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Air System Engineering and Technology Conference - Europe

5 November 2019

How Fan Energy Index is Used in Regulations

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An Inside Guide to FEI for Regulators

- Fan Energy Index Primer
- FEI for Sizing and Selectin Fans
- AMCA and ISO Standards for FEI
- FEI in Energy Codes, Standards, & Regulations
- FEI Fine Points

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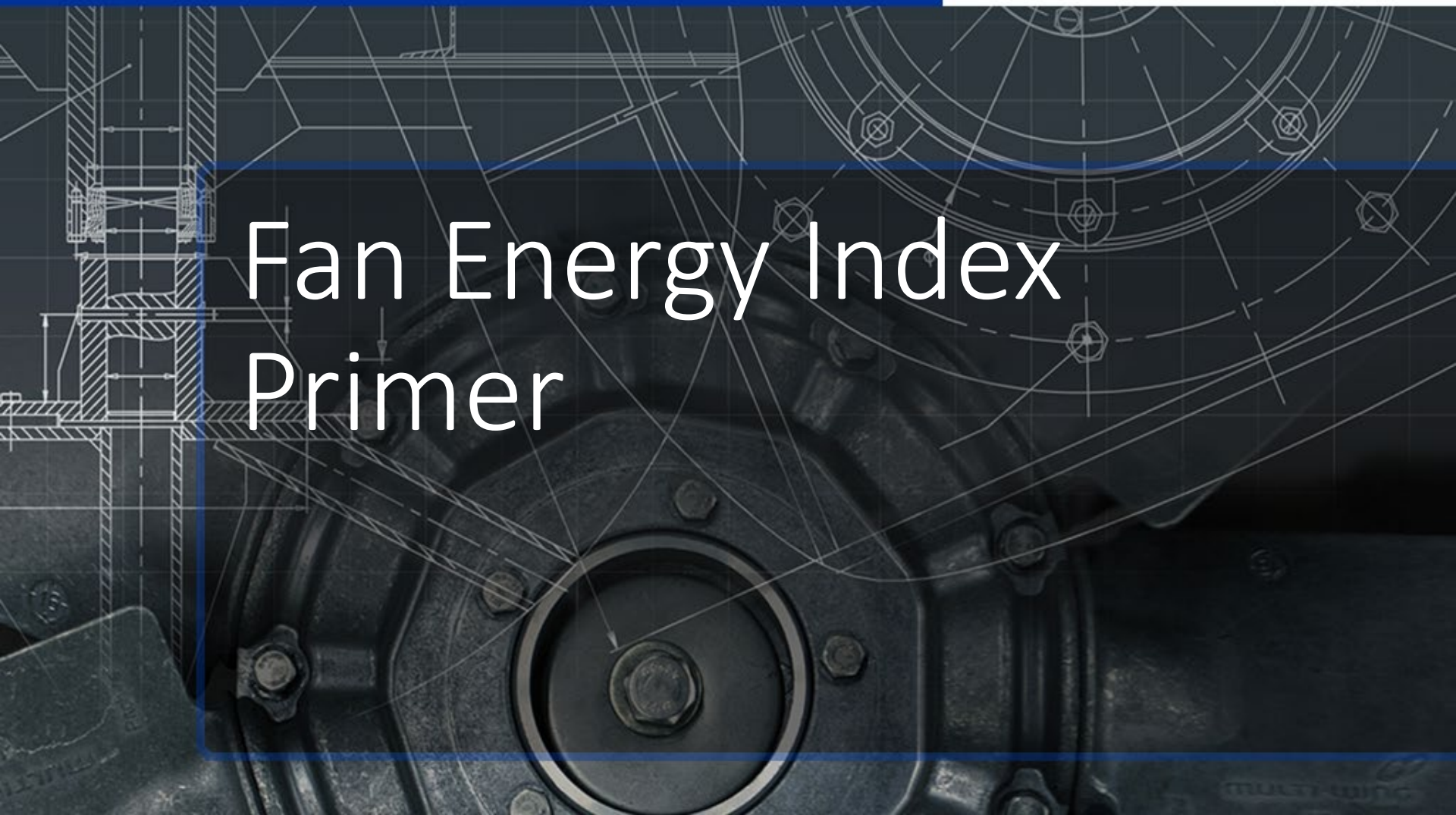


Fan Energy Index Primer

Fan Energy Index Primer

- Origin of FEI is from a USA federal regulation that has yet to finish
- Along the way, Fan Efficiency Grade proved untenable
  - Not wire-to-air
  - Peak total efficiency only
  - Needed a sizing/selection window applied by designers
  - Could not work with low-pressure fans, such as power-roof ventilators

Fan Energy Index Primer

- …and by the way, yes, DOE did consider FMEG
- Fan Motor Efficiency Grade (FMEG) also was untenable
  - Does not cover part-loads,
  - Reference the 2013 DOE “Framework Document” that laid out DOE’s early research and thinking

Fan Energy Index Primer

- Long story short, FEI was developed to cover:
  - Wire to air
  - Part-load conditions
  - Static and total pressure
  - Most fan types
  - Includes fans testable to:
    - Most commercial/industrial fans: AMCA 210/ISO 5801
    - Jet fans: AMCA 250 / ISO 13350
    - Induced flow fans: AMCA 260

Fan Energy Index is a Ratio

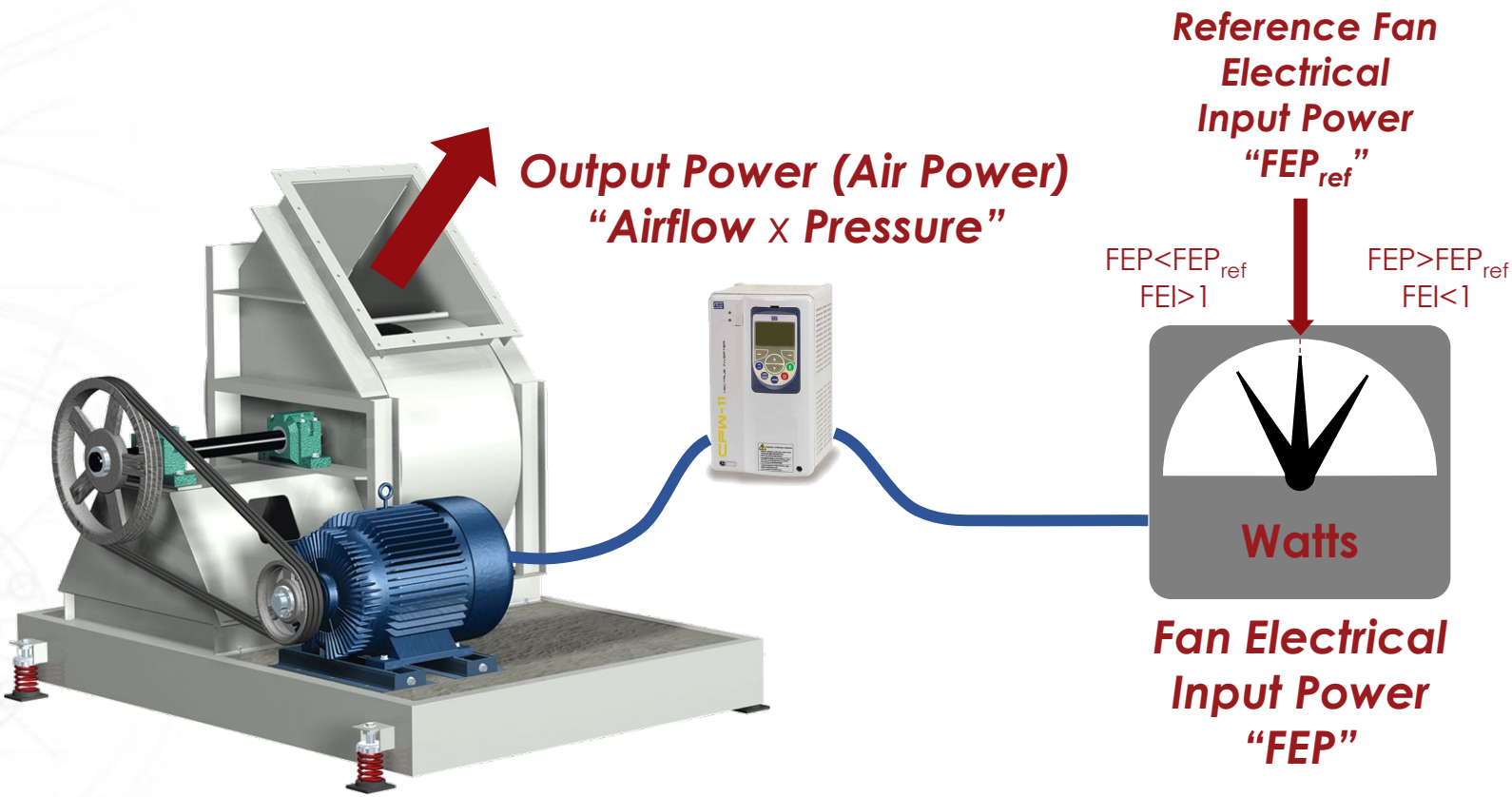
$$FEI = \frac{Reference\ Fan^{*}\ Electrical\ Input\ Power}{Actual\ Fan\ Electrical\ Input\ Power}$$

