High Volume Low Speed (HVLS) Fans:

Updates on COVID Guidance and Federal Energy Regulation

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HVLS Fans: Updates on COVID Guidance and Federal Energy Regulation

PURPOSE

The purpose of this presentation is to detail the LDCF provisions in relevant codes and standards, and to instruct on the U.S. Department of Energy regulation and its metric-change for these products to CFEI. Additionally, takeaways from a recent study that provides guidance on the operation of LDCF in particular industrial settings will be presented. The presentation also will briefly describe the AMCA test standard for LDCF, and how AMCA tests and certifies LDCF products.

HVLS Fans: Updates on COVID Guidance and Federal Energy Regulation

LEARNING OBJECTIVES

At the end of this presentation, you will be able to:

1. Describe LDCF provisions in some energy, fire, and mechanical codes and standards.
2. Describe the U.S. Department of Energy regulation and the new LDCF efficiency metric, Ceiling Fan Energy Index (CFEI).
3. Explain suggested guidance for the operation of LDCF resulting from a recent research project.
4. Identify the AMCA test standard for LDCF and how these products are tested and certified by AMCA.

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Senior Manager, Advocacy,
AMCA International

- Joined AMCA in 2019
- Supports AMCA advocacy initiatives in North America codes, standards, and regulations
- Primary staff liaison to committees within AMCA, ASHRAE, NFPA, IAPMO & others
- BSc, MSc Mechanical Engineering from Colorado School of Mines

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Christian Taber

Principal Engineer – Codes & Standards,
Big Ass Fans

- M.S. in mechanical engineering & biosystems engineering; B.S. in chemical engineering
- ASHRAE certified High-Performance Building Design Professional and Certified Energy Manager
- Chair, N.A. Air Movement Advocacy Committee
- Served on AMCA committees 230, 214, 211, 208 and 11 and ASHRAE – Standards Committee, SSPC 90.1

Today's Agenda

- **Aaron Gunzner:**
  - LDCF Provisions in NFPA, ASHRAE, ICC
  - Basics of Federal Regulations for Large Diameter Ceiling Fans
- **Christian Taber:**
  - New Metric for LDCF Efficiency Regulations: Ceiling Fan Energy Index (CFEI)
  - COVID research project results and guidance for operation in industrial environments
  - LDCF Testing and Certification

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LDCF Provisions in NFPA, ASHRAE, ICC

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LDCF Provisions in NFPA 13-2019

- NFPA Standard 13, *Standard for the Installation of Sprinkler Systems*
- Definition: **“3.3.93 High Volume Low Speed Fan.**

  A ceiling fan that is approximately 6ft (1.8m) to 24ft (7.3m) in diameter with a rotational speed of approximately 30 to 70 revolutions per minute.”

  - DOE definition of LDCF starts at 7-ft and includes fans without HVLS properties,
  - So, NFPA definition does not align with federal law definition
  - Diameter paired with RPMs is vague about whether it applies to a product or not
  - AMCA may propose changes in next revision cycle

LDCF Provisions in NFPA 13-2019

- **Sections 19.2.7, 20.6.7 - installation of HVLS Fans:**
  1. Max. fan diameter shall be 24ft (7.3m)
  2. Centered approximately between four adjacent sprinklers
  3. Vertical clearance from fan to sprinkler deflector shall be minimum of 3ft (0.9m)
  4. All HVLS fans shall be interlocked to shut down immediately upon a waterflow alarm. (In accordance with NFPA 72 where applicable.)

- **Annex A – Explanatory Material**
  - Shutdown within 90 sec by the VFD; based on 2011 research

LDCF Provisions in NFPA 72-2019

- NFPA Standard 72, *National Fire Alarm and Signaling Code®*
- Section 21.8 HVLS Fans.
  - “Where required by NFPA 13, all HVLS fans shall be interlocked to shut down upon actuation of a sprinkler waterflow switch that indicates waterflow in the area served by the fans.”

LDCF Provisions in IMC and IECC

- International Mechanical Code (IMC) and International Energy Conservation Code (IECC)
- 2018 IMC Section 929.1; 2021 IMC Section 930.1 – Large-Diameter Ceiling Fans
  - “Where provided, large-diameter ceiling fans shall be tested and labeled in accordance with AMCA 230, listed and labeled in accordance with UL 507, and installed in accordance with the manufacturer’s instructions.”
- 2021 IECC Section C403.9 – Large-diameter ceiling fans.
  - “Where provided, large-diameter ceiling fans shall be tested and labeled in accordance with AMCA 230.”
- Proposal for 2024 IECC: similar language to 90.1-2019 addendum **aw** [on upcoming slide]

LDCF Provisions in ASHRAE 90.1-2019

- *Energy Standard for Buildings Except Low-Rise Residential Buildings*
- There are some parts missing in DOE compliance certification requirements
  - The 90.1 standard helps to fill these in
  - Also - DOE rulemaking in process working to address this
- 2019 version does not include new CFEI requirements; however, addendum **aw** to 2019 covers this and will be in the 2022 version.

LDCF Provisions in ASHRAE 90.1-2019

- **“Section 6.4.1.3 Ceiling Fans**

  Large-diameter ceiling fans shall be rated in accordance with 10 CFR 430 Appendix U or AMCA 230. The following data shall be provided:

  a. Blade span (blade tip diameter)

  b. Rated airflow and power consumption at the maximum speed

- **6.4.1.3.1**

  The data provided shall meet one of the following requirements:

  a. It is determined by an independent laboratory.

  b. It is included in a database published by USDOE.

  c. It is certified under a program meeting the requirements of Section 6.4.1.5.

- **Exception to 6.4.1.3.1**

  Ceiling fans not covered in the scope of 10 CFR Part 430.”

LDCF Provisions in ASHRAE 90.1-2019 - errata

- Informative note added to Section 6.4.1.3 pointing to Informative App. F for U.S. DOE requirements for U.S. applications
- Includes references for locations in CFR for definition and test procedure

Source - Errata Sheet for ANSI/ASHRAE/IES Standard 90.1-2019 (I-P), dated July 26, 2021:
https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20errata/errata%20for%20ashrae-ies%20standard%2090/90.1-2019-ip-erratasheet-7-26-2021-.pdf

LDCF Provisions *upcoming* in ASHRAE 90.1-2022

- All 6.4.1.3 language on previous slide is struck, replaced by the below…
- **CFEI definition:**

Ceiling fan energy index (CFEI): the ratio of the electric input power of a reference *ceiling fan* to the electric input power of the actual *ceiling fan* as calculated per AMCA 208 with the following modifications to the calculations for the reference fan: using an airflow constant (Q_0) of 26,500 cfm (12.507 m^3/s), a pressure constant (P_0) of 0.002700 in. of water (0.6719 Pa), and a fan *efficiency* constant (η_0) of 42%.

- "Ceiling Fan *Efficiency* Requirements" Table 6.8.1-21 added to Section 6.4.1.1 Minimum Equipment *Efficiencies*
- Table F-6 for U.S. applications
- Test procedure added to Normative References –

  10 CFR Part 430, Appendix U – Uniform Test Method for Measuring the Energy Consumption of Ceiling Fans

Basics of Federal Regulations for Large Diameter Ceiling Fans

U.S. Large Diameter Ceiling Fan Regulation

- Prior to the U.S. DOE regulation, ceiling fan regulations were being developed state-by-state, which could have led to a variety of efficiency metrics and test standards.
- The DOE regulation preempted state regulations and established uniform test methods, metrics, and requirements.
- DOE “product” regulations are legally enforceable provisions of the U.S. Code of Federal Regulations.
- Developed and enforced by the U.S. DOE Appliance and Equipment Standards Program.

