ASSOCIATION OF HOME APPLIANCE MANUFACTURERS

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December 6, 2018

Via E-Mail

Robert Burchard
U.S. Environmental Protection Agency

roomaircleaners@energystar.gov

Re: ENERGY STAR Room Air Cleaners Version 2.0 Specification Discussion Guide

Dear Mr. Burchard:

On behalf of the Association of Home Appliance Manufacturers (AHAM), I would like to provide our comments on the ENERGY STAR Room Air Cleaners Version 2.0 Specification Discussion Guide (Oct. 2018).

AHAM represents manufacturers of major, portable and floor care home appliances, and suppliers to the industry. AHAM's membership includes over 150 companies throughout the world. In the U.S., AHAM members employ tens of thousands of people and produce more than 95% of the household appliances shipped for sale. The factory shipment value of these products is more than $30 billion annually. The home appliance industry, through its products and innovation, is essential to U.S. consumer lifestyle, health, safety and convenience. Through its technology, employees and productivity, the industry contributes significantly to U.S. jobs and economic security. Home appliances also are a success story in terms of energy efficiency and environmental protection. New appliances often represent the most effective choice a consumer can make to reduce home energy use and costs.

AHAM supports EPA and the Department of Energy (DOE) in their efforts to provide incentives to manufacturers, retailers, and consumers for energy efficiency improvement, as long as product performance can be maintained for the consumer. AHAM strongly supports a change from dust CADR to smoke CADR which is used to calculate room size and is a proxy for the smallest particulates in consumers' homes.

AHAM also encourages EPA to ensure that any revisions to the specification are supported by sound data. We also are concerned by the consideration of possible deviations from AHAM/ANSI AC-1 in the context of an ENERGY STAR specification revision and instead urges DOE to join AHAM's task force that works to revise that standard if there are changes to the test DOE would like to see.

I. Scope

EPA indicated that it has learned that some air cleaners can emit potentially harmful byproducts and that it intends to exclude product types that do so. EPA referenced as examples formaldehyde, carbon monoxides, and fragrances. EPA asked how it could verify that contaminants are excluded.

There is no national or international standard to test an air cleaner for production of harmful byproducts. Nor has EPA or any standard defined what the term "harmful byproduct" would include. Without a definition or a standard to measure, it would be difficult if not impossible for EPA to address these emissions in an ENERGY STAR specification. Research would need to be done into what constitutes a harmful byproduct and how to measure it.

Furthermore, as we have commented in the past, EPA must not stray from its strategic vision for the ENERGY STAR program, which is to reduce greenhouse gas emissions by removing barriers in the market that deter consumers and others from purchasing the most energy-efficient product model that otherwise meets their needs. The ENERGY STAR program must remain squarely focused on energy efficiency and not create design, performance, or other requirements. Manufacturers themselves have the most interest in ensuring that consumers receive superior performance and are satisfied with the product, regardless of the energy efficiency of the product.

II. CADR

The Version 1.2 efficiency criteria are based on dust CADR, but, as EPA noted, ANSI/AHAM AC-1-2015 (AHAM AC-1) measures CADR for smoke and pollen particles as well. EPA noted that smoke CADR is used to calculate recommended room size and used by manufacturers to measure room air cleaner performance. EPA sought feedback on establishing energy efficiency requirements for smoke and pollen removal efficiency in addition to dust.

AHAM proposes that EPA continue to require measurement of only one particle type for purposes of mitigating test burden, and **we strongly urge EPA change from dust CADR to smoke CADR**. During the development of the Version 1.0 specification, AHAM advocated for EPA to set its criteria based on smoke CADR and opposed use of dust CADR. As EPA acknowledged in the Discussion Guide, smoke is used to calculate room size and to measure room air cleaner performance. Tobacco smoke was chosen to determine room size because of its extremely small size and because it is a common global indoor pollutant.

In addition, it is industry practice to use smoke as the internal measure for testing performance. AHAM AC-1 uses a specific engineering tobacco smoke to generate the smoke CADR. The size of the smoke particles (.09 micrometer to 1.5 micrometer) are 100 to 1000 times smaller than the width of a human hair. Thus, even if a consumer does not smoke, tobacco smoke is a surrogate for much smaller fine particles that may be found in a home. Accordingly, AHAM currently believes smoke is the best and only necessary particulate for EPA to use to set its ENERGY STAR qualification criteria.

III. Efficiency Assessment

Based only on a sample of ENERGY STAR qualified air cleaners, EPA purported to examine how product efficiency has improved since the Version 1.0 specification was released in 2004. EPA claims that Figure 1 in the Discussion Guide "shows the trend toward greater efficiency (based on when ENERGY STAR models were available on the market). The trendline [*sic*] on this graph begins at just greater than 2 CADR/Watt (the Version 1 ENERGY STAR level) for products available when the ENERGY STAR specification first took effect, and ends around 4 CADR/Watt for products released in 2018."

