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Greenheck Group / Michael Wolf Comments - Title 20 Phase II Pre-Rulemaking, Commercial and Industrial Fans & Blowers

Additional submitted attachment is included below.

June 16, 2017

California Energy Commission
Docket Unit, MS-4
1516 Ninth Street
Sacramento, CA 95814-5512

RE: *DOCKET: 17-AAER-06, Commercial and Industrial Fans & Blowers, Title 20 Phase II Pre-Rulemaking*

I am writing in response to the May 11th, 2017 California Energy Commission (CEC) webinar meeting pertaining to the CEC Rulemaking for Commercial and Industrial Fans & Blowers.

Credentials:
With over 31 years of HVAC experience with the Greenheck Group, a leading manufacturer of commercial and industrial fans and blowers, I look forward to contributing to the CEC rulemaking process. Having held positions in engineering, sales, marketing, software development and general management, I have a solid foundation to provide meaningful commentary to the fan regulatory process. I'm currently, or have been, active in the development of test standards and codes with industry trade associations including ASHRAE, AMCA, AHRI, UL, NFPA, ICC and others. I participated on the U.S. Department of Energy's Working Group responsible for developing recommendations on Commercial and Industrial Fan Energy Regulation. I am also a member of the U.S. Department of Energy's Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC). Over the past several years I have had the opportunity to work with colleagues, industry associations, competitors, energy advocates, customers, and others on practical approaches for reducing fan energy consumption. I look forward to using what I've learned to help guide the CEC rulemaking process for Commercial and Industrial Fans & Blowers.

In addition to my professional experience, I will also be able to draw from a vast network of support within the Greenheck Group. The Greenheck Group is comprised of a number of brands including Greenheck, Unison Comfort Technologies, Innovent, Valent, Precision Coils, Accurex, Airolite and GlobeAire. Headquartered in Schofield, WI, Greenheck has offices and manufacturing facilities in Wisconsin, California, Kentucky, North Carolina, Mexico, and India. Greenheck employs more than 3,600 people worldwide, including over 2,000 in the United States and more than 200 in California. With over 70 years in the fan and blower manufacturing business, Greenheck is a worldwide leader in the manufacture of air-movement, conditioning and control equipment, systems and services. Greenheck's extensive product offering includes commercial fans and industrial blowers, laboratory exhaust systems, dedicated outdoor air systems, energy recovery ventilators, air handling equipment, make-up air equipment and kitchen ventilation systems. Related products include air-control dampers, fire and smoke control dampers, heating and cooling coils as well as architectural and mechanical louvers. Greenheck equipment is used in all types of commercial, institutional, and industrial buildings and applications ranging from comfort ventilation to industrial processes.

Industry Associations

Greenheck engineers are actively involved with many government and industry organizations working to establish performance standards and application guidance related to HVAC systems and related products. Examples include:

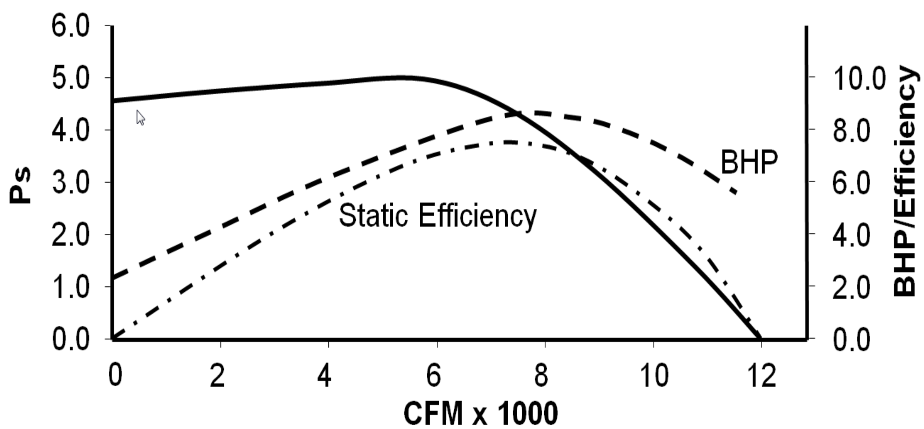
- United States Department of Energy (DOE)
- International Standards Organization (ISO)
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)
- Air Movement & Control Association (AMCA)
- Air-Conditioning, Heating, & Refrigeration Institute (AHRI)
- International Code Council (ICC)

