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Proposal Information Template – Commercial and Industrial Fans and Blowers

2017 Appliance Efficiency Standards

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Purpose

This document is a report template to be used by researchers who are evaluating proposed changes to the California Energy Commission's (Commission) appliance efficiency regulations (Title 20, California Code Regulations, §§ 1601 – 1608). This report specifically covers Commercial and Industrial Fans and Blowers.

The purpose of this document is to provide an outline of a simple to understand and enforce energy metric to improve equipment efficiency, similar to all other appliance metrics used for energy savings.

Product/Technology Description

Commercial and industrial fans and blowers (or "fans") are used in a wide variety of applications such as commercial building HVAC systems, commercial kitchen exhaust systems, industrial processes, and agricultural ventilation.

There are three basic types of fan impellers discussed for regulation: axial, centrifugal, and mixed flow. In an axial fan, the air enters and exits the impeller parallel to the shaft axis. In a centrifugal fan, the air enters the impeller parallel to the shaft axis and exits perpendicular to the shaft in a radial direction. Finally, in a mixed flow fan, the direction of airflow through the impeller takes on characteristics that are intermediate between axial and centrifugal fans: the air exist the fan in a direction that is neither parallel nor perpendicular to the shaft. (We do not discuss the details of a cross-flow fan).

Fans can be either direct-drive or belt-drive. In a direct-drive fan, the fan impeller is directly connected to the motor, and there are no power transmission losses. In a belt-drive fan, the fan impeller is connected to the motor through a set of belts and sheaves mounted on the motor shaft and fan shaft, and there are associated power transmission losses. The speed of a direct-drive fan can be adjusted by changing the speed of the motor, for example by using a variable frequency drive (VFD), and there are associated VFD losses. The speed of a belt-drive fan can be adjusted by adjusting the belts and sheaves. Although in development, technology to produce economical motors for horse-powers greater than 1, which will run at speeds where a fan operates most efficiently in a direct drive configuration, do not currently exist.

Fans can be driven by various types of motors including single-phase motors, three-phase induction motors, and advanced motor technologies such as electronically commutated motors (ECMs).

Wheel	**Equipment Category**
Axial	Vaneaxial-Inline-(Includes Jet Fans with Vane)
Axial	Tubeaxial-Inline-(Includes Jet Fans without Vanes)
Axial	Panel Propeller Fans
Axial	Power Roof/Wall Ventilators
Centrifugal	Housed Backwardly Inclined-Single Thickness and Airfoil
Centrifugal	Housed Forward Curved
Centrifugal	Housed Radial Bladed
Centrifugal	Un-Housed
Centrifugal	Inline
Centrifugal	Power Roof/Wall Ventilators
Mixed Flow	InLine
Circulators	Circulating Fans: Ceiling Fans, Box Fans, Table Fans, Personal Coolers
Specialty	Air Curtains

Specialty	Ceiling Exhaust Fans
Specialty	Crossflow Fans
Specialty	Laboratory Exhaust Fans-Induced or High Velocity Discharge

There is no distinction between supply and exhaust fans (some fans are both supply and exhaust). All fans regardless of category have an energy metric based upon Total Efficiency and Total Pressure, which is the true measure of a fan's energy utilization. This is true of any machine, working on aero- or hydrodynamic principles, regardless of whether or not it is a fan, and includes both the Kinetic Energy and the Potential Energy used by the fan.

Please note that there is no distinction between unducted fans and ducted fans. In fact so called ducted fans are used in unducted applications and vice versa. It is simpler and aerodynamically correct to use Total Pressure for both ducted and unducted fans.

We do break out Forward Curved Fans separately. As seen below, this will allow for an increase in the energy efficiency of embedded products without causing the conundrum that you are faced with using other metrics, where you either have to exempt embedded product from becoming more efficient from the use of more efficient fans (or operation points), or you have to not exempt embedded product to obtain an increase in efficiency--- but this causes a tremendous investment cost on the part of the fan customer. Regulated embedded product constitutes the single greatest use of fan energy in the United States/California and un-regulated embedded product constitutes the second greatest use of fan energy.