There are several flaws with this approach and EPA should not be basing its analysis of whether a revised ENERGY STAR specification for room air cleaners is justified on this arbitrary best fit analysis.

First, the graph plots air cleaners by model without any representation of shipments. The model-based analysis here does not account for market share of energy star products. While the graph does appear to show there are some models above the current ENERGY STAR efficiency level, these models may only represent a small portion of total shipments, which may well be a niche market. Without shipment weighting the models, the "trend line" misrepresents the ENERGY STAR market. The majority models shipped may, in fact, be below the drawn trend line and hover around the ENERGY STAR eligibility criteria level. AHAM recommends EPA reexamine their efficiency assessment to factor in shipments and reassess the line of best fit and calculate the R^2 value.

Second, AHAM disagrees with EPA's contention that the graph shows any sort of trend. It is unclear how many models each point on the graph represents. Without that information, it is difficult for stakeholders to test the trend line or fully comment on it. Even if we assume that each point represents a single model, the plot appears to be more of a scatter plot and the "trend line" looks like a force fit. The trend line looks arbitrary especially without disclosure of the R^2 value. We believe the line is outside the bounds of credible trend assessments. The scatter plot does not show a strong correlation—more data with a clear breakdown of numbers of products is needed to be able to obtain any meaningful information.

At best, the graph merely shows that more ENERGY STAR models have been introduced into the market since the Version 1.0 specification was introduced in 2004. And we question even the accuracy of that representation—the graph shows only six models available before 2007 (assuming each dot represents a single model), which we believe is an indication of a lack of a full set of data across the full timeline making it difficult to determine any sort of trend.

Moreover, the graph only depicts ENERGY STAR models—there is no representation of non-ENERGY STAR models. Using this plot to support a change to the specification is inaccurate. As identified in the 2017 ENERGY STAR Unit Shipment Data Summary and in Section V of this discussion guide, shipments of ENERGY STAR air cleaners only represent 39 percent of the entire market. If EPA uses this "trend line" to set a specification limit, EPA will improperly be developing a specification based on only 39 percent of the market and on an averaged linear trend line. AHAM believes this will only create a further divide in the market. There will be

less or no incentive for manufacturers to convert non-ENERGY STAR models, as the gap will be too great to re-design and maintain an affordable cost for consumers. EPA may also actually run the risk of diminishing ENERGY STAR penetration for air cleaners.

EPA acknowledged that it does not have the data to include non-ENERGY STAR models in the plot and asked if manufacturers could provide that data. AHAM members indicated that such data would be very burdensome to provide. It is not usual practice for manufacturers to test CADR/Watt for non-ENERGY STAR products. Thus, to provide that data, manufacturers would need to test all of their non-ENERGY STAR models.

For all of these reasons, AHAM strongly disagrees that the data EPA presented demonstrate that there is a trend toward greater efficiency.

IV. Technology Options

EPA indicated that it believes the primary source of reduced energy consumption and improvement in efficiency is the motor and stated that some manufacturers have changed from AC motors to DC motors or more efficient AC motors. EPA is interested in understanding the prevalence of DC motor products in the market today and in the near future. EPA is also interested in feedback on new technology that may be implemented.

AHAM notes that EPA should ensure that it does not set criteria that would require use of a specific technology or dictate design. Manufacturers should be the ones to decide which technology and design options they choose to meet eligibility requirements.

Moreover, EPA needs to do a more thorough analysis of the design and technology options. It is not enough to simply state that certain technologies are available to improve efficiency. EPA needs to determine what the degree of the efficiency improvement is for each identified technology and which technology options would be required to meet various levels that EPA might consider setting as criteria. And then, EPA needs to evaluate the cost and other barriers to incorporating those technologies. EPA's goal should be to determine whether available technologies are economically and technologically feasible to incorporate and to determine what the resulting cost and payback period to consumers would be.

V. Network Connected Products

EPA sought feedback on a number of questions related to connected products. AHAM expects that its members will provide individual feedback on these questions as this is a developing area. AHAM notes, however, that EPA should be careful not to include criteria that would impede innovation in this area. This includes increasing the stringency of standby levels. Although network mode is not and should not be considered part of standby mode, it is possible that new features related to connectivity could cause an increase in standby power. Thus, increasing the stringency of the standby level could inhibit innovation of features that consumers want. And it may not allow for an overall increase in efficiency because it is possible that network mode features could improve overall efficiency.

The bottom line is that these work together and EPA should not view any single mode in a silo. Moreover, AHAM generally opposes the separate regulation of standby and active modes. The two modes should be combined into a single requirement.