Greenheck's involvement with the aforementioned groups is largely focused on development of standards, regulations and programs that result in energy efficient HVAC systems as well as practical selection and application of energy efficient products manufactured for these systems. Greenheck is continuously working with these organizations and other industry members to provide constructive, consistent and substantial insight regarding industry standards and regulations.

Considerations Regarding Regulation of Commercial and Industrial Fan Energy Consumption:

Two important elements to consider as a foundation for developing regulation on fan energy consumption are:

1. The Subject regulation needs to focus on reducing fan energy consumption rather than simply focusing on improving fan efficiency. Consider the fan performance curve of a typical fan (see diagram below).



This curve shows that the Static Efficiency for a fan can vary from 0% to a peak efficiency of around 80% (peak efficiency will vary by fan type). Depending on the application requirements of a fan (e.g. flow, pressure, space constraints, sound, etc.) focusing on only peak efficiency can be misleading and will not always result in the use of a fan that minimizes energy consumption.

2. The Subject regulation needs to consider that a single fan is often applied to a nearly infinite variation of operating conditions (i.e. airflow and pressure). To effectively minimize fan power consumption these operating conditions need to be taken into account. For example, fans and blowers installed in systems that include filters will need to operate over a wide range of resistance to airflow (i.e. pressure drop) as filters become dirty. It is also common to vary the speed of a fan to match the airflow or pressure requirements of the system/process (note; affinity laws for fans make slowing a fan's speed to match the requirements of system/process one of the most effective ways to reduce fan energy). As the fan curve above shows, there will be considerable variation in power consumption over the performance range for a given fan.

While item number 2 may fall outside the scope of how fans are regulated, I encourage consideration as to how Title 20 fan regulation can be leveraged with Title 24 application regulation to achieve real overall energy savings.

<u>Stakeholders impacting Commercial and Industrial Fan Energy Consumption:</u>

When considering a regulation to reduce energy for commercial and industrial fans and blowers, it is important to consider that the end consumer (i.e. building owner or facility manager) often has little knowledge or influence over the buying decision for the product. In the case of commercial and industrial fans and blowers the key stakeholders include:

1. **Owners**
    - Establish building needs and end use objectives.
2. **Architects and Design Engineers**
    - Develop designs and specifications to meet project objectives and compliance with building and energy codes. Energy consumption may or may not be an important consideration of the project.
3. **General Contractors and Sub-Contractors**
    - Work to purchase and install equipment and components that meet specifications of the architect and design engineer. Contractors are usually responsible for assuring equipment, components and installation comply with building and energy code requirements.
4. **Manufacturers**
    - Work to design and manufacture equipment and components that minimize energy consumption in a cost-effective manner and create a preference for their products in the market.

Regulation that can leverage the needs of these multiple stakeholders will ultimately drive maximum energy savings.

Comments on Regulating Commercial and Industrial Fan Energy Consumption:

When considering the market dynamic described above the best way to maximize energy savings for commercial and industrial fans and blowers is to focus first on the overall system that the fan is being used and then work your way down to the equipment in the system, then down to the product in the equipment &/or system and finally down to the components in the product.