$$FEI = \frac{FEP_{ref}}{FEP_{actual}}$$

* Reference fan is defined in AMCA 208; more detail at end of presentation.

Wire-to-Air Metric

Wire-to-Air Metric



FEI – Fan Energy Index

$$FEI = \frac{Reference\ Fan^{*}\ Electrical\ Input\ Power}{Actual\ Fan\ Electrical\ Input\ Power}$$

$$FEI = \frac{FEP_{ref}}{FEP_{actual}}$$

- FEP_{ref} and FEP_{actual} calculated at the same output power (duty point)
- FEI is a relative measure of power required for a given duty point – relative to the *Reference Fan*

Fan Energy Index Primer

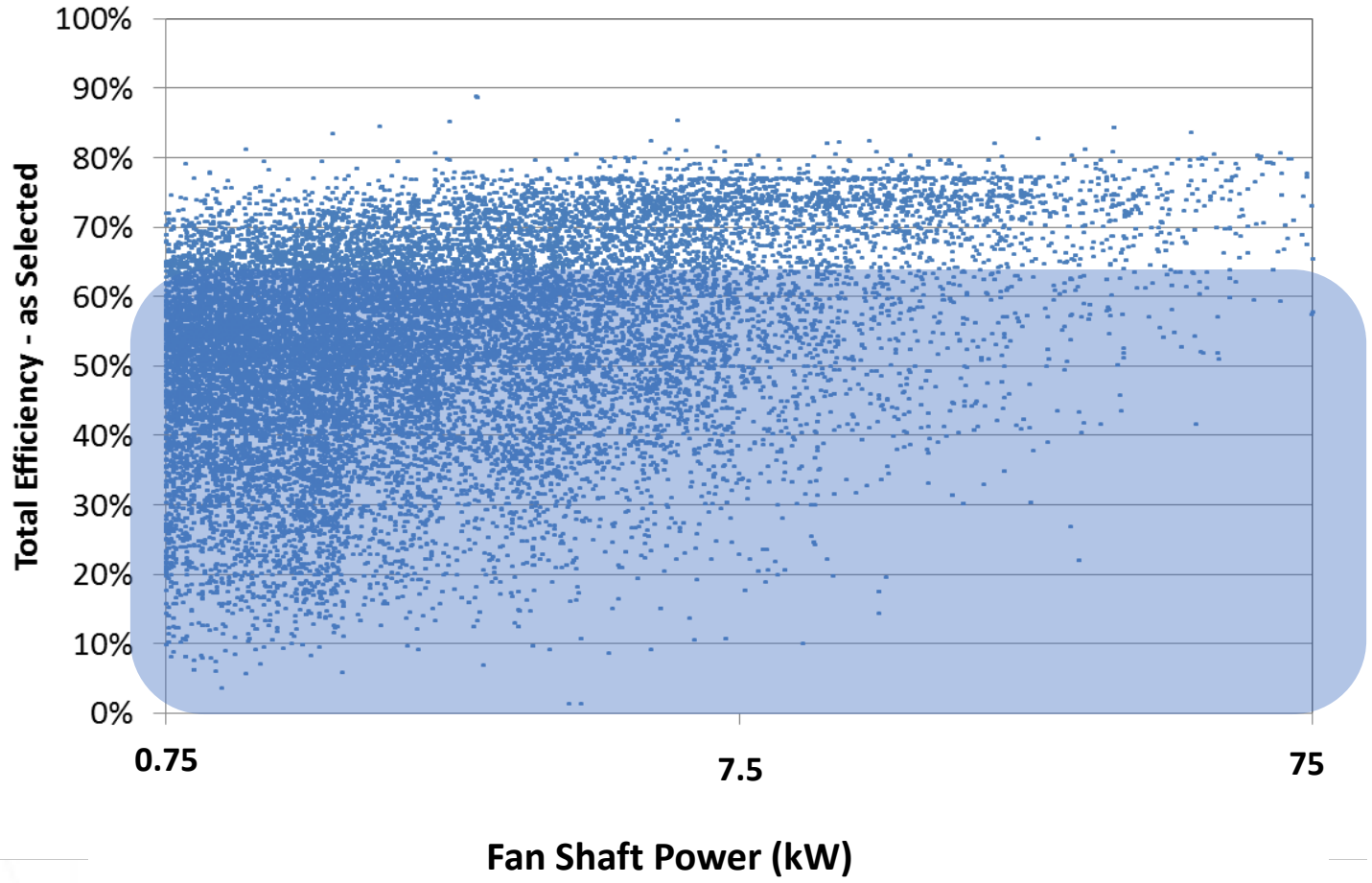
- FEI
  - Is a wire-to-air metric
  - Is a Electric-motor-driven-system metric
  - Covers part-loads
  - Is a rating for:
    - Most commercial/industrial fans: AMCA 210/ISO 5801
    - Jet fans: AMCA 250 / ISO 13350
    - Induced flow fans: AMCA 260
    - Large and small fans