VI. Product Classes

EPA provided data that it believes demonstrates that products with larger CADR sizes are, on average, more efficient and indicated that it is considering evaluating efficiency criteria based on a product's size.

AHAM does not have a position on whether EPA should evaluate efficiency criteria based on a product's size. But, whatever approach EPA decides to take, it should ensure it does not push certain sizes of room air cleaners from the market. Generally, we believe larger air cleaners are more expensive and, thus, if EPA sets levels that are too difficult for smaller air cleaners to meet, it is possible that lower income families would no longer be able to afford the most efficient room air cleaners.

In fact, according to a recent study conducted for AHAM, 64 percent of consumers indicated that price was important to them in purchasing their air cleaner, second only to ease of use. *See* Portable Home Appliances Saturation and Usage Study, conducted by for AHAM by the Stevenson Company (February 2018) (AHAM Portable Appliances Study). The average income of respondents to the survey was $62,000, but approximately 50 percent had incomes lower than $50,000 including almost half of those indicating an income less than $25,000. *Id.* This could indicate that that a large number of room air cleaner purchasers are low-income families where a price increase for these essential products will disproportionately impact them negatively. *Id.*

VII. Filter Requirements

The current ENERGY STAR criteria do not reference specific filter types. EPA indicated that, based on its Air Cleaner Consumer Guide, it believes filter type influences room air cleaner performance. As a result, EPA listed and defined in the Discussion Guide the filter types it believes apply to room air cleaners. EPA indicated that it is considering requiring a specific filter type or filter efficiency to ship with products to qualify for ENERGY STAR. EPA sought feedback from stakeholders on this consideration and asked if most room air cleaner filters undergo efficiency testing.

AHAM objects to EPA specifying filter types or efficiency in order to demonstrate ENERGY STAR eligibility for several reasons.

1. CADR is not dependent on any particular filter or technology. So, if EPA specifies a particular filter or technology, it would essentially just be specifying a component. It will not change the CADR. AHAM objects to EPA dictating design requirements for products. As discussed above, the ENERGY STAR program should be focused on its primary mission to drive efficiency and should not dictate design.

2. In response to EPA's inquiry about whether most room air cleaner filters undergo efficiency testing, the answer is no. It is not required for ENERGY STAR and AHAM AC-1 does not require it for determining the CADR claim. Thus, adding this testing would significantly increase the burden to qualify a room air cleaner for ENERGY STAR and may be a disincentive for manufacturers to do so.

3. High efficiency particulate air (HEPA) claims are based on the filter component alone. In other words, the component may be considered HEPA, but the full device would not be. Moreover, a requirement to have a specific type of filter does not equate to having better pollutant reduction or a better CADR. A full machine HEPA definition does not yet exist for room air cleaners, though it may for other products. Moreover, a requirement to have a specific type of filter does not equate to having better pollutant reduction or a better CADR. A filter rating does not equal clean air—it is the system performance that determines the cleaning performance.

VIII. Fan Noise

EPA indicated that it believes the amount of noise generated by fans can be a concern for consumers, "who have cited noise as a reason for decreasing the speed of their air cleaner (thereby lowering the health benefits) – or even turning it off or not using it." EPA indicates that room air cleaners "achieve best air cleaning performance at maximum fan speed, resulting in noise levels that may be too high for consumers." EPA sought feedback on whether manufacturers include claims on noise on product packaging and whether ANSI/AHAM AC-2-2006 is the best method on which to base a noise floor. EPA also asked if there is an appropriate sound performance floor for room air cleaners and what options are available to reduce product noise at maximum fan speed.

AHAM does not disagree that EPA should evaluate whether performance or other features will be negatively impacted by any specification level it proposes. It is important for features and performance to be maintained as efficiency requirements become more stringent. EPA should, however, stop short of mandating performance levels or certain designs in its specifications. Manufacturers themselves have the most interest in ensuring that consumers receive superior performance and are satisfied with the product, regardless of the energy efficiency of the product. It should not be the role of government, particularly in a voluntary program authorized to set energy efficiency criteria, to set performance or design requirements.

Even if AHAM did not object to performance or design requirements, including fan noise, in ENERGY STAR specifications, in this case, EPA has not demonstrated that fan noise is a significant consumer concern that an ENERGY STAR should address. EPA cites its Residential Air Cleaners Technical Summary, which indicates that some studies, as old as 2009 and 2012, have speculated that operating noise was a reason that air cleaners were turned off during sleeping hours. But there does not appear to be sufficient data to indicate that consumers turn off or reduce use of air cleaners due to noise.