Based on my experience the best approach to minimize fan related energy consumption and maximize fan related energy savings is to prioritize and consider harmonization of regulatory requirements as follows:

1. *Regulation of Ventilation Systems* (e.g. ASHRAE 90.1, IECC, CEC Title 24)
2. *Regulation of Heating, Air-conditioning, Refrigeration and Ventilation Equipment* (e.g. DOE regulated equipment, CEC Title 20 regulated equipment)
3. *Regulation of Individual Fans* (TBD)
4. *Regulation of Individual Fan Components* (e.g. motors, impellers, housings, appurtenances, etc.)
    - To the best of my knowledge, motors are the only individual fan component being regulated at this time. <u>I am NOT advocating regulation of other individual fan components. I am only attempting to explain the hierarchy related to maximizing the impact of fan energy regulation.</u>

Before providing further commentary on these four items, it is important to consider the impact of the following three items have on fan energy consumption:

1. Airflow (CFM) - Higher airflow results in larger energy consumption.
2. Pressure Drop/Resistance to airflow (Ps) - Higher Pressure Drop results in larger energy consumption.
3. Fan Design/Selection - Selecting the correct fan design at an optimal performance range will minimize energy consumption.

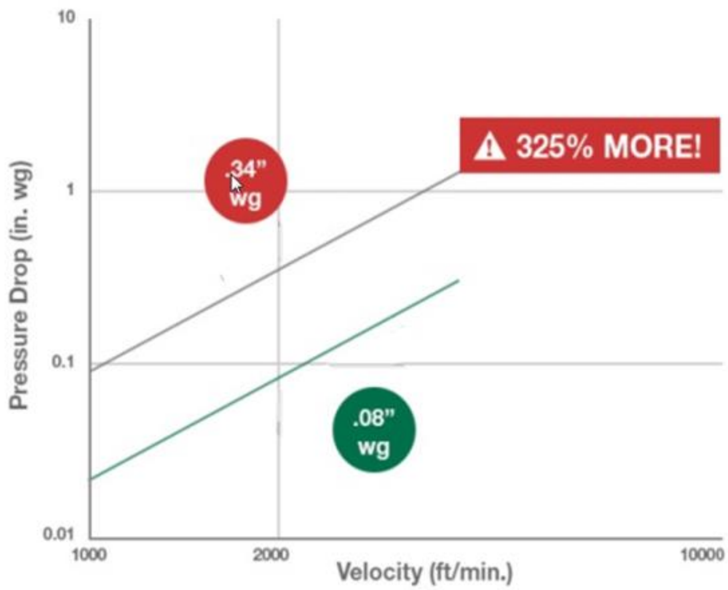
Please keep these items in mind when considering the comments below.

<u>Regulation of Ventilation Systems</u>

Energy Standards such as ASHRAE 90.1, Energy Codes such as the ICC International Energy Conservation Code (IECC) and CEC Title 24 are examples of regulations that establish requirements for HVAC energy usage in commercial buildings. These standards and codes place limits on fan power consumption that require architects, design engineers, contractors and manufacturers to effectively account for all 3 of the items listed above. As explained above, this creates a mechanism and accountability for architects, designer engineers, contractors and manufacturers to reduce energy consumption.