Overview

We are proposing the metric described in the first NODA released by the Department of Energy on December 10, 2014. This NODA is attached to this submission.

Table 1: Summary of Proposal

Topic	**Description**

Description of Standards Proposal/Framework of Roadmap	The proposed metric is similar to the one proposed by the United States Department of Energy in the first released NODA. This metric applies to Commercial Building and Industrial Fan Applications. It is a metric which utilizes the peak efficiency of a given fan and extends that peak efficiency across a wide range of performance (to 115% of the fan's flow at peak efficiency) in order to insure the fan's energy output is improved by the manufacturer, regardless of the point of operation. For Agricultural and Horticultural Applications the metric proposed is the University of Illinois Bioenvironmental and Structural System Laboratory (BESS) cfm/watt metric. An agricultural or horticultural application is defined as one which involves the use of fans and blowers for the commercial growing of live plants or animals. This CFM/Watt metric has already been used extensively in California (and many other states) for utility rebate programs for fans used in agricultural and horticultural applications.
Technical Feasibility	The metric for Commercial Buildings and Industrial Fans is with reasonable modifications for the specific type of equipment, identical to all metrics used in the past by both Federal, State, and other entities to improve energy efficiency, either by a required minimum equipment efficiency or by various rebate programs. Whenever a fan is tested according to industry accepted standards, the data required for this metric is captured. As mentioned above the metric proposed for Agricultural and Horticultural Applications has already been successfully used for rebate programs in the State of California. A labeling and enforcement program which is both practical and straightforward. The metrics will improve the efficiency of the equipment sold in the State of California (and will probably increase the efficiency of equipment sold anywhere else that buys from a vendor who sells into the State of California).
Energy Savings and Demand Reduction	This is difficult to determine. The Department of Energy estimated .157 quads at a EL1 level for the United States over 30 years. There were several assumptions taken into consideration for this estimate and we would need to know the specific assumptions California would want to use.
Environmental Impacts and Benefits	By increasing the efficiency of the equipment itself, either as a "standalone" product or as an embedded product, energy savings will occur, and this will reduce electrical consumption and carbon emissions.

Economic Analysis	First the metrics would increase the energy savings of all sectors of the California economy, resulting in lower expenditures for energy being consumed by fans and blowers. Secondly, because the metrics impose a higher level of efficiency on the part of the manufacturer, there will be little if any increased costs to the consumer. Of course, there will be some investment cost on the manufacturer, and this will be recovered in product price. But with the metrics recommended, the investment will undoubtedly be amortized across all fan customers regardless of their location in the world. On the other hand, a metric which relies on enforcing a change in the consumer's behavior has only one way to increase energy savings---namely to impose that the particular California customer bear all of the investment cost for the savings. Thirdly, the simplicity of the metrics proposed, will result in less effort on the part of the California customer to realize savings and less effort and administration on the part of California regulatory authorities to administer and enforce the regulation. Fourth, both Europe and Asia have adopted metrics for energy savings similar to the ones proposed herein. By adopting this metric you are assured that American manufacturers and in particular California fan manufacturers will have the motivation to "keep up" with foreign competition. This will not be the case otherwise.
Consumer Acceptance	We believe that consumers of all fans, both standalone fans and embedded fans, will readily accept this metric because it maximizes their energy savings while minimizing investment cost.
Other Regulatory Considerations	The proposed metrics will not interfere with any other local, state, or federal regulations or pending legislation.

Methodology

A metric similar to the one proposed for Commercial and Industrial Fan was developed by AMCA at the request of ASHRAE and is currently part of ASHRAE 90.1. The Department of Energy in its first NODA expanded on this same metric by insuring that the metric covered an increase in efficiency for a wide operating range of the fan. The original metric was developed in conjunction with European representatives and is the metric used in Europe. See EU327. We feel that this type of metric will continue to be used in Europe and will of course evolve, but will not be replaced by another metric. A metric similar to the one proposed has been adopted in ASIA. ASIAN fan representatives have indicated they do not intend to change to another metric as the type of metric proposed is simple and easy to understand and will result in energy savings.