Fan Energy Index Primer

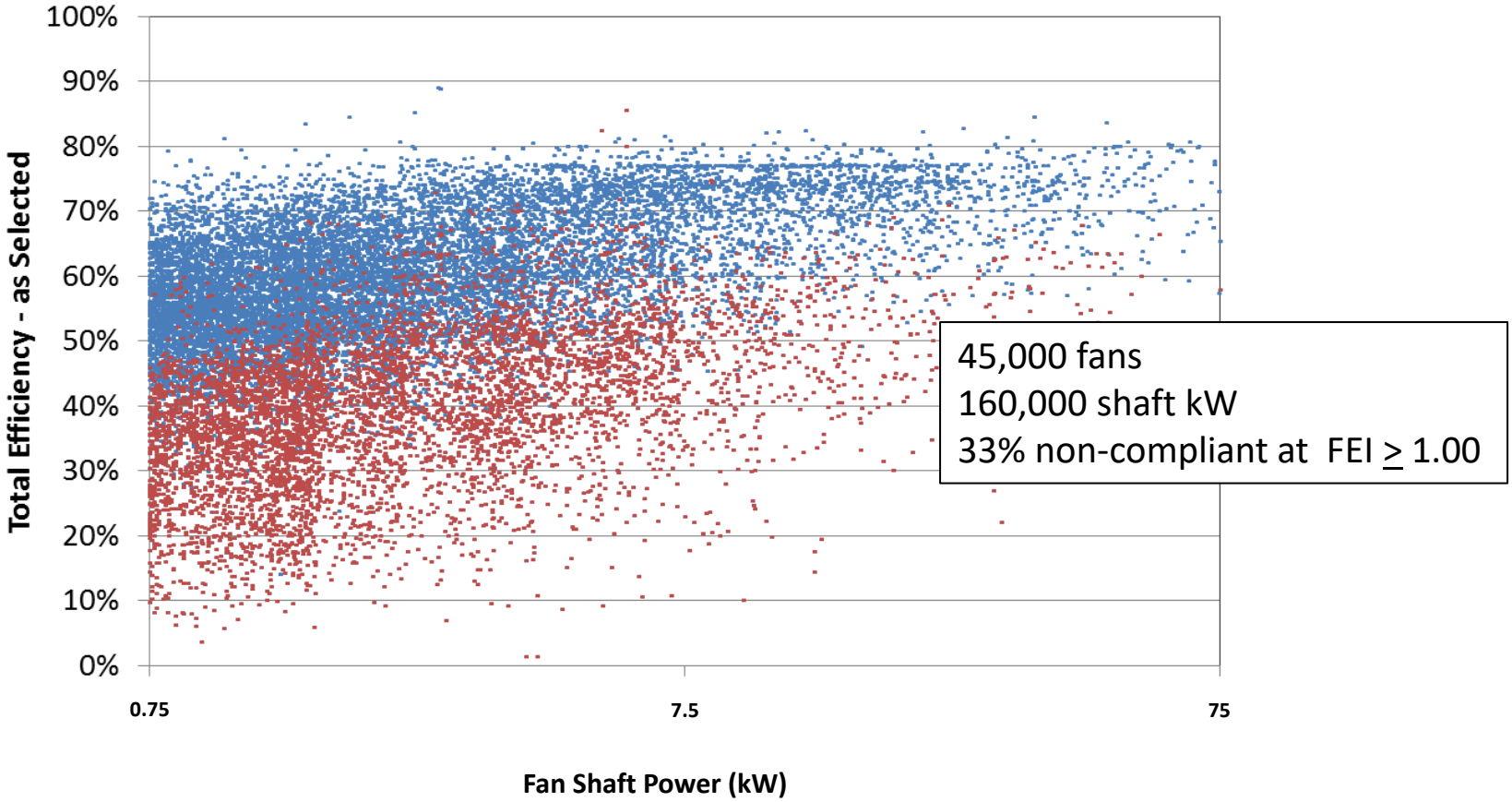
- FEI is an OPERATING POINT METRIC
  - Fan efficiency is highly dependent on where the fan is operating on the fan curve
  - Fans typically selected to provide airflow at a designated duty point
    - Airflow
    - Pressure
    - Air Density (sea level vs. high elevation)
  - Turns out, help is needed for selecting fans

Engineers Selections at Duty Point

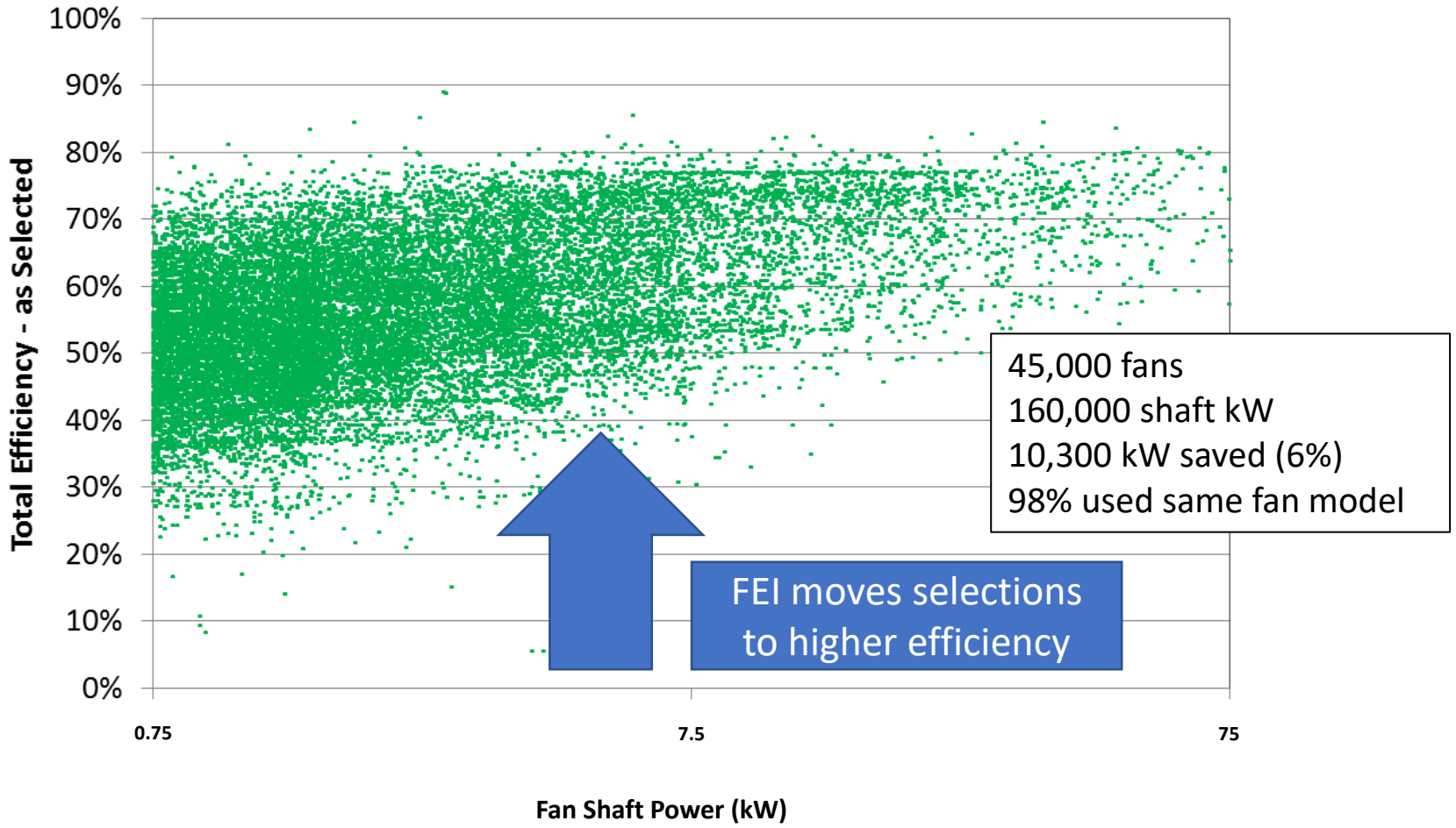
One Company's entire 2012 fan sales
45,000 fans, 160 kW



