AMCA International
Response to U.S. Dept. of Energy
Framework Document for Commercial and Industrial Fans
(Published January 28, 2013)

Docket No.: EERE-2013-BT-STD-0006 / RIN 1904-AC55

May 31, 2013

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Items are DOE's original question, in bold, and include page number from the Framework Document. AMCA responses are below the question.
Item 1-1 DOE seeks comment on whether a labeling rule would be technologically or economically feasible, result in a significant conservation of energy, or assist consumers in making purchasing decisions. ....6 As discussed in AMCA's comments submitted in response to DOE's request for information, RFI EERE-2012-BT-NOA-0037, on March 19, 2013, labels can be applied to commercial and industrial fans. The common practice is for the presence of labels to inform code authorities regarding compliance with code requirements, and to inform contractors, owners and operators regarding the rating or efficiency of the product. With respect to assisting purchasing decisions, for commercial and industrial fans that are manufactured by AMCA International members, the utility of the label depends on the distribution channel through which a fan is sold. For fans that are built-to-order, customers (engineers, contractors, owners' representatives, etc.) do not see the product they are buying before it arrives at the project location. The selection decision, for the majority of equipment sold as built-to-order, occurs after the customer reviews the catalogs or electronic/software-generated selection output data. For products built as stock items and typically shipped to a stocking location in the marketplace, customers are more likely to see a label and be informed by it. For built-to-order and stock fans, AMCA believes the real purpose of a label is to inform the customer, code official or owner's representative of compliance with code requirements and affirm that the product complies with the selection they have made. With respect whether labels would lead to energy savings, the answer is yes. Labeling to inform code authorities helps to enforce code requirements, and AMCA believes that easier enforcement generally translates into more enforcement, and that more enforcement means greater energy savings. If buyers know that the codes will be enforced, they are more likely to make code-authorized selections. Maintenance and replacement behaviors are also influenced by information secured to the product on the nameplate or a label. AMCA members acknowledge that such information (efficiency ratings and compliance certification) should be displayed on our products.
Item 1-2 DOE seeks comment on information that it should consider requiring for display on any prospective label, as well as factors DOE should consider regarding the size, format, and placement of any such label. ....6 As discussed in AMCA's comments submitted in response to DOE's request for information, RFI EERE-2012-BT-NOA-0037, AMCA supports the idea of requiring efficiency ratings, code compliance, and third party certification or listing information to be displayed, but strongly recommends that the DOE labeling requirements be consistent with the requirements being considered by the IECC (International Energy Code Council)

model energy code, in a fan-efficiency provision proposed by AMCA and ASHRAE as CE234-13 in the ICC's "2013 Proposed Changes to the International Energy Conservation Code – Commercial Provisions," The PDF of this document can be downloaded directly from ICC's website at http://tinyurl.com/buw9sts.. A single label on the product would best inform commercial and industrial consumers.

Furthermore, AMCA members believe that labels should be required to inform code officials, installation contractors and owners' representatives regarding the fan's performance relative to regulatory requirements and the customers' own selection criteria. Code officials, commissioning providers, test & balance contractors, and installation contractors are those who most often see commercial products prior to issuing a certificate of occupancy. Enforcement of any requirement to display information on the product will logically require building and energy code provisions that reflect DOE requirements. For these reasons, we strongly urge DOE to rely on building and energy code provisions being established for labeling of fans.
AMCA would also like DOE to consider an issue that pertains to listing and labeling in the IECC model energy code. Today, model code language defines "listing" and "labeling" to require only periodic factory visits as due diligence following a single initial compliance test. For safety-related compliance of commercial products, this seems reasonable. During periodic visits, the inspector from the listing and labeling agency compares the product in production to the records which describe the product that was tested, to be certain that changes in production have not been made which may compromise safety performance.

However, when these definitions, which require periodic factory visits, are applied for efficiency listing and labeling, they are ineffective for two reasons:

a) Observation and measurements at the factory of the production units cannot be sufficiently detailed to determine how the product will perform against the tight performance tolerances that typify rating standards. Therefore, factory visits serve no useful purpose when considering product efficiency compliance.

b) Appropriate diligence to show continued compliance with rating standards and efficiency requirements requires a periodic test, not just a periodic visit. AMCA-certified ratings require a check test every three years, which, although it is far more costly, represents a much higher level of diligence than periodic factory visits.

Therefore, AMCA strongly recommends that DOE propose a change to model code language that would recognize periodic performance check tests as an allowed diligence substitute for periodic factory visits with respect to listing and labeling associated with product performance ratings or efficiency levels which are unrelated to safety compliance. We also suggest that DOE cultivate support from a variety of stakeholder groups and associations for this code change proposal.

Item 2-1 DOE requests data on how fans are sold. Specifically DOE requests data on market share of fans 1) sold by themselves, 2) sold attached to or integrated with motors only, 3) sold attached to or integrated with both motors and VSDs, 4) sold physically separate from but priced together with a motor only, or 5) sold physically separate from but priced together with both a motor and VSD. DOE would appreciate these data by size, equipment category (see section 5.2.1), and application. 7

AMCA is continuing to research this answer and may be in a position to provide information at a later date.

Item 2-2 DOE requests comment on the suggested definition for crossflow fan, specifically regarding whether this fan is a type of centrifugal fan. 8

A crossflow fan is not a type of centrifugal fan. A crossflow fan is a fan in which the fluid path through the impeller is in a direction essentially at right angles to its axis both entering and leaving the impeller at its periphery.

Item 2-3 DOE requests comment on the suggested definition for blowers. 9

AMCA does not recognize the difference between fans and blowers, and believes that the definition of blowers in the framework document is not material because the terms "fan" and "blower" are used interchangeably in the U.S. market.

Item 2-4 DOE requests comment on the suggested definitions for safety fans. Specifically, are other safety features not included in the above definition that should be included? 9

AMCA suggests that fans that are used even intermittently for safety be excluded from the rulemaking process. Any fan that has even an occasional duty to ventilate in a life safety situation will be designed fist for the life safety requirements and second for the optimization of performance. It is AMCA's opinion that designing for efficiency will compromise the life safety duties of safety fans. Efficiency reducing requirements that enable operation in life safety include robust designs for temperature and seismic conditions, increased clearances for high temperature expansion and reversibility.

Item 2-5 DOE requests comment on the suggested definitions for fans and other terms listed in section 2.1.1. 10

AMCA has reviewed the definitions and has made edits to many of them, and added several others. The definitions are provided as Appendix 1 to this document.

Item 2-6 DOE requests comment and information on the following trends: 1) increasing shipments of fan-motor-transmission packages and 2) increasing shipments of direct-driven fans in the U.S. market. Are there any other trends in the commercial and industrial fans market that might influence the scope of this rulemaking that DOE should be aware of and are not listed here?....... 10

AMCA has surveyed its members for input on trends for fans shipped with belt-drives and electronic drives. The results are provided as a table below. AMCA members were asked to indicate the market trend over the past three years for each fan class if fans purchased with belt drives or electronic drives were increasing, decreasing, or remaining the same.

Answers were coded as 1 for decreasing, 2 for remaining the same, and 3 for increasing. The results show that for most fan categories, belt-drive shipments are decreasing and electronic drives are increasing. ECM motors are assumed to be included in the "electronic drives" responses.

	Belt Drives	**Electronic Drives**
Vane Axial Fans	1.9	2.3
Tube Axial Fans	2.0	2.0
Panel Prop Fans	2.0	2.4
Housed Centrifugal BI	1.9	2.3
Housed Centrifugal FC	1.6	2.0
Housed Centrifugal Radial	2.0	2.2
Unhoused Centrifugal	1.8	2.3
In-line Centrifugal and Mixed Flow	1.7	2.4
Centrifugal Powered Roof Vents	1.5	2.5
Axial Powered Roof Vents	2.1	2.3
Circulating Fans	1.4	2.4
Air Curtains	1.7	2.4

An error in the survey neglected to ask for input on induced flow fans.

Regarding "other trends," one is the increasing use of ECM motors in single-phase applications. Another trend is the appearance of fan-efficiency requirements being adopted into national model codes and standards, such as ANSI/ASHRAE/IESNA 90.1-2013, and the 2012 International Green Construction Code. Code change proposals were submitted toward the 2015 International Energy Conservation Code, and a continuous maintenance proposal is being prepared by AMCA for ANSI/ASHRAE/USGBC/IESNA 189.1. ASHRAE 90.1, IECC, and IgCC requirements or proposed requirements are based on AMCA 205 fan efficiency grades.

Item 2-7 DOE requests comment on the consideration of standards for axial fans, centrifugal fans, mixed flow fans, safety fans, and blowers as defined in section 2.1.1. 10

AMCA recommends the DOE consult ANSI/AMCA 205-12, which defines the energy efficiency classification for fans and introduces the concept of Fan Efficiency Grade (FEG). AMCA also recommends the DOE consult ASHRAE 90.1-2013, Section 6.5.3.1.3, which pertains to fan selection and application of FEGs in the fan market.

Item 2-8 DOE is aware of another type of fan, the contra-rotating fan, popular in the European Union, and requests information on this fan type; specifically, are they sold in the U.S. market and should be considered in the scope of coverage for the rulemaking?........ 10

Contra-rotating fans are a specialty two-stage axial fan used where space is limited, and discharge pressure conditions are high, such as may be the case in mining operations. The demand and use of such fans in the U.S. market are rare and therefore AMCA recommends that contra-rotating fans be excluded from DOE regulation.

Item 2-9 DOE requests comment on whether establishing standards for fans defined inclusive of the motor transmission, and controls could increase the beneficial use of VSDs in the field and whether interested parties believe the benefits of such a standard would outweigh any negatives, such as the potential use of VSDs in applications for which it is not suited. DOE seeks comment on the market share of fans (by type) that would be used in applications that would benefit from VSDs, as well as those where use of a VSD could result in increased energy use. In particular, whether there are specific fan types that are almost always used, or alternatively, very rarely used, in applications that would benefit from a VSD. .... 12.

AMCA does not support regulating fans inclusive of motors and drives because we do not see an increase in the beneficial use of VSDs. Anecdotally, we are aware that based on cost-benefit analyses, there is a significant market penetration of VSDs in the fan market; however, these VSDs are provided downstream in the supply chain – not by AMCA members.

Unlike the pump industry, the fan industry already uses a highly efficient means of adjusting speed in a particular application. This happens through the use of belt drives and pulleys. This approach allows a fan to be cost effectively adjusted to the exact speed required to maximize the efficiency of the fan operating in a particular system. The use of belt drives to achieve this is an extremely cost effective method of achieving optimum applied efficiency for fixed volume systems.

Item 2-10 DOE requests data and information on whether fans are more often combined with motors, VSDs, or both by the fan manufacturer or by distributors/contractors. 12

AMCA is continuing to research this answer and may provide information at a later date.

Item 2-11 DOE requests information on how often and in what circumstances the intended application is known when the fan is sold. 12

AMCA has surveyed its members on how often they know the intended application for fans sold in **terms of airflow rate and pressure at design conditions.** The results varied considerably by fan category. Average responses, shown below by fan category, were weighted by market share data from AMCA's statistical program. Generally, manufacturers do not know application characteristics, such as facility type, intended use, constant vs. variable air volume applications, etc. It should not be assumed that what manufacturers' representatives/distributors know, the manufacturers themselves will know.

% of time you know the airflow rate and pressure at design conditions:

Vane Axial Fans	Tube Axial Fans	Panel Prop Fans	Housed Centrifugal BI
100%	69%	83%	89%

Housed Centrifugal FC	Housed Centrifugal Radial	Unhoused Centrifugal	In-line Centrifugal and Mixed Flow
56%	96%	84%	79%

Centrifugal Powered Roof Vents	Axial Powered Roof Vents	Circulating Fans	Air Curtains
86%	94%	78%	72%

Item 2-12 DOE requests comment on whether standards should be considered only for fans with an impeller diameter less than 98 or equal to inches and whether that impeller diameter distinction is appropriate for all fans equipment classes being considered in this rulemaking. 12

AMCA concurs with the 98-inch impeller limit, but we advise DOE that most manufacturers labs' are limited to a test size diameter of 1 meter. The Fan Laws are used to calculate larger sizes, which is allowed under the AMCA Certified Ratings Program because this method results in conservatively calculated performance data.

Item 2-13 DOE requests comment on whether to similarly consider a minimum fan diameter in this rulemaking. 13

As discussed in Item 2-14, AMCA strongly believes that the most important threshold for a minimum fan size is starting at > 5 HP.

Item 2-14 DOE requests comment on considering standards for fans with power requirements between 125 W and 500 kW for this rulemaking. 13

AMCA supports having the scope of coverage range from > 5 HP and <= 200 HP. This makes the lower end of scope consistent with ASHRAE 90.1-2013, which was also proposed by AMCA and ASHRAE as the lower limit in IECC-2015.

There are several reasons for AMCA's position on having the rulemaking begin at fans > 5 HP:

1. Consistency with new building codes and standards provides manufacturers, designers, contractors, building owners, distributors, and other industry stakeholders with a uniform compliance and enforcement regime for a product undergoing its first regulatory experience.
2. This range constitutes approximately 50% of the known connected horsepower, based on AMCA market estimates. We believe this is a high fraction of the extant market for a first-time regulation.
3. This range is sensitive to the needs of small businesses, which comprise more than 80% of AMCA members and DOE's own estimate of small-business fan manufacturers. Smaller fans are more expensive to re-engineer and re-tool because of their smaller size and tighter tolerances.
4. Many fan manufacturers have products from small fans (less than 1 HP) to large fans (more than 100 HP). Phasing the scope of coverage by fan size is reasonable; not phasing in the scope of coverage will place an undue burden on all manufacturers, and especially the small-business fan manufacturers.
5. Starting at fans > 5 HP keeps the regulation from impacting residential applications, thus ensuring that DOE's regulatory intent of affecting only commercial and industrial fans is maintained.
6. Having the upper range at 200 HP max is substantiated by the small number of units shipped between 200 HP and 500 HP, which is a small fraction of the total HP shipped, and typical fans over 200-HP are already at a high efficiency (> 70%), therefore regulation of fans exceeding 200 HP will produce little, if any, efficiency gain. This is a mature market and we have reached near theoretical maximums at these high-HP fans.
7. The real opportunity in fans over 200 HP lies in the retrofit market. Systems using these fans change over time. The result is a fan that was sold at a 70-85% efficiency rating operating in the 50% or lower range. There is tremendous energy

saving to be found by driving a retrofit market for fans above 200 HP. AMCA believes that this is beyond the scope of this rulemaking but offers it as a suggestion that a significant opportunity for energy savings, if it somehow could be explored.

Item 2-15 DOE requests comment on these exclusions, specifically regarding whether they should be applied to this rulemaking. Why or why not? Are there any other fan characteristics that DOE should consider as criteria for exclusion? 13

AMCA agrees with the exclusions listed above that are from EU 327/2011 Article 3, Section 4, but also suggests other exclusions in EU 327/2011 that are included in Article 1, Section 3:

1. Fans designed specifically to operate in potentially explosive atmospheres
2. Fans designed for emergency use only, at short-time duty, with regard to fire safety requirements
3. Fans designed specifically to operate:
    a. Where temperatures of the gas being moved exceed 100°C
    b. Where ambient temperatures for the motor, if located outside the gas airstream, driving the fan exceed 65°C.
    c. Where the annual average temperature of the gas being moved and/or the operating ambient temperature for the motor, if located outside the gas stream, are lower than -40°C.
    d. In toxic, highly corrosive or flammable environments or in environments with abrasive substances.

The exclusions above define a broader industrial market. In these markets data indicates that the average installed efficiency exceeds 70%. These products represent a mature market where power consumption and efficiency have been part of the purchase decision for many years. Furthermore the utility of the application coupled with the first cost of these systems have driven efficiencies to a much higher level than in other applications.