U.S. Large Diameter Ceiling Fan Regulation

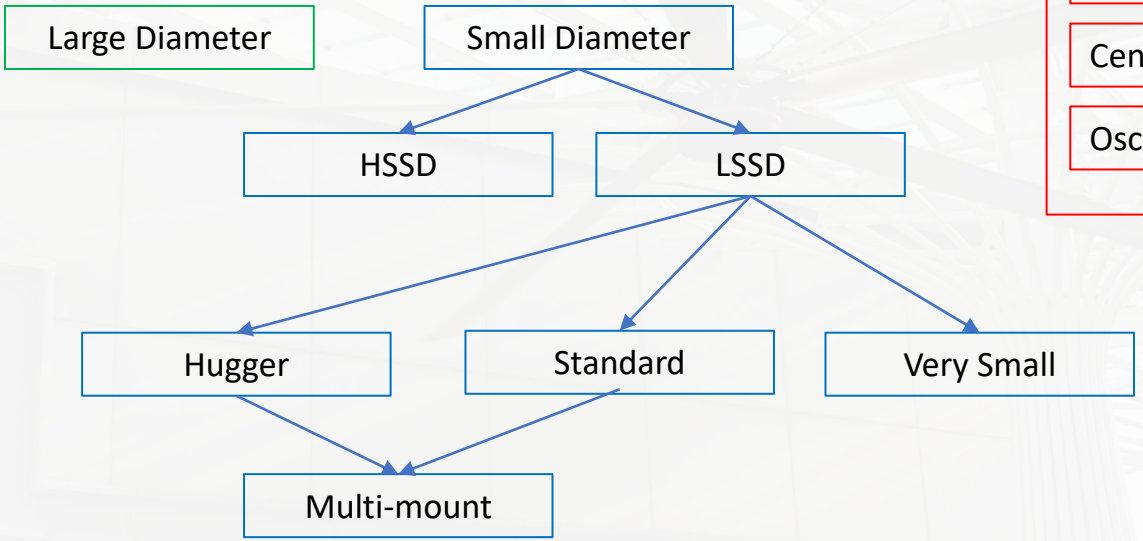
- **Basics**
  - A federal energy efficiency regulation has two main parts:
    - Test Procedure
    - Energy Conservation Standard
  - Test procedure is *a regulation* that defines
    - Regulatory metric and method(s) of test, including start date
    - Product classes
    - Scope - covered and excluded products
  - Energy conservation standard establishes
    - Design criteria
    - Minimum efficiency performance standard (MEPS) by product class
    - Compliance filing requirements, including start date of enforcement
    - Enforcement provisions (surveillance), including testing, penalties
  - Administrative laws such as these are published in the U.S. Code of Federal Regulations (CFR)

U.S. LDCF Regulation

- **Basics**
  - Test Procedure
    - Use “definitions” to establish product classes and regulatory metrics
    - Establishes a uniform test procedure for all covered products
      - DOE will consider industry test standards and not use, use, or refine
    - Ceiling fan test procedures published July 24, 2016
      - LDCF use ANSI/AMCA 230-15
      - Other product classes use a different procedure
    - “On or after January 23, 2017, manufacturers of ceiling fans…must make any representations with respect to energy use or efficiency in accordance with the results of testing pursuant to this appendix.”

Product Classes

All product classes that are covered or exempt must be explicitly defined.



Exempt Fans

- Highly Decorative
- Belt Driven
- Centrifugal
- Oscillating

U.S. LDCF Regulation

- **Establishment of the LDCF Product Class:**
  - *(10 CFR 430.2 – Definitions). The term "ceiling fan" means a nonportable device that is suspended from a ceiling for circulating air via the rotation of fan blades.*
  - *(10 CFR 430, Appendix U to Subpart B (1.11)). Large-diameter ceiling fan means a ceiling fan that is greater than seven feet in diameter.*
  - …
- **Establishment of the LDCF Test Procedure:**
  - *(10 CFR 430, Appendix U to Subpart B (3.4)).* The test apparatus and instructions for testing large-diameter ceiling fans must conform to the requirements specified in sections 3 through 7 of AMCA 230-15 …with the following modifications:
    - 3.4.1. The test procedure is applicable to large-diameter ceiling fans up to 24 feet in diameter.
    - Etc.

U.S. Ceiling Fan Regulation

- **Basics**
  - Energy conservation standard establishes
    - Design criteria
    - Minimum efficiency performance standard (MEPS)
    - Exempt product classes
    - Compliance filing requirements, including start-date of enforcement
    - Enforcement provisions (surveillance), including testing, penalties
  - Final rule published January 19, 2017; effective January 20, 2020
  - Updated May 27, 2021 for Ceiling Fan Energy Index
    - Became immediately enforceable

U.S. LDCF Regulation

- *Establishment of Energy Standard (Efficiency Requirement)*
  - (10 CFR 430.32(s)(2)). Large-diameter ceiling fans manufactured on or after January 21, 2020, shall have a CFEI greater than or equal to

    (A) 1.00 at high speed; and

    (B) 1.31 at 40 percent speed or the nearest speed that is not less than 40 percent speed.

U.S. LDCF Regulation

- *Establishment of Energy Standard (Efficiency Requirement)*

  …

  - 430.32(s)(2)(ii). 5. Calculation of Ceiling Fan Energy Index (CFEI) From the Test Results for Large-Diameter Ceiling Fans:
    - Calculate CFEI, which is the FEI for large-diameter ceiling fans, at the speeds specified in section 3.5 of this appendix according to ANSI/AMCA 208-18, (incorporated by reference, see § 430.3), with the following modifications:
    - (1) Using an Airflow Constant (Q0) of 26,500 cubic feet per minute;
    - (2) Using a Pressure Constant (P0) of 0.0027 inches water gauge; and
    - (3) Using a Fan Efficiency Constant ($\eta 0$) of 42 percent.

Canada…

- U.S. Dept. of Energy and Natural Resources Canada (NR Canada) have a working relationship formalized in a memorandum of understanding (MOU).
- Generally, U.S. appliance/equipment efficiency regulations are adopted into Canadian regulations.
- As of July 19, 2021, NR Canada specifies “ceiling fan efficiency” for LDCF, and DOE still defines “ceiling fan efficiency” using cfm/w.
  - *Ceiling fan efficiency means the ratio of the total airflow to the total power consumption, in units of cubic feet per minute per watt (CFM/W).*
- Therefore, CFEI not yet applicable to Canadian efficiency regulation.

Extract From NR Canada Website

Energy efficiency standard

78 (1) The energy efficiency standard for a ceiling fan is the standard as set out in 10 C.F.R. §430.32(s)(2)(i).

Testing standard

(2) A ceiling fan complies with the energy efficiency standard if it meets that standard when tested in accordance with testing procedures established by 10 C.F.R. Appendix U that are applicable to a ceiling fan as defined in section 75.

Information

79 For the purpose of subsection 5(1) of the Act, the following information must be collected in accordance with 10 C.F.R. Appendix U and provided to the Minister in respect of a ceiling fan:

(a) its type;

(b) its blade span;

(c) its air flow at high speed;

(d) its ceiling fan efficiency; and

(e) its standby power consumption expressed in watts.