Moreover, EPA indicates in its summary that "[i]ntervention studies do not indicate what noise levels would encourage more hours of use." Thus, even if EPA were to move forward with noise

requirements, it is difficult to understand upon which basis it would set noise criteria. In addition, just as there may be some users who do not like white noise, there are likely other users who like the white noise a fan creates and some may even use it to aid with sleep. Thus, EPA should not assume that just because some users may reduce or cease use of an air cleaner due to noise, consumers universally object to fan noise.

EPA should not set fan performance criteria especially without sound data demonstrating a problem needing a fix or a level some consumers might find acceptable.

To respond to EPA's specific discussion questions:

1. Some manufacturers may include metrics on air cleaner noise on packaging.

2. ANSI/AHAM AC-2-2006 is a method available for manufacturers to support claims regarding noise. And this partners with AC-1. It is not an international standard.

3. EPA appears to be making fan noise an efficiency/energy use issue. But that is not how manufacturers or the available tests treat it. There is no tested interaction between energy and sound. Less power does not necessarily mean less sound. More importantly, setting a sound requirement could negatively impact the primary purpose of the product which is to clean the air. EPA should not set criteria that would negatively impact the primary purpose of the product.

IX. Standby Power

EPA indicated that it is anticipating making the standby power requirement more stringent and sought feedback on what functions, if any, may be limited by a decreased standby power limit.

Increasing the stringency of the standby power requirement may impact a number of functions:

1. Decreasing allowable standby could impact any automatic function. For example, as discussed above, it could impede innovation of network mode features (though, to be clear, network and standby modes are different modes). It could also inhibit manufacturers' ability to provide automatic functions that require sensors to operate.
2. Decreasing allowable standby could also impact particulate or VOC sensors which primarily serve to increase efficiency overall.

AHAM notes that the data provided in Figure 3 in the Discussion Guide does not include non-ENERGY STAR qualified product data. Accordingly, it is a skewed picture of the data and does not represent the market. This is especially true given that only about 39 percent of air cleaner shipments are ENERGY STAR qualified.

X. Market Assessment

In its market assessment, EPA indicates that market penetration of ENERGY STAR certified room air cleaners is only 39 percent. EPA cites as its reasoning for the need for a revised specification that ENERGY STAR certified models represent 68 percent of models available. These two data points together do not necessarily support revision of the specification. Although

there are a moderate number of available models that are ENERGY STAR certified, only 39 percent of the shipments are ENERGY STAR qualified. EPA's focus should be on the market penetration, not on the number of available models. Here, the market penetration paints a picture of consumers placing more importance on factors other than ENERGY STAR when purchasing a room air cleaner. This is borne out by AHAM research which shows that, though some consumers do consider energy efficiency an important factor in making their air cleaner purchase, the top five reasons consumers stated for selecting an air cleaner are ease of use; product cost; product features; product safety features; and product volume, capacity, or output. *See* AHAM Portable Appliances Study.

XI. Testing

EPA indicated that it intends to update its test method to reference ANSI/AHAM AC-1-2015. AHAM agrees that EPA should update its reference to the most recent AHAM standard without deviation. The updates AHAM made to the test set up which EPA and DOE indicate are "significant," are in fact minor changes and should not deter EPA and DOE from updating its reference. We note that AHAM will soon publish AC-1-2018 and EPA and DOE should consider adopting that version instead. When it is published, we would be glad to provide it to EPA and DOE.

DOE and EPA indicated that they have identified several areas for investigation and possible revision. AHAM appreciates that DOE and EPA are interested in improving the test and we welcome DOE's participation in AHAM's task force which is actively reviewing the standard. The best venue for DOE to suggest changes and for those changes to be explored is in the standards setting forum, not the revision of the test procedure cited by a voluntary program. Thus, AHAM strongly opposes changing the test requirements in the context of an ENERGY STAR specification revision and would instead invite DOE to participate in AHAM's revision efforts.

Changing consensus standards through a regulatory process not only violates Presidential mandates requiring Federal agencies to rely upon consensus standards, but will also cause confusion for manufacturers and consumers as CADR and CADR/Watt would be tested using different methods.[1] Relying on only parts of a voluntary consensus standard and changing other parts creates a government-unique standard. This result should not be permitted.

In addition to AHAM's overarching opposition to DOE and EPA making changes to AHAM AC-1 through an ENERGY STAR specification, rather than through engagement in the standards development process, we comment below on the technical aspects of DOE and EPA's proposals. We also attach, at Appendix A, AHAM's Air Cleaner test FAQ document which may provide DOE and EPA with some additional context as to why the test is conducted the way it is. AHAM AC-1 has a rich and long history that is important to understand before changes are made.

[1] *See* Circular A-119, Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities (2016) (citing Executive Orders 12866, 13563, 13609, and 13610) (requiring Federal agencies to use voluntary consensus standards in lieu of government-unique standards in their regulatory activities, except where inconsistent with law or otherwise impractical).