Item 2-16 DOE requests comment on the percentage of fan motors estimated to be covered by the small and medium electric motor standards. Specifically, does the industrial plant motor study performed by WSU represent the commercial and industrial fan industry as a whole? Why or why not? 14

AMCA surveyed its members on this question, and the response showed that only three of the respondents agreed; eight disagreed, and 10 answered, "do not know." Several of the respondents provided supporting comments, as follows:

Disagree	The most common motors in our commercial industry are fractional, single-phase motors.
	In terms of number of motors, only 20% are subject to "NEMA"

	efficiency regulations. About 50% are sub-fractional (< 1/8 hp).
Disagree	Our data supports a split of 45% single phase and 55 % all other phases
Disagree	This number is much closer to 100% for us.
Disagree	We sell more than 10% of our fans with single-phase motors.
Agree	Most of our products are commercial and are used (but not sold) with > 1-HP NEMA induction motors
Don't know	60% of the motors used in our air curtains are less than 1HP, 115/1/60.
Disagree	The breakdown on motor size might be applicable the load profile, hours of operation and duty factor are not at all related

Item 2-17 DOE seeks comment on the market share (by fan type) and applications of fans that are driven by equipment other than electric motors. 14

AMCA has surveyed its members for input on market share by fan type on fans that are driven by equipment other than electric motors. Except for a 1% market share for Tube Axial fans, all other fan categories were effectively 0%.

That being said, in the industrial markets we see alternative forms of drives. These are typically steam turbine and engine driven fans. The engine driven fans are used typically in portable systems where electricity might not be readily available. These applications would include remote mining and drilling operations as an example. Also many engine systems have radiator-cooling fans that are driven by the engine that the fans are cooling. For example, this is common in the automotive industry. Steam turbine driven fans are typically found in industrial plants where steam is readily available and in an overabundant supply or where simply the presence of electricity can present a dangerous situation like in many petrochemical processing operations.

Even with the alternative drives utilized in the industrial portion of AMCA's market, it is likely that over 95% of fans are driven by electric motors.

Item 2-18 DOE requests comment on the transmission types to be considered in this rulemaking. 14

AMCA believes the transmission systems defined are more than adequate.

Item 2-19 DOE requests comment on the types of VSDs sold with fans and whether there is efficiency variability (and if so, to what extent) among VSDs. 15

VSDs in fans take several forms. Steam turbines, magnetic couplings, fluid couplings, electrically commutated motors and variable frequency drives (VFDs) are all forms of VSD. AMCA does not have the expertise to compare and contrast the potential energy savings of these different methods of offering speed control to fans beyond the fact that mechanical speed control devices all suffer from mechanical losses and electrical speed control systems suffer from electrical losses.

AMCA cannot comment upon the relative energy advantages of one over another nor can we compare and contrast items within either of the classifications.

Item 3-1 DOE requests comment on the use of the AMCA 210-07 test procedure as a base for the development of a DOE test procedure. .... 16.

With the exception of induced flow fans, which should be tested in accordance with AMCA 260, AMCA recommends AMCA 210 as the primary test procedure. AMCA does have test standards for air curtains and circulating fans; however, we believe these fan types should be exempted from the ruling.

Item 3-2 DOE requests comment on for what other applications crossflow fans are used and the breakdown of crossflow fan use across the fans market in those applications. ...... 17.

Of the 21 fan manufacturers responding to AMCA's survey, only two make crossflow fans. They commented that their crossflow fans are used for industrial applications where a blanket of uniform air velocity is needed (paper, printing), and for space heating and electronics cooling. Neither of these companies make air curtains.

Additionally, the two largest domestic manufacturers of air curtains responded to this survey, and they stated that they do not use crossflow fans, and that crossflow fans are popular in air curtains used overseas.

Although crossflow fans are much less efficient than conventional fans, they are used when no other choice is feasible. In many instances, a conventional, more efficient, fan would have to be fitted with energy-robbing inlet and outlet fittings, raising the demand for air power from the efficient fan - such the that lower air power demand on the crossflow fan more than compensates for its inefficiency. In other words, the crossflow fan may be much less efficient, but it will use less energy because its configuration so dramatically lowers the demand for air-power from the fan.

In Europe, the early versions of fan efficiency regulations will force crossflow fans off the market, which means that applications that demand a crossflow air curtain design will go unserved. An unserved opening with no air curtain will consume far more energy than an opening protected by an air curtain with an inefficient fan.

The market for air curtains with crossflow fans is very small, and the aggregated power of crossflow fans in service is small. AMCA therefore recommends that crossflow fans be excluded from DOE regulations.

ITEM 3-3 DOE requests comment on the applicability of AMCA Standard 210-07 in coordination with AMCA Standard 220-05 for measuring performance of crossflow fans.

No, ANSI/AMCA 220-05 (2012) is used to test air curtains only. Crossflow fans should be excluded from regulation.

ITEM 3-4 DOE requests comment on whether air curtains must be tested for performance in use with a motor, or whether fan performance as recorded through AMCA 210 test methods would provide accurate performance estimates.

AMCA recommends that air curtains be excluded from the regulation.

ITEM 3-5 DOE requests performance data for crossflow fans.

AMCA recommends that crossflow fans be excluded from regulation.

Item 3-6 DOE requests comment on the ability of using a clean air only test procedure to determine the efficiency of fans designed for dust air or material handling applications that could be compared to fans not designed for handling such materials that are in the same equipment classes (see section 5.2 for equipment class discussion). 17

AMCA recommends that clean air be used to test fans designed for dust or material handling applications. Duct and material affect density and fan efficiency is not a function of density.

Item 3-7 DOE requests comment on which test configuration should be considered for each of the considered equipment classes. .... 18.

AMCA recommends that air curtains and circulating fans be excluded from the regulation, AMCA 260 should be used for induced flow fans, and that AMCA 210 should be used for the remainder.

AMCA recommends that the manufacturer be allowed to select the test configuration in order to meet the needs of their customers. Having the test configurations imposed by the regulation would present an undue burden on manufacturers, and could have adverse impacts on consumers' choices. AMCA standards require test configurations be reported with efficiency ratings; AMCA recommends that DOE follows this approach.

Item 3-8 DOE requests comment on requiring an air straightener at the outlet for axial fans tested in configuration B or D. 18

The use of the straightener applies to a subclass of housed axial fans called tube axial fans. Vane axial fans and unhoused axials (circulating fans) are not affected by the provision in ISO 5801 requiring the straightener. In actuality, the straightener adds to the uncertainty of the test rather than reducing it.

The purpose of the straightener is not related to creating reproducible test data. The purpose of the straightener is to prevent significant tangential flow from a high swirl fan from impacting pressure taps located downstream of a fan when fan performance is measured at the fan's outlet. If the straightener was not present, flow hitting the pressure taps tangentially could cause an erroneous measurement of fan static pressure. The flow straightener is not a part of the fan, so the pressure drop caused by the straightener must be added to the pressure measured at the pressure taps. There is no measurement method to do this, so a fully developed flow profile free from swirl is assumed, and the pressure drop of the straightener is calculated by an equation and added to the pressure measured at the pressure taps. The problem with this approach is that the flow from a tube axial fan is never fully developed and never free from swirl, so the add-back of the calculated pressure drop of the straightener is too low and the tube axial's performance results are penalized. One could say that the flow straightener actually adds to the inconsistency of tube axial test results because the pressure drop across the straightener is always calculated incorrectly, and the magnitude of the error changes with each performance point and with each fan. See the paper on stratighteners, *Industrial Fans – Performance Testing Using Standardized Airways,* by Mark Stevens of AMCA International. The paper was given at an IMechE conference in London in 2003 and published in the IMechE journal (The paper is provided as Appendix 2 these comments for the docket.) AMCA 210 solves this problem by measuring tube axial performance at the inlet instead of the outlet. Because no pressure measurements are made on the outlet, no straightener is used to condition the outlet flow, hence the straightener's uncontrolled and variable pressure drop errors are omitted. On a final note, ISO 5801 is currently under review by ISO TC 117 Working Group 7, of which AMCA staff and members are nominated experts. The German delegation proposed changing ISO 5801 in this area to make it agree with AMCA 210. The consensus of the WG voted in agreement with the German proposal.
Item 3-9 DOE requests comment on the use of publicly available performance data in lieu of original test data. .... 19 AMCA operates an ISO 17065 accredited certification program that members and non-members participate in. When AMCA checks catalog or selection program data of members' certified ratings, the published ratings are compared to the base test data. In addition, AMCA selects fan models not previously tested and requires manufacturers to supply physical fans for testing as part of its periodic check test procedure applied to all certified products. For fans with AMCA certified ratings, the use of published ratings, base test data or check test data will, therefore, yield the same result. For products that are not certified, base test data from an independent accredited lab should be used to assess the validity of published ratings. AMCA and member companies have thousands of tests that prove the fan laws correctly predict fan performance and efficiency under standardized conditions. Base data used for ratings represents an adjustment to base test

data, which (of necessity) tests using non-standard air. AMCA agrees to the necessity of detailed catalog data based on certified ratings, or base test data validated from an ISO 17025 accredited laboratory to judge compliance.
Item 3-10 DOE requests fan performance data generated from AMCA 210 tests. .... 19 Fan performance data is published by manufacturers. Base and check test data collected at the AMCA laboratory is owned by the manufacturer, and covered by confidentiality agreement, which are required under AMCA's accreditation as a certification body. Such data may be available from manufacturers under cover of a confidentiality agreement between DOE representatives and the manufacturers. While actual test data is owned by the manufacture, AMCA requires certified product ratings be made available in the public domain, and that AMCA be empowered to check the validity of such certified ratings at any time using base test data generated or confirmed at AMCA's accredited lab.

Item 3-11 DOE requests comment on the considered efficiency metric approaches. 20

Fan Efficiency Grade (FEG) is a good fan efficiency metric that indicates the aerodynamic quality for fans with ducted discharges. FEG documentation acknowledges the fact that smaller fan diameters of a given product line will have lower peak total efficiencies than larger fan diameters. This metric has been adopted by ASHRAE 90.1-2013 and the IgCC-2012 (International Green Construction Code), and is currently being considered for inclusion in the IECC-2015 (International Energy Conservation Code) and ASHRAE 189.1-2014.

Specifying FEG alone, however, is not a guarantee of fan energy savings. AMCA recognized this when it created AMCA Standard 205, *Energy Efficiency Classifications for Fans*, and required that fan selections must be made within 15 points of peak fan total efficiency. Checking a fan for FEG compliance can be accomplished by a simple aerodynamic test. The results of the fan test can also be used to predict the performance of the fan at an infinite combination of speeds and operating conditions by using the Fan Laws.

Fan motor efficiency grade (FMEG) was defined by ISO 12759, *Fans – Efficiency Classifications for fans*, and includes the overall efficiency of the fan, motor and drive. This metric was adopted by the European Union and became law in January 2013 under Commission Regulation (EU) No 327/2011. The Europeans selected this metric based on peak efficiency because they most commonly sell direct driven product with dedicated motors/drives. The FMEG metric recognizes the aerodynamic quality of non-ducted fans is best represented by static efficiency and the aerodynamic quality of ducted fans is best represented by total efficiency.

FEG was chosen by the United States because most products sold in the U.S. are belt driven and have a large number (hundreds of thousands for most manufacturers) of end use? items when all of the different motor and drive permutations are considered. Also, FEG is a metric that is based on testing and has a third party validation of performance. FMEG is an extended-product metric based on both test and the application of factors and is self-certified by the manufacturer.

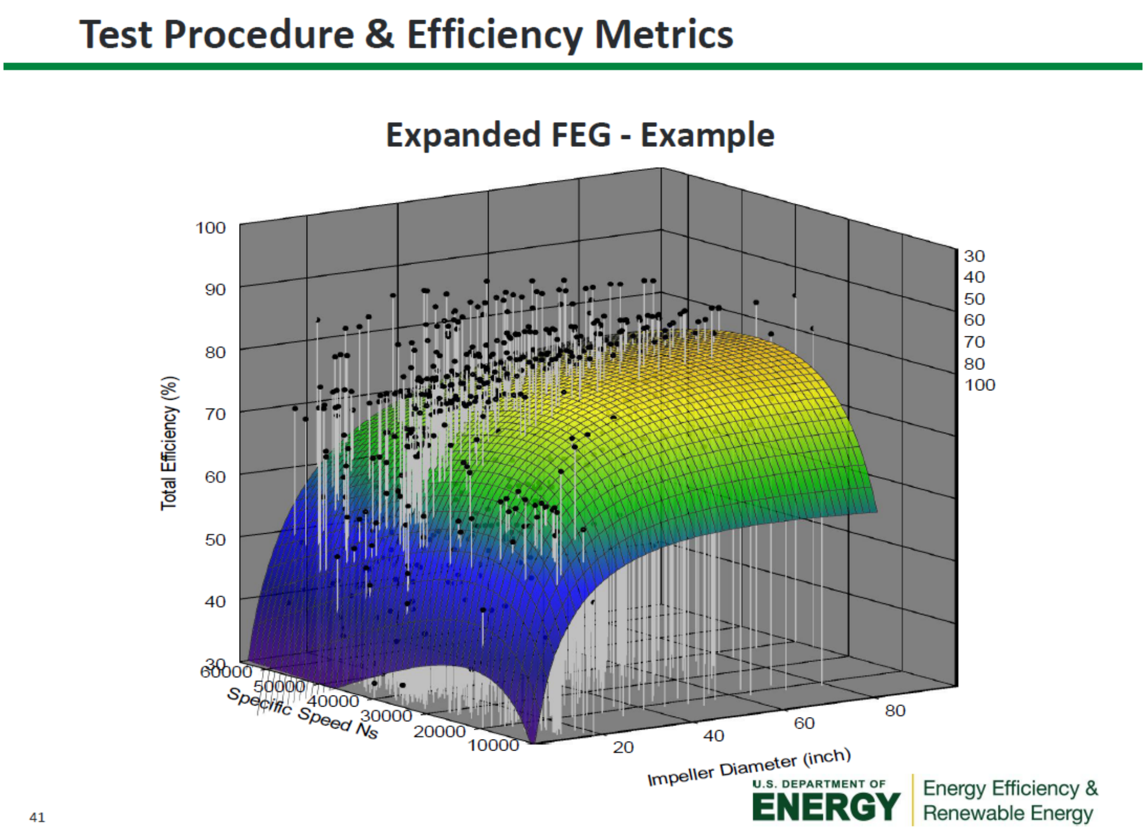
One shortcoming of a single-value metric applied to all fans is that specifying too high a number would eliminate fans designed for low-pressure applications that actually consume less energy! ASHRAE recognized this unintended consequence and chose to exempt power roof ventilators from their FEG requirements in ASHRAE 90.1-2013.

Wire-to-Air is another metric that AMCA is currently developing that determines the ratio of the output air power (CFM x pressure) to the input electrical power (kW in). This metric would be a combination of tested fan efficiency and rated or calculated efficiency of motors and drives.

VFD (Variable Frequency Drives) – Because fan manufacturers rarely sell VFDs with their fans, AMCA members are not interested in a regulation that includes the performance of the VFD. Currently, VFDs are not regulated and accurate information on their efficiency at full load as well as part load is not known. Fan manufacturers do not want to be held accountable for a component that they don't manufacture or sell.

At the DOE Framework Document public hearing, a slide in the presentation contained a comment indicating that the DOE is interested in expanding the FEG approach to incorporate operational conditions of the fan; DOE would evaluate efficiency against combinations of size and operational parameters, for example, diameter and specific speed.

Additionally, the following plot was displayed:



AMCA is interested in understanding the content of the plot. For instance, we would be interested in what the scale at the top right portion of the graph pertains to.

AMCA would also be interested in understanding the value of the additional calculation of specific speed in the metric. Consulting *Fan Engineering* (Howden Buffalo, Inc. 1999), the fan laws allow a plot of specific speed vs. efficiency to describe an entire product line – or at least an entire product line that is scaled using the fan laws. The peak efficiency on the plot of specific speed vs. efficiency would describe the peak efficiency for that model scaled to any size using the fan laws. Because the fan laws allow scaling based on diameter, it would appear that having an additional axis for diameter over-specifies the metric. Using the fan laws, all the data points in the above graph could, in theory, be scaled to a single diameter for comparison, or similarly, using specific speed vs. efficiency should make diameter irrelevant.

AMCA would also appreciate the opportunity to recreate the above plot using data collected by

AMCA. AMCA is interested in a detailed algorithm – a step-by-step approach – to calculate, in particular, the specific speed used in the plot.