Selections Compliant FEI ≥ 1.00 (Blue) and Noncompliant FEI < 1.00 (Red)



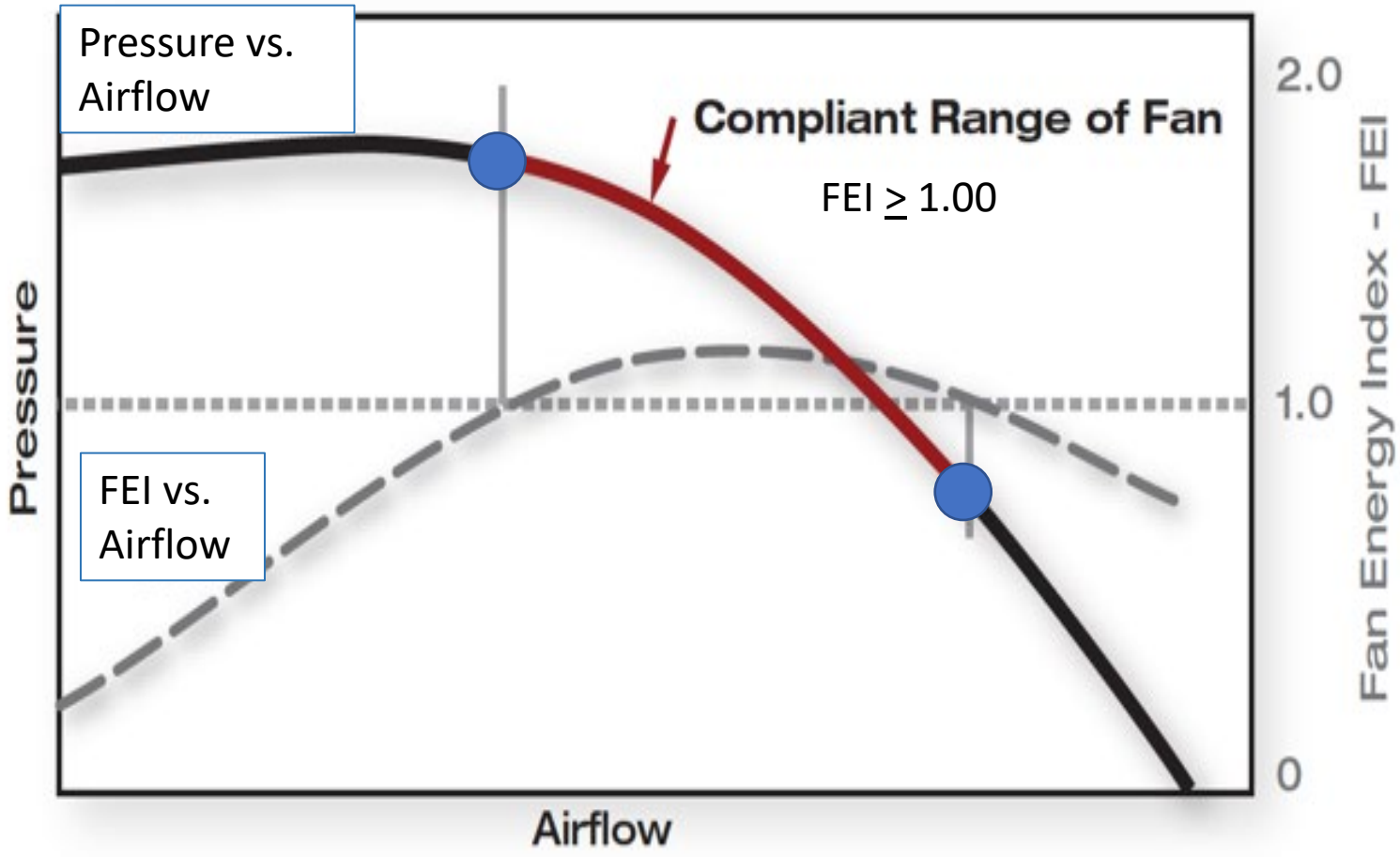
Revised Fan Selections – All compliant FEI ≥ 1.00



Fan Energy Index Primer

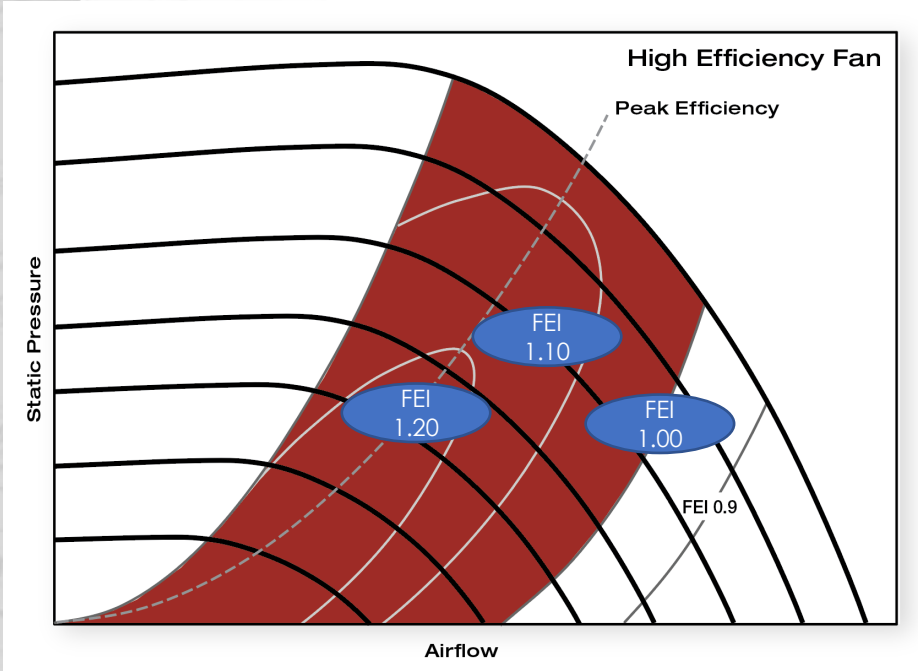
- FEI seeks to improve fan sizing and selection
- Enables comparisons of:
  - Different fan types
  - Different fan sizes
  - Different motor and drive combinations
- Given a statutory or design requirement and duty point, FEI defines “compliant ranges of operation”

