Basics of Fan Energy Index (FEI) and how it promotes energy conservation and efficiency in fan system design

AMCA ASIA INSITE SEMINAR – DELHI, INDIA
28th March 2025

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CK So – Director of Regional Affairs, AMCA Asia

- Joined AMCA Asia 2023
- Leading AMCA Asia advocacy activities in Asia
- AMCA International Board of Director in 2016-2018
- Involved in air movement industry since 2000



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Outline

- FEI Basics and its benefits
- How FEI saves energy
- FEI in Constant Speed Applications
- FEI in Variable Air Volume (VAV) Systems
- Why and How to Specify AMCA-Certified FEI Ratings
- AMCA Resources for FEI

FAN ENERGY INDEX BASICS

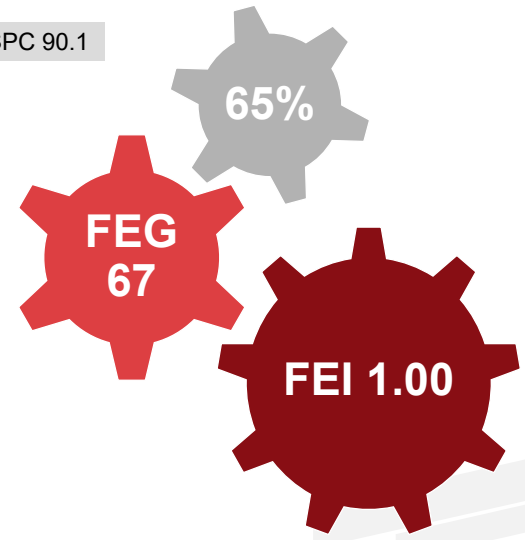
Abridged History of Fan Efficiency Metrics

~2007: ASHRAE TC 5.1, SSPC 90.1

2010: ISO and AMCA standards
2013: ASHRAE 90.1
2015: International Energy Conservation Code (IECC)

Note: Sizing window is 15 percentage points of peak total efficiency

2015: U.S. DOE Public Negotiations
2019: ASHRAE Standard 90.1
2021: IECC
2022: California Title 20 Regulation
2023: DOE Test Procedure

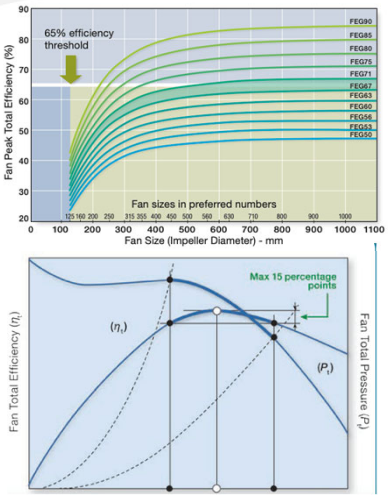


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What Happened to Fan Efficiency Grade?

- FEG being replaced by FEI as design metric



Fan Size (mm)	Fan Speed (rpm)	Fan Power (kW)	Actual Total Efficiency (%)	FEG
460	3,238	8.8	40.1	85
510	2,561	7.2	49.5	85
560	1,983	6.0	59.0	85
610	1,579	5.0	69.1	85
685	1,289	4.6	75.8	85
770	1,033	4.3	82.5	85
920	778	4.5	78.7	85

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Problems with FEG that Led to FEI

- Not wire-to-air
  - No inclusion of motors, transmission, speed controllers
- Peak total efficiency only
- Requires a selection window applied by designers
  - Selection window not documented on fan;
  - Hard to carry through project phases
  - Difficult to enforce by code officials
- FEG ratings misleading
  - Substantially overstates efficiencies in the smaller sizes

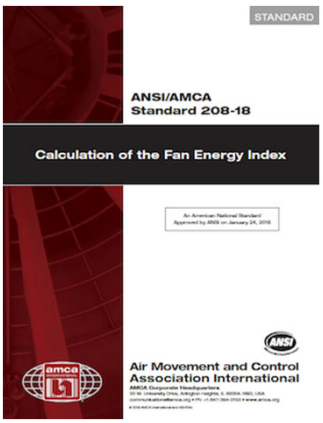
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FEI – Fan Energy Index