Item 3-12 DOE requests data and/or sources of information for developing the representative load profiles for each fan equipment class (see section 5.2.1 for equipment class discussion)... 21

Such data may be available from the HVAC or building modeling community. Member and non-member companies of AMCA may also research and monitor such information. AMCA has no such data. AMCA members do collect data related to operating conditions at which fans are sold and possibly the efficiency of the selections customers make. AMCA will share the data it has collected from its members in this regard along with our recommendations and computations of savings that will result from different efficiency minimums DOE may wish to test. AMCA would like to call DOE's attention to AHRI Standard 1210, where part load operation at 100%, 75%, 50%, and 40% are referenced on variable volume applications.

Item 3-13 DOE specifically requests comment on the part-load airflow test points that would represent a typical variable load for a fan as well as how many part-load test points it should consider.. 21

When fans are tested in accordance with AMCA 210, the entire performance curve is generally tested, from free air to shut-off.

AMCA recommends an FEG metric for a fan efficiency regulation, which is characterized at peak fan total efficiency. Part load operating points, arrived at from changes operating speed, will have same efficiency as the full load test point, as the Fan Laws have no effect on efficiency.

Item 3-14 DOE is interested in what test points, in addition to conditions at peak total efficiency, are appropriate for a variable load metric and how many test points should be included to address the complete operating range of fans with or without VSDs. 21

See AMCA's response to Item 3-13

Item 3-15 DOE requests comment on an appropriate efficiency calculation to capture the energy efficiency impacts of VSDs. Specifically, DOE requests comment on the use of an input power based efficiency versus an overall peak efficiency when comparing efficiencies. 22

AMCA has adopted an FEG efficiency metric to characterize fan efficiency, and AMCA is currently developing a wire-to-air efficiency metric. The wire-to-air metric will allow for the direct measurement of wire-to-air efficiency when desired and when the electrical components are known and available for testing, and will also allow for standardized efficiencies for motors, VFDs, belts etc. when these components are not available or not known at the time of test. AMCA believes that the application of a "wire-to-air" efficiency metric should wait until this global industry standard is established.

This committee developing this wire-to-air standard is a truly global committee, with half of the committee members from North America (with one of these members working for a subsidiary of a large German fan company) and the other half from Asia. Two of the Asian committee members are responsible for the developing Chinese national standard GB19761. It is our expectation that GB19761 will be amended to include AMCA's wire-to-gas standard with eventual adoption of the standard by China's AQSIQ.

Item 3-16 DOE requests comment on the FMEG efficiency metric. 22

See AMCA's reply to Item 3-15.

Item 3-17 DOE requests comment on the use overall efficiency for fans sold with both motors and VSDs. 23

Please see AMCA's reply to Item 3-15.

Item 3-18 DOE requests comment on the use input power based efficiency for fans sold with motors where VSDs are a design option to improve efficiency.

Based on earlier responses, at this point in time AMCA recommends sticking to an efficiency metric based on a fan without a drive.

AMCA realizes that it is important to get a "watts in" metric, and its members worldwide are working on a global standard and a publication with listing rules similar to AMCA 211 based on "wire-to-air" efficiency metric similar to that described in the Framework document, using either testing of the assembly or testing of the fan and minimum drive and motor efficiency levels.

Item 3-19 DOE requests comment on the metrics discussed above, including whether a weighted average metric should be developed under the third metric option. 24

Please see AMCA reply to Item 3-15.

With regard to the third metric option, it should be noted that VSDs do not improve the efficiency of the fan, but they can reduce the consumed power of the fan by changing the fan's speed such that the fan's output matches the requirements of the system.

Item 3-20 DOE recognizes that the same fan may in some cases be sold bare shaft or in conjunction with a motor or motor/control package. DOE seeks comment on any issues that may result from having different metrics for fans sold alone and fans sold with motors or VSDs. ….. 24

Please see AMCA reply to Item 3-15.
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Item 5-1 DOE requests information that would contribute to the market assessment for fans that would be covered in this rulemaking, especially for those equipment classes designated in section 5.2. Examples of information sought include current equipment features and efficiencies, equipment feature and efficiency trends, and historical equipment shipments and prices. 28

AMCA recommends that DOE use AMCA's fan classes as described in Item 5-3.

AMCA surveyed its members that manufacture fans and asked them to indicate what equipment and features are sold with fans in each of the classes.

The table below provides examples of the equipment and features sold with fans in each of the fan classes being recommended by AMCA. The majority of these features are not included when fans are rated for performance, and therefore are not included when determining fan efficiency ratings.

Fan Class	**Equipment / features sold with fan**
Vane Axial	Guard, drain, access door
Tube Axial	Guard, drain, access door, and motor covers
Panel Prop	Wall housings, rain covers, dampers, guards
House Centrifugal BI	Flange connectors, mounting isolators, dampers, drains, electrical cables/connectors, labels, guards, drain, split housing, access door
House Centrifugal FC	Flanges, drains, cables, labels, guards, drain, split housing, access door
House Centrifugal Radial	Flanges, guards, drains, split housing, access door
Unhoused Centrifugal	Partial width impeller, electrical cables/connections, labels, inlet rings, acoustic enhancement, peizo ring, precision balance, spring isolation. Guards.
In-line Centrifugal and Mixed Flow	Speed controller, mounting isolators, motor covers, guards, custom paint, electrical cables/connections, labels
Centrifugal PRV	Increasingly specified with EC motor; dampers, curbs, speed controllers, custom paint, electrical cables/connections, labels
Axial PRV	Dampers
Circulating Fans	Custom paint, electrical cables/connections, labels
Air Curtains	Electric heat, door switches, VFDs, time delays to prevent continuous cycling the unit on/off, door activation switches (only on when door is opened)

Item 5-2 DOE requests comment on the estimates of the number of U.S. fan manufacturers and the number of small businesses in the industry........................ 29

DOE estimates that there are approximately 140 establishments in the commercial and industrial fan industry. AMCA believes DOE's estimate is low. AMCA estimates that there are approximately 212 fan manufacturers that sell fans in the United States. Of these, 165 are members of AMCA International. These numbers do not include companies that make fans for their own equipment, such as those for ovens, dust collectors, car wash blowers, paint booths, etc. The numbers also do not include companies that buy fan parts, such as impellers, and adds a drive component; this number alone could be thousands of companies.

DOE estimates that 123 of the 140 (~88%) fan manufacturers are small businesses based on Small Business Administration's definition (having fewer than 500 employees). Approximately 80% of AMCA fan-manufacturer members have annual revenues under $10 million dollars; and 97% have annual revenues under $50 million per year. AMCA does not track employment statistics of its members; however, based on the revenue numbers reported by members, AMCA estimates that more than 90% of its members would meet the Small Business Administration's definition of "small businesses."

Item 5-3 DOE welcomes comments on whether there are other design characteristics that should be considered when establishing equipment classes. 29

Yes, other design characteristics should be considered when establishing equipment classes:

1) **Installation** – e.g., roof/wall mounted vs. ducted. Modifications made to fans to lower installation cost or protect the fan from the weather will impact fan efficiency.

2) **Operating pressure** – fans designed to be efficient at high pressure are not always efficient when applied at lower pressures. Fans with a low peak total efficiency can actually consume less energy at lower pressures than fans with a high peak total efficiency. Examples are powered roof/wall ventilators.

3) **Absence of outlet duct –** if a metric based on total efficiency is used for fans that are generally applied without a duct on their outlet, the unintended consequence may be increased power consumption. It is beneficial from an energy consumption perspective to minimize the fan velocity pressure for non-ducted fans.

   Non-ducted discharge fans should not be rated with a metric that is based on fan total efficiency. They should use fan static efficiency, which is proportional to energy consumed in a configuration without an outlet duct. This would typically apply to the following equipment classifications: panel fans, unhoused centrifugal, centrifugal power roof/wall ventilators, and axial power roof/wall ventilators.

4) **Acoustics** – There are some situations where a less efficient fan is desirable because it meets acoustical requirements expressed in building codes and standards or by project's where acoustics are of particular concern. Forward curved fans, for example, are highly

compact and quiet fans, although less efficient than counterparts.

5) **Safety –** Induced flow fans were developed to elevate exhaust plumes to meet air quality requirements.

Based on DOE's rationale and AMCA's notes above, AMCA recommends that DOE adopt AMCA's fan class represented in Table 1, with definitions in Table 2 (which are pulled from Appendix 1 unless otherwise noted).

Table 1: AMCA Fan Classes (Categories) Recommended for DOE Framework Document

Fan Class/Category	Fan-Type Definition
Vane Axial	An axial -flow fan with cylindrical housing with guide vanes before or after the impeller, or both.
Tube Axial	An axial-flow fan with a cylindrical housing and no guide vanes
Panel Fans	An axial fan without a cylindrical housing, which is mounted in an orifice plate or ring. Also known as a propeller fan.
Housed Centrifugal Backward Bladed	A type of centrifugal fan with a housing and with impeller blades that are positioned to direct the airflow out of the impeller in the direction opposite to the impeller rotation. Blade profiles can be flat, curved, or airfoil in shape. Industry practice distinguishes fans based on blade profiles as Backward Inclined (flat); Backward Curved (curved); and Airfoil.
Housed Centrifugal Forward Curved	A type of centrifugal fan with a housing and with impeller blades curved to direct the airflow out of the impeller in the direction of the impeller rotation.
Housed Centrifugal Radial Bladed	A type of centrifugal fan with a housing and with impeller blades positioned to direct the airflow out of the impeller perpendicular to the axis of impeller rotation.
Unhoused Centrifugal	A centrifugal fan without a housing.
Induced flow fans	A housed fan with a nozzle and a windband and whose outlet airflow is greater than its inlet airflow due to induced airflow. All of the flow entering the inlet will exit through the nozzle. The flow exiting the windband will include the nozzle flow plus the induced flow.
Centrifugal Inline and Mixed Flow	*Centrifugal inline:* A housed fan with a centrifugal impeller designed to be mounted between duct sections with air flowing in an axial direction at the inlet and outlet.

	Mixed flow: A fan in which the fluid path through the impeller is essentially between 20 and 70 deg. relative to the axis of rotation.
Centrifugal Power Roof/Wall Ventilators	A fan consisting of a centrifugal impeller with an integral drive in a weather-resistant housing and with a base designed to fit, usually by means of a curb, over a roof or wall opening.
Axial Power Roof/Wall Ventilators	A fan consisting of an axial impeller with an integral driver in a weather-resistant housing and with a base designed to fit, usually by means of a curb, over a roof or wall opening.
Circulating Fans – EXEMPT	From ANSI/AMCA 230-12: A non-ducted fan used for the general circulation of air within a confined space. Various types of air circulating fans are defined in ANSI/AMCA 230-12.
Air Curtains & Crossflow Fans - EXEMPT	*Air Curtain:* From ANSI/AMCA 220-05 (rev 2012): Directionally-controlled airstream, moving across the entire height and width of an opening, which reduces the infiltration or transfer of air from one side of the opening to the other and/or inhibits insects, dust or debris from passing through. For the purposes of this definition, "air curtain" and "airstream" are synonymous. *Crossflow fan:* A fan in which the fluid path through the impeller is in a direction essentially at right angles to its axis both entering and leaving the impeller at its periphery.

Here are the deviations from the proposed DOE Equipment Classes in Table 3:

- Change "Axial – Housed" and "Axial – Unhoused" into separate classes for "Vane Axial," "Panel," and "Tube Axial". Vane Axial fans are efficient machines with straightening vanes that are used in ducted applications. Panel fans have no straightening vanes and are usually non-ducted. Tube Axial fans should have their own category and should be tested and rated with a ducted discharge.

- Divide the "Centrifugal Clean Air Housed" into two classes, "Housed Centrifugal – Backward Inclined" and "Housed Centrifugal – Forward Curved" to preserve the Forward Curved (FC) products. Although FC fans don't have total efficiencies as high as BI fans, when applied at low pressures they are lower first cost, are more compact, generate lower sound levels and can actually consume less energy.

- Combine "Centrifugal Dust Air Housed" and "Centrifugal Material Handling Housed" into one class – "Housed Centrifugal – Radial Bladed".

- Eliminate "Blowers – Axial" and "Blowers – Centrifugal". These fans will be absorbed into other categories. AMCA does not recognize a distinction between fans and blowers; these terms which are used interchangeably in America.

- Eliminate "Axial Safety Fans" and "Centrifugal Safety Fans". Fans used for life safety applications (like emergency smoke exhaust) are often modified in such a way to reduce the fan efficiency (increased running clearances, belt tubes, other appurtenances). Their usefulness and utility should not be measured by fan efficiency and they should be exempt from this regulation.

- Exempt fans in the category of "Crossflow Housed" because of their intended use to create a wide "ribbon" of velocity. Crossflow fans are sometimes used in Air Curtains, especially overseas, and in specialized industrial applications.

- "Circulating Fans" and "Air Curtains (including Crossflow Fans)" should be in their own categories due to their unique designs, but AMCA recommends that they should be exempt from this regulation because fan efficiency is not a good measure of their intended purpose or usefulness. These types of fans are used as energy-conservation measures, to reduce cooling loads by substituting air motion or by reducing air infiltration/exfiltration with a kinetic barrier. Regulating their fan efficiency could increase their costs and compromise their performance, thus curtailing their use, thereby increasing net energy consumption.

Item 5-4 DOE requests comment on whether the development of separate equipment classes, and thus separate efficiency standards, is necessary to accommodate different performance characteristics of fans sold bare shaft versus fans sold with the motor, transmission, and/or controls. 30

Yes, separate efficiency standards would be required. Bare-shaft-fan (fan) minimum efficiency levels are appropriate for fans offered without motor and drive and an integrated wire-to-air minimum efficiency level as previously described (based on a combination of tested fan efficiency and rated or calculated efficiency of motors and drives) may be appropriate for fans, which are sold as a package.

Item 5-5 DOE requests comment on splitting axial fan types into housed and unhoused equipment classes or whether a single equipment class would sufficiently represent axial fan applications. 31

Please see AMCA's response to 2-5, set forth in Appendix 1. The different types of fans identified there reflect the diverse needs of multiple applications, which have resulted in different aerodynamic solutions and design categories. AMCA considers the definition of axial fans incomplete and not consistent with industry terminology. Fans used for life safety should be excluded.

Item 5-6 DOE requests comment on what types of axial fan designs or characteristics are unique to axial-type safety fans...................................... 31

Fans that serve life-safety and process-safety applications often have physical attributes that distinguish them. For example, fire-life-safety fans must function at high temperatures in compliance with applicable UL and NFPA requirements. Not all safety related fan applications are differentiated, however.

Item 5-7 DOE requests comment on whether there are any other commercial or industrial applications (beyond clean air, dust air and material handling) that should be considered while defining equipment classes for centrifugal fans. 31

As previously submitted, AMCA has supplied a categories list identifying class by fan type as opposed to application. Safety fans, such as fans used in smoke and heat management systems, should not be considered for equipment classes.

Item 5-8 DOE requests comment on the considered groupings of housed centrifugal fans. Specifically, DOE requests comment on the use of air quality (Clean Air, Dust Air, Material Handling) and geometrical design descriptors for classification purposes. 32

Please see AMCA's response to Item 5-3.

Item 5-9 DOE requests comment on whether the Dust Air, Material Handling, and Crossflow fan equipment classes should be split into housed and unhoused categories. 32

Please see AMCA's response to Item 5-3. Dust Air and Material Handling should be combined into one equipment classification – "Housed Centrifugal – Radial Bladed". An unhoused category is not required. AMCA strongly recommends that Crossflow fans be excluded from the regulation, because these fans are designed and purchased to meet specific conditions that are unable to be met with more efficient and aerodynamic designs.

Item 5-10 DOE requests comment on setting crossflow fans as a separate equipment class within the centrifugal fans category. 32

AMCA recommends that crossflow fans should be excluded from regulation. The marketplace has already confined these fans to very limited applications where crossflow designs are required, because they are inexpensive and inefficient relative to more conventional alternatives.

Item 5-11 DOE requests information about the specific design characteristics of crossflow fans. 33

Please see AMCA's response to Item 5-10.