The Agricultural and Horticultural Metric was developed by a number of utility companies and the University of Illinois and has been in existence for approximately 30 years and has been used in numerous rebate programs aimed at increasing fan energy efficiency, including rebate programs in California. It is similar to various Energy Star metrics.

Both proposals would limit regulation to fans between 1 BHP and 200 BHP.

Proposed Standards and Recommendations

Commercial Building and Industrial Fan and Blower Applications

Proposed Definitions

Some of the definitions given below have been developed by AMCA's Fan Committee and incorporated into various standards. Some of these definitions have been developed by the Department of Energy.

Symbol	Definition
Q_{BEP}	flow at best (maximum) fan total efficiency η_{BEP}
Q_{110}	flow at 110% of Q_{BEP}
Q_{115}	flow at 115% of Q_{BEP}
Q_{FD}	flow at free delivery point (at 0” fan static pressure)
η_{BEP}	fan total efficiency at the best efficiency point for the fan model
η_{110}	fan total efficiency at flow of Q_{110}
η_{115}	fan total efficiency at flow of Q_{115}
η_{FD}	fan total efficiency at free delivery point (at 0" fan static pressure)
η_{TW}	3 point weighted average of fan total efficiency-- This value must be above or equal to minimum required by regulation
η_{TWT}	η_{TW} times transmission loss for belt drive fans

Proposed Test Procedure

This metric would use AMCA 207, 210, and 211 for testing. All tests necessary for determination of the 3 point BEP have been in place for years and are ISO standards.

Proposed Standard Metrics

Wheel	Equipment Category	Minimum 3pt BEP including

		transmission losses
Axial	Vaneaxial-Inline-(Includes Jet Fans with Vane)	64
Axial	Tubeaxial-Inline-(Includes Jet Fans without Vanes)	53
Axial	Panel Propeller Fans	50
Axial	Power Roof/Wall Ventilators (Note this is really an axial fan embedded in a structure to prevent the entry of outside elements. If you took the fan out it would have the same efficiency as other axial fans)	40
Centrifugal	Housed Backwardly Inclined-Single Thickness and Airfoil	64
Centrifugal	Housed Forward Curved	57
Centrifugal	Housed Radial Bladed	50
Centrifugal	Un-Housed	57
Centrifugal	Inline	44
Centrifugal	Power Roof/Wall Ventilators (Note this is really a centrifugal fan embedded in a structure to prevent the entry of outside elements. If you took the fan out it would have the same efficiency as other centrifugal fans).	40
Mixed Flow	InLine	47
Circulators	Circulating Fans: Ceiling Fans, Box Fans, Table Fans, Personal Coolers	Exempt
Specialty	Air Curtains	Exempt
Specialty	Ceiling Exhaust Fans	Exempt
Specialty	Crossflow Fans	Exempt
Specialty	Laboratory Exhaust Fans-Induced or High Velocity Discharge	Exempt
Life-Safety Fans	As defined by AMCA	Exempt

The values given for minimum efficiencies were determined in 2013. Also enhancements have occurred to the data base developed for this data. These numbers would need to be checked against the new data base and modified to correspond with the Department of Energy's proposed EL1 in the attached NODA. Please note that the minimum efficiency shown is not the peak efficiency, but the efficiency averaged over the range of fan performance up to either 115% of the peak or free delivery.

Proposed Framework

In the DOE NODA of December 2014, a three point Best Efficiency Point Metric was presented to both **require** fan manufacturer's to produce energy efficient fans, as well as to insure that at points far to the right of the peak efficiency—at 10% and 15% of flow, energy efficient fans were being produced by the manufacturer. The benefit of this metric is as follows:

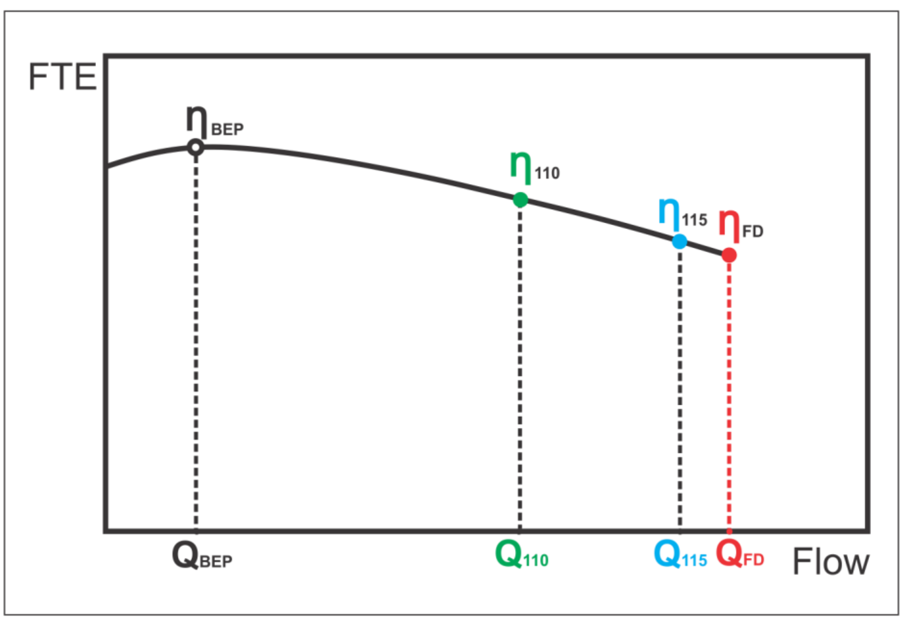
1. Requires efficient flow at flow points far away to right of Peak Efficiency as well as at the Best Efficiency Point (BEP).

2. Allows for an independent metric so that both code inspection and enforcement are quick, easy, and accurate. One does not have to determine if the fan manufacturer and/or the customer and/or the specifying engineer (all of which can be located either in the United States or overseas-- for specification and product shipped to the US) is following the IEC code and California Energy requirements. Inspection is based upon a label which can be backed up with third party.

3. This approach does not require Code Officials to determine who might be "gaming" the system which can happen repeatedly and frequently with any dependent metric approach, with almost no chance of effective code inspection or enforcement.

Recommendation:

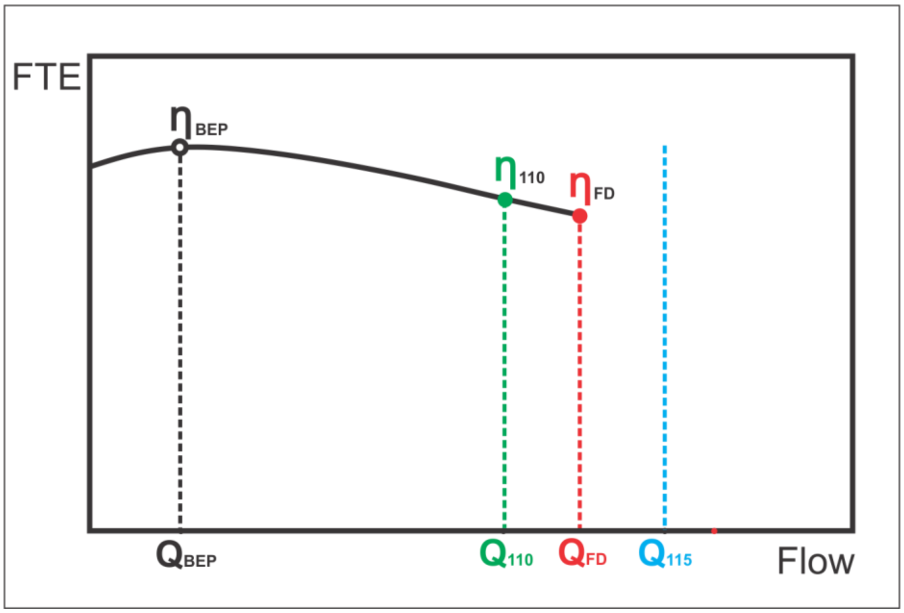
Remove the application requirement from the current wording and introduce three fan total efficiency points for determination of minimum energy qualification (BEP with 100% flow, FTE at 110% and 115%), similar to what is presented in the DOE NODA. An additional requirement has to be made – if the 110% flow or both 110% and 115% flows are past free delivery flow, the values of efficiencies for those flows are going to be replaced in the calculation by the efficiency at the free delivery flow.