A. Contaminate Level

DOE and EPA sought feedback on decreasing contaminate levels to be more representative of consumer use conditions.

AHAM AC-1 has a long history and the contaminate levels have been thoroughly investigated to determine the amount of particles that are within range of the equipment and will allow 20 minutes of test time. Introducing fewer particles will not allow the test to be run accurately and would severely diminish the repeatability and reproducibility of the test. And decreasing the number of particles will prevent differentiation of CADR levels. Accordingly, AHAM would strongly oppose decreasing the contamination level in the test room.

B. Contaminate Type

DOE and EPA sought feedback on whether the ENERGY STAR criteria should continue to be evaluated using dust or whether pollen and smoke should be evaluated. As AHAM discusses fully above, AHAM strongly supports EPA using only the smoke CADR to set its eligibility criteria. AHAM would oppose a requirement to test all three CADRs because it would significantly increase test burden.

DOE and EPA asked about the possibility of filling a test room with multiple contaminants simultaneously to measure the full range of performance for a product and asked how that approach would impact test burden.

AHAM would strongly oppose an approach that would fill a room with all three contaminants (or more than one at a time). Different sizes of particles have different settling rates and including them all in the room at the same time will make testing difficult and increase test burden. Different particle counters are required for each contaminate. And the different settling rates will significantly decrease the reproducibility and repeatability of the test. AC-1 has long tested each contaminate separately because it is both more accurate and simpler from a testing perspective. DOE and EPA should not change this long-settled and rational practice.

C. Control Speed

DOE and EPA indicated that testing air cleaners on the highest air cleaning mode may not incentivize the development of more efficient controls, motors, and fans that could be designed to operate more energy-efficiently at lower speeds. DOE and EPA welcomed feedback on an appropriate control speed setting for testing room air cleaners.

AHAM encourages DOE to participate in our AC-1 task force and raise this issue for discussion. An ENERGY STAR specification revision is not the best venue to discuss or make such a change.

D. Test Duration

DOE and EPA indicated that they believe some filter technologies may be more effective, but their performance benefits may not be captured in a 20-minute test and sought feedback on a longer rating test period for air cleaners.

AHAM notes that a longer test would require more particles in the air or would necessitate steadily adding particles to the room. The latter approach would increase variation because it would remove the steady state condition in the room. Importantly, neither approach would provide more accurate CADR information than the current approach. AHAM would be glad to further discuss this with DOE to provide more context.

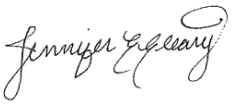
E. Filter Condition

DOE and EPA note that the current test uses a new filter for each test and indicates that this may not be representative of consumer operation. DOE and EPA sought feedback on the applicability of a used filter test and how performance may vary as filter usage time increases.

There is a test, AHAM AC-3, which evaluates how a product performs over time. But this test is more burdensome, particularly because it requires loading in a plenum which is quite difficult. AHAM notes that other products are not tested in this way, and were DOE and EPA to require used filters for air cleaners it would be departing from precedent. Also, and perhaps most importantly, different technologies would have different considerations and it would be incredibly difficult to establish a fair filter condition requirement for the ENERGY STAR program.

AHAM appreciates the opportunity to submit comments on the the ENERGY STAR Room Air Cleaners Version 2.0 Specification Discussion Guide and would be glad to further discuss these matters should you so request.

Best Regards,



Jennifer Cleary
Vice President, Regulatory Affairs

APPENDIX A

Frequently Asked Questions about Testing of Portable Air Cleaners

August 6, 2018

The EPA has recently released their 2nd Edition of their Guide to Air Cleaners in the Home and their 3rd Edition of Residential Air Cleaners, a Technical Summary.(link). In the Technical Summary, EPA highlights "*To use portable air cleaners, furnace filters, or other duct-mounted air cleaners to good effect, it is crucial to understand the difference between two parameters that influence the performance of air-cleaning devices:* ***efficiency*** *and* ***effectiveness****. The efficiency of an air-cleaning device is a fractional measure of its ability to reduce the concentration of pollutants in the air that passes once through the device. The fractional efficiency of a device is measured in a laboratory, where all relevant variables are controlled. The effectiveness of an air-cleaning device or system is a measure of its ability to remove pollutants from the spaces it serves in real-world situations.*

The most helpful parameter for understanding the effectiveness of portable air cleaners is the ***clean air delivery rate (CADR)****, which is a measure of a portable air cleaner's delivery of relatively clean air, expressed in cubic feet per minute (cfm). The CADR is a product of the fractional removal efficiency for a particular pollutant and the airflow rate through the air cleaner.*[1]"

Many firms in the portable air cleaner industry make CADR performance claims validated using the ANSI/AHAM AC-1 test method which measures the reduction of pollutants. The test method is widely used and recognized and has been accepted as the foremost test procedure for measuring performance through particulate removal for over 30 years.
The purpose of this document is to provide expert answers to important questions about the AC-1 test method, the Clean Air Delivery Rate and the AHAM Verifide® certification program administered by the Association of Home Appliance Manufacturers. This FAQ will also examine key technical aspects of AC-1 and CADR such as room size, sensors, particulates, and airflow rate.