Item 5-12 DOE requests comment on what types of centrifugal fan designs or characteristics are unique to centrifugal-type safety fans. 33

Fans that serve life-safety or process-safety applications often have physical attributes that distinguish them from general ventilation fans.

For example, fire-life-safety fans must function at high temperatures in compliance with applicable UL and NFPA requirements. Operating at high temperatures may require the use of special construction materials and components to resist the elevated temperatures. Design changes may also be required to provide additional running clearance between the inlet and wheel to account for housing growth, as well as non-optimal wheel-inlet overlap to account for different expansion rates for the housing, wheel and or shaft. These changes will reduce fan efficiency.

Fans designed to handle explosive, corrosive or abrasive gases, again require specialized materials and components depending on the environment. Special shaft seals, thick protective coatings, and wear plates on the wheel and housing can all reduce fan efficiency.

AMCA recommends that DOE eliminate "Axial Safety Fans" and "Centrifugal Safety Fans" as classes. Fans used for life safety applications (like emergency smoke exhaust) are often modified in such a way to reduce the fan efficiency (increased running clearances, belt tubes, other appurtenances). Their usefulness and utility should not be measured by fan efficiency and they should be exempt from this regulation.

Item 5-13 DOE requests comment on setting a separate equipment class for blowers. 33

AMCA believes the definition of blowers in the framework document is not material, as the terms "fan" and "blower" are used interchangeably in the U.S. market.

Item 5-14 DOE requests comment on whether there is a need of more than one blower equipment class to account for the differences between centrifugal and axial blowers. ... 33

AMCA believes the definition of blowers in the framework document is not material, as the terms "fan" and "blower" are used interchangeably in the U.S. market.

Item 5-15 DOE requests comment on setting a separate equipment class for mixed flow fans. 33

Please see AMCA's response to Item 5-3. Mixed Flow fans are in an equipment class that includes Centrifugal Inline fans.

Item 5-16 DOE requests comment on whether there are differences among mixed flow fans that might warrant more than one equipment class for this fan type. 33

Please see AMCA's response to Item 5-3 and 5-15. Mixed Flow fans are in an equipment class that includes Centrifugal Inline fans.

Item 5-17 DOE requests comment and/or information on the effect of different materials on efficiency. 34

Material choices vary because they have different strength, corrosion resistance, resistance to chemical reaction, temperature (fire resistance), and spark resistance. Ensuring that the most efficient fan is selected for the duty will save more energy than materials considerations.

Item 5-18 DOE requests comment on whether there are other fan blade materials that should be included in the list above.. 35

Other materials including, but not limited to, copper, brass, nickel, titanium and ceramic are used to deal with special needs related to the duty or safety code requirements of a fan application (i.e. strength, spark or abrasion resistance).

Item 5-19 DOE requests comment on whether there are compatibility issues with certain fans and VSDs DOE should be aware of when considering a VSD as a means to improve fan efficiency. 35

The paragraph above, *Variable Speed Drives*, states that "Variable speed drives … can be used as a means to improve efficiency for fans." A VSD adds to losses, and therefore does not improve the efficiency of a fan system; however a VSD can be used to lower part load power consumption.

Compatibility issues between fans and VSDs are generally related to resonance, which can occur at specific fan operating speeds. These speeds are not predictable, and are dependent on the fan as well as the installation condition. VSDs must be programmed to prevent operation at these speeds and limited to prevent operation of the fan above its maximum design speed. They must also be programmed for compatibility with the supplied motor. In some cases, frequent speed changes have the potential to reduce the life of the impeller due to fatigue.

Natural excitation occurs in all mechanical systems at some driving frequency. Good examples of this phenomenon are the tuning fork or a guitar string. Excited by mechanical forces, they resonate and vibrate, creating sound. A fan can do the same thing. However in rotating machine like a fan that excitation can be destructive. A fan that operates at fixed speed has the advantage that the manufacturer needs to be sure that excitation does not occur at, or near, the operating speed of the fan. A fan sold in variable speed needs to avoid such excitation across the operating range of speeds or the natural frequency of the installed system needs to be understood so that the VFD can be programmed to avoid running at the detrimental speeds. Some commercial fan systems are designed to operate above the first critical frequency where excitation exists and thus variable speed could force a change the mechanical design of the product. Most industrial systems are designed to operate below the first critical frequency and thus offer a clean operating range from 0 to 100% speed.

There may be other issues related to compatibility between VSDs and motors. However, AMCA members do not generally design or manufacture either motors or VSDs, so AMCA is not in a position to comment regarding these compatibility issues.

Item 5-20 DOE welcomes comments on the preliminary technology options identified in this section and whether there are other technology options it should consider. In commenting on technology options, please discuss their impacts, if any, on safety, performance, and user utility. 36

AMCA observes that the industry has been driven for over 100 years to improve the aerodynamic efficiency of air movement devices. Our members are not aware of any paradigm shifting under-exploited technologies that could benefit society from additional research and development aimed at improving the aerodynamic efficiency of fans.

Item 6-1 Are there any technologies, including those listed in section 5.3, that DOE should not consider because of any of the four screening criteria? If so, which screening criteria apply to the cited technology or technologies? 37

AMCA does not see any reason to eliminate any of the technology options due to the screening criteria.

Item 7-1 Once DOE establishes any representative equipment classes and representative units, it selects a baseline model as a reference point for each representative unit from which to measure changes resulting from the design options. DOE develops separate engineering analyses for each baseline model analyzed. DOE intends to use fan teardowns and fan efficiency (determined from fan performance tests) to develop cost-efficiency relationships for the fans analyzed. DOE intends to develop the necessary test procedures through a test procedure rulemaking, as discussed in section 3.DOE welcomes inputs from interested parties on a methodology that would be appropriate for determining the max-tech models for each fan analyzed. 38

The fan industry is a mature industry with mature designs and manufacturing processes. As such the efficiencies of the products represented in the suggested product classifications are quite near maximum technology. While some gains can be found in substituting higher performing products for lower performing products, AMCA believes the greatest pick up will be in limiting the misapplication of products in the market. Fans have a very steep efficiency curve meaning that the efficiency of the applied product drops very quickly as the fan is applied at pressure and flow points away from its peak efficiency. Fan application ranges overlap considerably. The combination of this fact and the steep efficiency curve creates a scenario where a smaller lower cost fan is applied far from its peak efficiency. While AMCA understands that the DOE cannot regulate the application of these products, AMCA believes that its industry's utilization and reliance on software based selection and pricing programs offers an opportunity to solve this problem.

AMCA believes that limiting the "marketable" or "sellable" range of our product to 15% from the fan's peak efficiency would provide a huge potential savings in fan energy consumption in the under-200-HP range of product.

Item 7-2 DOE seeks input on the methods and approaches used by manufacturers to improve the efficiency of fans. 38

Computational fluid dynamic modeling and flexible manufacturing concepts are being used to better match custom designed fans to application conditions. Such techniques require significant investment and may be beyond the financial capabilities of smaller organizations. But even with utilizing these technologies, AMCA members would emphasize these tools are not sufficiently powerful to eliminate the need for the building prototypes or samples to test models and additionally test high production fan product line designs that exploit the geometric similarity foundation, which enables use of fan laws for determining accurate ratings. AMCA members

also face limitations in manufacturing, materials and the price elasticity of demand that are considered in new designs.
Item 7-3 DOE welcomes comment from interested parties on the best methodology for scaling the representative units to other fan sized within the equipment class............. 38 Measuring the performance characteristics of a fan series for all possible speeds and sizes is not a practical undertaking due to the number of tests involved and/or limitations of test facilities. Therefore, scaling of test data to other speeds and sizes is a common practice in the fan industry in the United States as well as worldwide. The so-called Fan Laws offer a means to scale test data to other speeds and fan sizes. However, application of the Fan Laws is subject to inaccuracies due to Reynolds number effects, manufacturing tolerances, and other mechanical factors, such as bearing losses that do not follow the established Fan Laws. The FEG curves (AMCA 205) described earlier clearly show this effect in that peak fan efficiency drops sharply for fan sizes less than about 20 inches. The Fan Laws would otherwise predict no variation in peak efficiency as a function of fan size. Accuracy of the fan laws for predicting fan performance deteriorates as scaled performance point departs from the tested performance point. To this end, the AMCA Certified Ratings Program restricts the use of Fan Laws in establishing untested fan performance in a way that assures that the calculated performance is conservative. For example, the CRP only allows scaling of fan size to larger sizes whereas scaling to smaller sizes could lead to the fan efficiency being overstated. AMCA strongly recommends that the DOE consider testing several fan sizes within a fan classification to assure adequate performance coverage where fan efficiency varies strongly with impeller diameter. Scaling of fan sizes larger than 40 inches (per FEG curves) using the fan laws would be acceptable. AMCA also recommends the use of the fan laws for speed scaling of test data for a given fan size when the tested fan is operated at speeds no less than 67% of the maximum speed published by the manufacturer. For a more detailed technical and scientific explanation of fan laws used for rating fans, and the practical limits of this approach, please refer to AMCA 211 Appendix D.
Item 7-4 DOE seeks fan test data to improve DOE's understanding of fan performance to select appropriate representative units for the respective equipment classes. .... 38 Fan performance data is published by the manufacturer. Base and check test data is owned by the manufacturer, and covered by confidentiality agreements, which are required under AMCA's accreditation as a certification body. Such data may be available from manufacturers under cover of a confidentiality agreement between DOE representatives and the manufacturers.
Item 7-5 For each equipment class, DOE welcomes comment on methods and approaches that DOE intends to employ to determine potential fan efficiency improvements. Detailed information on fan performance and the incremental manufacturing costs (e.g., material costs, labor costs, overhead costs, building conversion capital expenditures, tooling/equipment conversion capital expenditures associated with more efficient designs, research and development (R&D) expenses, and marketing expenses) would be useful. ...

41

Some AMCA members may be able to provide such information under cover of individual confidentiality agreements. AMCA would like to communicate here that improvements in aerodynamic efficiency of fans that result in increased cost to the consumer may be justified if such improvements result in a reduction of fan energy at the operating conditions experienced in the field. A likely unintended consequence of such an increase in cost, however, would be for consumers to compensate for any noticeable increase in price by selecting in general, a smaller, less efficient, lower cost fan. As a result the actual efficiency of the installed fan may decline, and the energy consumed may increase. Proposed regulations to impose limits on allowable selection ranges such as ASHRAE 90.1 attempt to influence consumers toward more efficient fan selections.

Item 7-6 DOE welcomes comment on the markup approach proposed for developing estimates of manufacturer selling prices. 41

AMCA has no comment related to this item.

Item 7-7 DOE welcomes comment on the proposed approach to determine the relationship between manufacturer selling prices and fan efficiency. 41

While AMCA in general agrees with DOE's approach as described in Section 7 of the framework document, AMCA believes that the fan market is mature, and opportunities for cost effectively increasing fan efficiency are modest. Increases in efficiency gained through design are low compared to the cost to implement such improvements.

The fan market is a competitive market. Multiple manufacturers offer similar types of fans, with the prices of the fans being very competitive. Market factors associated with sales for specific projects can be the determining factor, not necessarily the bill of material alone.

Item 7-8 DOE welcomes comment on the conversion costs required to improve the efficiency of the fans to various levels, as well as what portion of these costs would be passed on to the consumer. 41

AMCA recognizes that regulation could lead to a movement from one type of fan (lower efficiency) to another type of fan (higher efficiency) that is already on the market. Purchase cost for a higher-efficient fan is generally higher because more efficient fans are more expensive to manufacture. Customers, however, often make purchase decisions based on lowest first cost, and generally select lower-cost/lower-efficiency fans for commercial and industrial applications.

As discussed in item 7-5, regulatory pressure toward a higher efficiency fan that is more expensive could direct sizing and selection toward a smaller size. Under-sized fans consume more energy for the same duty than larger fans, so regulatory pressure for higher efficiency fans that does not consider sizing and selection could result in more efficient fans consuming more energy by virtue of being undersized.

ANSI/AMCA 205-12 addresses fan efficiency through the Fan Efficiency Grades (FEG), and addresses sizing/selection by requiring that fans be sized and selected to operate within 15 percentage of points of their of peak total efficiency, i.e., "The fan operating efficiency at all intended operating point(s) shall not be less than 15 percentage points below the fan peak total efficiency."

ASHRAE 90.1 and the IgCC have adopted ANSI/AMCA 205-12 and the combination of an FEG with a sizing/selection window into their fan efficiency requirements.

Regarding passing higher costs onto customers, we would expect that 100% of extra costs for higher efficiency will be passed onto customers. Rebates and other incentives could dampen these cost pass-throughs.

Item 7-9 DOE requests comment on limiting representative unit selection to fan size(s) that include the most available units….. 42

Many fans are configured or built to order. In fact in the proposed power range for the rule some fans are built custom to the order. When this occurs, fan designers utilize the "fan laws" which rely on basic laws of physics to accurately predict a product's performance that is scaled from a test sample to the full scale product. As fans get smaller, there can be a small impact to efficiency due to the increases in mechanical drag and friction represented in the product's Reynolds number. Due to this reality, fans that are scaled up from a smaller model will always perform slightly better than the model.
There is no scaling of size effect beyond the issue of improper selection and application for a lower first cost fan described previously.

Item 7-10 DOE requests comment on the selection of additional fans at both larger and smaller sizes to determine a fan size-efficiency scaling relationship. DOE requests comment on the number of additional fans to test to develop the size-efficiency scaling relationship. 42

See AMCA's answer to 7.9.

Item 7-11 DOE requests comment on the method of using fan unit efficiencies as the basis for determining efficiency levels. .... 42.

As communicated at the DOE public hearing discussing this framework, AMCA requests diligence in selecting the range of products selected to determine efficiency levels and that an adequate sampling occurs to accurately represent the population of products within an equipment class.

Item 7-12 DOE seeks comment on the selection, appropriate features, and performance characteristics of baseline models for each equipment class. Specifically, DOE requests comment on choosing the least efficient fan design as the baseline model for the equipment class. DOE will define the characteristics of the proposed baseline models based on comments from interested parties in addition to DOE's analysis. 43

AMCA does not agree with the assertion in Section 7.3 of the Framework Document that "energy conservation standards for fans do not exist." Please refer to ANSI/AMCA 205-12, ASHRAE 90.1-2013, and the IgCC-2012 green building model code, all of which draw upon and reference AMCA 205 and AMCA 210. Happily, the certified published ratings for AMCA member models accurately define efficiency levels at all conditions according to AMCA 210. Ratings under AMCA 210 are based on the smallest fan size in a range, which is the least efficient model in that range. AMCA believes that projections of energy savings after regulations go into effect should be compared to the current mix of sales in the marketplace, and not compared to the least efficient model in each category.

Item 7-13 DOE welcomes comment on whether there are proprietary designs it should consider for any of the fan designs under consideration in this rulemaking and, if so, how DOE should acquire the cost data necessary for evaluating these designs........... 43

All designs and cost data are proprietary. DOE will need to consult with individual manufacturers under nondisclosure agreements for this information.

Item 7-14 DOE seeks input from interested parties regarding the range of efficiency levels that should be examined as part of its analysis. 44

All products with published AMCA certified rating data that are commercially available should be considered. Products without third party certification of their rating data in an accredited laboratory should either be ignored or such testing should be performed before efficiency levels are considered.

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Item 7-15 DOE requests comment on whether manufacturers generally do not offer fans of varying efficiencies that meet the same duty requirement. 44

Fan manufacturers offer many models and sizes of fans with varying efficiencies to meet the same duty requirement.

Within a given model of fan, there are typically three to eight different fan sizes (impeller diameters) that will meet one duty requirement (CFM and pressure), but will have different efficiencies. The selection of size is based not only on considering the operating efficiency at the design point (i.e., power consumption), but also physical fan size, weight, sound level and first cost.

There are also many different models of fans that meet the same duty requirement. These fans have different peak efficiencies, operating efficiencies, mounting configurations, physical size, motor and drive configurations, materials of construction, sound levels, price points and other variable characteristics.

Selecting a fan with a high peak efficiency in no way guarantees low energy use when applied to an off peak point of operation. Unlike electric motors that have a relatively flat efficiency curve from full load to about 50% load, fans have a "bell shaped" efficiency curve that drops off rapidly on either side of the system resistance curve that goes through the peak efficiency or

"Best Operating Point" of a fan curve. If fan regulation specifies peak fan efficiency only, consumers will typically select a smaller, less expensive fan size in an effort to save on first cost.