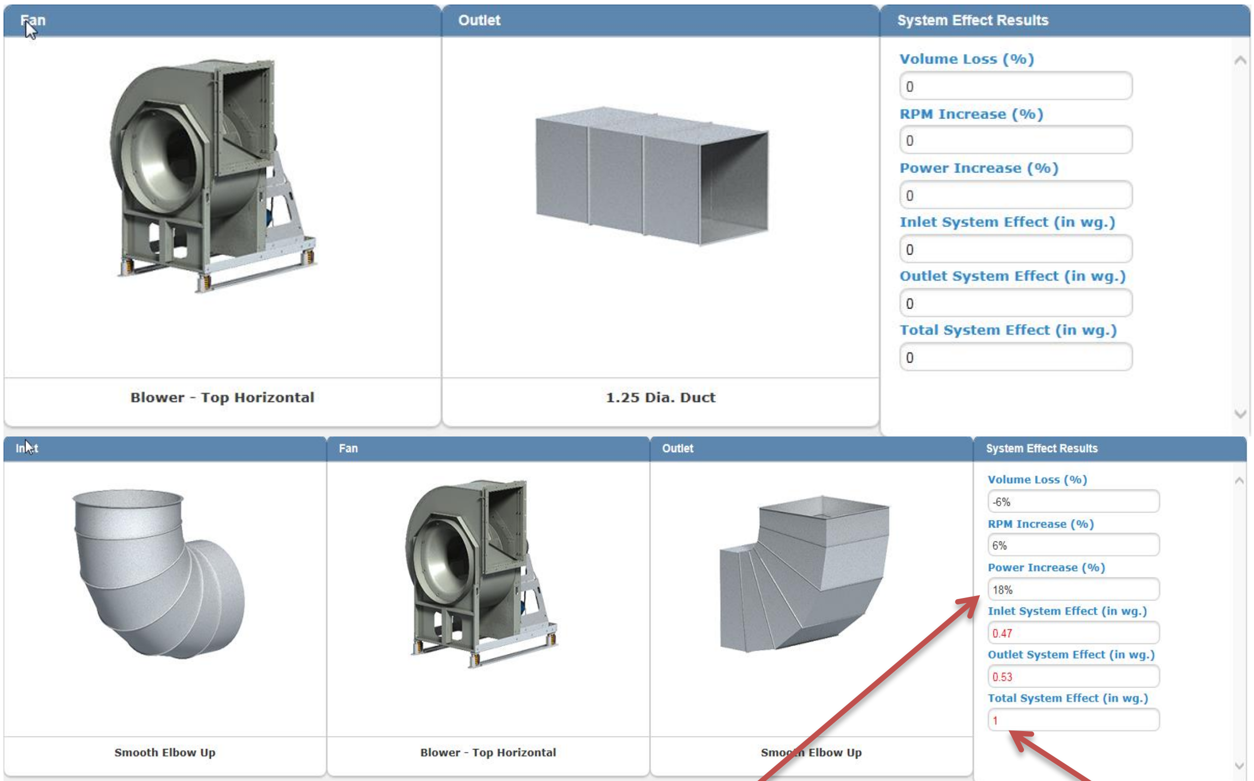
While existing standards and codes are moving in the right direction, there is tremendous opportunity to leverage and reduce HVAC fan energy consumption further through more emphasis and requirements regarding accurately accounting for Pressure Drop and the resulting optimization of the fan design/selection.

To further explain, consider that many ventilation designs do not accurately account for the pressure drop of components such as grilles, dampers and louvers. The graph below shows the comparable pressure drop of two dampers of the same size and airflow.



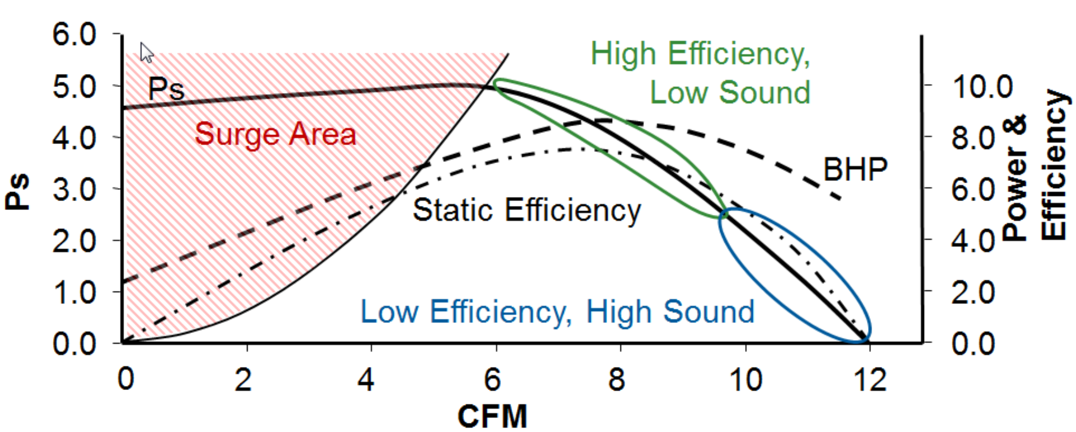
It is intuitive that a damper with 325% more pressure drop will result in a significant increase in fan power consumption. Failure to accurately account for the pressure drop of specific components, such as dampers, will be compensated for in the fan selection. The result will be a fan that is under-optimized for the application and will likely require significantly more power consumption than necessary to meet the airflow requirements of the system.