AHAM VERIFIDE Independently Tested. Consumer Trusted.

The ANSI/AHAM AC-1, like all AHAM and ANSI standards, is subject to periodic review for improvement to take into account updated residential environmental conditions. It is transparent and publicly available, not proprietary or limited to one company's private, unaccountable use. The ANSI/AHAM AC-1 method was first developed in the mid-1980's. The test method or "standard" is a peer-reviewed method under the jurisdiction of the American National Standards Institute, which monitors standards development bodies and accredits them for producing open, consensus, and peer-reviewed standard test methods. The designation of "AHAM" (the

Association of Home Appliance Manufacturers) identifies the organization that takes responsibility for organizing and convening the committee of experts to write and review the standard. AHAM is an ANSI accredited standards development body and has been developing peer-reviewed and widely used consensus test methods for household appliances since the organization's inception in 1967.

This standard has been updated eight times since its first ANSI accreditation in 1988. It is now in a 2015 edition with a 2018 update in process. About every 3 years, the test method is updated with the best available knowledge. The standards committee is composed of manufacturers, research individuals, government labs, private laboratories, and academic professionals in the area of indoor air pollution reduction. In this way, the standard not only is improved but subject to scrutiny and comments from experts across the world. The standard is always improving to keep up with current technology.

The AC-1 basic framework is repeated in test methods in Canada, Korea, Japan and China. Dozens of laboratories in many of these countries and others have performed the same type of reduction testing as in ANSI/AHAM AC-1 for decades. Recently, the International Standards Organization (ISO) and International Electrotechnical Commission (IEC) have been studying standards that are based on the principles of ANSI/AHAM AC-1 for the development of global air cleaner standards.

How are household, portable air cleaners tested?

The important thing to remember in any testing is that if we want to compare the performance of air cleaners of different sizes, different shapes, and different technologies, there needs to be a way to separate the performance of the air cleaner machine from the natural air cleaning which incurs in indoor air also known as "natural decay".

To accomplish this, under the AC-1 method, contaminants or pollutants are released into a test chamber with the air cleaner in the "off" mode and the gradual settling of the air contaminant is measured over time. Then, the test is repeated with contaminants at the same level and the air cleaner in the "on" mode to measure a total air cleaning rate. The natural air cleaning or "natural decay" is subtracted from the total air cleaning to provide just the cleaning by the air cleaner, in other words - "air cleaner decay". In this manner, the cleaning performance is an open-ended number system called Clean Air Delivery Rate (CADR). It is a rate of cleaning from high concentration to low concentration. CADR often is described as the amount of clean air that the air cleaner contributes to the room in a given amount of time. Once a CADR number is determined through testing, it can be applied to most room sizes by mathematical conversions. While the CADR is measured in a chamber of a particular size, its application is not restricted to rooms that are the same size as the chamber.

What is CADR?

CADR is an important tool for comparing the overall performance of different models of air cleaners. Clean Air Delivery Rate (CADR) is a measure of the reduction rate (cleaning speed) of specific particulates by an air purifier or other filtration system in a controlled environment.

CADR is measured in cubic feet per minute or in cubic meters per hour. Three particles (engineering tobacco smoke, fine dust and paper mulberry pollen), representing fine, medium and large particles respectively, are used in the CADR testing of air cleaners. The higher the CADR numbers, the better the overall ability of the unit to clean your indoor air. CADR represents the filtered airflow, which can be translated to understand square footage or square meters for a room size that can be cleaned.

Is CADR a standard term for measuring Air Cleaner performance?

The United States Environmental Protection Agency recognizes the value of CADR and describes CADR in this manner:

"*A helpful parameter for understanding the effectiveness of portable air cleaners is CADR. The CADR is a measure of a portable air cleaner's delivery of relatively clean air, expressed in cfm. For example, an air cleaner that has a CADR of 250 for dust particles can reduce dust particle levels to the same concentration as would be achieved by adding 250 cfm of clean air to the space.*

*It is also important to note that a portable air cleaner's removal rate also competes with other removal processes occurring in the space, including deposition of particles on surfaces, sorption of gases, indoor air chemical reactions, and outdoor air exchange. Thus, while a portable air cleaner may not achieve its rated CADR under all circumstances, the CADR value does allow comparisons among portable air cleaners***.**"[2]

How is CADR measured?