This is why the DOE should consider that consumers may react to higher cost, higher efficiency fan designs by selecting lower cost smaller sizes, such that the power consumed by the installed fan is greater even though the peak aerodynamic efficiency is improved.

Regulation that does not address the selection range allowable or efficiency at the design point is likely to result in the unintended consequence of increased energy use. Further, DOE analysis will show that limiting the selection range, or limiting the minimum efficiency at the selected point of operation, has far greater potential for savings of energy than simply improving the aerodynamic design of fans.

AMCA members are not opposed to regulations that encourage the improvement of fan aerodynamic efficiency, but believe that a regulation which does not address efficiency at the operating point runs the risk of being undermined by customer selection behaviors which compensate to reduce their purchase cost and increase energy consumption.

Item 7-16 DOE welcomes comment on whether there are outside regulatory changes that DOE should consider in its engineering analysis of fans. 44

AMCA members have experienced several examples where customers concern with EPA regulations have kept them from doing the right thing as it relates to energy based retrofits. Industrial customers are very concerned about triggering new source compliance standards and are passing on saving thousands of KW as a result of this fear.

Fan-efficiency requirements have so far been adopted into national model codes and standards: ANSI/ASHRAE/IES 90.1-2013, and the 2012 International Green Construction Code (IgCC). The IgCC provisions were based on what is now an outdated version of AMCA 205 and should not be consulted for DOE's purposes. Code change proposals for 2016-IgCC are being developed, as well as a continuous maintenance proposal for ASHRAE 189.1-2014, which will update the direction "green codes" (above baseline) should go.

ASHRAE 90.1-2013 fan efficiency requirements and what has been proposed for IECC-2015 represent the direction that AMCA believes DOE should take for a first-time fan efficiency regulation. ASHRAE 90.1-2013 has this language:

6.5.3.1 Fan System Power and Efficiency
6.5.3.1.3 Fan Efficiency. Fans shall have a Fan Efficiency Grade (FEG) of 67 or higher based on manufacturers' certified data, as defined by AMCA 205. The total efficiency of the fan at the design point of operation shall be within 15 percentage points of the maximum total efficiency of the fan.

Exceptions:

a. Single fans with a motor nameplate horsepower of 5 hp or less

b. Multiple fans in series or parallel (e.g. fan arrays) that have a combined motor nameplate horsepower of 5 hp (4kW) or less and are operated as the functional equivalent of a single fan.
c. Fans that are part of equipment listed under 6.4.1.1 Minimum Equipment Efficiencies – Listed Equipment – Standard Rating and Operating Conditions.
d. Fans included in equipment bearing a third-party-certified seal for air or energy performance of the equipment package.
e. Powered wall/roof ventilators (PRV).
f. Fans outside the scope of AMCA 205.
g. Fans that are intended to only operate during emergency conditions.

Note that Exception a. places the low end of the requirement at 7.5 nameplate HP and above, with no upper limit.

Exception b. eliminates a loophole for fan arrays that could consist of fans 5-HP and smaller configured operate as a single fan.

Exception c. avoids layering component standard into equipment already having efficiency requirements.

Exception d. extends the exemption to certified equipment that might not have an efficiency regulation. This exemption provides relief to manufacturers that would otherwise need to redesign products and undergo factory changes and recertification.

Exception e. takes into account that Fan Efficiency Grades combined with a 15-percentage point sizing/selection window (based on maximum fan total efficiency) could result in overly large/expensive selections that use more energy. A different approach for PRVs and other low-pressure products is being developed, as discussed in AMCA's comments to DOE about fan classes (see Item 5-3).

Exception f. makes clear that fans that cannot have an FEG calculated in accordance with AMCA 205 is outside the scope. This would include, for example, air curtains.

Exception g. exempts fans that are used exclusively for emergency operations. Dual-purpose fans, for example, would be covered by the requirement. AMCA realizes that safety fans would need a more precise definition in order not to be covered.

ASHRAE 90.1 and proposed IECC requirements are based on AMCA 205, which defines how to calculate fan efficiency grades, and which prescribes that fans be sized and selected within 15 percentage points of fan peak total efficiency. The IgCC-2012 requirements are based on AMCA 205-10, which is outdated. AMCA expects that ASHRAE 189.1-2013 and IgCC-2015 requirements will consistent with ASHRAE 90.1 and proposed IECC requirements.

Note that AMCA's proposal to add 90.1-2013's fan efficiency provisions into IECC-2015 was approved at the preliminary hearings in April 2013. The proposal goes beyond 90.1-2013 by requiring third-party-certified FEG ratings and labeling. The AMCA proposal was supported by

ASHRAE, and won approval unanimously from the IECC panel.

There are fire and safety standards as well by NFPA and UL, such as UL 762 Label for inline grease exhaust and NFPA 96 (Ventilation Control and Fire Protection of Commercial Cooking Operations).

Regional codes exist, such as OSHPD-California / International Building Code (IBC) seismic requirements and Miami-Dade County requirements for hurricane resiliency.

Any pending or future rulemakings for motors and commercial/industrial labeling may also impact the fans rulemaking.

Item 8-1 DOE requests information regarding the functioning of the manufacturer representatives/distributors for different equipment classes and market segments. 46

AMCA agrees that these are all important points of analysis but believe that you will get different answers for each segment from our different member companies. We would suggest that these items are covered in your interviews and that those interviews include companies that are representative across the diverse markets that our members serve.

Item 8-2 DOE requests information on other OEM market segments, and the downstream distributor channel, if any. 46

Please see AMCA's response to Item 8-1.

Item 8-3 DOE requests comments on the applications and market segments identified by interested parties and information on other market segments, including their corresponding distributor channel(s) and the trade association(s) representing the distributors. 47

Please see AMCA's response to Item 8-1.

Item 8-4 DOE requests comments on the proposed distribution channels and the share of industry shipments expected for each distribution channel for the commercial and industrial fans covered under this rulemaking in terms of either each specific equipment class in 5.2 or the broader equipment classes described above. 47

AMCA perceives that an important distribution channel was omitted, i.e.,

<u>Channel F (Rep Contractor):</u> Manufacturer → Manufacturers Rep → Contractor → User

AMCA surveyed its members and asked them to identify the fraction of fans sold by channel for each fan class. The results varied considerably by fan type. The table below summarizes the data by channel and fan class. The results are weighted by market share.

Fan Class	A	B	C	D	E	F
Vane Axial	56%	0%	0%	17%	1%	26%

Tube Axial	43%	2%	10%	20%	0%	24%
Panel Prop	34%	6%	5%	4%	0%	51%
House Centrifugal BI	26%	1%	1%	50%	1%	21%
House Centrifugal FC	65%	4%	4%	4%	0%	23%
House Centrifugal Radial	5%	1%	0%	90%	2%	2%
Unhoused Centrifugal	40%	4%	3%	51%	0%	2%
In-line Centrifugal and Mixed Flow	8%	16%	2%	5%	0%	68%
Centrifugal PRV	6%	10%	1%	4%	1%	77%
Axial PRV	1%	2%	0%	8%	0%	89%
Circulating Fans	0%	64%	0%	2%	17%	17%
Air Curtains	1%	28%	3%	1%	10%	58%

Channel A (OEM): Manufacturer → OEM → OEM Product Distributor → User	**Channel B (Distributor 1):** Manufacturer → Distributor → Contractor → User	**Channel C (Distributor 2):** Manufacturer → Distributor → User
Channel D (Direct End-User): Manufacturer → Manufacturers Rep → User	**Channel E (Direct End-User 2):** Manufacturer → Other → User	**Channel F (Rep Contractor):** Manufacturer → Manufacturers Rep → Contractor → User

Item 8-5 DOE seeks comment on other sources of relevant data that could be used to characterize markups for commercial and industrial fans. 48

Please see AMCA's response to Item 8-1.

Item 8-6 DOE requests feedback on its proposal to use incremental distribution channel markups for the LCC analysis. 48

Please see AMCA's response to Item 8-1.

Item 8-7 DOE seeks comment on appropriate transportation and shipping costs to include in the analysis and whether those costs are likely to vary for higher-efficiency equipment. ... 48

Transportation and shipping costs would be known by the manufacture. Generally, more efficient fan selections would result in larger fans, which would consume more shipping space and weight. Larger fans could also require additional installation costs due to increased weight and dimension.

Item 9-1 DOE requests input and recommendations for identifying high sales volume and large installed base market segments corresponding to specific industries and specific applications for which the fan equipment may have similar load profiles. 49

No comment.

Item 9-2 DOE welcomes recommendations on sources of data or analysis methods that would provide end-use load profiles for each of the commercial and industrial fans in the different market segments. 50

No comment.

Item 9-3 DOE requests input on ways to characterize fan sizing and selection practices for different equipment classes and applications and to help define the design or peak fan load for the purpose of generating normalized load profiles. For example, one question is whether load profiles should reflect normalization to the delivered air horsepower at the peak efficiency of the fan (at a given fan size and speed). 50

Peak efficiency used in rating fan FEG levels provides a useful means of comparing the aerodynamic efficiency of fans that serve applications with ducts on the fan discharge. They do not, however, adequately inform us about the full load efficiency of the fan at the design conditions of an application.

As described previously, there are many different sizes of fans that can be selected by the consumer, all of which will precisely meet the airflow and pressure requirements of the job, but which will vary widely in first cost, physical size and operating efficiency. Many fans have two modes of operation once installed - on and off. Some applications require the fan to throttle its capacity with system demand. These are called variable air volume (VAV) systems.

HVAC system modeling software can be used to estimate the load profile of the fan for VAV systems. However, full knowledge of the VAV system fan load profile teaches us nothing about the relationship of the efficiency of the fan at full load to its peak efficiency. This relationship is determined by the initial fan selection. ASHRAE 90.1-2013 limits fan selections to be made within 15 efficiency points of peak fan efficiency.

AMCA members do track the design conditions (full load only) of most fans purchased, and AMCA is researching the mix and average efficiency of such selections for the majority of the market. Once Equipment Classifications are finalized, AMCA can provide this information by Equipment Class for the market in aggregate based on manufacturer order history

Item 9-4 DOE welcomes comment on methods for determining generic (non-market segment specific) load profiles for fan equipment classes considered in this rulemaking........ 50

Please see AMCA's response to Item 9-3.

Item 9-5 DOE welcomes comment on the current penetration level of variable-speed drives in the installed base of products or applications for each of the equipment classes considered in this rulemaking. 50

AMCA is continuing to research this answer and may provide information at a later date.
Item 9-6 DOE requests comment and recommendations on the number of analyzed sizes to be selected for each equipment class. .... 51 This is a significant and complex issue, especially if the scope of the regulatory framework includes the breadth (classes) and depth (sizes) that DOE is proposing. There are a variety of fans within each class. DOE will have to sample different sizes of each product type and develop different load profiles for each type. AMCA would be happy to work with DOE and NAVIGANT to develop a sampling methodology.
Item 9-7 DOE requests comment and recommendations on the range of and number of fan rotation speeds over which the analysis should be carried out for different equipment classes. .... 51 Typically, the Fan Laws are used to calculate a range of fan speeds from the test at a single speed.
Item 9-8 DOE requests information on current industry practices and recommendations on the selection of representative operating points for a given rotational speed. DOE welcomes comment on whether the analysis should be extended to a range of operating points away from the peak efficiency. .... 51 It is typical industry practice to test a fan at a single speed from free air to shut-off in order to characterize the fan's performance over its entire operating range. The actual number of points needed depends on complexity of the fan curve. HVAC system modeling software can be used to estimate the load profile of the fan for VAV systems. However, full knowledge of the VAV system fan load profile teaches us nothing about the relationship of the efficiency of the fan at full load to its peak efficiency. This relationship is determined by the initial fan selection. ASHRAE 90.1-2013 limits fan selections to be made within 15 efficiency points of peak fan efficiency. Some AMCA members do track the design conditions (full load only) of most fans purchased, and AMCA is researching the mix and average efficiency of such selections for the majority of the market. Once Equipment Classifications are finalized, AMCA can provide this information by Equipment Class for the market in aggregate based on manufacturer order history As to "whether the analysis should be extended to a range of operating points away from the peak efficiency," AMCA answers Yes. The Annual Energy Consumption calculation should first consider how far the design operating point is from the peak efficiency for a typical selection at design conditions. Then a load profile, as well as an overall operating efficiency profile, should be used for this analysis.
Item 9-9 DOE requests comment and estimates to establish the mean value and the ranges of likely values for motor, transmission, and motor control efficiencies. .... 51 Please see AMCA's reply to Item 3-15.

Item 10-1 DOE welcomes comment on the factors that impact the installation costs for fans and on whether installation cost increases with higher-efficiency equipment. 53

Installation costs are affected by many factors including size, weight, mounting location and field assembly (if required) as well as ductwork and electrical connections. Generally, more efficient fan selections would result in larger fans being used, which could lead to some installation cost increases due to the added weight and size.

Item 10-2 DOE welcomes input on the proposed methodology for estimating current and future electricity prices for the fans covered under this rulemaking. 53

AMCA has no corrections to this methodology, but asks a question of its own: Has DOE ever analyzed the performance (accuracy) of its projections of electricity prices from previous rulemakings, and it its projections, had they been more accurate, would have led to different regulatory approaches? How sensitive are rulemakings to projections for electricity prices?

Item 10-3 DOE invites comment on how repair costs may change for more efficient fans. DOE also invites comment on repair practices, how they may change for more efficient fans, and how energy use patterns may impact equipment repair and maintenance. 54

Repair costs are generally unrelated to fan efficiency. However, more efficient fan selections may result in larger fans being used, which could increase repair costs. This increase may be offset by reduced repair frequency due fans operating at lower speeds and loads.

Item 10-4 DOE welcomes information that will assist in determining an appropriate distribution of fan lifetimes for the equipment classes covered in this rulemaking..54.

AMCA generally agrees with the referenced average lifetime of 15 years, with light duty fans being slightly shorter and heavy duty fans being longer.

AMCA reminds DOE that a 15-year lifetime with no distinction of fan class or fan application was used in the Technical Support Document for Motors, *Preliminary Technical Support Document: Energy Efficiency Program For Commercial Equipment: Energy Conservation Standards For Electric Motors*, July 23, 2012

Table 8.2.26 presents the average application lifetimes used in the LCC [14,15,16,17].

Table 8.2.26 Average Application Lifetime

Application	Average Lifetime *Yr*
Air Compressor	15
Fans	15
Pumps	11
Material Handling and Processing	20
Other	15

24

Item 10-5 DOE welcomes input on the proposed approaches for estimating discount rates for fan users. 54

AMCA has no comment on this item.

Item 10-6 DOE requests data on the efficiency distribution and welcomes comment on the likelihood and degree of improvement in efficiency of commercial and industrial fans in the next 5 to 10 years as a result of market forces or industry trends. 55

Most manufacturers endeavor to improve the efficiency of new designs, consistent with their manufacturing abilities and limitations, simply because more efficient designs are preferred in the marketplace - provided price premiums do not represent a material change from historical levels for the buyers.

AMCA members recognize a trend of the market to demand higher efficiency fans, but have never quantified the magnitude of the trend, or the impact on average installed fan efficiency levels.

Item 11-1 DOE welcomes comment on the shipments projection methodology. DOE invites comments regarding the selection of appropriate economic drivers and sources of data for historical shipments and shipment breakdowns by equipment class. 55

AMCA has no comment except that say that availability of shipment data depends on manufacturer and fan type. In survey of its members, years of available shipment data were provided by most of the respondents to the survey. The following table shows the un-weighted average of the responses by fan class. Additionally, notes that two companies had data going back 15 and 22 years while most other respondents had only two to five years of data, so the averages are skewed toward higher numbers.

Fan Class	Average Shipment Data Availability (years)
Vane Axial	9
Tube Axial	9
Panel Prop	8
House Centrifugal BI	10
House Centrifugal FC	10
House Centrifugal Radial	10
Unhoused Centrifugal	8
In-line Centrifugal and Mixed Flow	9
Centrifugal Powered Roof/Wall Ventilator	8
Axial Powered	

Roof/Wall Ventilator	
Circulating Fans	11
Air Curtains	7

Item 11-2 DOE requests historical shipments data for each of the considered equipment classes. 55

See response to Item 11-1.