- Defined in AMCA 208 / ISO 12759 Part 6 (*Calculation of the Fan Energy Index*):

$$FEI = \frac{Reference\ Fan\ Electrical\ Input\ Power\ (FEP_{ref})}{Actual\ Fan\ Electrical\ Input\ Power\ (FEP)}$$

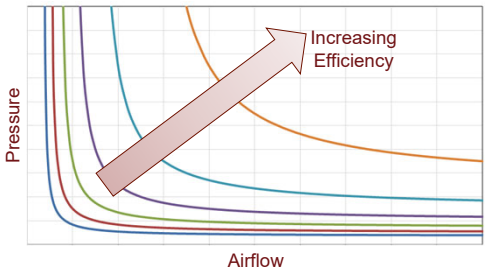
- FEP_{ref} and FEP calculated at the same airflow and pressure
- FEI is a relative measure of power required for a given duty point – relative to the *Reference Fan*



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The Reference Fan (Because Everyone Always Asks…)

- Think of the Reference fan as a "Reasonably Efficient Fan"…
  - Documented in AMCA 208-18 / ISO12759 Part 6
  - Empirical function of fan efficiency vs. airflow and pressure is independent of:
    - Fan type
    - Fan size
    - Motor type
    - Belt or direct drive
  - Fixed in time – cannot EVER change the reference fan because this would make all previous FEI ratings incomparable



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The Reference Fan (Because Everyone Always Asks…)

- Think of the Reference fan as a *"Reasonably Efficient Fan"…*
  - Non-specific fan type, but can deliver required airflow and pressure at specified shaft-input power
  - V-Belt transmission
  - No speed control
  - 4-Pole, 60-Hz IE3 motor

$FEI = \frac{(FEP_{ref})}{(FEP)}$ *FEI > 1 means the fan consumes less power than the reference fan at the given operating point*

$$FEP_{ref,\,i} = H_{i,\,ref}\left(\frac{1}{\eta trans,ref}\right)\left(\frac{1}{\eta mtr,ref}\right)\left(\frac{1}{\eta ctrl,ref}\right)$$

$$\eta_{tras,\,ref} = 0.96\left(\frac{H_{i\,ref}}{H_{i,\,ref}+1.64}\right)^{.05}$$

$$\eta_{mtr,\,ref} = A.[log_{10}(H_{t,\,ref})]^4 + \mathrm{B}.[log_{10}(H_{t,\,ref})]^3 + C.[log_{10}(H_{t,\,ref})]^2 + D.[log_{10}(H_{t,\,ref})]^1 + E$$

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FEI Advantages

- Wire-to-air – includes fan, transmission, motor, speed control
- Considers off-peak fan efficiency
- Static or total pressure, as appropriate
- Applicable to commercial and industrial fans testable to:
  - Most commercial and industrial fans – AMCA 210 / ISO 5801
  - Circulating fans – AMCA 230
  - Jet fans – AMCA 250 / ISO 13350
  - Induced flow lab-exhaust fans – AMCA 260
- Off-peak performance – where fans are much more often operated

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Benefits of FEI

- Clarity
  - FEI includes effect of losses from fans, motors, and drives
  - FEI rating allows instant identification of compliance
- Flexibility
  - Fan selections allow variety of fan types, sizes, motors, and drives
  - Facilitates consideration of budget, acoustics, form factor, etc.
- Simplicity
  - Intuitive metric that directly reflects power consumed by the fan
- Greater energy savings
  - Net result is greater energy savings and lower lifecycle cost

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HOW FEI SAVES ENERGY

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How FEI Saves Energy

- FEI “right-sizes” fans
- Fan efficiency is highly dependent on where the fan is operating on the fan curve.
- Fans are typically selected to provide airflow at a designated duty point.
  - Airflow
  - Pressure
  - Air Density (sea level vs. high elevation)

