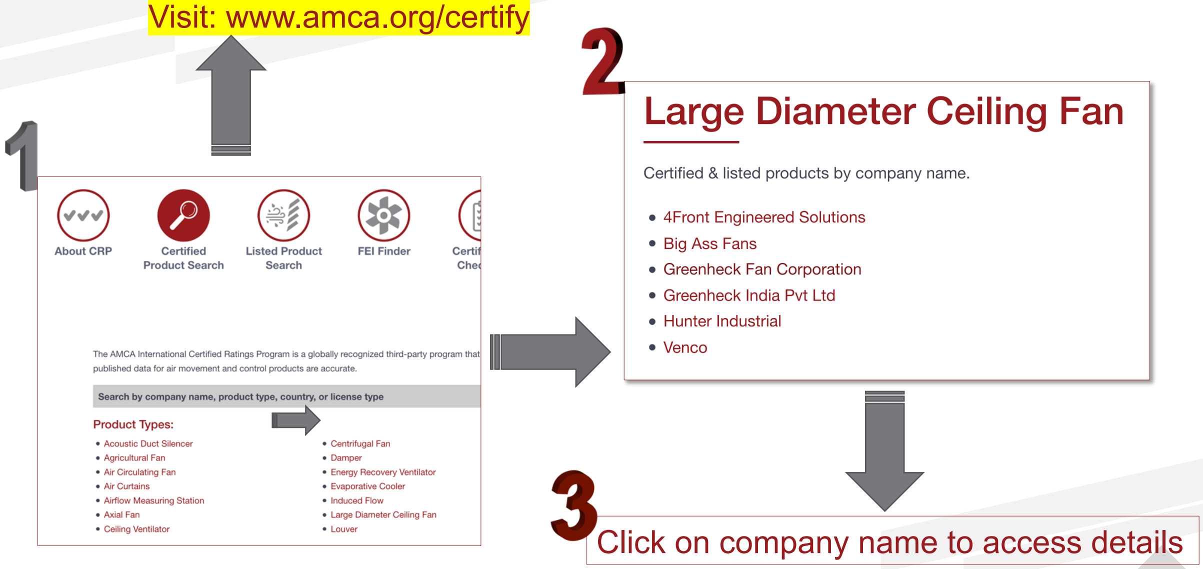
60

Find Certified Ratings at AMCA CRP Database

Visit: www.amca.org/certify



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61

Suggested Reading and Resources

- AMCA International
  - www.amca.org
- AMCA Certified Ratings Program
  - www.amca.org/certify
- AMCA Large-Diameter Ceiling Fan (HVLS) Web Page
  - www.amca.org/ldcf
- AMCA Publications & Standards
  - www.amca.org/store
- National Institute for Occupational Safety and Health; 2009. Environmental control of tuberculosis: basic upper-room ultraviolet germicidal irradiation guidelines for healthcare settings
  - https://www.cdc.gov/niosh/docs/2009-105/pdfs/2009-105.pdf?id=10.26616/NIOSHPUB2009105
- Center for the Built Environment Thermal Comfort Tool (and heat stress analyzer)
  - https://comfort.cbe.berkeley.edu/fan_heatwaves

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62

THANK YOU! QUESTIONS?

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63

Today's Speakers Ready for Questions…

Mr. Pallab Kar
Greenheck India Private Ltd.

Mr. Christian Taber
Big Ass Fans

Mr. Aaron Gunzner, PE
AMCA International

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64

BONUS SLIDES

65

History of Problems with AMCA 230

Claim: *"Ratings based on AMCA 230 Test Standard."* --- But which edition???

Year	Thrust	Volumetric Flow Rate	Input Power
1999	**Incorrect—**No conversion for density	**Incorrect—**based on actual atmospheric density, but calculation exaggerated by multiplication factor of 1.414 (√2)	**Incorrect—**No conversion for density
2007	**Correct–**Conversion to standard air density	**Not calculated**	**Incorrect—**No conversion for density
2012	**Correct–**Conversion to standard air density	**Incorrect—**uses converted thrust, but actual atmospheric density	**Incorrect—**No conversion for density
2015	**Correct–**Conversion to standard air density	**Correct—**uses converted thrust and standard air density	**Incorrect—**No conversion for density
2015: 2021 erratum	**Correct–**Conversion to standard air density	**Correct—**uses converted thrust and standard air density	**Correct**
2023	**Correct–**Conversion to standard air density	**Correct—**uses converted thrust and standard air density	**Correct**

66

AMCA 230-99 – that's the big error…

9.4 AIRFLOW RATE. Airflow rate shall be calculated according to the following:

$$Q = \sqrt{\frac{2AF_t}{\rho_o}}$$ Eq.9.5 SI

$$Q = 60\sqrt{2}\sqrt{32.174}\sqrt{\frac{AF_t}{\rho_o}}$$ Eq.9.5 I-P

Where: (definitions)

Q = Fan Airflow rate, m^3/s (cfm)
A = $\pi(D/2)^2$, m^2 (ft^2)
F_t= Force due to thrust, Newtons (pounds)
ρ_o = density of atmospheric air, kg/m^3 (lb_m/ft^3)

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67