Item 11-3 DOE welcomes comment on how an energy conservation standard for fans might impact shipments of the equipment covered in this rulemaking. 56

AMCA does not believe that the energy conservation standard envisioned will change the demand for air-power required to serve the market. Air system design improvements, which will be encouraged through actions envisioned to be included in a consensus agreement between AMCA members, environmental advocates and other affected parties will, we trust, reduce the air power needed to serve the thermal, ventilation and process needs of the market. To the extent higher efficiency fans cost more, and are priced at a higher level, AMCA believes that customers will compensate by selecting smaller, less efficient fans unless the conservation standard incorporated into DOE regulations favorably impacts selections decisions in the marketplace. Of course, if rulemaking forces the use of larger more efficient fans, the sales value of the market will increase to offset reductions driven by more efficient air system designs.

Item 12-1 DOE requests comment on whether it should pursue a roll-up or shift approach for the national impact analysis. 56

AMCA believes the roll-up efficiency case is most realistic.

Item 13-1 DOE welcomes comment on what, if any, consumer subgroups are appropriate in considering standards for fans...................................... 58

The energy effectiveness of air curtains, which is the amount of energy not used by air conditioning equipment when air curtains are operating, depends on a high velocity uniform jet of air from the air curtain's discharge. Air curtains often use crossflow fans for this purpose. If crossflow fans were to be regulated, or removed from the market due to regulation, they would no longer be available to air curtain manufacturers, thus increasing the energy consumption of air conditioning equipment because of less effective air curtains.

Item 14-1 DOE seeks comments on the subgroups of the fan equipment manufacturers that it should consider in a manufacturer subgroup analysis. 60

14-A (From Public Hearing presentation): DOE seeks comment on small businesses that could be impacted by potential energy conservation standards for commercial and industrial fans, as well what these impacts might be.

Of AMCA's 306 member firms worldwide, 125 member companies manufacture fans for sale in the U.S., and of these, all but seven are located in North America. Approximately 80% of AMCA members have annual revenues under $10 million dollars; and 97% have annual revenues under $50 million per year. AMCA does not track employment statistics of its members; however, based on these revenue numbers, AMCA estimates that more than 90% of its members would meet the Small Business Administration's definition of "small businesses" (having fewer than 500 employees).

Small businesses have limited capital resources to rapidly design and retool a complete family of more efficient aerodynamic fan designs. Most of these companies offer fan lines enabling customers to meet a wide range of application conditions, with each line having a different cost, size and efficiency. This means that most companies manufacture more than one type (class) of fan, and do so across a wide variety of sizes. Therefore, a regulatory scope that includes many different types of fans across many sizes will unfairly impact small business because they would likely have to address their entire line of products simultaneously from design through retooling, development and dissemination of sales and marketing materials and product documentation, distribution, training impacts, etc.

Furthermore, if DOE pursues an "extended product" approach that includes motors and electronic drives (VFDs, VSDs, etc.), it would change how AMCA members conduct their business to account for products they currently do not manufacture or test.

Impacts to small businesses are exacerbated if DOE changes how fans are regulated from how they are currently being regulated by building and energy codes, as explained in AMCA's responses to Items 7-16 and 14-2.

Item 14-2 DOE welcomes comments on other existing regulations or pending regulations it should consider in examining cumulative regulatory burden. 60

Please refer to AMCA's response to Item 7-16 for background information on the codes and standards for energy efficiency and high-performance/green construction referenced below.

AMCA fully expects the new and pending requirements of ASHRAE 90.1, International Energy Conservation Code, International Green Construction Code, and ASHRAE 189.1 to drive fan efficiencies higher, with corresponding cost increases to AMCA members for certifying and labeling fans and updating their printed/electronic literature and sizing/selection software.

Furthermore, the increase in number and scope of regional (state/municipal) requirements for safety etc. are having corresponding increases in regulatory burden.

As these product costs rise in response to regulatory burden, the market could compensate by selecting smaller, less-efficient fans that comply with regulations, but which consume more energy, unless regulations on practice/process prevent them from doing so.

Cumulative burden is exacerbated on small businesses (especially) because their investments for

marketing/sales materials (printed and electronic literature, Website pages, sizing/selection software, staff, distributor, and customer training, etc.) could be made moot by a DOE regulation that is substantially different. Small businesses would not only have to invest in their redesign/retooling, but in all of the marketing/communications/training materials and time, as well.
Item 15-1 DOE welcomes input from interested parties on its proposed approach to conduct the utility impact analysis. .... 61 AMCA would like to know how DOE intends to adjust its utility-impact analysis in tandem with EPA emissions regulations on power plants, commercial and industrial boilers, growth of sustainable power, and changes in commercial buildings and industrial processes during the time that DOE develops the fan rulemaking and begins to enforce it.
Item 16-1 DOE welcomes comments on its proposed approach to assessing national employment impacts. .... 62 AMCA questions if DOE has ever looked back on its equipment and appliance rulemakings to determine if its employment impacts are accurate. Have businesses grown or contracted/closed under DOE regulations? If DOE has not looked back on regulatory impacts, how can it have confidence its projections are accurate?
Item 17-1 DOE welcomes comments on its proposed approach to analyzing emissions impacts on potential standards for commercial and industrial fans. AMCA would like to know how DOE intends to adjust its emissions analysis in tandem with EPA emissions regulations on power plants, commercial and industrial boilers, growth of sustainable power, and changes in commercial buildings and industrial processes during the time that DOE develops the fan rulemaking and begins to enforce it.

APPENDIX 1: DEFINITIONS

Fan: A rotary bladed machine designed to convert mechanical power to air power in order to maintain continuous flow from the inlet(s) to outlet(s). Energy output is limited to 25 kJ/kg of air. A fan contains the following basic components:

a) Impeller(s): Rotary bladed aerodynamic component responsible for the total energy increase of the airstream delivered by the fan.

b) Fan Structure: Any integral component(s) necessary to support the impeller, alter(s) the energy-composition of the airstream, or direct(s) flow into or out of the impeller. These components must be present when testing to develop performance ratings of the fan.

Note: If the motor by its presence affects the fan aerodynamically, then the motor enclosure is part of the fan structure and needs to be physically present during the fan performance testing.

c) Inlet: Surface(s) bounded by a portion of the fan structure across which air enters the fan.

d) Outlet: Surface(s) bounded by a portion of the fan structure from which air exits the fan.

Fan boundaries for purposes of establishing energy efficiency:

Input Boundary: Interface across which mechanical power is delivered to the fan.

Output Boundary: Surface(s) across which air power is delivered.

Bare Shaft Fan

AMCA recommends that DOE replace use of "bare shaft fan" with "fan" as defined above.

Drive

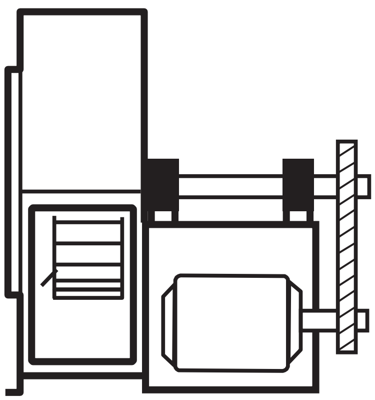
Component(s) used to power the fan, such as the motor, mechanical transmission, and motor/control system.

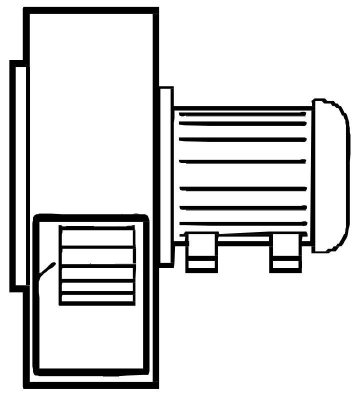
Driven fan

AMCA recommends DOE not use the term, "driven fan," and instead use "Fan with Drive).

*Fan with Driv*e

A fan with drive. Examples shown below.





Direct-Driven Fan

A fan with the impeller coupled to an electric motor along a common axis of rotation.

Belt-Driven Fan

A fan with a motor connected through a belt (s) and pulleys mounted to the motor shaft and fan shaft.

Gear-Driven Fan

A fan driven by a motor connected through a gearbox.

Axial Fan

No change to DOE definition in framework document.

Tube Axial Fan

An axial-flow fan with a cylindrical housing and no guide vanes

Vane Axial Fan

An axial -flow fan with cylindrical housing with guide vanes before or after the impeller, or both.

Panel Fan

An axial fan without a cylindrical housing, which is mounted in an orifice plate or ring. Also known as a propeller fan.

Centrifugal Fan

Fan in which the airflow enters the impeller essentially parallel to its rotation axis and leaves the impeller essentially perpendicular to this axis.

Housed Centrifugal

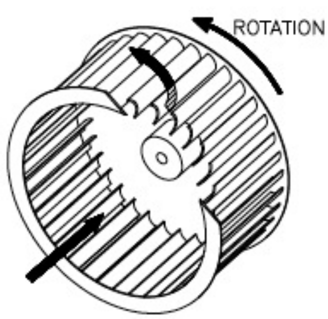
A centrifugal fan with a housing intended to be ducted on the inlet and/or outlet.

Unhoused Centrifugal

A centrifugal fan without a housing

Housed Centrifugal - Forward Curved

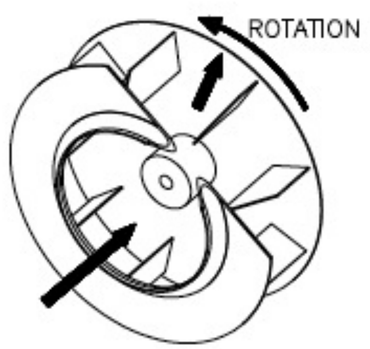
A type of centrifugal fan with a housing and with impeller blades curved to direct the airflow out of the impeller in the direction of the impeller rotation.



FORWARD CURVED

Housed Centrifugal - Radial Bladed

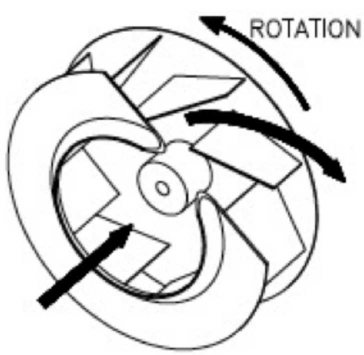
A type of centrifugal fan with a housing and with impeller blades positioned to direct the airflow out of the impeller perpendicular to the axis of impeller rotation.



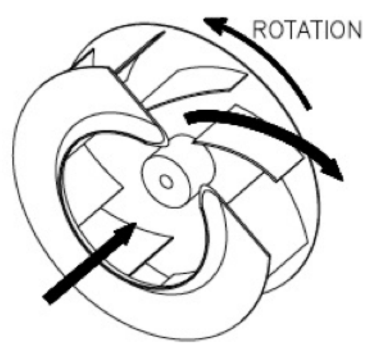
RADIAL BLADED

Housed Centrifugal - Backward Bladed

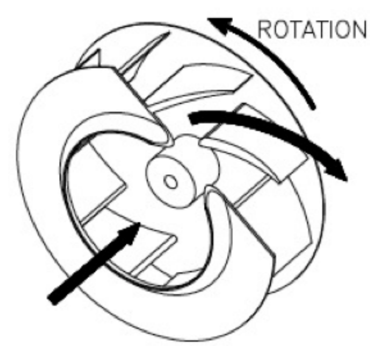
A type of centrifugal fan with a housing and with impeller blades that are positioned to direct the airflow out of the impeller in the direction opposite to the impeller rotation. Blade profiles can be flat, curved, or airfoil in shape. Industry practice distinguishes fans based on blade profiles as Backward Inclined (flat); Backward Curved (curved); and Airfoil.



BACKWARD INCLINED



BACKWARD CURVED



AIRFOIL

Crossflow Fan

A fan in which the fluid path through the impeller is in a direction essentially at right angles to its axis both entering and leaving the impeller at its periphery.

Mixed Flow Fan

A fan in which the fluid path through the impeller is essentially between 20 and 70 deg. relative to the axis of rotation.

Induced Flow Exhaust Fan

A housed fan with a nozzle and a windband and whose outlet airflow is greater than its inlet airflow due to induced airflow. All of the flow entering the inlet will exit through the nozzle. The flow exiting the windband will include the nozzle flow plus the induced flow.

Centrifugal Inline

A housed fan with a centrifugal impeller designed to be mounted between duct sections with air flowing in an axial direction at the inlet and outlet .

Centrifugal Power Roof/Wall Ventilator

A fan consisting of a centrifugal impeller with an integral drive in a weather-resistant housing and with a base designed to fit, usually by means of a curb, over a roof or wall opening.

Axial Power Roof/Wall Ventilator

A fan consisting of an axial impeller with an integral driver in a weather-resistant housing and with a base designed to fit, usually by means of a curb, over a roof or wall opening.

Variable Speed Drive (VSD)

VSD - A device that controls the speed of an impeller during operation.

Adjustable speed drive

A device that allows changes to the speed of an impeller while at rest.

Specific Ratio

AMCA recommends eliminating this definition because it is only used in the definition of a blower, and AMCA recommends eliminating use of the term blower.

Fan Total Pressure

The difference between the total pressure at the fan outlet and the total pressure at the fan inlet.

Fan Velocity Pressure

The velocity pressure corresponding to the average velocity at the fan outlet.

Fan Static Pressure

The difference between the fan total pressure and the fan velocity pressure. Therefore, it is the difference between static pressure at the fan outlet and total pressure at the fan inlet.

Fan Total Efficiency

The ratio of fan power output to fan power input.

Fan Static Efficiency:

The fan total efficiency multiplied by the ratio of fan static pressure to fan total pressure.

Peak Fan Efficiency

Maximum fan total efficiency with the fan speed and air density being fixed.

Blower

AMCA recommends eliminating this term as a separate class because AMCA does not recognize the difference between *fans* and *blowers*.

Appendix 2: Industrial Fans – Performance Testing Using Standardized Airways

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ABSTRACT

The fan air performance test standard ISO 5801 *Industrial fans – Performance testing using standardized airways* was adopted in 1997 and is essentially an amalgamation of various national test standards. To ensure a consistent determination of fan static pressure amongst the included standards, the requirement of a defined common airway on the outlet of the test fan was added to standards where they had not been required. AMCA Standard 210 was one of these test standards. AMCA Standard 210 itself does not yet require a standardized airway due to concerns that the effect of the standardized airway is overly detrimental to the measured performance of certain types test fans.

What the standardized airway does is reduce the tangential velocity component of the fan's airflow so as to not mistakenly measure the tangential flow's velocity pressure as fan static pressure. Because different types of fans have differing tangential velocities, the effect of the standardized airway varies with the test fan and performance point. Anecdotal evidence has shown that the standardized airway can reduce measured total efficiency by as much as seven percent for axial fans without vanes.

AMCA International performed a series of tests on backward curved, forward curved, tubeaxial and vaneaxial fans in an effort to find additional common ground

between AMCA 210 and ISO 5801. It was intended that the results of the project would answer three questions. Ease of manufacture of the étoile straightener and its mandatory inclusion in ISO 5801 (most of the time) were motivations for this project.

1. Can AMCA 210's egg crate straightener be replaced with the standardized airway's étoile straightener?
2. Can AMCA 210's ten diameter pressure measurement duct be replaced with the standardized airway?
3. Can AMCA 210's short simulated duct be replaced with the standardized airway?

DISCUSSION

The testing performed for this project was conducted on a limited number of fans, five to be exact.

Fan Type	Description	Impeller Diameter
Axial	Tubeaxial	762 mm (30 in.)
Axial	Vaneaxial, 2-1 Tip-to-hub ratio	762 mm (30 in.)
Axial	Vaneaxial, 3-2 Tip-to-hub ratio	762 mm (30 in.)
Centrifugal	Forward Curved	686 mm (27 in.)
Centrifugal	Backward Curved	762 mm (30 in.)