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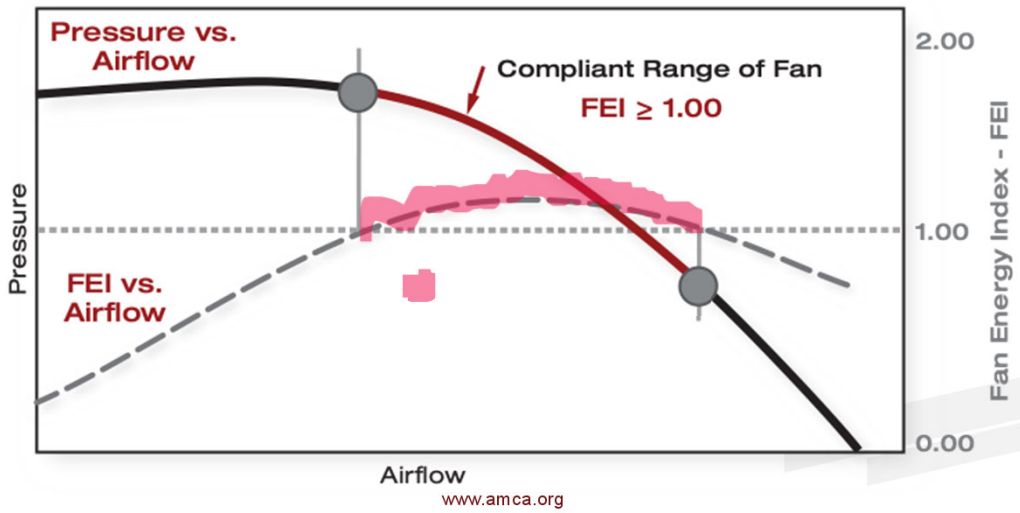
How FEI Saves Energy

- FEI is calculated at a duty point the engineer decides is most meaningful
  - Maximum airflow ever expected, or,
  - Where fan operates high percentage of time
- Unless FEI minimum required by code or regulation, engineer selects the FEI level most appropriate for a project
  - Can vary with fan and application for same project
  - FEI usually set higher for centrifugal fans compared to axial
  - Higher pressure fans have higher FEI levels

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FEI Defines Compliant Range for Selection

Example: Requirement is for FEI ≥ 1.00



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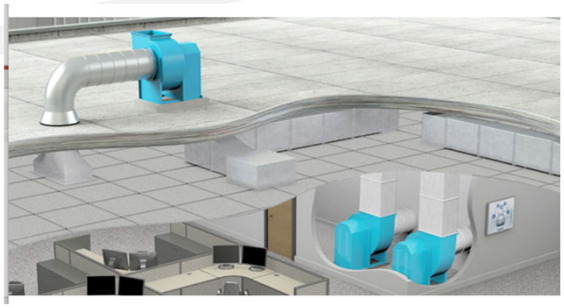
FEI Improves Fan Selections

- Enables comparisons of:
  - Different fan types
  - Different impeller configurations and sizes
  - Different motor and drive combinations

- All at the same design duty point!
- This is what gives engineers a lot of flexibility
- Use manufacturer software to run alternative models and configurations

Example – Stand Alone Fan

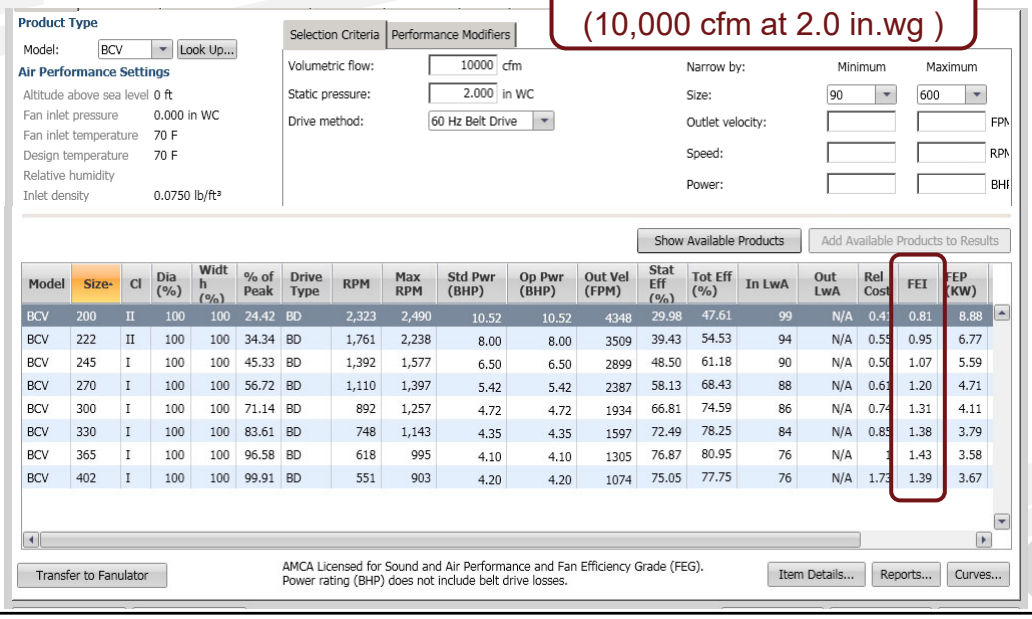
Utility set:



- 4.72 m^3/s (10,000 cfm)
- 500 Pa (2.0 in.wg) static pressure
- Sea level (standard atmospheric pressure)

Utility Set

4.72 m³/s at 500 Pa static
(10,000 cfm at 2.0 in.wg)



Product Type
Model: BCV Look Up...
Air Performance Settings
Altitude above sea level 0 ft
Fan inlet pressure 0.000 in WC
Fan inlet temperature 70 F
Design temperature 70 F
Relative humidity
Inlet density 0.0750 lb/ft³

Selection Criteria | Performance Modifiers
Volumetric flow: 10000 cfm
Static pressure: 2.000 in WC
Drive method: 60 Hz Belt Drive
Narrow by: Minimum Maximum
Size: 90 600
Outlet velocity:
Speed:
Power:

Show Available Products | Add Available Products to Results

Model	Size	Cl	Dia (%)	Width (%)	% of Peak	Drive Type	RPM	Max RPM	Std Pwr (BHP)	Op Pwr (BHP)	Out Vel (FPM)	Stat Eff (%)	Tot Eff (%)	In LwA	Out LwA	Rel Cost	FEI	FEP (KW)
BCV	200	II	100	100	24.42	BD	2,323	2,490	10.52	10.52	4348	29.98	47.61	99	N/A	0.41	0.81	8.88
BCV	222	II	100	100	34.34	BD	1,761	2,238	8.00	8.00	3509	39.43	54.53	94	N/A	0.55	0.95	6.77
BCV	245	I	100	100	45.33	BD	1,392	1,577	6.50	6.50	2899	48.50	61.18	90	N/A	0.50	1.07	5.59
BCV	270	I	100	100	56.72	BD	1,110	1,397	5.42	5.42	2387	58.13	68.43	88	N/A	0.61	1.20	4.71
BCV	300	I	100	100	71.14	BD	892	1,257	4.72	4.72	1934	66.81	74.59	86	N/A	0.74	1.31	4.11
BCV	330	I	100	100	83.61	BD	748	1,143	4.35	4.35	1597	72.49	78.25	84	N/A	0.85	1.38	3.79
BCV	365	I	100	100	96.58	BD	618	995	4.10	4.10	1305	76.87	80.95	76	N/A	1	1.43	3.58
BCV	402	I	100	100	99.91	BD	551	903	4.20	4.20	1074	75.05	77.75	76	N/A	1.73	1.39	3.67

Transfer to Fanulator
AMCA Licensed for Sound and Air Performance and Fan Efficiency Grade (FEG).
Power rating (BHP) does not include belt drive losses.
Item Details... Reports... Curves...

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Zooming in…



Show Available Products | Add Available Products to

Size	RPM	Max RPM	Std Pwr (BHP)	Op Pwr (BHP)	Out Vel (FPM)	Stat Eff (%)	Tot Eff (%)	In LwA	Out LwA	Rel Cost	FEI	FE (K
200	2,323	2,490	10.52	10.52	4348	29.9	47.61	99	N/A	0.41	0.81	
222	1,761	2,238	8.00	8.00	3509	39.4	54.53	94	N/A	0.55	0.95	
245	1,392	1,577	6.50	6.50	2899	48.5	61.18	90	N/A	0.50	1.07	
270	1,110	1,397	5.42	5.42	2387	58.1	68.43	88	N/A	0.61	1.20	
300	892	1,257	4.72	4.72	1934	66.8	74.59	86	N/A	0.74	1.31	
330	748	1,143	4.35	4.35	1597	72.4	78.25	84	N/A	0.85	1.38	
365	618	995	4.10	4.10	1305	76.8	80.95	76	N/A	1	1.43	
402	551	903	4.20	4.20	1074	75.0	77.75	76	N/A	1.73	1.39	