Test particulates of tobacco smoke, dust or pollen are injected into the test chamber at a known level. Sophisticated, electronic particle-counting devices monitor the exact concentration and size of the particles. The first test is conducted without the air cleaner being turned on. This procedure establishes the natural decay rate of the particles that will be subtracted from the rate established during the second test when the air cleaner is turned on. The Clean Air Delivery Rate (CADR) is the difference between the two rates. By subtracting the natural decay, the air cleaner is not credited with any performance that is attributed to gravity (natural settling).
Technically speaking, CADR equals the "air cleaner ON removal rate" minus the "natural decay rate" multiplied by the test chamber volume (which is 1,008 cubic feet or 28.4 cubic meters).
CADR = [Rate air cleaner on - natural decay] x 1008

Particulate size ranges tested for are:

Tobacco smoke	0.09 microns to 1.0 microns
Dust	0.5 to 3.0 microns
Pollen	0.5 microns to 11.0 microns

[2] US EPA "Residential Air Cleaners (Third Edition): A Technical Summary, 2018. https://www.epa.gov/sites/production/files/2018-07/documents/residential_air_cleaners_-_a_technical_summary_3rd_edition.pdf

Room Size ratings based on CADR were developed in consultation with the government to ensure usefulness, and application to the consumer. The Room Size is calculated based on the removal of at least 80 percent of smoke particles in a steady-rate room environment, assuming one air change per hour with complete mixing in the room.

Why determine room size based on removal of tobacco smoke?

Tobacco smoke was chosen because of its extremely small size, as well as, for being a common global indoor pollutant. Method AC-1 uses a specific engineering tobacco smoke to generate the smoke CADR. The size of the smoke particles are 100 to 1000 times smaller than the width of a human hair. Therefore, even if a consumer does not smoke, tobacco smoke is a surrogate for much smaller fine particles that may be found in a home.

How can I know if my air cleaner cleans the air?

A number of sources can cause indoor air pollution. This includes contaminants from outdoor air, particulates that you bring in from outside, particles on pets or our clothing, and from sources inside the home such as cooking, smoking, candles burning, and house dust. All portable air cleaners have two important common elements. 1. An Air Flow system and 2. A filtering system. It is these two systems working together that removes pollutants from the room. Neither the quantity or velocity of the air flow, nor the efficiency of the filter, by themselves, tell the consumer the amount of cleaned air generated. While the density of the filter may be important to trap very small particles, if all or most of the air of the air cleaner does not pass through the filter, you are not getting much benefit. Therefore, filters are critical but not sufficient to evaluate air cleaner performance.

However, you can observe the air cleaner in operation. Larger particles will be noticed collecting on filters of the air cleaner - larger ones on the pre-filters and smaller ones on the primary filters. You will notice that a mesh fiber filter will slowly darken or change color, and that the plates or wires on electronic filters will become coated as collection takes place. You may also notice less dust on surfaces and a fresher cleaner smell in the air since the air cleaner is now collecting those particles. Eventually, you will notice the airflow will reduce as the filters slowly load with particles. You may notice arcing for an electronic filter which is a sign of high loading. Arcing and low airflow are generally signs that a filter change or cleaning is needed. (Consult the owner's manual). These are all signs your air cleaner is performing properly.

Room size

How large is the AC-1 test chamber used for air cleaner testing and why is it that size?

Most of the household, portable room air cleaner test methods around the world use a chamber volume of about 30 cubic meters. The actual dimensions for most of the chambers are: 10 ½ ft. by 12 ft. by 8 ft. high (1,008 ft^3). In meters, this is 3.2m x 3.7m x 2.4 m high (28.4 m^3). (Note - If your ceiling height is higher than 8 feet, the square foot coverage of the air cleaner will be less than the room size shown for the air cleaner).

The size of the chamber is not specific to any particular air cleaner type. The test chamber is not intended to represent a certain size room in a home. Rather, it is a standard chamber, which can allow for accurate, uniform, and repeatable test measurements. These standard measures are applied to engineering and mathematical equations that can be scaled up or down as appropriate per room size. The key is the amount of clean air produced by the air cleaner, not whether a test chamber is the same as the room in your house.

What is the largest room size that AC-1 evaluates?

The suggested Room Size for an air cleaner is based upon the CADR obtained for reducing cigarette smoke concentrations (See Annex E of the standard). The Room Size is based upon the ability of the air cleaner in CADR to reduce the concentration of particles by 80 % in a room at steady state to a new steady-state when the air cleaner is operating. This includes contributions from room sources and infiltration of air from outside as well as other rooms connected to the one where the air cleaner is in use. A standard first-order differential equation that includes these contributions is utilized for the calculation, and that is summarized as:

Room Size (square feet – ft^2) = cigarette smoke CADR x 1.55

Room Size (square meters – m^2) = Room Size (ft^2) x 0.093

The maximum allowable CADR that can be measured by the AC-1 method in the chamber is 450, so the maximum room size that the standard can confidently predict performance would be a room of 698 ft^2 (64.8 m^2).