Fan inlet and outlet conditions can also significantly increase pressure drop and are often not accounted for in the system design and/or fan installation. The diagrams below demonstrate the impact elbows on the inlet and outlet of a centrifugal blower can have on a fan's energy consumption.



In this example, adding an elbow to the inlet of the fan and replacing the straight duct on the discharge of the fan with an elbow increases the Pressure Drop (i.e. Total System Effect) by 1 in. wg. and the fan power consumption by 18%. (ref. Greenheck System Effect Simulator - https://ses.greenheck.com/)

To further demonstrate how pressure drop impacts fan design and selection consider the representative fan curve below.



Note that fans are never selected in the "Surge Area" of a fan curve and most manufacturers do not publish performance or allow software selections in this portion of the performance curve. The reason is that fan performance is often not stable in this area of the curve (i.e. flow and pressure will fluctuate dramatically causing the fan to "surge"). When a fan is in "surge," it will often fail to meet performance requirements of the system, possibly cause damage to ventilation system components (e.g. such as duct work) and may ultimately lead to a mechanical failure of the fan. As a result, selections are made to the right of the "Surge Area."

Fans will use the least amount of energy and generally run quieter when the operating point (airflow and pressure drop) is in the "High Efficiency, Low Sound" portion of the fan curve. However, if pressure drop and/or system effect is not accurately accounted for the fan may be at risk of operating in the "Surge Area" after installation. To account for this, fan selections are often made in the "Low Efficiency, High Sound" portion of the fan curve. The FEI metric defined by the ASRAC Working Group addresses this situation by limiting selection points in the "Low Efficiency, High Sound" portion of the fan curve in much the same way selection points are limited in the "Surge Area" portion of the fan curve. The positive outcome is that design engineers will become more diligent in accounting for pressure drop of components and the inlet and outlet conditions of the fan.

The items above can be further enforced as part of the energy code (e.g. Title 24) compliance process. For example, fan power requirements established by Title 20 need to be evaluated as part of the Title 24 plan review process before issuing a building permit. This will help assure items such as pressure drop and system effect are accounted for as part of the system design. This can be complimented as part of the final commissioning process before issuing a certificate of occupancy.

Regulation of Heating, Air-conditioning, Refrigeration and Ventilation Equipment

Fans are often incorporated (embedded) by original equipment manufacturers (OEMs) in products designed to heat, condition, ventilate and/or create pressurization. To maximize equipment efficiency and minimize power consumption it is best to consider fan power as part of the overall power consumption of the equipment the fan is embedded into. Energy consumption of fans embedded in equipment will also be impacted by the same pressure drop and system effect issues described in the previous section. As such, the best way to account for these items and minimize embedded fan energy consumption is to evaluate the fan as part of the overall equipment power consumption.

Exhaust air energy recovery devices are prime examples of HVAC equipment that can consume higher amounts of fan energy while at the same time reducing the overall energy consumption of the equipment. For example, adding an air-to-air energy recovery device to a 2,100 cfm DX-DOAS unit will increase the overall fan power by 342%, but during typical operation in dehumidification season the unit will use approximately 22% less energy than a unit without the air-to-air energy recovery device (see table below).

	Without Energy Recovery	With Energy Recovery
Supply Fan Shaft Power (Bhp)	0.22	0.80
Exhaust Fan Shaft Power (Bhp)	0.15*	0.82
Total Fan Shaft Power (Bhp)	0.37	1.62
Total Fan Electrical Input Power (kW)	**0.33**	**1.46**
Compressor Full Load Power (kW)	14.0	7.4
Dehumidification Season Power Consumption(kW-h)**	**17,770**	**13,922**

** Typically in this configuration the DX-DOAS unit does not include the system exhaust fan, but an exhaust fan or other airflow control device will be required for space pressurization. Fan shaft power was estimated using a 50% static efficient selection at the AHRI-920 rated duct pressure.*

*** Operation was assumed to be 12 hours a day, 5 days a week based on an average DX-DOAS season length. Design conditions used were from AHRI Standard 920. Includes fans, energy wheel, compressor, and control power.*

The point of this example is not to imply that regulation of a fan will discourage, or prevent the use of energy efficient equipment. The point is that evaluating the fan as part of the overall power consumption and energy saving capability of a piece of equipment will generate much, much more energy savings than regulation of the individual fan.