FEI Range for Constant Speed Fan

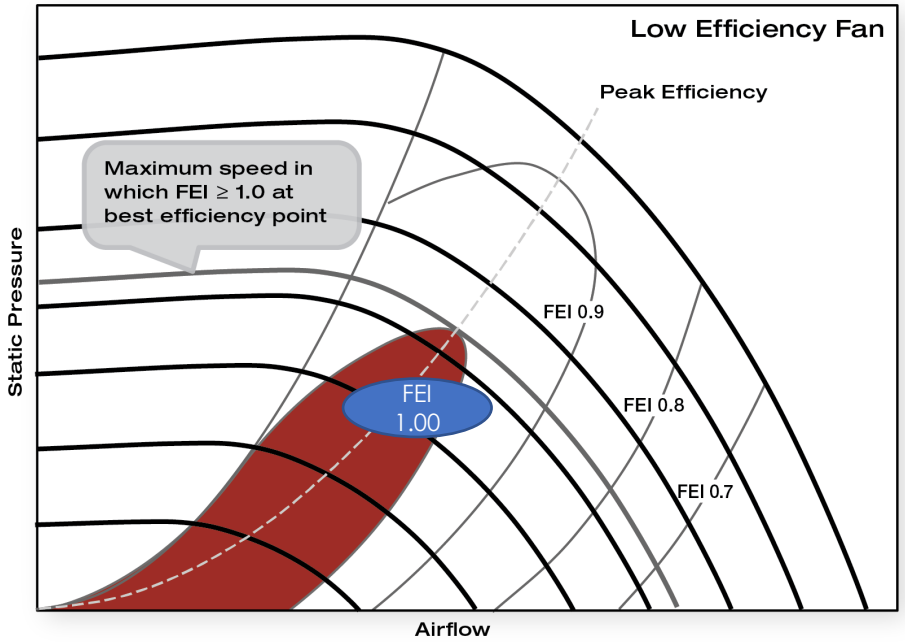


Compliant Range (FEI ≥ 1.00)

For variable fan speeds



EFFICIENT FAN



INEFFICIENT FAN

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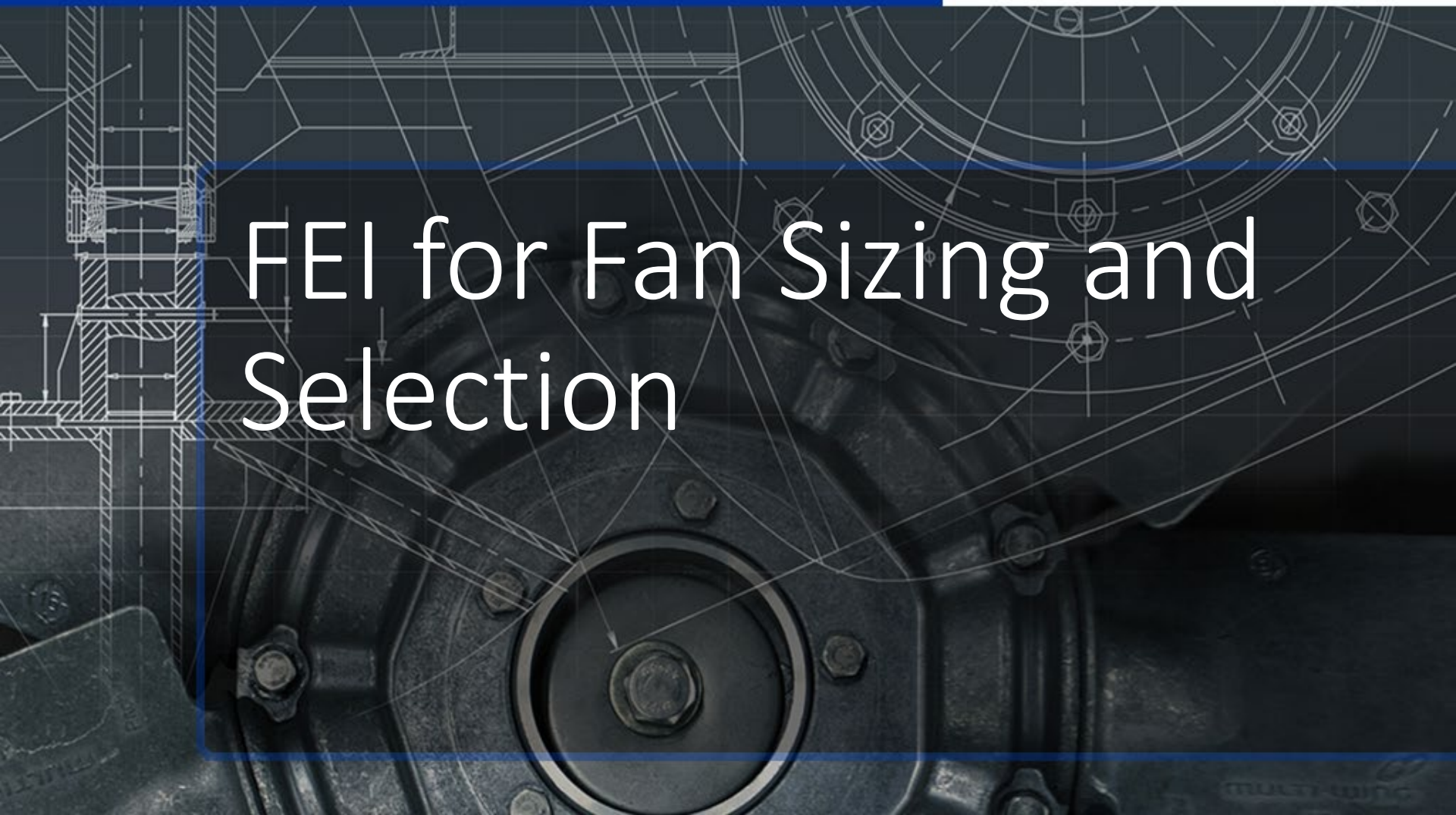


FEI for Fan Sizing and Selection

Compliant

Best

FEI in Sizing/Selection

Duty Point 10,000 cfm at 3-in-wg P_t (4.72 m^3/s at 750 Pa)

FEP_{ref} = 7.14 kw for all fan sizes

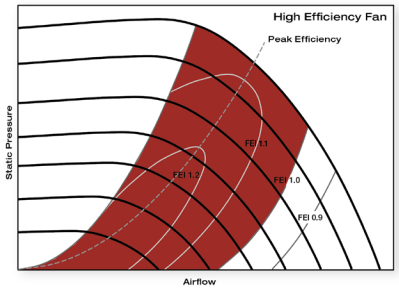
Size (mm)	Speed (rpm)	Power (kW)	Total Eff (%)	FEG	FMEG	FEI
460	3,238	8.8	40	85	62	0.67
510	2,561	7.2	50	85	62	0.83
560	1,983	6.0	59	85	62	0.99
610	1,579	5.0	69	85	62	1.16
685	1,289	4.6	76	85	63	1.28
770	1,033	4.3	83	85	66	1.39
920	778	4.5	79	85	67	1.32

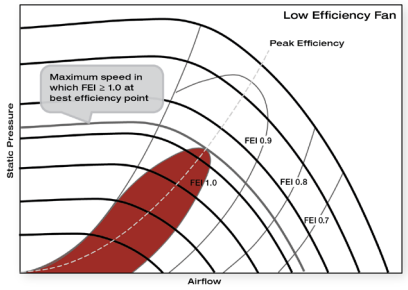
Comparison of Fan Selections – A vs. B

For a given duty point, $FEP_{ref}[A] = FEP_{ref}[B]$

$$FEI\ [A] = \frac{FEP_{ref}\ [A]}{FEP_{act}\ [A]}$$

$$FEI\ [B] = \frac{FEP_{ref}\ [B]}{FEP_{act}\ [B]}$$





- *Higher FEI means lower power consumed*
- *Larger bubble means less power consumed over wider operating range*
- *FEI advantage drives poorer performers from market*

Sizing/Selection Example:

- **FEI requirement is FEI ≥ 1.00 at engineer's selected duty point:**
  - **Air flow rate**: 18,000 cfm (8.50 m^3/s)
  - **Air pressure:** 5.4 in. w.g. (1,345 pascal)
  - **Air density:** standard (sea level)

  - For constant flow, duty point is at 100% flow
  - For VAV:
    - **40% flow:** 7,200 cfm (4.25 m^3/s)
    - **70% flow:** 12,800 cfm (5.95 m^3/s)
    - **100% flow:** 18,000 cfm (8.50 m^3/s)

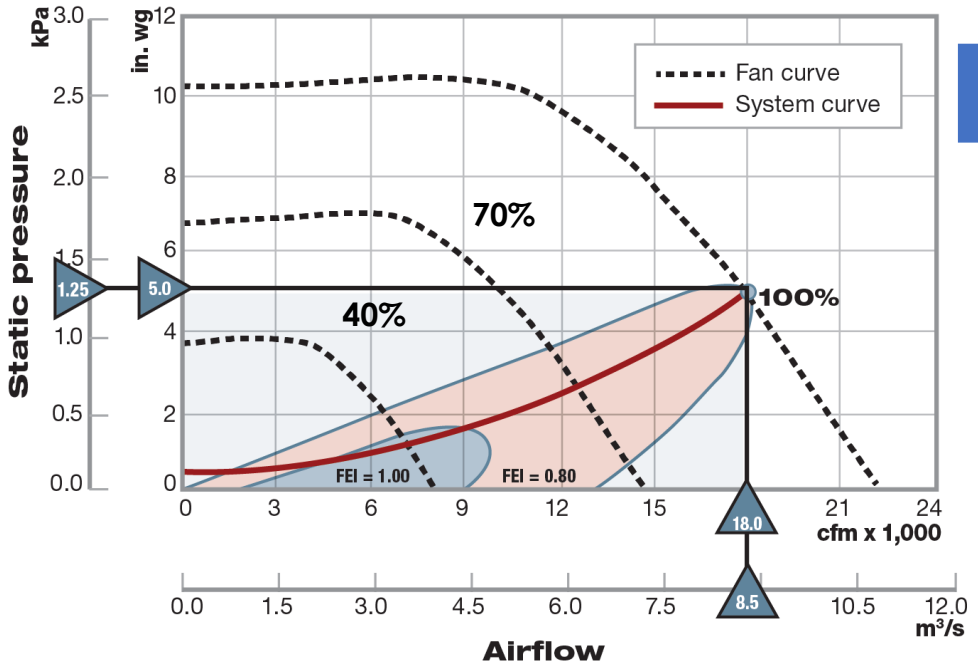
Example Constant Flow

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

Which Selection is Best?

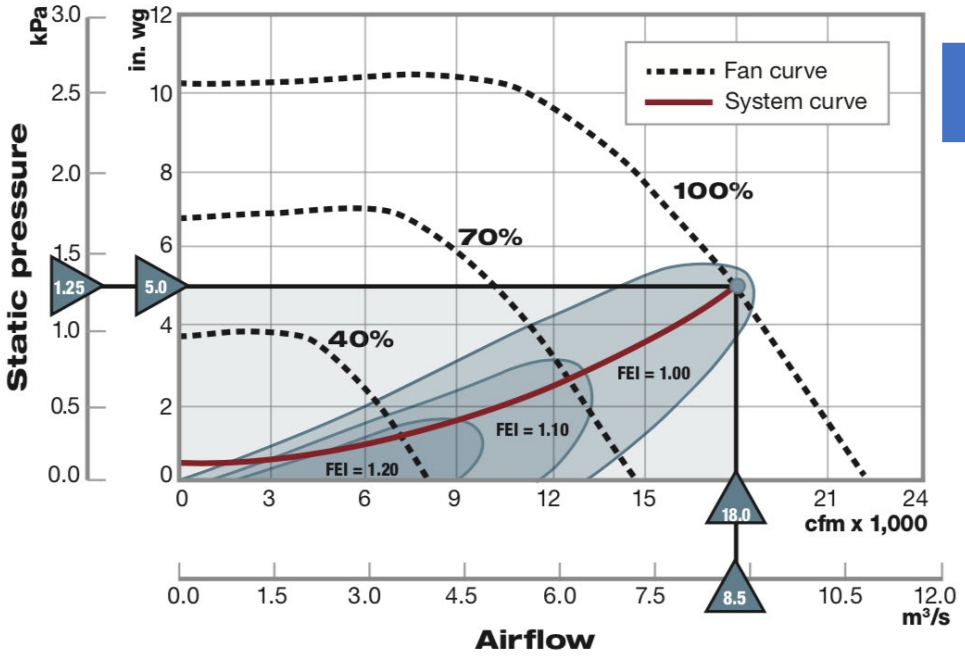
Impeller diameter in (mm)	Fan Impeller Type (all double width)	FEI @ 40% Flow	FEI @ 70% Flow	FEI @ 100% Flow
18 (464)	Airfoil	1.05	0.89	0.90
20 (508)	Airfoil	1.17	1.06	1.05
22 (565)	Airfoil	1.21	1.15	1.13
24 (622)	Airfoil	1.24	1.25	1.23
27 (686)	Airfoil	1.20	1.23	1.21
16 (406)	Backward inclined	1.05	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

464 mm Backward-Inclined Fan is Non-Compliant at 70% and 100% Flow



18 (464)	Backward inclined	40% 1.02	70% 0.90	100% 0.82

565-mm Backward Inclined Fan is Compliant at 40%, 70% and 100%



22 (565)	Backward inclined	40% 1.21	70% 1.05	100% 1.05

What is the right selection?

- All fans with FEI ≥ 1.00 are compliant
- Free to consider other decision criteria:
  - Form factor
  - Weight
  - Budget
  - Energy cost
  - Acoustics
  - Availability

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AMCA and ISO Standards for FEI

Testing and Rating Standards

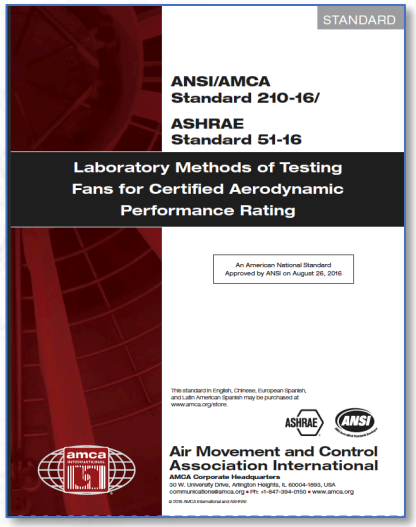
Rating Test Standard AMCA 210

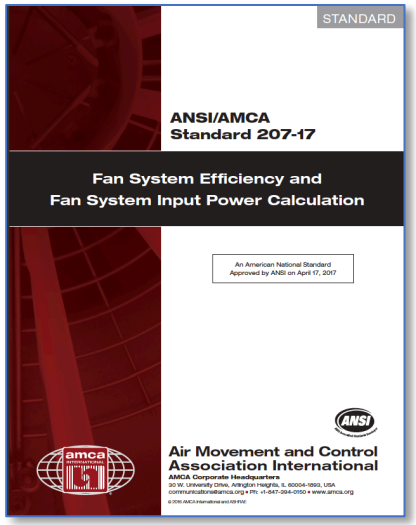
ISO 5801

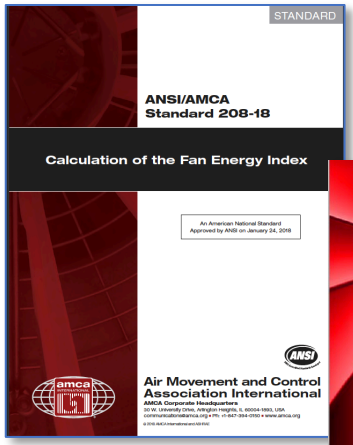
Part-load calculation for motors, VFDs, belts via AMCA 207