The fans above were tested in the following configurations. Every test was performed in Installation Type D, ducted on the inlet and outlet. Tests using AMCA Figures 12 and 15 normally use a short simulated duct on the outlet, two to three diameters in length, to model a ducted outlet configuration for Installation Types B and D.

Config.	Test Standard	Figure	Description	Exceptions
1	AMCA 210 ISO 5801	7 72e	Outlet test. Pitot traverse for flow and pressure	None
2	AMCA 210 ISO 5801	7 72e	Outlet test. Pitot traverse for flow and pressure	Star in lieu of egg-crate straightener
3	ISO 5801	72d	Outlet test. Pitot traverse for flow, duct Piezometer ring for pressure	None

4	AMCA 210 ISO 5801	10 72h	Outlet test. Chamber nozzles for flow, duct Piezometer ring for pressure	None
5	AMCA 210 ISO 5801	10 72h	Outlet test. Chamber nozzles for flow, duct Piezometer ring for pressure	Star in lieu of egg-crate straightener
6	AMCA 210 ISO 5801	12 73b	Outlet test. Chamber nozzles for flow, chamber Piezometer ring for pressure	None
7	AMCA 210 ISO 5801	12 73b	Outlet test. Chamber nozzles for flow, chamber Piezometer ring for pressure	Common part in lieu of short outlet duct
8	AMCA 210 ISO 5801	15 75d	Inlet test. Chamber nozzles for flow, chamber total pressure tube for pressure.	None
9	AMCA 210 ISO 5801	15 75d	Inlet test. Chamber nozzles for flow, chamber total pressure tube for pressure.	Common part in lieu of short outlet duct

Representative drawings of the test configurations are shown in Figures 1 through 5.

As noted above, this test project was designed from an AMCA 210 perspective, so AMCA 210 equations were used to develop the test results and portions from ISO 5801 were used where necessary. For instance, when a star straightener was used in lieu of an egg-crate straightener, we used the pressure drop equation for the star straightener from ISO 5801.

We wanted to understand more about the effects of the Common Part. It is understood that the intended effect of the Common Part is to prevent swirl energy from being unduly credited to the fan's performance. But, what if the Common Part has an unintended effect on the fan's actual performance, i.e. a system effect like those described in AMCA Publication 201? Comparing test results taken from the fan's inlet against test results taken from the fan's outlet, help break apart the various effects of the Common Part on the test fan.

Due to the abundance of test data, we also had the opportunity to test the "transitive" property of fan testing. That is,

If, according to ISO 5801,

Common Part = AMCA Figure 7,

And, if, according to AMCA 210

AMCA Figure 7 = AMCA Figure 12

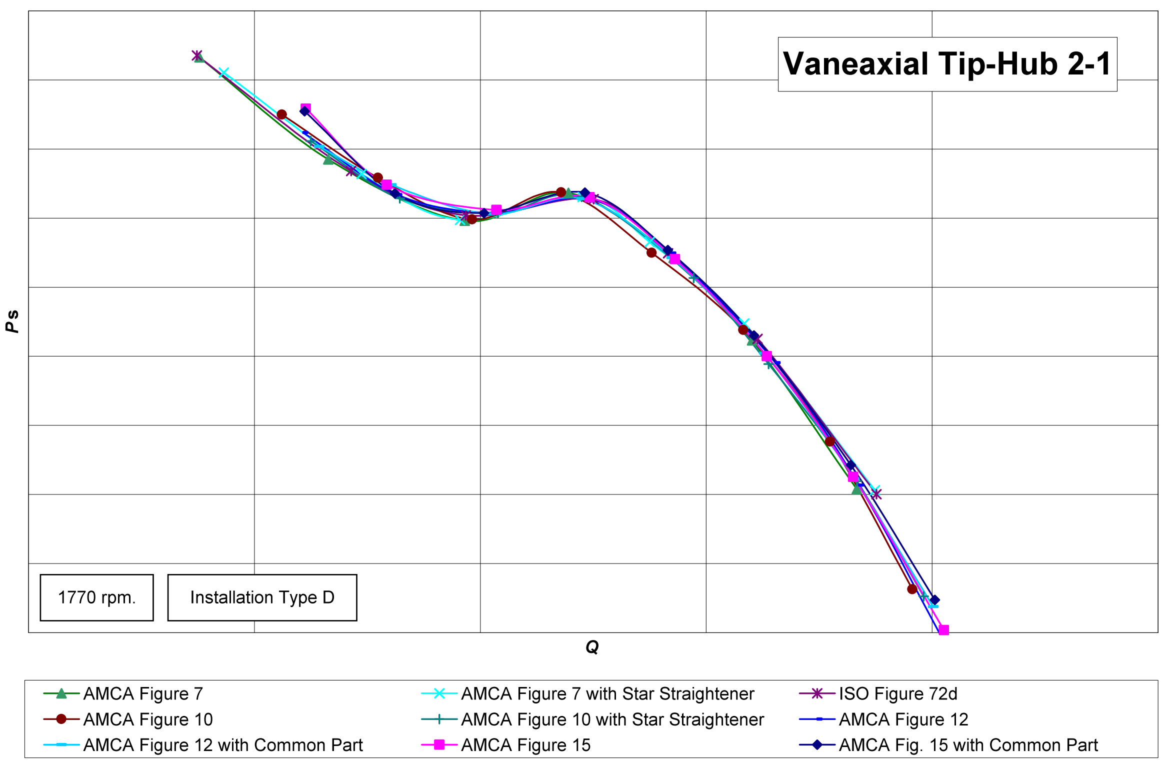
Does

AMCA Figure 12 = Common Part?

RESULTS – VANEAXIALS AND BACKWARD CURVED FANS

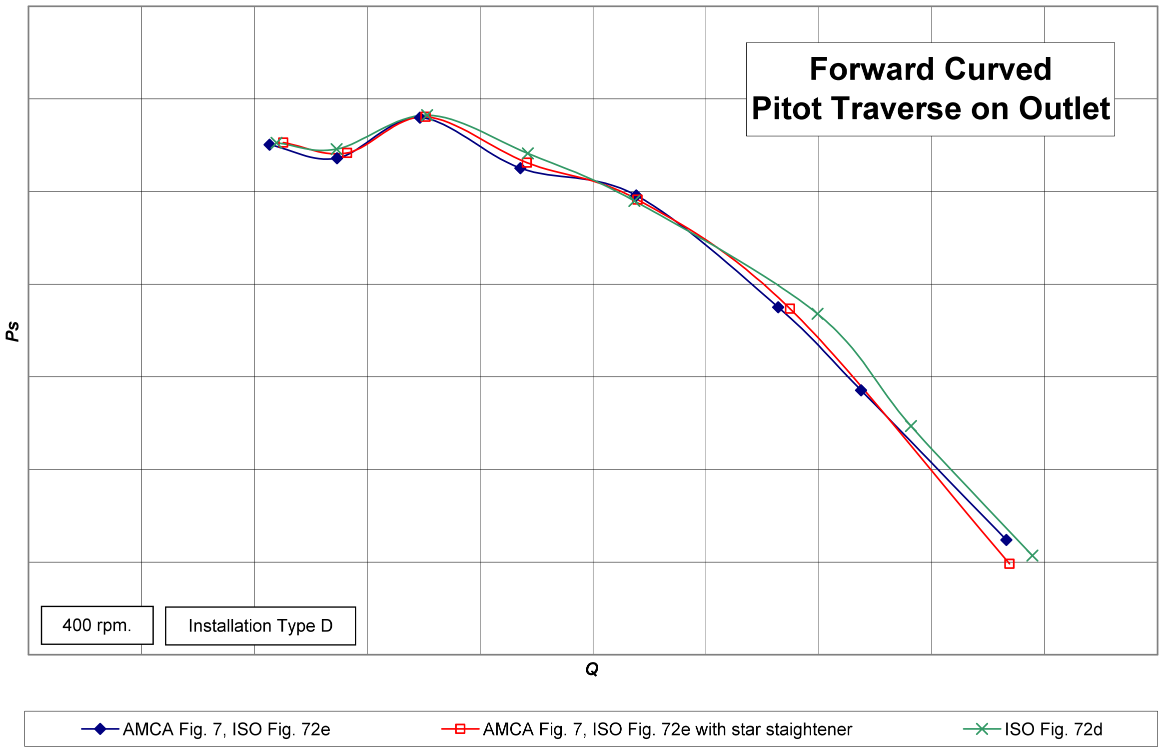
As expected, the answers to all of the questions stated above depended on the type of fan under test. Graphed test results on the two vaneaxials and backward curved fan showed very tight groupings regardless of the test configuration. Test results of one of the vaneaxials are shown for illustration.

Based on these results for the vaneaxials and backward curved fans we resolved that the egg-crate straightener could be replaced with the étoile straightener, AMCA's ten diameter pressure measurement duct could be replaced with the Common Part, and AMCA's short simulated duct could be replaced with the Common Part.

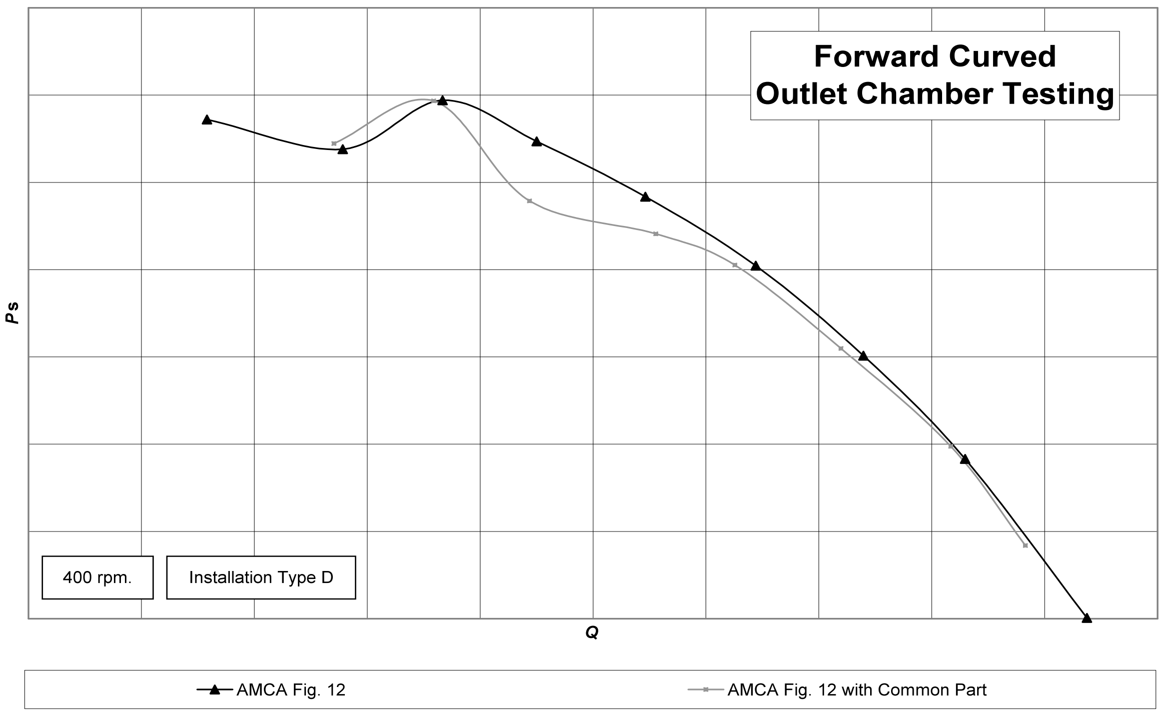


RESULTS – FORWARD CURVED FAN

The below test results indicated to us that the egg-crate straightener could be replaced with the étoile straightener, and AMCA's ten diameter pressure measurement duct could be replaced with the Common Part for forward curved fans.

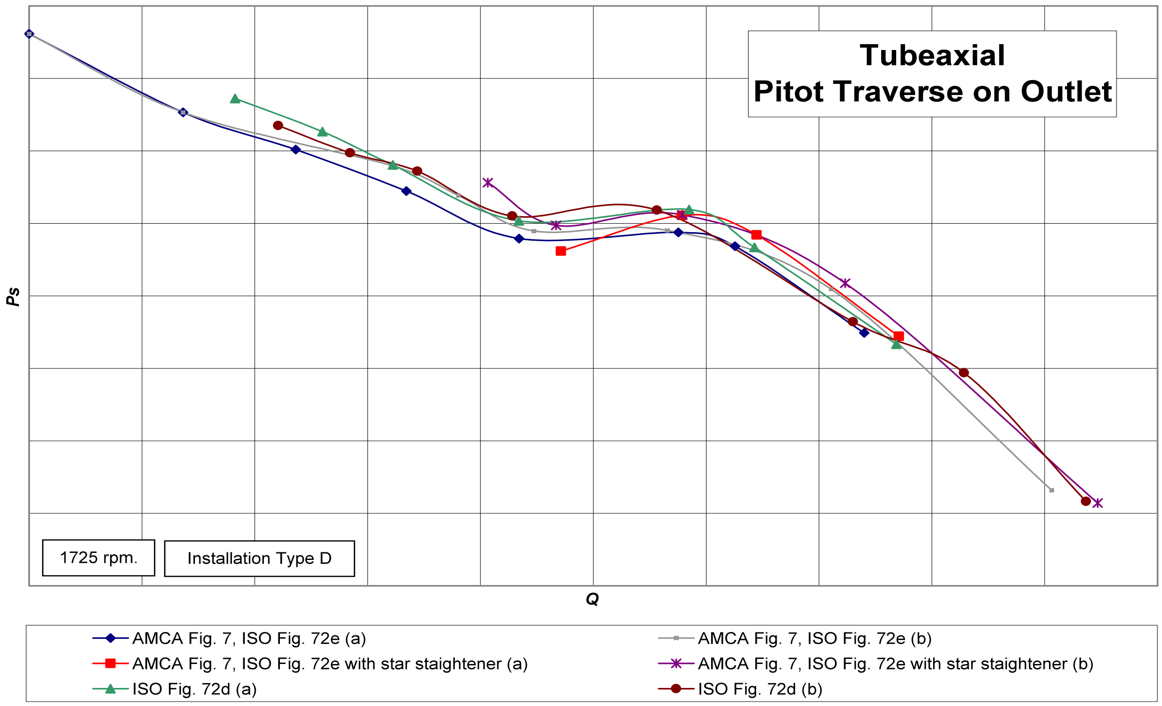


We did not feel that the short simulated duct could be replaced by the Common Part, as test results with the Common Part and chamber included a dip to the right of peak of the curve that was not present in the other test results.



RESULTS – TUBEAXIAL FAN

The tubeaxial was much less well behaved and, in fact, as shown below, we had trouble obtaining consistent results from test to test using the same test configuration for tests using the Pitot traverse.

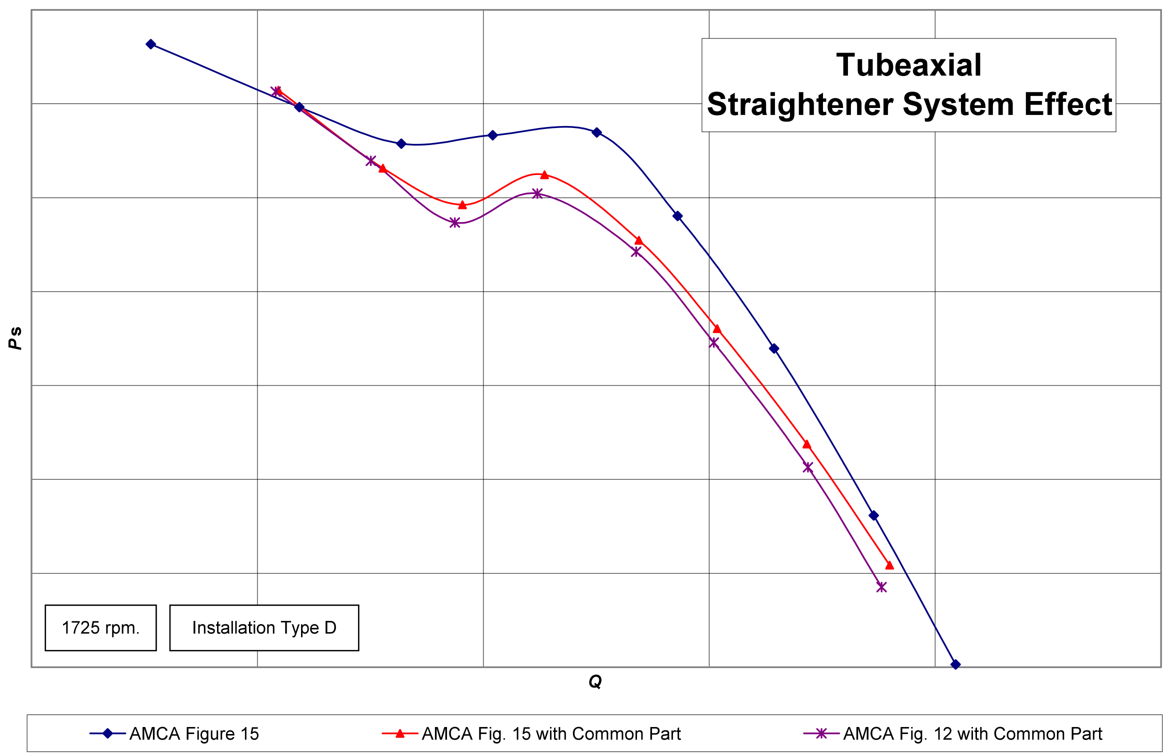


From these test results, we could not come to conclusions regarding the performance of the straighteners or duct lengths, other than to recommend avoiding Pitot traverse tests of tubeaxial fans.