Regulation of Individual Fans

Regulating individual fans in a way that drives energy savings while minimizing regulatory loop holes, preventing unintended consequences and is easy to assimilate by the market is a challenge. Many of these challenges have been vetted over the past several years. First as part of developing fan energy regulation language in ASHRAE 90.1 and still further as part of the ASRAC Working Group Term Sheet recommendations for the DOE Commercial and Industrial Fan & Blower rule.

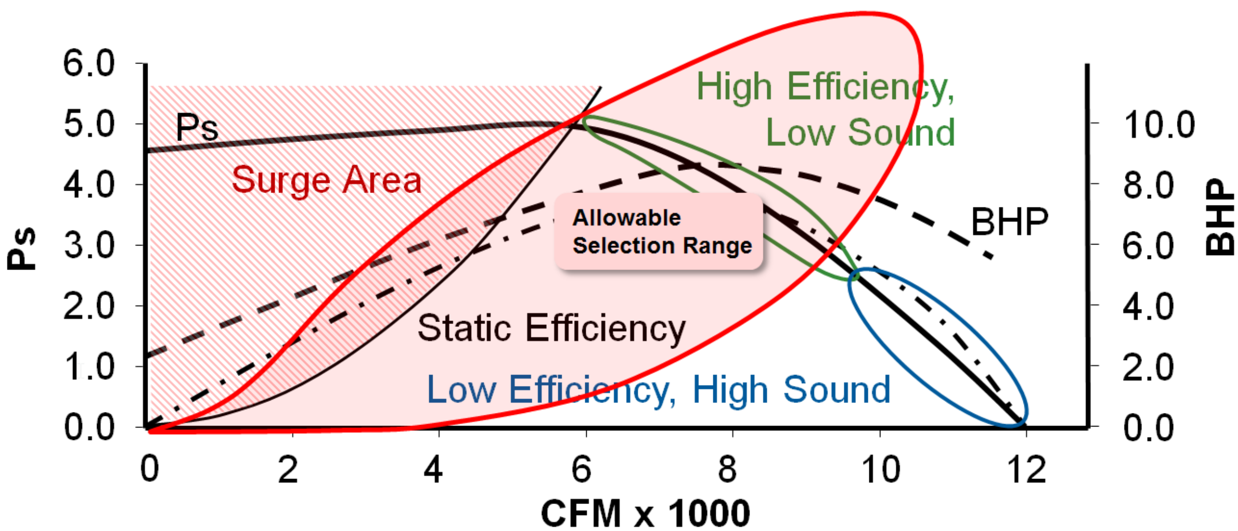
Based on the cumulative efforts from past years, I recommend the CEC use the ASRAC Working Group Term Sheet and related comments as a basis for developing a CEC rule for commercial and industrial fans and blowers. I further recommend the CEC reference the work being done by AMCA to develop a Certified Ratings Program (CRP) for the Fan Energy Index (FEI) and Fan Electrical input Power (FEP) defined in the ASRAC Term Sheet.

While the ASRAC Working Group achieved consensus on many of the issues related to the challenges of regulating individual fans, there are a few items I'd like to comment on in more detail. These include:

- Energy Metric
- Fan Categories/Equipment Classes
- Efficiency Levels
- Replacement Fans