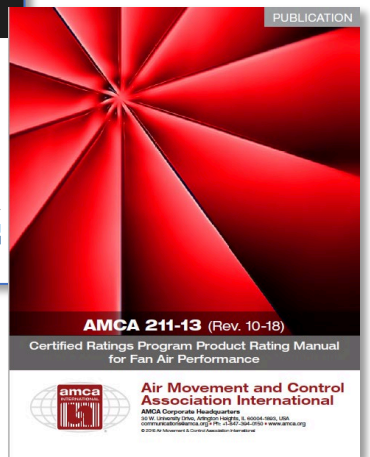
FEI calculated using AMCA 208

and AMCA 211









AMCA and ISO Standards for FEI

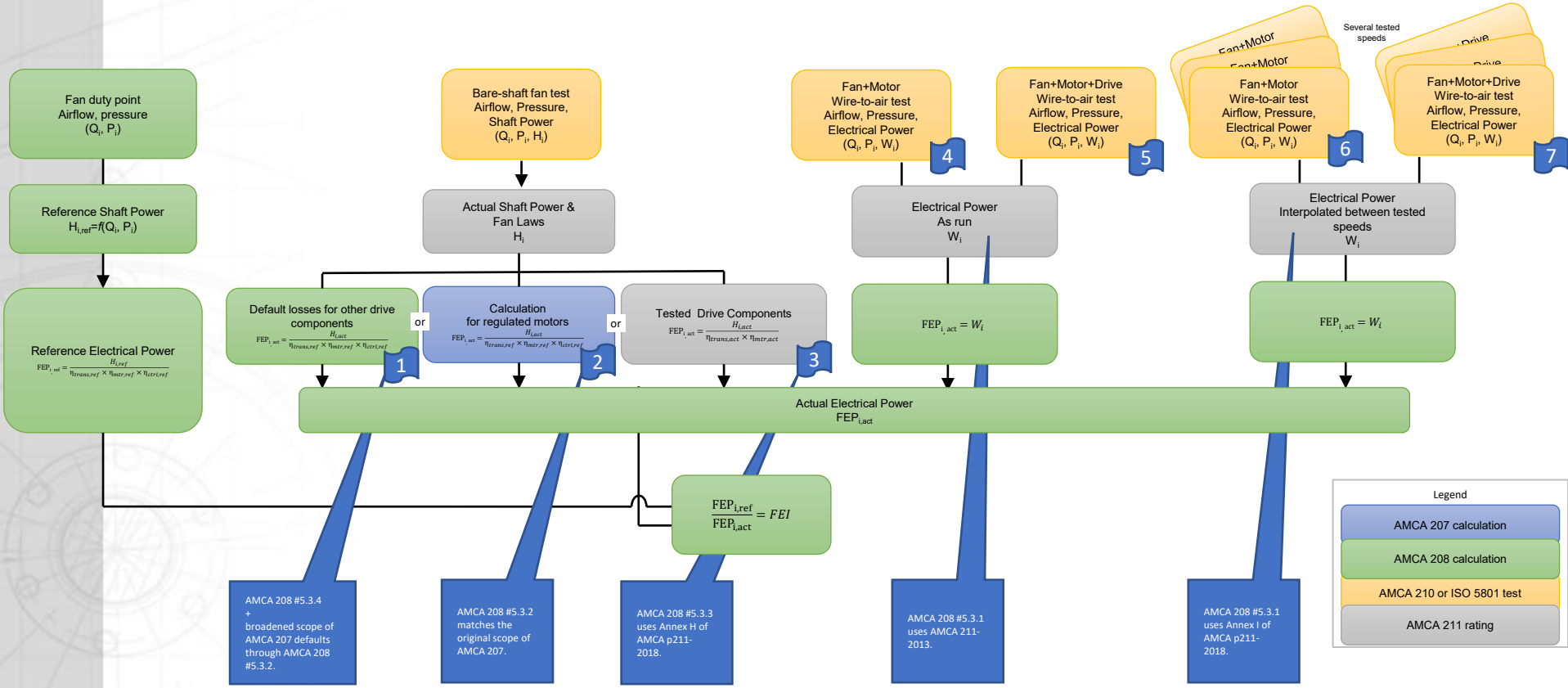
- AMCA 207-2017
  - ISO 12759-2-2019 (Standard Losses)
- AMCA 208-2018
  - ISO 12759-6 (In committee-draft phase)
- AMCA 210 = ISO 5801
- AMCA Publication 211 (Fan-rating certification)
  - No ISO equivalent

Manufacturer's Selection Software Will:

- …create selection regions or "bubbles" when given a required operating point
- …identify which portions of a fan curve are **compliant to a given FEI requirement (example. FEI $\geq$ 1.00)**

- Given the compliance results from the manufacturer software, engineers select the best option for project
  - Acoustics
  - Budget
  - Form Factor
  - Availability

Manufacturer and Regulator View:



AMCA and ISO Standards for FEI

- AMCA 214 is being developed to create a single source “test standard” for FEI ratings
  - References AMCA 210/ISO 5801
  - Merges relevant sections of AMCA 207, 208, 211
  - Resolves questions that emerged from the exercise
- AMCA 214 is still in an ANSI-compliant committee
  - Committee includes non-members representing energy efficiency organizations
  - Several members are also members of AHRI

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FEI in Codes, Standards and Regulations

FEI as a Regulatory Metric

- State Energy Codes adopt a model energy code or standard (IECC or ASHRAE 90.1)
  - States often update on 3-year cycles
  - Will take many years for FEI to replace FEG
- States can change model code/standard language
  - Without federal preemption, states can opt for FEG

FEI as a Regulatory Metric

- State efficiency regulations trump state energy codes
  - FEI is currently preferred by California
- Federal regulations trump state regulations
  - DOE has stalled fan regulation, so states taking lead

FEI in Codes, Standards & Regulations

- Model energy **standard** — ASHRAE 90.1 - 2019
- Model energy **code** — International Energy Conservation Code (IECC) - 2021
- Model high-performance building (green) building **standard/code** — ASHRAE 189.1 / Intl. Green Construction Code (IGCC) -2020
- **State** building energy **codes** — California Title 24; states that adopt ASHRAE 90.1 or IECC
- **Federal** efficiency **regulations** — U.S. Dept. of Energy
- **State** appliance **regulations** — California

DONE
NEARLY DONE
PROGRESSING
STALLED

Baseline ASHRAE 90.1 and IECC Language

- FEI ≥ 1.00 ; 0.95 for VAV, at engineer's selected duty point
- Covered
  - Standalone fans (including PRVs) ≥ 1.00 HP or ≥ 0.89 kW
  - Embedded fans and fan arrays > 5,0 HP or > 4.1 kW
- Exempt
  - Fans embedded in equipment that is regulated or 3rd party-certified for air performance or energy performance
  - Reversible tunnel ventilation fans
  - Fans for high temperatures, explosive atmospheres, high temperatures, or emergency conditions
  - Ceiling fans

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FEI Fine Points

Common Questions

- Reference fan
- Enforcing a operating point metric
- Where are the FEI ratings?