$$Q_{110} = 1.10\, Q_{BEP} \qquad Q_{115} = 1.15\, Q_{BEP}$$

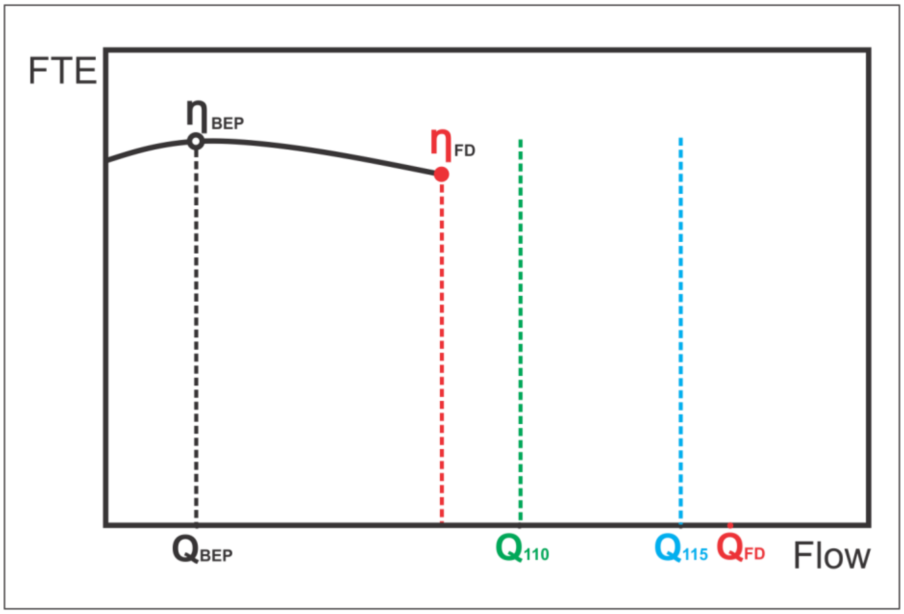
In this case $Q_{115} \le Q_{FD}$ and the weighted total fan efficiency η_{TW} is then

$$\eta_{TW} = (\eta_{BEP} + \eta_{110} + \eta_{115}) / 3.$$



In this case $Q_{110} \le Q_{FD}$ and $Q_{115} \ge Q_{FD}$ and the weighted fan total efficiency η_{TW} is then

$$\eta_{TW} = \frac{1}{3}\left(\eta_{BEP} + \eta_{110} + \eta_{FD}\right).$$



In this case $Q_{110} \geq Q_{FD}$ the weighted fan total efficiency η_{TW} is then

$$\eta_{TW} = \frac{1}{3}\left(\eta_{BEP} + \eta_{FD} + \eta_{FD}\right).$$

Note: All quantities are determined from fan performance at a constant fan speed.

Calculation of weighted fan total efficiency η_{TW} *for determination of three point BEP metric*

If $Q_{115} \leq Q_{FD}$ then

$$\eta_{TW} = (\eta_{BEP} + \eta_{110} + \eta_{115}) / 3$$

If $Q_{110} \leq Q_{FD}$ and $Q_{115} \geq Q_{FD}$ then

$$\eta_{TW} = \frac{1}{3}\left(\eta_{BEP} + \eta_{115} + \eta_{FD}\right).$$

If $Q_{110} \geq Q_{FD}$ then

$$\eta_{TW} = \frac{1}{3}\left(\eta_{BEP} + \eta_{FD} + \eta_{FD}\right).$$

For belt drive fans η_{TWT} (total efficiency including belt losses) is calculated for belt drive fans by multiplying the transmission efficiency as calculated in AMCA 207 and multiplying by η_{TW}.