New Metric for LDCF Efficiency Regulations: Ceiling Fan Energy Index (CFEI)

New Metric for LDCF Efficiency Regulations

- **Ceiling Fan Energy Index (CFEI)**
  - Calculated at two speeds – 100% and 40% of max RPM
  - Intended as a regulatory metric
  - Allows for high utility (airflow) products
  - More difficult to “game” than CFM/W based metrics
  - Very similar to AMCA 208’s FEI, except different constants

New Metric for LDCF Efficiency Regulations

$$FEI = \frac{\text{Actual Fan Efficiency}}{\text{Reference Fan Efficiency}} = \frac{\cancel{\text{Actual Fan Air Power}}}{\text{Actual Fan Electric Power}} \Big/ \frac{\cancel{\text{Reference Fan Air Power}}}{\text{Reference Fan Electric Power}}$$

$$FEI = \frac{\text{Reference Fan Electric Power}}{\text{Actual Fan Electric Power}}$$

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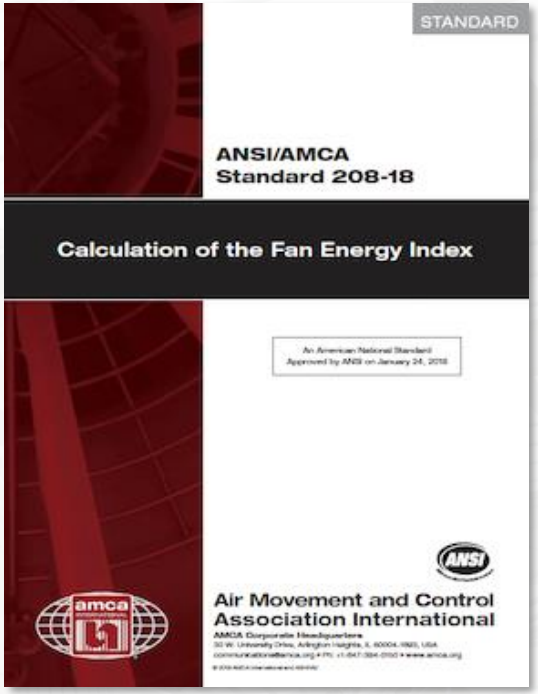
How To Calculate CFEI

- **Use AMCA Standard 208-18**
  - FEI equation for total pressure
  - Airflow Constant: Q_0 = 26,500 cfm
  - Pressure Constant P_0 = 0.0027 in. WG
  - Fan Efficiency Constant h_0 = 42 percent

  - Metric Equivalents (from AMCA 211 draft)
  - Airflow Constant: Q_0 = 12.507 m^3/s
  - Pressure Constant P_0 = 0.6719 pascals



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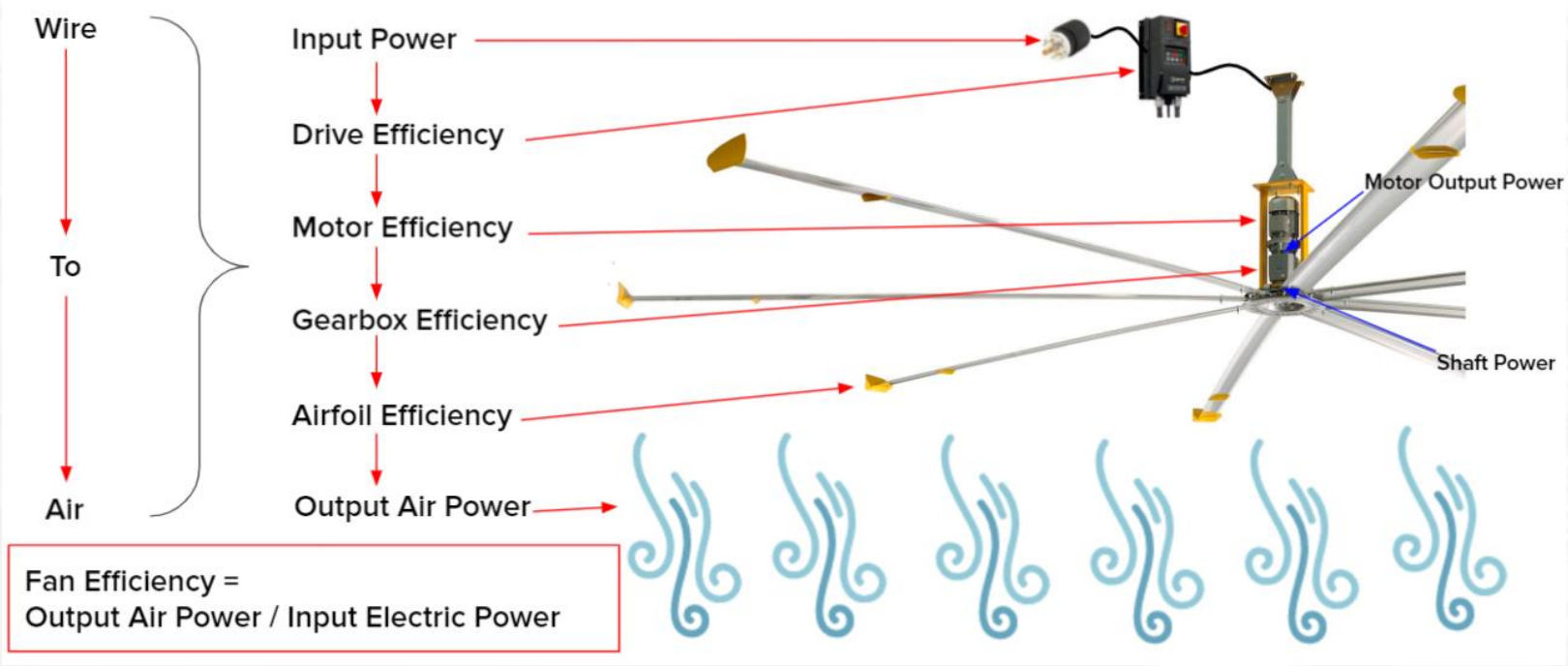
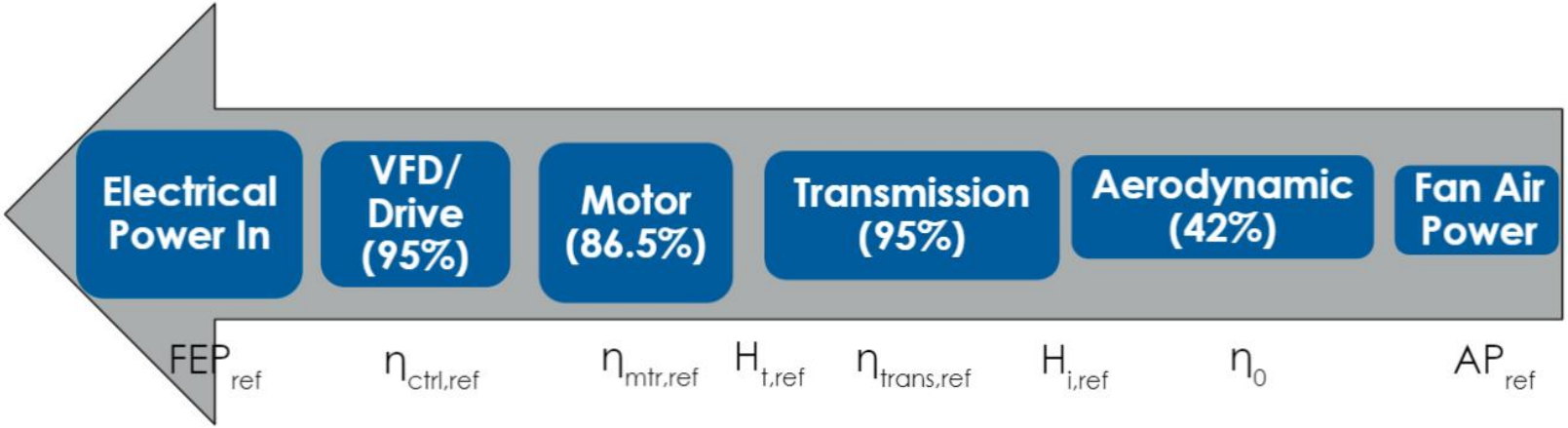
Ceiling Fan Efficiency - Wire-to-Air