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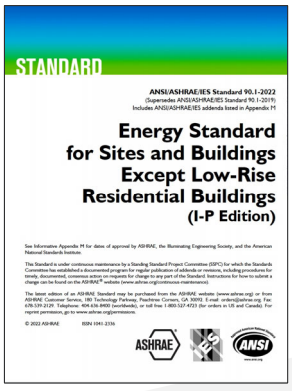
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APPLYING FEI IN CONSTANT SPEED AND VAV SYSTEMS

ASHRAE 90.1 Provides Guidance

- 2019 and later
- Useful even if not required

Each fan shall have a fan energy index (FEI) of 1.00 or higher at its highest design airflow rate. Each fan used for a variable-air-volume system that meets the requirements of Section 6.5.3.2.1 shall have an FEI of 0.95 or higher at its highest design airflow rate.



Sizing/Selection Example

- ASHRAE 90.1-2019:
  - FEI ≥ 1.00 at fan system design conditions (duty point)
  - FEI ≥ 0.95 for VAV

  - Air flow rate: 8.50 m3/s (18,000 cfm)
  - Air pressure (static): 1,350 pascal (5.4 in.wg)
  - Air density: Standard (sea level)

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Example Constant Flow

FEI ≥ 1.00

For constant flow, duty point is at 100% required airflow

Impeller diameter in (mm)	Fan Impeller Type (all double width)	FEI @ 100% Flow
18 (464)	Airfoil	0.90
20 (508)	Airfoil	1.05
22 (565)	Airfoil	1.13
24 (622)	Airfoil	1.23
27 (686)	Airfoil	1.21
18 (464)	Backward inclined	0.82
20 (508)	Backward inclined	0.93
22 (565)	Backward inclined	1.05
24 (622)	Backward inclined	1.16
27 (686)	Backward inclined	1.17

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Guidance for VAV Systems

- Because slowing a fan's rotational speed generally increases the FEI rating:
  - Best duty point for VAV is hottest day of year, needing 100% airflow.
  - Select fan to have an acceptable FEI rating at the 100% flow rate.
  - This will ensure fan is compliant at loads below 100% flow rate.
- If the fan meets the FEI requirement at the peak condition the fan likely to meet the FEI requirement at lower flow conditions.
- Use engineering discretion to determine operating point for FEI selection

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Example VAV

FEI ≥ 0.95

For VAV, hypothetical duty points are:
- 40% flow: 4.25 m^3/s (7,200 cfm)
- 70% flow: 5.95 m^3/s (12,800 cfm)
- 100% flow: 8.50 m^3/s (18,000 cfm)

Impeller diameter in (mm)	Fan Impeller Type (all double width)	FEI @ 40% Flow	FEI @ 70% Flow	FEI @ 100% Flow
18 (464)	Airfoil	1.05	0.89	0.90
20 (508)	Airfoil	1.17	1.06	1.05
22 (565)	Airfoil	1.21	1.15	1.13
24 (622)	Airfoil	1.24	1.25	1.23
27 (686)	Airfoil	1.20	1.23	1.21
16 (406)	Backward inclined	1.05	0.83	OVERSPEED
18 (464)	Backward inclined	1.02	0.90	0.82
20 (508)	Backward inclined	1.11	0.94	0.93
22 (565)	Backward inclined	1.21	1.12	1.05
24 (622)	Backward inclined	1.22	1.18	1.16
27 (686)	Backward inclined	1.19	1.20	1.17

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What is the right selection for this example?

- All fans with FEI ≥ 1.00 (CS) or 0.95 (VAV) are compliant
- Engineering discretion for other criteria leads to selection:
  - Form factor
  - Weight
  - Budget
  - Energy cost
  - Acoustics
  - Availability
  - Operating environment: industrial – mining – tunnel

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WHY AND HOW TO SPECIFY AMCA-CERTIFIED FEI RATINGS

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AMCA Certified FEI Ratings

- Comparing FEI ratings for many fan types, sizes, motor/drive combinations and fan configurations is complex
- AMCA certifies manufacturer software, not just fans
- Check for FEI certifications at www.amca.org/certify
- Most ratings found using manufacturer's sizing/selection software
- Download software from manufacturer website

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AMCA.org/certify "Product Search"

Certified Rating Program Product Search

The AMCA International Certified Ratings Program is a globally recognized third-party program that gives buyers, specifiers and users assurance that manufacturers published data for air movement and control products are accurate.