Motor efficiency is determined by requiring that the motors used on a fan or blower are those regulated by the United States Department of Energy. This regulation is no different in scope than that which would be imposed by users of regulated fans and blowers which is consumed in "embedded" product such as air handlers.

In the background of all of the equations given above is a simple and elegant single two digit minimum metric (e.g., 75%) for each fan which must be met by the Fan Manufacturer, and which must appear on the fan label, and which can be tested by a third party accredited lab, either through the trade association AMCA, or through other accredited third parties. Market testing for enforcement by the California Department of Energy (or anyone else) can easily be done at any time on a random basis to insure compliance by the manufacturer.

Proposed Reporting Requirements

Required Report is shown below:

Manufacturer	Model	Wheel Type	Equipment Category	3 point BEP	Date Updated

Analysis of Proposal

A proposal very similar to the one above was made by the Department of Energy in December of 2014. Since that time other proposals have been developed, but are extremely complex and almost impossible to enforce. This proposal is the easiest to implement and enforce in order to increase energy efficiency of fans and blowers.

Scope/Framework

Included in the proposal are fans and blowers which consume 95% of the power between 1 HP and 200 HP.

Fans excluded either are regulated through other means such as Energy Star, or have negligible sales in the California (or the entire United States), or are used for safety purposes. Fans defined by AMCA, which are called Safety fans are also exempt. All of these fans will constitute no more than 5% of energy consumed and probably less.

The only significant motor category not regulated by the US Department of Energy is TEAO/TENV motors. This is because an agreed upon test standard had not been developed. That is no longer the case and a proposed regulation for TEAO/TENV motors will most likely be developed by the time this standard becomes fully effective.

Agricultural and Horticultural Fan and Blower Applications

Proposed Definitions, Proposed Test Procedure, Proposed Standard Metrics, Proposed Framework

Definitions, Test Procedures, and Framework are covered at the following website:

www.bess.illinois.edu

Proposed standard metrics should be developed in conjunction with BESS.

This metric is the simplest and most straightforward of all-- CFM/WATT at a given static pressure. It would be desirable to use this metric for all fans but it is not practical. Fans for these uses have a limited number of models, static pressure points, motor types, and accessories, approximately 300 variations. Fans for Commercial and Industrial Use have an unlimited number of static pressure points and a tremendous amount of variation in motor types and accessories, and the market is served by thousands and thousands of models. All of this requires the above 3 point metric.

Product Efficiency Opportunities

Improving fan aerodynamic design is the most significant method for improving the product's efficiency.

Technical Feasibility

Please see attached NODA and associated spreadsheet.

Statewide Energy Savings

Please see attached NODA and associated spreadsheet as well as comments in Table under Overview.

Cost-effectiveness

Please see attached NODA and associated spreadsheet as well as comments in Table under Overview.

Environmental Impacts/Benefits

The recommendation does not have any potential adverse environmental impacts. This metric can only decrease atmospheric emissions (including ozone depleting gases). There are no environmental or energy impacts associated with material extraction, manufacture, packaging, shipping to the job site, or other activities associated with implementing the measure.

Impact on California's Economy

Please see comment in Table above under Overview.

Consumer Utility/Acceptance

Please see comment in Table above under Overview.

Manufacturer Supply Chain Timelines

We would suggest you use the same timeline period of implementation as is usually granted by the United States Department of Energy.

Other Regulatory Considerations

There is no interference with other Federal, local regulations, legislation, or voluntary agreements to the extent that the viability of the proposed standard is problematic or strengthened.

Conclusion

This metric directly improves the energy efficiency of the product. It is similar to all other metrics for driving improved energy efficiency. One example would be the EPA miles per gallon metric for automobiles for both city and highway driving. This metric is simple and enforceable. Otherwise you would do away with this metric and control the operation of the speed of the car. The problem is the ability to enforce this degree of complexity. The efficiency of automobiles will not change under these circumstances.

References

Please see attached NODA and associated spreadsheet. A one point variation of this metric is part of the IECC and IGCC codes and ASHRAE 90.1 standard.

Appendices

These metrics are too simple and elegant to have Appendices.