Calculating Reference Fan Electrical Input Power



AP_{ref} = Air power (aka output power)
η_0 = Fan efficiency constant
$H_{i,ref}$ = fan shaft power (ref fan)
$\eta_{trans,ref}$ = transmission efficiency (ref fan)

$H_{t,ref}$ = motor output power (ref fan)
$\eta_{mtr,ref}$ = motor efficiency (ref fan)
$\eta_{ctrl,ref}$ = controller efficiency (ref fan)
FEP_{ref} = Fan electrical input power (ref fan)

Example CFEI – LDCF 100% RPM

- **Actual 24’ LDCF**
  - 235,000 CFM (~600W of Air Power)
  - 1,530 W input power

- **Reference 24’ LDCF**
  - 235,000 CFM
  - 600W Air Power / 42% / 93% / 87% / 100% ≅ 1,770 W
  - 1,770 W input power

CFEI = 1,770 W / 1,530 W = 1.16

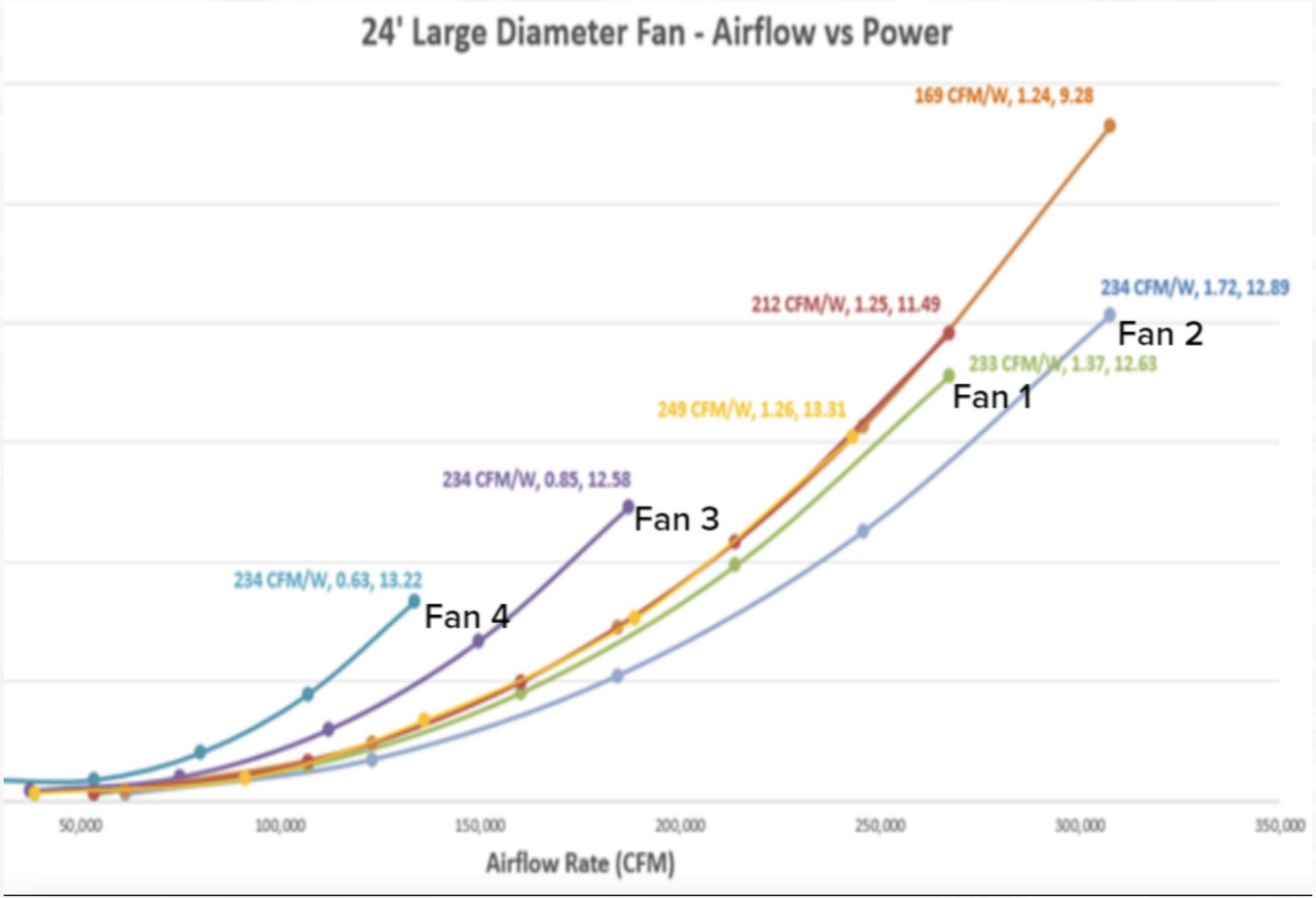
$$CFEI = \frac{FEP_{ref}}{FEP_{actual}}$$

CFEI Calculation – Step by Step

Fan	Fan 1	Variable	
Diameter	24' (288")	-	Measured - 10 CFR 430, App U
Airflow (Act)	235,000 cfm	Q_i	Measured - 10 CFR 430, App U
Input Power (Act)	1,530 W	FEP_{act}	Measured - 10 CFR 430, App U
Total Pressure (Act)	0.0168 in wg	$P_{t,i}$	Calculated - AMCA 208, Eq A.1 IP
Shaft Power (Ref)	1.91 hp	$H_{i,ref}$	Calculated - AMCA 208, Eq 5.3 IP
Trans Effic (Ref)	92.40%	$\eta_{trans,ref}$	Calculated - AMCA 208, Eq 5.5 IP
Motor Output (Ref)	2.07 hp	$H_{t,ref}$	Calculated - AMCA 208, Eq 5.6
Motor Effic (Ref)	87.16%	$\eta_{mtr,ref}$	Calculated - AMCA 208, Eq 5.7 IP
Control Effic (Ref)	100%	$\eta_{ctrl,ref}$	Calculated - AMCA 208, Eq 5.8
Input Power (Ref)	1,772 W	FEP_{ref}	Calculated - AMCA 208, Eq 5.2 IP
$CFEI_{100}$	1.16	$FEI_{t,i}$	Calculated - AMCA 208, Eq 5.1