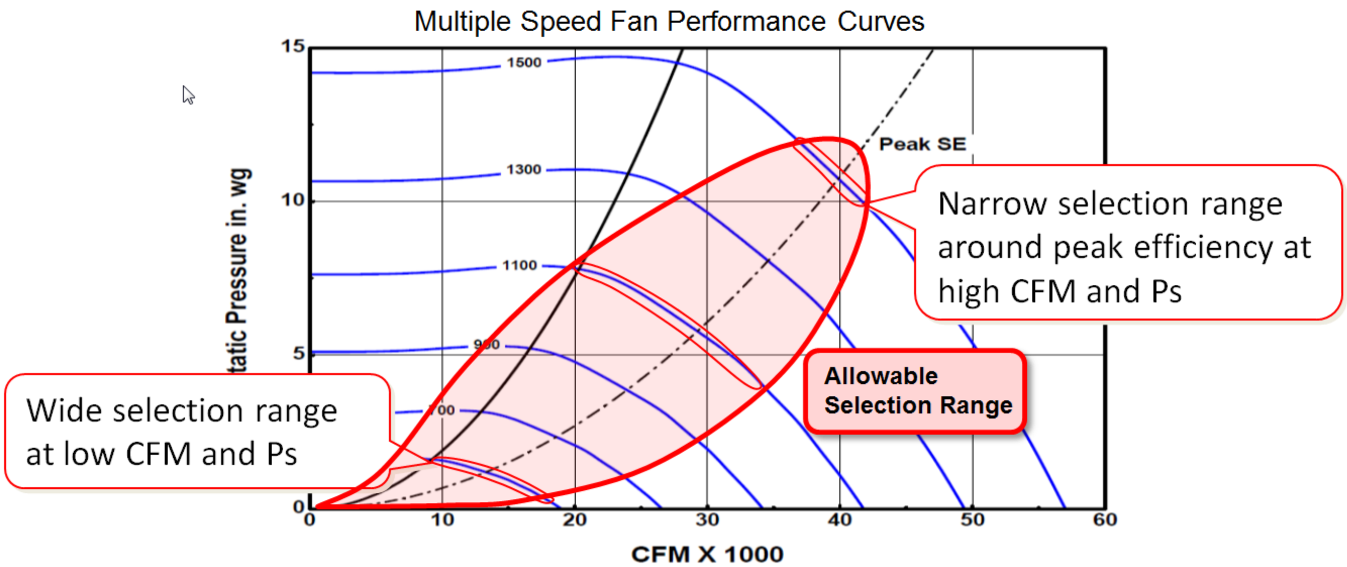
Energy Metric – As described above, fans are often applied across a wide range of airflow and pressure drop conditions. This issue creates both a challenge and an opportunity as it relates to fan energy regulation. The Fan Energy Index (FEI) and Fan Electrical input Power (FEP) metrics outlined in the ASRAC Working Group term sheet address this airflow/pressure drop challenge and create an opportunity to apply a unique approach to the regulation requirements for fans. While there is some concern related to challenges that arise from regulating a range of operating points, rather than a single or limited number of operating points, I am confident these concerns are being addressed as part of the AMCA Certified Ratings Program and will be further addressed as standards such as ASHRAE 90.1, and codes such as IECC and California Title 24 adopt the FEI metric.

The Fan Energy Index (FEI) establishes a performance bubble over a range of operating points that meet fan energy requirements set by the regulation (see graph below).



The FEI metric will reinforce positive market behavior by design engineers, contractors and manufacturers. The performance bubble will encourage design engineers and contractors to optimize system design and fan installation to assure fans perform within the allowed operating range. Fan manufacturers will strive to develop fans with a large performance bubble to meet the requirements of design engineers and installing contractors.

A typical FEI bubble also provides a wide performance range at low flows and pressures where fans use less power. The performance range will be smaller at high flows and pressures where fans consume more power (see graph below). This characteristic of the FEI metric makes it a practical tool for driving fan energy savings.



While the FEI metric is unique to other regulatory metrics, it a practical metric for fans based on the following:

1. FEI will limit fan power based on the fans range of operation.
    - Not simply the BEST point of operation.
2. FEI will leverage natural market dynamics to help drive energy savings.
    - System designers can specify FEI levels to meet specific energy consumption objectives.
    - System Regulations such as ASHRAE 90.1, CA Title 24, etc. can establish minimum FEI levels across a multitude of fan categories and applications.
3. FEI is a good comparison of relative **energy** consumption across all fan categories and applications.
    - This will help facilitate adoption in the market.
4. FEI can be used to incent/rebate “stretch” metrics.
    - While energy standards, codes and regulations can establish minimum efficiency levels for FEI, utilities and other energy advocate groups can establish incentive programs that exceed the minimum regulatory requirements.
5. FEI can be used with ALL fans.
    - Existing metrics, such as the FEG metric in ASHRAE 90.1, are limited and require exceptions for many types of fans and applications.