Reference Fan

(From AMCA 208)

For fans with a <u>ducted outlet</u>:

$$H_{i,\,ref} = \frac{(Q+0.12) \times (P_t+100)}{\eta_{t,ref}\,(66\%} \quad \text{SI}$$

For fans with a <u>non-ducted outlet</u>:

$$H_{i,ref} = \frac{(Q+0.12) \times (P_s+100)}{\eta_{s,ref}\,(60\%} \quad \text{SI}$$

Coefficients of 66% for ducted; 60% for non-ducted have meaning

Reference Fan

- The efficiency coefficients ensure required ducted fan efficiency is higher than for a non-ducted fan
- The reference fan is not a single fan, but conceptual fan based on:
  - Produces required airflow and pressure at specified shaft input power
  - Motor efficiency based on 4-pole, 60-Hz, IE3 motor
  - V-belt transmission
  - No speed control

Reference Fan

- The curves described by the coefficients are continuous
  - Accommodates product substitution
  - No arbitrary advantage of one product over another.
- The curves are shaped correctly.
  - Highest efficiency demands are placed on fans that are expected to create “intermediate” flows and pressures
  - Less demand on fans with either high-pressure/low-flow or high-flow/low-pressure requirements.

Reference Fan

- The flow coefficient creates a curve correlated to the FEG curves
  - AMCA did not want to stray too far from this already accepted metric.
  - This required an assumed a constant outlet velocity regardless of diameter (2000 fpm?).
- Coefficients ultimately negotiated and agreed upon by U.S. Department of Energy ASRAC Working Group of industry stakeholders and DOE in September 2015

Reference Fan

- Note to regulators:

DO NOT CHANGE REFERENCE FAN IN REGULATIONS

- Renders FEP and FEI values unique to regulation
- No consistency of FEP and FEI outside regulatory boundary
- Messes everything up
- Instead, adjust FEI higher or lower

Enforcing an Operating Point Metric

- California Title 20 regulation is making progress
- But every regulating entity will have their own rules
- AMCA petitioning DOE to complete “test procedure” regulation to stabilize metric definition and test procedure

AMCA Certified Ratings Program: FEI

- AMCA certifying fans and manufacturer software for FEI
  - 275 product lines thus far
- FEG certifications will continue
- Check for FEI certifications at www.amca.org/certify
  - Click on ”Certified Product Search” and search by “license type”
- Modifying selection software is complex

Benefits of FEI

Clarity

- FEI covers fans, motors, and drives --- "fan system" efficiency rating
- FEI rating allows instant identification of compliance

Flexibility

- Fan selections allow variety of fan types, sizes, motors, and drives
- Facilitates considerations for budget, acoustics, form factor, etc.

Simplicity

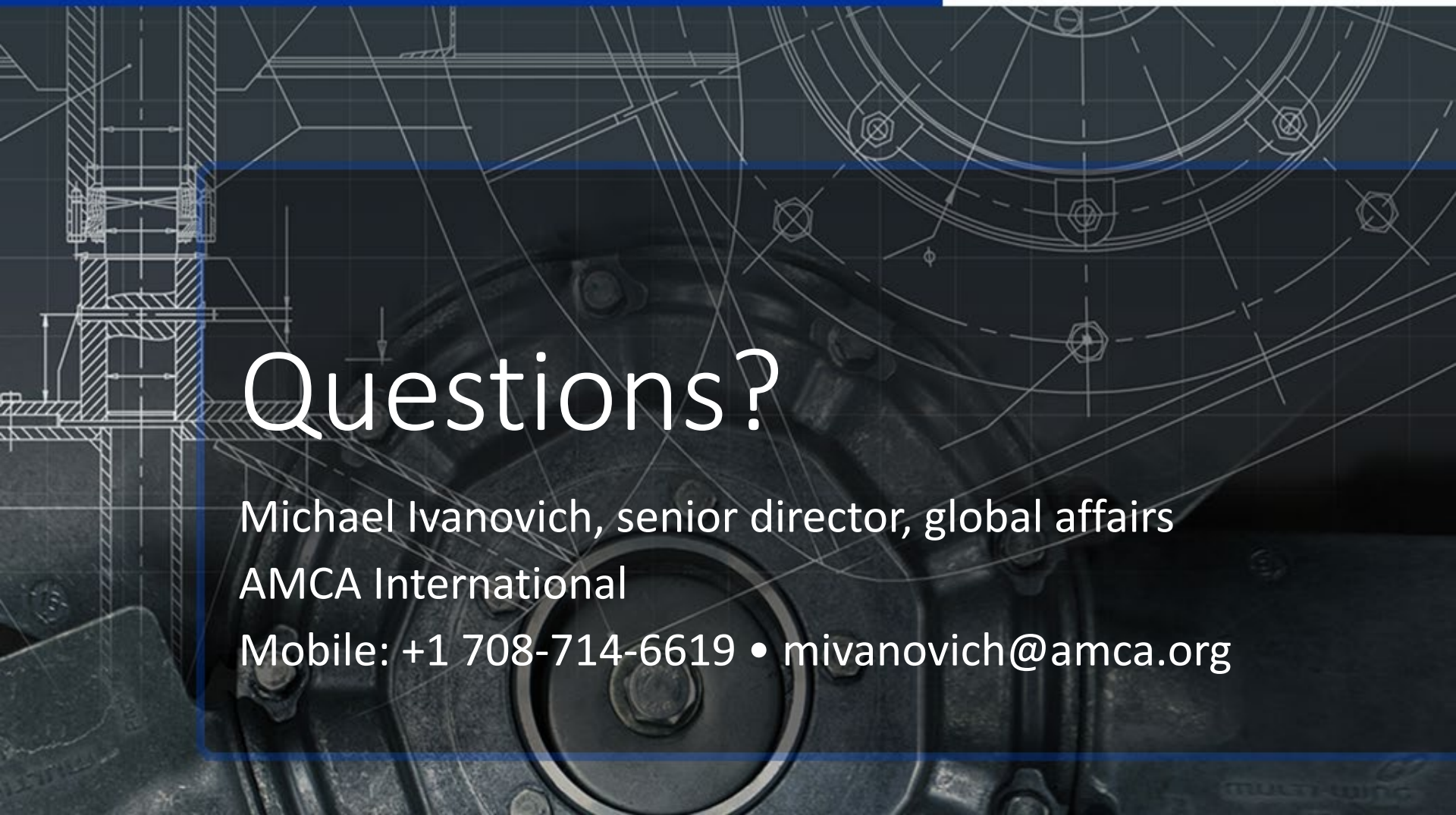
- Intuitive metric that directly reflects power consumed by the fan

Greater energy savings

- Benefits above mean greater energy savings and lower lifecycle cost

Resources

- AMCA International: **www.amca.org**
- AMCA certifying FEI ratings: **www.amca.org/certify**
- AMCA 208 standard (free for 2019): **www.amca.org/store**
- AMCA microsite for FEI training, technical papers, PowerPoints, and regulatory status: **www.amca.org/fei**



Questions?

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