CFEI Requirements

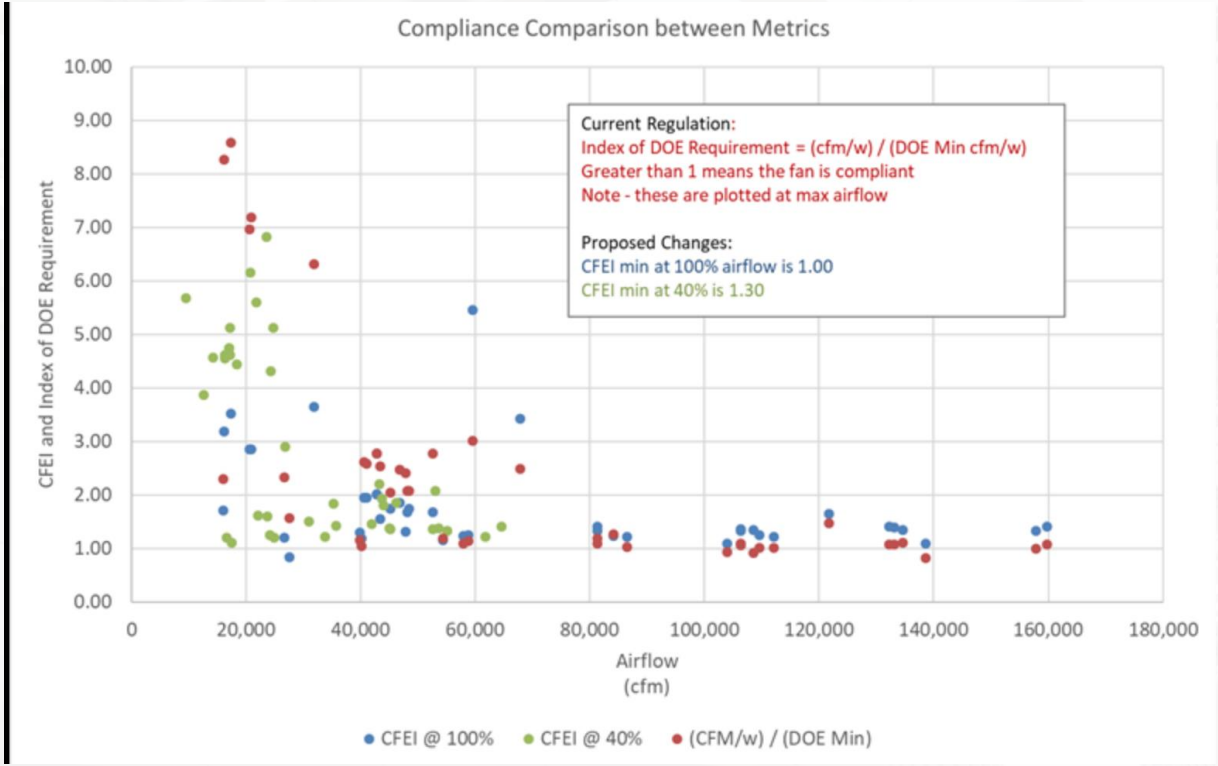
- Using DOE test procedure (AMCA 230-15), LDCF tested at 100% and 40% speeds only
  - High Speed: 100%
  - At 40% or speed closest to 40% without going under 40%
- Using “modified” AMCA 208-18, calculate CFEI
  - CFEI $\geq$ 1.00 at high speed (100%)
  - CFEI $\geq$ 1.31 at 40% speed or speed closest to 40% without going lower
- Optional measure standby power
  - Not included in CFEI
  - May be required in future DOE regulations


24' Large Diameter Fan - Airflow vs Power
169 CFM/W, 1.24, 9.28
212 CFM/W, 1.25, 11.49
234 CFM/W, 1.72, 12.89
Fan 2
233 CFM/W, 1.37, 12.63
Fan 1
249 CFM/W, 1.26, 13.31
234 CFM/W, 0.85, 12.58
Fan 3
234 CFM/W, 0.63, 13.22
Fan 4
50,000
100,000
150,000
200,000
250,000
300,000
350,000
Airflow Rate (CFM)

Power vs. Airflow and CFEI

- Previous slide shows input power versus airflow for four fans.
- Fans 1-4 all have the same cfm/W.
- For a given airflow, the lower the curve is on the chart, the more efficient the fan.
- Lowest curve: Fan 2 has a CFEI of 1.72 at 100%
- Highest curve: Fan 4 has a CFEI of 0.63 at 100%.
- Illustrates how a bad fan can be pass with cfm/W metric but not with a low CFEI.

AMCA Lab Data for LDCF Compliance Rate cfm/Watt vs CFEI



AMCA Lab Data for LDCF Compliance Rate cfm/Watt vs CFEI

- Previous slide shows an index for cfm/W vs. CFEI
- Index (red dots) are very close to 1.00 at highest airflows
  - Below 1.00 is non-compliant
    - Indicates that future fans will have harder time being compliant
  - Blue dots (100% airflow CFEI) at these dots trend higher than 1.00
    - Indicates that CFEI provides cushion for higher-performance/utility fans

CFEI Legislative Timeline

01-21-20	LDCF Federal Rule Enforcement begins
02-05-20	H.R. 5758 introduced by B. Guthrie (R-KY) and J. Schakowski (D-IL) to Congress "Ceiling Fan Improvement Act"
	Vote by House Energy and Commerce Committee
12-09-2020	Vote by Full House
	Received by Senate and Referred to Committee on Energy and Natural Resources
	Omnibus Bill voted by House, included Energy Act 2020, which included Ceiling Fan Improvement Act
	Omnibus Bill voted by Senate
12-27-2020	Omnibus Bill signed by President Donald Trump
05-26-2021	Federal Register publishes Codification

10 CFR 430.32 - Energy and water conservation standards and their compliance dates (5/27/21)

Product class as defined in Appendix U	Minimum efficiency (CFM/W) [1]
Very small-diameter (VSD)	D ≤ 12 in.: 21.
	D > 12 in.: 3.16 D-17.04.
Standard	0.65 D + 38.03.
Hugger	0.29 D + 34.46.
High-speed small-diameter (HSSD)	4.16 D + 0.02.

[1] *D is the ceiling fan's blade span, in inches, as determined in Appendix U of this part.*

(ii) Large-diameter ceiling fans manufactured on or after January 21, 2020, shall have a CFEI greater than or equal to—

(A) 1.00 at high speed; and

(B) 1.31 at 40 percent speed or the nearest speed that is not less than 40 percent speed.

https://www.federalregister.gov/documents/2021/05/27/2021-10882/energy-conservation-program-energy-conservation-standards-and-test-procedures-for-ceiling-fans

Takeaways from AMCA International LDCF Study

Purpose of Study

- Some COVID-19 guidance includes operation of ceiling fans
  - Guidance does not seem to apply to HVLS fans or warehouses
- **To contribute to the body of COVID-19 guidance for commercial and industrial facilities, with focus on the role of large-diameter ceiling fans (LDCF) without supplemental air treatment**
  - LDCF: U.S. Department of Energy defined product class for ceiling fans having a blade span greater than 7 ft (2 m)
  - High Volume, Low Speed (HVLS) fans; some LDCF are not HVLS
- U.S. only because of regional construction and occupancy characteristics
  - Some slides to not have metric equivalents

Purpose of Study

- Warehouses selected as subject building type/application
- Warehouses are critical to supply chain, and increasingly so
  - Second largest building type in USA based on square footage (office bldg. #1)
  - https://www.constructiondive.com/news/warehouse-construction-boom-to-continue-next-year/513592/
  - https://www.globest.com/2019/06/21/e-commerce-demand-pushes-us-warehouse-construction-to-record-levels/?slreturn=20210920114228
- COVID outbreaks happen in warehouses
  - https://www.wsws.org/en/articles/2021/08/30/pdx9-a30.html
  - https://www.thestar.com/business/2021/10/06/at-warehouses-construction-sites-and-manufacturers-vaccine-mandates-are-rare-and-they-dominate-outbreaks-on-the-job.html