Fan Categories/Equipment Classes - The industry is challenged on how best to handle Housed Centrifugal Blowers that utilize Forward Curved (FC) wheel technology. Since many FC fans are embedded in equipment, regulated and unregulated, this issue is also part of the commentary regarding Embedded Fans.

There are two 2 schools of thought regarding FC Fans. The first is that they provide the same application utility as Housed Centrifugal Blowers that utilize Backward Inclined (BI) and Airfoil (AF) wheel technology. As such, FC fans should be grouped in the same fan category/equipment class as BI & AF fans. The second is that FC fans provide a unique utility that is of primary value for fans embedded in equipment. This value is related to more desirable size and sound characteristic of FC fans as compared to BI and AF fans. As such, FC fans should have a separate fan category/equipment class than other fans.

To help move the discussion forward, I recommend that the CEC evaluate FC fans separately from BI and AF fans. Based on this evaluation, a decision can be made with regard to the need for a separate fan category or equipment class for FC fans.

Efficiency Levels – The ASRAC Working Group Term Sheet failed to provide a recommendation regarding establishing minimum FEI (maximum FEP) levels for fans. This was largely driven by concerns regarding around the uncertainty of regulatory requirements, a new, untested metric, energy saving projections, cost impacts to manufacturers, cost impact to the market, etc. To help facilitate dialog and develop acceptable FEI levels I recommend:

1. Reevaluation of the NODA energy and cost analysis specific to CA using new and updated data from manufacturers and other stakeholders.
2. Working with stakeholders (e.g. California Utilities, Energy Advocacy Groups) to coordinate and compliment minimum regulatory requirements with stakeholder incentives/rebates that will drive requirements for fans that use less power than the regulation may initially mandate.

Replacement Fans – I believe the FEI metric will effectively address replacement fans. FEI defines an allowable performance range for a fan. The challenge with replacement fans is that many times when a fan is being replaced, the fan performance is not known. The primary consideration for a replacement fan is often trying to find a replacement fan to fit into the same location as the original fan. The FEI metric allows manufacturers to supply a replacement fan that will provide the same "fit" as the original fan and compliment the fit with the allowable performance range that will provide the least amount of energy consumption. While it is possible that when the fan is installed it operates outside of the allowable performance range, I believe natural market dynamics will minimize this "loophole" opportunity.

Regulation of Individual Fan Components – As stated previously, to the best of my knowledge, motors are the only individual fan component being regulated at this time. I believe energy regulations on motors to be of value to the industry. However, I do not see value nor do I advocate extending this logic to other fan components, such as impellers, housings, etc. As stated earlier, I am NOT advocating regulation of individual fan components. I am only attempting to explain the hierarchy related to maximizing the impact of fan energy regulation.

In summary, I recommend the CEC:

1. Consider how best to leverage and harmonize building system regulation (e.g. CEC Title 24) with fan product regulation (e.g. CEC Title 20).
2. Consider the ASRAC Term Sheet and subsequent AMCA CRP as the basis for CEC Title 20 fan product regulation.

In closing, I appreciate the opportunity to support this regulatory effort and am prepared to provide additional details regarding historical data and the potential impact the regulation will have on the market. Examples include data related to historical product application, purchase costs, production costs, redesign costs, performance, fan selection, etc. I can also share analysis related to energy and cost estimates associated with DOE NODA efficiency levels, fan categories, etc. I have provided much of this data to the DOE through nondisclosure agreements with Navigant Consulting, LBNL and others. I can provide similar information more specific to California as requested. Please let me know if this is of interest.

Respectfully Submitted,

Mike

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