We suspected that an adverse velocity profile or Pitot tube misalignment were the major causes of the spread in test results, but we encountered a similar but smaller spread in results when we measured static pressure by using a Piezometer ring and measured airflow with nozzles (AMCA 210 Figure 10, ISO 5801 Figure 72h). We began to consider whether or not it was appropriate to measure tubeaxial performance on the outlet of the fan at all due to the velocity profile, and that perhaps we should be looking to test tubeaxial fans at the inlet instead.

This led to the next discussion, which was, if we test a tubeaxial fan on the inlet, why would one want to put a Common Part on the outlet if no pressure measurements are taken there and no flow conditioning is necessary? And further, if the Common Part affects the fan's performance in Figure 15, is the Common Part, in addition to conditioning the flow for static pressure measurement, also imparting a system effect on the test fan?

The below graph does indeed show a reduction in measured performance when a Common Part is added to an AMCA Figure 15 setup, presumably indicating that the Common Part adds its own System Effect to a tubeaxial fan's performance. We did not see this same effect for the vaneaxials, backward curved and forward curved fans that were tested.


Tubeaxial
Straightener System Effect
Ps
Q
1725 rpm.
Installation Type D
AMCA Figure 15
AMCA Fig. 15 with Common Part
AMCA Fig. 12 with Common Part

"TRANSITIVE PROPERTY" OF FAN TESTING

Finally, we wanted to resolve the following issue:

If, according to ISO 5801,

Common Part = AMCA Figure 7,

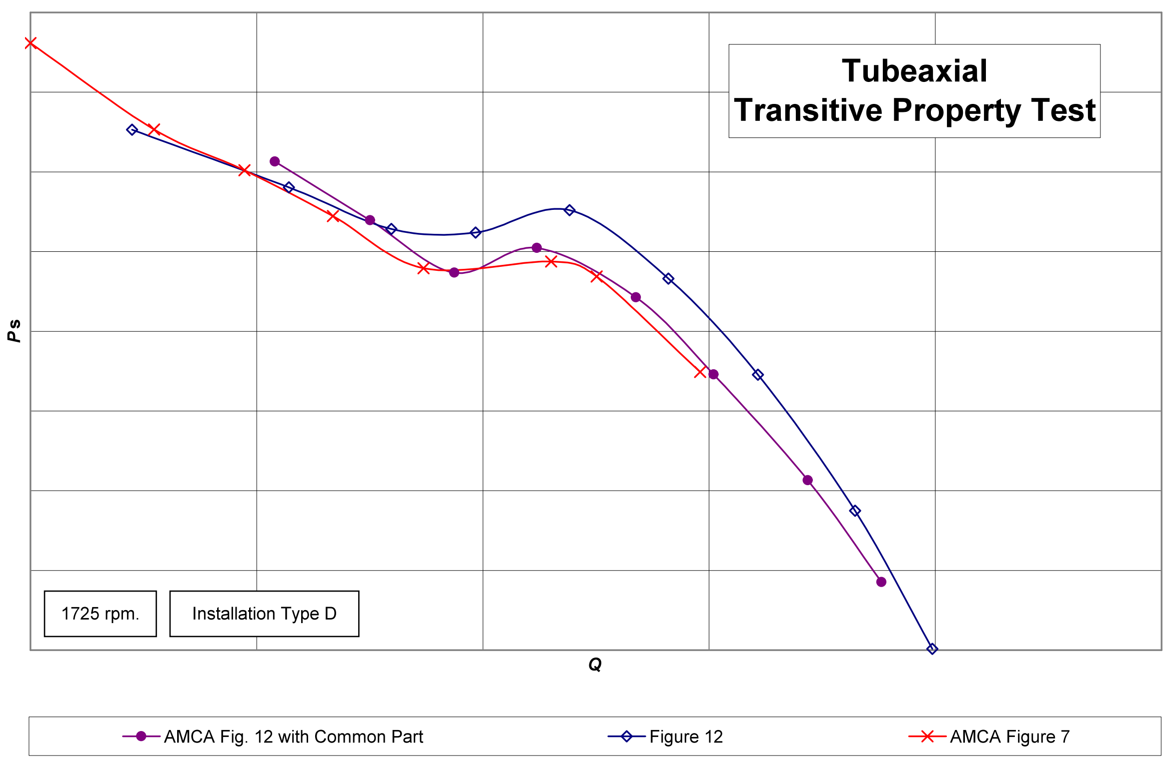
And if, according to AMCA 210,

AMCA Figure 7 = AMCA Figure 12

Does

AMCA Figure 12 = Common Part?

The answer is; sometimes. For the vaneaxials, backward curved and forward curved fans, the above equations held. For the tubeaxial, the equations above did not hold, and the cause was that AMCA Figure 7 ≠ AMCA Figure 12 for tubeaxial fans, as shown in the graph below.



RECOMMENDATIONS

At the end of the project, and perhaps this was known before we started, questions regarding straighteners and the Common Part really only become interesting when there is “significant outlet swirl”, as described by ISO 5801. When significant swirl is present, the definition of the test apparatus (should it include a straightener, or not) becomes important.

Regarding the question as to whether or not AMCA 210’s egg crate straightener could be replaced with the standardized airway’s étoile straightener, it would be recommended here, based on the test results for the vaneaxials, backward curved and forward curved fans, that the étoile straightener could be used in lieu of the egg-crate straightener. A similar recommendation could be made regarding the substitution of AMCA’s 10D pressure measurement duct with ISO 5801’s setup in Figure 72d.

Something different entirely would be recommended for tubeaxials. It is recommended here that tubeaxials not be tested in any configuration where swirl energy is not allowed to dissipate and expand “as if in an unconfined space.” The words in quotes are from AMCA 210. In other words, avoid testing tubeaxials where static pressure is measured in a duct with a flow straightener. The reasons? Firstly, swirl from the outlet plays havoc on static pressure measurement, and neither the egg-crate nor the étoile straighteners are adequate. Secondly, it was found that the standardized airway, of either the 10D or Common Part type, imparts a System Effect on the fan. See the AMCA Figure 15 results with and without the Common Part on the outlet. Finally, AMCA Figure 7 ≠ AMCA Figure 12 (or Figure 15) for tubeaxial fans, and the fact that a straightener impacts fan performance points to the chamber test as the better method.

Regarding whether or not AMCA 210’s short simulated duct can be replaced with the standardized airway; in light of the above discussion on the tubeaxial, this substitution would not be recommended. The same would be said for the forward curved fan, as a difference in test results was found. No significant differences in test results were found for vaneaxials and the backward curved fans, but a recommendation can not be made to allow this substitution for these fans, as it would add to the cost of the test and insert a difference between the air performance and sound test setups.

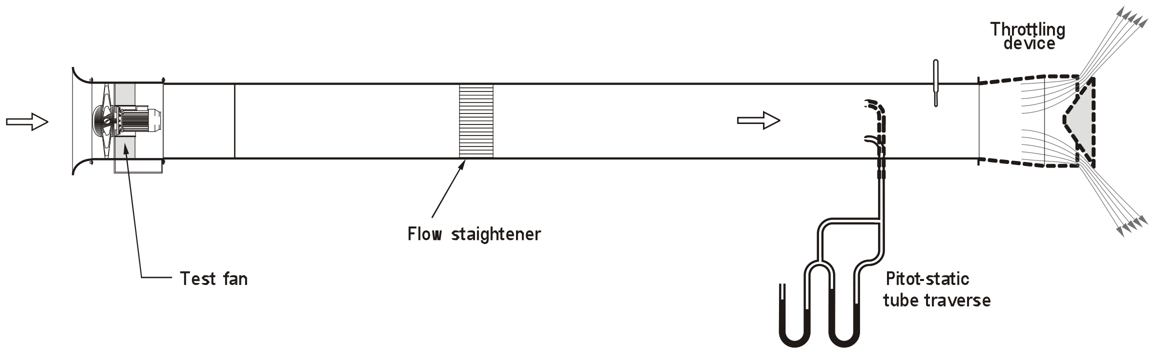


Figure 1: ISO 5801 Figure 72e, AMCA 210 Figure 7, Pitot traverse on outlet

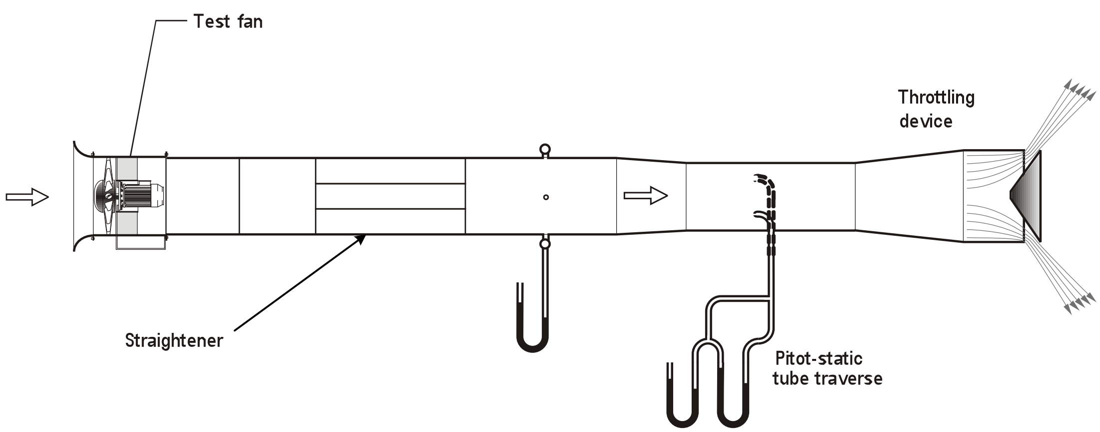


Figure 2: ISO 5801 Figure 72d, Pitot traverse on outlet

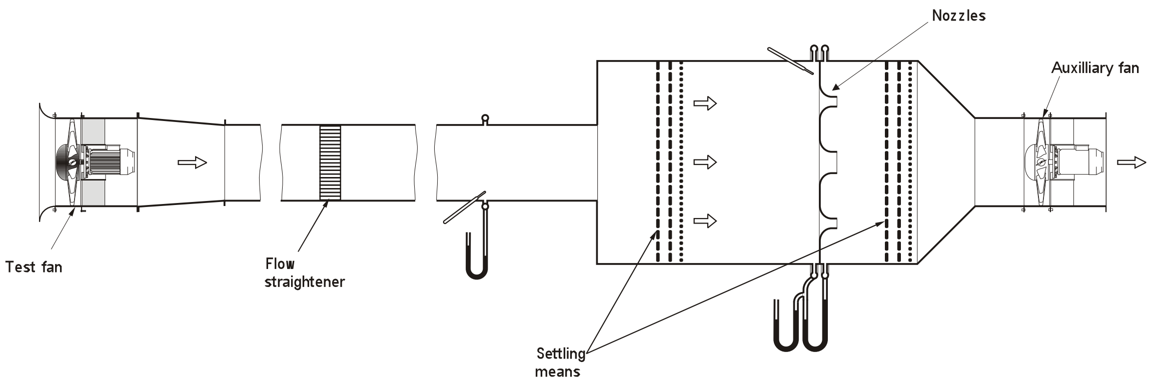


Figure 3: ISO 5801 Figure 72h, AMCA 210 Figure 10, Pressure measurement duct and chamber on outlet

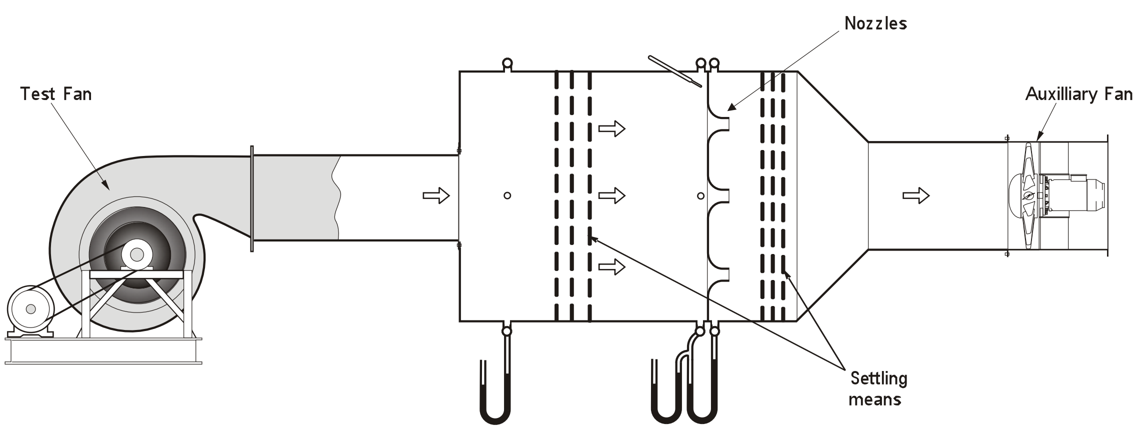


Figure 4: ISO 5801 Figure 73b, AMCA 210 Figure 12, Outlet chamber

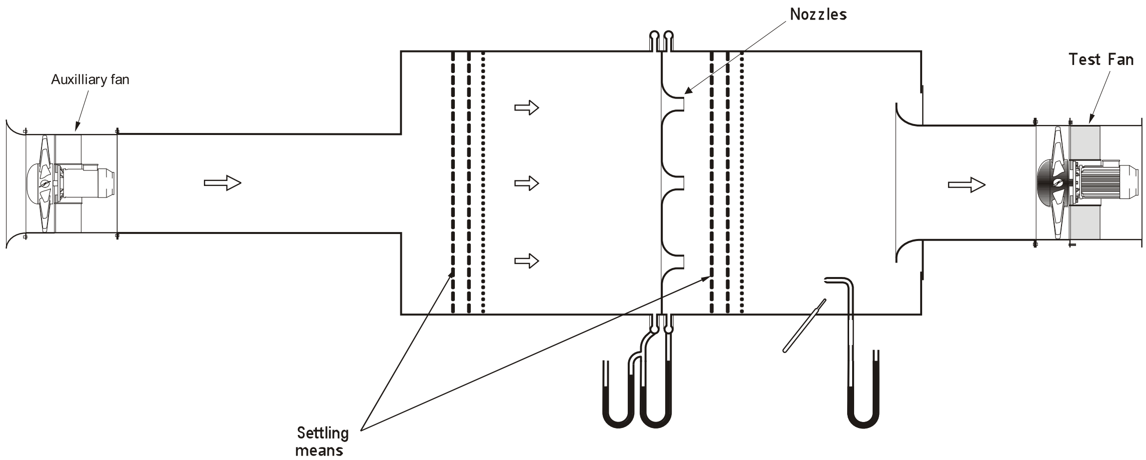


Figure 5: ISO 5801 Figure 75d, AMCA 210 Figure 15, Inlet chamber