Project Team

SCIENCE TEAM			
Name	**Title**	**Affiliation**	**Project role/contribution**
Liangzhu (Leon) Wang, PhD, P.Eng.	Associate professor, Department of Building, Civil, and Environmental Engineering	Concordia University	Principal investigator
William P. Bahnfleth, PhD, PE	Professor, architectural engineering Chair, ASHRAE Epidemic Task Force	The Pennsylvania State University	Science-team leader
Edward A. Nardell, MD	Professor, departments of Environmental Health and Immunology and Infectious Diseases	Harvard T.H. Chan School of Public Health	Infectious diseases and study of ceiling fans for control of infectious diseases
Jovan Pantelic, PhD	Research scientist, building science	Well Living Lab Inc.	Infectious diseases
Paul Raftery, PhD	Professional researcher	Center for the Built Environment, University of California, Berkeley	Ceiling-fan modeling
Geoff Sheard, DSc	President	AGS Consulting LLC	Computational-fluid-dynamics modeling and fan engineering
Pawel Wargocki, PhD	Associate professor, departments of Civil Engineering and Indoor Environment Chair, ASHRAE Epidemic Task Force Science Applications Committee	Technical University of Denmark	Indoor-air-quality expertise
INDUSTRY TEAM			
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Thomas Catania, Esq.	Board member	Institute for Energy Innovation	Regulatory communications
Aaron Gunzner	Senior manager, advocacy	AMCA International	Staff liaison
Mark Stevens	Executive director	AMCA International	Member relations
Christian Taber	Principal engineer, codes and standards	Big Ass Fans	Warehouse model, LDCF modeling
Mike Wolf, PE	Director, regulatory business development	Greenheck Fan Corp.	Regulatory communications


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Guidance for Large-
Diameter Ceiling Fans
Over a 12-month period, Air Movement and Control Association, in collaboration with an international team of scientists, engineers, and researchers, executed a series of numerical simulations to investigate the impact of large-diameter ceiling fans on COVID-19 exposure in a warehouse.
Photograph courtesy of Greenheck Fan Corp.
BY MICHAEL IVANOVICH, AARON GUNZNER, AND SCOTT ARNOLD, AMCA INTERNATIONAL
Numerous studies of airflow and performance characteristics of circulating fans have been undertaken.[1,2,3,4,5,6] Relatively few, however, are focused on aerosol transmission of airborne pathogens in large industrial spaces, a shortage all the more noticeable during the coronavirus disease 2019 (COVID-19) pandemic.
To contribute to and improve the body of COVID-19-prompted guidance for the operation of circulating fans, Air Movement and Control Association (AMCA) International commissioned numerical-simulation studies of airborne-particle and aerosol transmission with large-diameter (greater than 2.1 m [7 ft]) ceiling fans (LDCF). The focus of the studies was warehouses in the United States, in which LDCF commonly are used for comfort cooling and destratification. The results, however, also are applicable to many manufacturing/industrial facilities.
To promote integrity in the design and execution of the research and ensure the conclusions drawn from the study are valid, AMCA assembled "industry" and "science" teams (Table 1). Consisting of representatives of AMCA member companies and members of the AMCA staff, the industry team provided expertise in the application and performance of products, while the science team, made up of authorities in infectious diseases, indoor-air quality, fans, and computer modeling, including two leading members of the ASHRAE Epidemic Task Force, advised on the project setup and reviewed the intermediate and final results. Because COVID-19 infection rates are poorly understood and varying with mutations, the study focused on particle concentrations as an indicator of exposure risk.
Following is a high-level summary of the project's findings and resultant guidance. For information on the simulation methodology, setups, assumptions, validations, and results, see the final report, "AMCA COVID Guidance for UNDUCTED Fans – Modeling Ceiling Fans," prepared by Liangzhu (Leon) Wang, PhD, P.Eng.; Senwen Yang; Runzhong (Alvin) Wang; Mohammad Mortezazadeh, PhD; Jiwei Zou; and Chang Shu of Concordia University, at https://bit.ly/COVID_LDCF.
The Building
Based on the U.S. Department of Energy (DOE) commercial reference building for warehouses (Figure 1a), the warehouse in the study measured 100 m (330 ft) long by 46 m (150 ft) wide by 8.5 m (28 ft) tall with two AMCA-certified 6.1-m- (20 ft) diameter ceiling fans installed 36.6 m (120 ft)
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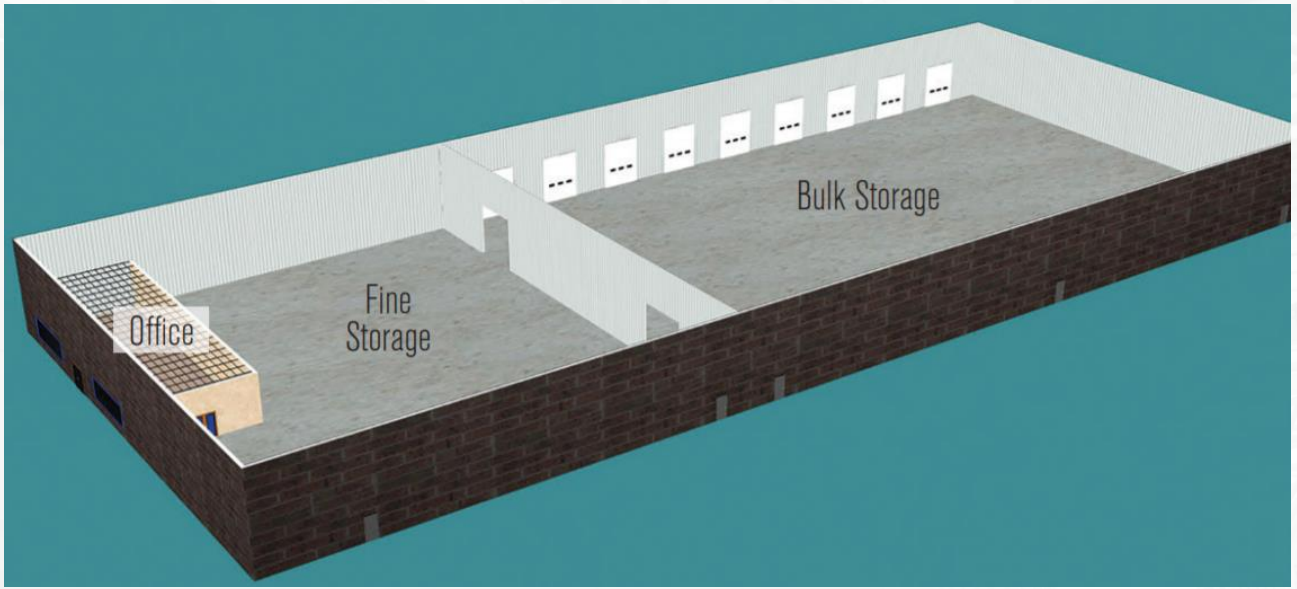
Warehouse - Building Overview

- Based on U.S. Department of Energy commercial reference building for warehouses
- Dimensions - 100m (330 ft) x 46m (150ft) x 8.5m (28ft)
- Chicago, IL USA



Simplified guidance

- Guidance based on season and worker-location with respect to fans:
  - Operate fans at the highest feasible speed while maintaining occupant comfort in the space.
  - Where possible, avoid locating occupants immediately downstream of each other for extended periods of time.
  - At high fan speeds (e.g. summer conditions) the simulations show a notable reduction in concentrations.
  - At low fan speeds (e.g. winter conditions) the simulations show a slight reduction in concentration in the region close to the fan (e.g. within three fan diameters), and no practical difference outside that region.