Search by company name or certification

Product Types:

- Acoustic Duct Silencer
- Agricultural Fan
- Air Circulating Fan
- Air Curtains
- Airflow Measuring Station
- Axial Fan
- Ceiling Ventilator
- Centrifugal Fan
- Damper
- Energy Recovery Ventilator
- Evaporative Cooler
- Induced Flow
- Large Diameter Ceiling Fan
- Louver
- Mixed Flow Fan
- Positive Pressure Ventilator
- Power Roof Ventilator
- Propeller Fan
- Single Room Air Handler
- Jet Fans

License Types:

- Air Performance
- Sound
- Air Leakage
- Water Penetration
- Wind Driven Rain
- CFM per Watt
- Efficiency
- FEG
- Positive Pressure Ventilator
- Airflow Measurement Station
- Acoustic Duct Silencer
- Induced Flow Fan
- Circulating Fan
- Wind Driven Sand
- FEI
- Energy Star
- Jet Fan

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Zooming in…

Shortcut: www.amca.org/find-FEI

Evaporative Cooler
Induced Flow
Large Diameter Ceiling Fan
Louver

- Propeller Fan
- Single Room Air Handler
- Jet Fans

Efficiency
FEG
Positive Pressure Ventilator
Airflow Measurement Station
Acoustic Duct Silencer
Induced Flow Fan

- Circulating Fan
- Wind Driven Sand
- FEI
- Energy Star
- Jet Fan

Partial List…

FEI

- Accurex, LLC
- Aerovent, A Twin City Fan Company
- Air Flow PVT. LTD.
- Dayton Electric Manufacturing Co.
- Delta Electronics, Inc.
- DongGuan Wolter Chemco Ventilation Ltd
- ebm-papst Inc.
- ebm-papst Motor (Shanghai) Co., Ltd
- Energy Industrial Company L.L.C.
- Enervex Inc.
- Greenheck Fan Corporation
- Greenheck Fan, S. de R.L. de C.V.
- Greenheck India Pvt Ltd
- INFINAIR ARABIA COMPANY LTD.
- Kruger Ventilation (Taiwan) Co., Ltd.
- Kruger Ventilation Industries (India) Private Limited
- Kruger Ventilation Industries Asia Co Ltd (KVA)
- Kruvent Industries (M) Sdn. Bhd.
- Larkin Industries, Inc.
- Loren Cook Company
- M.K. Plastics Corporation
- Maico Gulf LLC
- PennBarry
- Plasticair Inc.
- Swiss Rotors Sp. z o. o.
- Systemair GmbH
- Systemair India Pvt Ltd
- Systemair Sdn. Bhd.
- Twin City Fan Companies, Ltd

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FEI Certifications

- Worldwide manufacturers: 40
- Asia manufacturers: 18
-

amca WORLDWIDE CERTIFIED RATINGS
AIR PERFORMANCE
FEI FAN ENERGY INDEX
AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC.®

- Worldwide certified fan product lines: 745
- Asia certified product lines: 66

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How to Specify AMCA-Certified Fans

All (type) fans shall have a Fan Energy Index (FEI) rating greater than or equal to X and be certified to bear the AMCA Certified Ratings Program seal for air performance, sound performance, and Fan Energy Index.

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How to Specify AMCA-Certified Fans

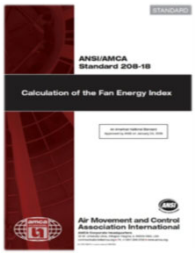
- Type: Generally inclusive of centrifugal, axial, and radial fans testable to AMCA 210 or ISO 5801
- X: The minimum FEI rating required by a code or regulation, or suitable for a project requirement.
- HOLD YOUR SPEC after submittals… beware substitutions.
- “Tested to … “ not the same, and test lab ideally a third-party laboratory

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Resources

- AMCA International: *www.amca.org*
- AMCA Certified ratings: *www.amca.org/certify*
- *AMCA Certified FEI ratings: www.amca.org/Find-FEI*
- AMCA Standard 208: *www.amca.org/store*

(Available for purchase)
(Free for AMCA members)



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THANK YOU!!

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