Logic behind the guidance

Where are most occupants located?	Summer conditions	Winter conditions
Close to the fan(s)	Operate fans downwards, at high speed	Operate fans at highest feasible speed that does not cause discomfort in either forward or reverse direction, whichever approach was used pre-pandemic[1]
Far from the fan(s)[3]	Operate fans downwards, at high speed	Operate fans at highest speed in either forward or reverse, whichever approach was used pre-pandemic[2]

Notes: Green/yellow/red color coding is an approximate indicator of how clear the effect was in the scenarios we simulated.
1: Simulations show slightly lower concentrations with reverse flow than with forward flow at a given low speed, but this is based on a much smaller number of simulated scenarios (two as opposed to the 16 for a typical forward-direction scenario) and is a small effect given simplifications and assumptions in the model. For simplicity, retaining the pre-pandemic direction is advised—unless reversing the fan allows for substantially higher fan speeds while avoiding draft at the occupied level.
2: Although simulations show a slight *increase* in average warehouse breathing concentration for fans at low-speed vs off, the distribution is far more uniform across the entire warehouse (i.e. no 'hot spots'). Based on feedback from the science team, overall this homogeneity is a net advantage as more mixing (i.e., dilution) is beneficial for times when workers who may be far apart for much of the workday meet and interact more closely. Lastly, the still-air results depend highly on model assumptions and simplifications (e.g., plume effectiveness, lack of local mixing, the presence of racks, etc.), and this small difference could be an artifact of those.
3: e.g. Most occupants located more than 3 fan diameters from the center of a fan for the majority of the day.

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Considering other scenarios

- Large spaces with high ceilings and few occupants may be comparable:
  - Hangars
  - Manufacturing facilities
  - Indoor sporting facilities without an audience (e.g. basketball court)
  - I.E., very high ventilation airflow/person and typical or low air changes per hour.
- Large spaces with dense occupancy are not comparable, further research needed:
  - Churches and similar venues
  - Gymnasiums
  - I.E., typical ventilation airflow/person and typical or low air changes per hour.

LDCF Testing and Certification

AMCA Certified Ratings Program (CRP)

- AMCA CRP certifies product ratings
  - Including large diameter ceiling fans
- Product certification
  - 6 licensees
  - 15 certified product lines
- Verify at www.amca.org/certify

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Find Certified Ratings

1

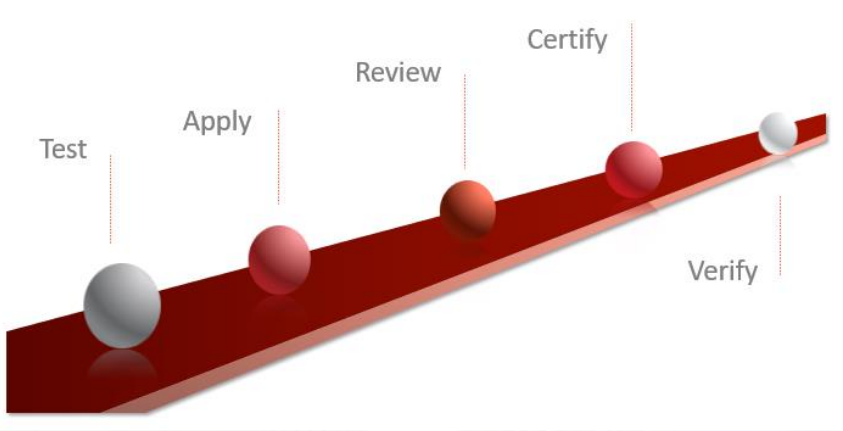
2

3

Click on company name to access detail

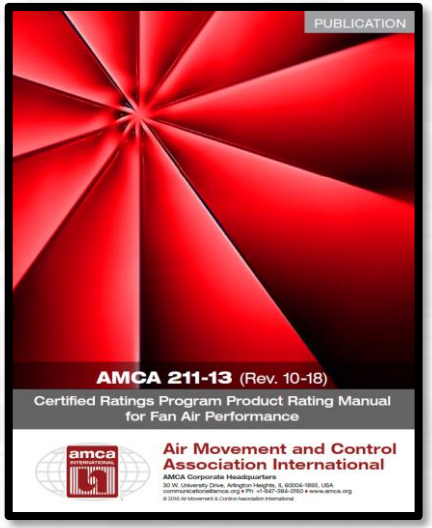
Certification Process

- AMCA HQ tests LDCF
  - AMCA-Accredited Lab
- AMCA issues test reports
- Licensee develops catalogs
- AMCA staff approves catalogs
- Verification test in 3-years



Certification Per AMCA Publication 211

- Operating manual for fan certifications
  - AMCA 211-13 (Rev. 10-18) (i.e., 2018)
  - Volumetric airflow rate
  - Fan system input power, phase, voltage and frequency
  - Efficacy (volumetric airflow rate/electrical input power)
  - Nominal impeller speed
  - Direction of operation
  - Available at no cost at www.amca.org/store



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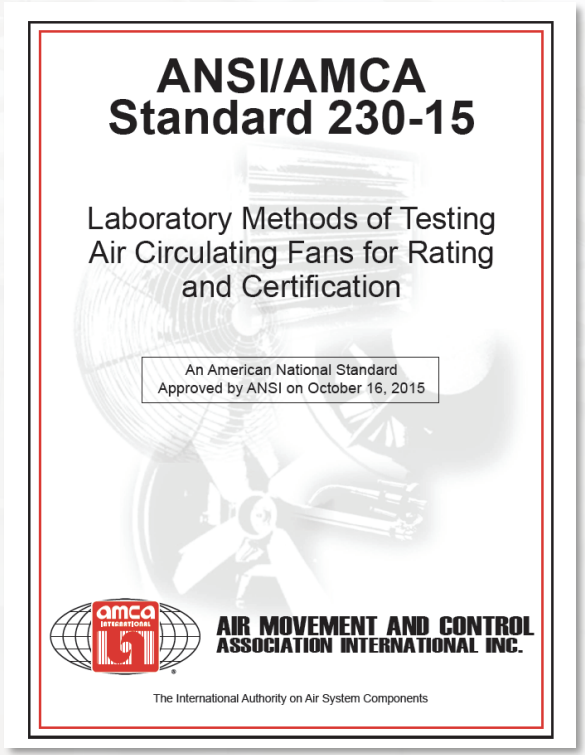
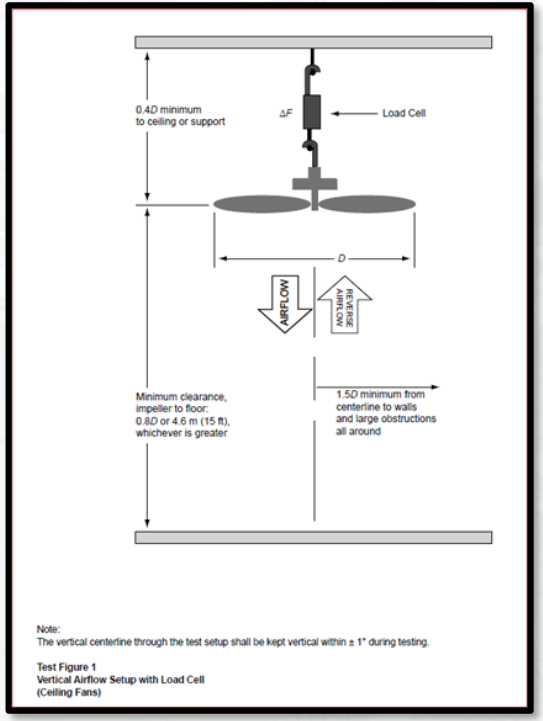
Laboratory Test Method

- ANSI/AMCA Standard 230-15 with erratum
  - Erratum published by AMCA May 6, 2021
  - Available at www.amca.org/LDCF
  - Converts electrical input power measurement for standard air density, making ratings independent of test location
- 10 CFR Part 430, Appendix U to Subpart B
- 10 CFR Part 430.32

LDCF Test Method

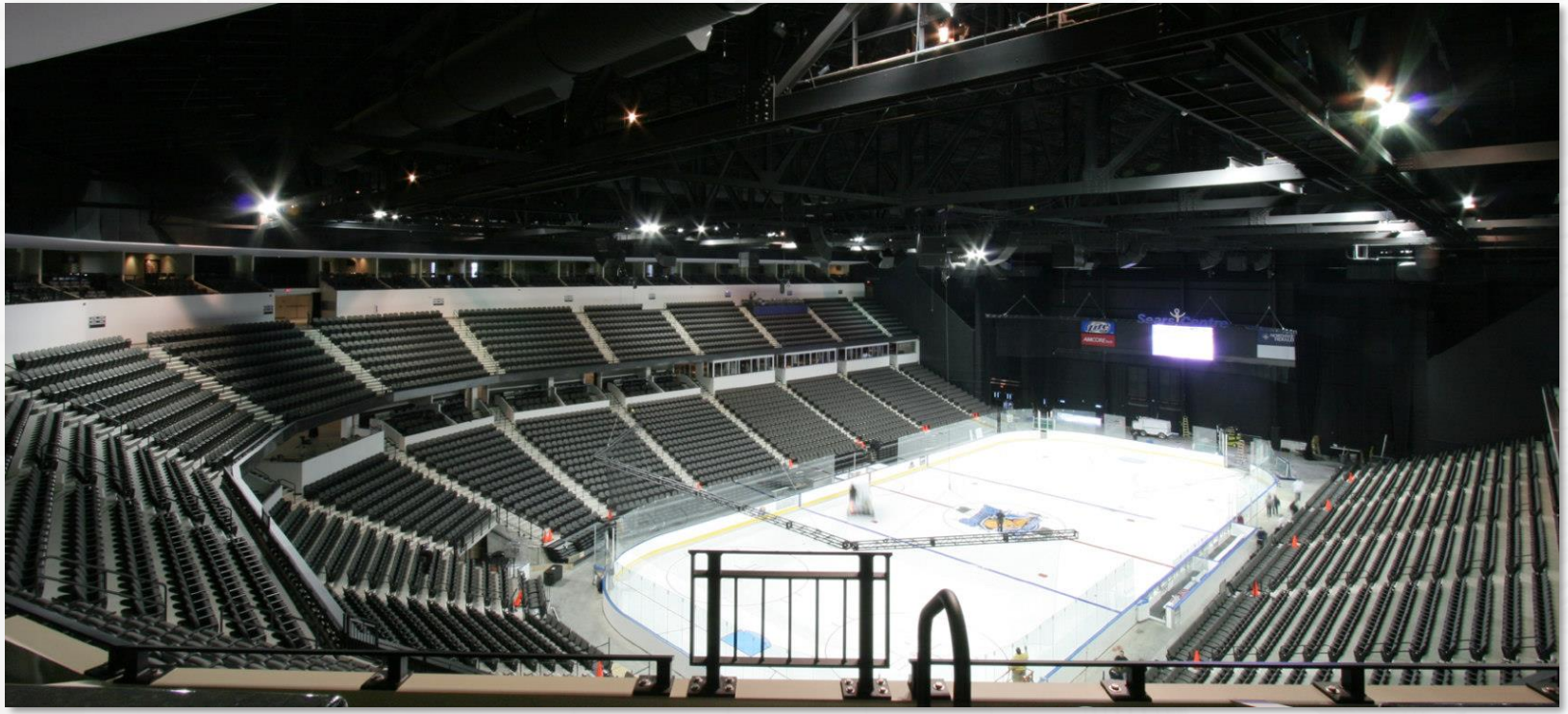




Where to test?

- Test facilities:
  - AMCA HQ Laboratory, Arlington Hts., Illinois
    - Blade spans 7.5-ft (2.3 m) to 18-ft (5.5 m)
    - AMCA HQ lab accredited by A2LA/ISO 17025
  - NOW Center, near Chicago
    - Previously known as Sears Center
    - Blade spans >18-ft (5.5 m)
    - 24-ft (7.3 m) is largest tested
- Manufacturer does not have to be a member to test at AMCA Lab or certify a product

NOW Center Fan Testing



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Where to Find LDCF Regulation Information

- AMCA LDCF Advocacy Web Page
  - www.amca.org/ldcf
- U.S. DOE Appliance and Equipment Standards Program
  - https://www.energy.gov/eere/buildings/appliance-and-equipment-standards-program
- DOE Ceiling Fan Regulations (and *listserver* signup)
  - https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=5
- Test Procedure
  - https://www.ecfr.gov/cgi-bin/text-idx?SID=9630460a5b59e8f0b16d3b0411a98094&mc=true&node=ap10.3.430_127.u&rgn=div9
- Energy Standard
  - https://www.ecfr.gov/cgi-bin/text-idx?rgn=div8&node=10:3.0.1.4.18.3.9.2
- Compliance database for ceiling fans for filed data:
  - https://www.regulations.doe.gov/certification-data/CCMS-4-Ceiling_Fans.html#q=Product_Group_s%3A%22Ceiling%20Fans%22
- Canadian ceiling fan efficiency regulation:
  - https://canadagazette.gc.ca/rp-pr/p2/2019/2019-06-12/html/sor-dors163-eng.html

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Other Resources

- **AMCA International:** www.amca.org
- **LDCF Testing at AMCA Lab:** www.amca.org/test
- **AMCA Fan Energy Index (FEI) Microsite:** www.amca.org/fei
- **AMCA Standards and Publications:** www.amca.org/store
- **AMCA White Papers:** https://www.amca.org/educate/#articles-and-technical-papers
- **AMCA Webinars:** www.amca.org/educate

  (PDH credit available via programs on AMCA Learning Platform)
- **AMCA Certified Ratings Program:** www.amca.org/certify

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Q & A

Survey QR Code:

Thank you for your time!

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*PDH credits and participation certificates will be issued electronically **within 30 days**, once all attendance records are checked and the completed online evaluations are received.*

Attendees will receive an email at the address provided on your 2022 AHR Expo registration, listing the total credit hours awarded and a link to a printable certificate of completion.

If you have any questions, please contact Lisa Cherney, Education Manager, at AMCA International (lcherney@amca.org).

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Bonus Slides

CRP Seal Usage

- Licensee must obtain license from AMCA to use CRP seal
- AMCA CRP seal shall be placed in catalogs, and in software outputs
- Licensee may affix AMCA CRP seal on certified product.

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