This relationship between cleaning rate in CADR and room size to clean to the 80% level has been verified by scientists at the National Institute of Standards and Technology (NIST) and recognized as reasonable by the U.S. Federal Trade Commission.

How can I know if the air cleaner will clean the size of my room?

The maximum suggested room size of an air cleaner can be calculated by knowing the CADR from the smallest particle or smoke test. The Room Size is determined by mathematical modeling the steady state and is based on the CADR baseline requirement to remove 80% of cigarette smoke particles between 0.1 and 1.0 micrometer on a steady-state (continuous) basis. This gives the consumer a way to relate CADR to the square feet or square meters of a room.

Room Size (ft^2) = CADR (Smoke) x 1.55;

Room Size (m^2) = CADR (Smoke) x 1.55 x 0.093

Sensors

Is this AC-1 test method only appropriate for certain technologies?

Almost any household, portable, room air cleaner can be tested using Method AC-1. An air cleaner that emits water or mists of vapor are adding particles to the room and would cause problems with the instruments and would interfere with the measurements to reduce particles from the chamber. Otherwise, any air cleaner technology, as long as it registers an air cleaning

function above the minimum (and below the maximum) level that can be measured, can be tested using this method. This method has been used to evaluate and compare many different types of air cleaning technology over the past 30 years.

Are all the speeds of an air cleaner tested in the AC-1 test method?

No. Because there is no universal way to test the speeds of all air cleaners and because "low" or "medium" in one air cleaner may be different from another, the test is performed in the highest speed setting. Consumers can then make an informed selection based on the air cleaner's highest performance level. As a comparison, just as your driving patterns may not be the same as what the government tests in a miles per gallon (or km per liter) test, using one standard method is critical to allowing a fair and full comparison in comparing miles per gallon. Certainly, as more air cleaners move to an automatic, self-adjusting mode through the use of sensors, the test methods will be adapted to accommodate these new features. The standards committees are working on this now, with expected proposals by 2019.

Why does AC-1 use one sensor?

The number of sensors in a testing chamber are irrelevant if the pollutant in the chamber is thoroughly mixed. Over the last 30 years, the AC-1 test method has been replicated in a number of chambers that are similar but of slightly different shapes and sizes to support this assumption. The AC-1 procedure uses a ceiling fan only before the test to make sure the pollutant is thoroughly distributed in the chamber. Then, that ceiling fan is turned off before the test. A small but high volume re-circulation fan is mounted in the chamber against a wall and out of the air-stream path of the air cleaner or the sampling port, so as not to interfere with the testing results. This re-circulation fan is used to keep the pollutant completely mixed in the chamber during the test. Thus, with the thorough mixing as has been specified in the AC-1 method, it does not matter whether you have one or more sampling ports.

In addition, if multiple sampling ports would be used, there is more complexity for sampling and the issue then becomes how you would correlate the results from multiple sensors on each test. This would have to be validated by many experts in air cleaning and multiple testing labs. The AC-1 test method has already been validated on various models over time. There would need to be extensive testing on all types of models of air cleaners in order to ensure that each air cleaner is subjected to the same mixture of pollutant when using multiple sensors. This would involve testing multiple chambers of the similar size in order to ensure that any performance test data was the same from test to test. Again, this is one of the major benefits of the AC-1 test procedure:

> ANSI/AHAM AC-1 it has been replicated across many types, sizes and technologies of air cleaners. It has been used in multiple chambers in many countries. Testing with reference units across these chambers have shown that the procedure can be not only valid for all air cleaners, but repeatable day to day in one chamber, and reproducible in multiple chambers and testing laboratories.

Particles:

What indoor pollutants are measured?

The most common pollutants in people's homes are particles and gases. Testing of particles has been measured and compared using the AC-1 method for CADR for several decades. Particles in our home environment come in many different sizes. Large particles that are between 5 and 11 micrometers in diameter are represented by pollen. Mid-sized particles from 1/2 to 3 micrometers are in the very small dust range and are represented by engineered standard fine dust. Very small particles are often less than 2 micrometers in diameter, and which can be drawn deeply into our lungs are represented by cigarette smoke from engineered cigarettes. The ANSI/AHAM AC-1 method tests three different ranges of particles from the larger pollen grains, to airborne dust, to fine particles like smoke. These test materials are surrogates or proxies for the range of particles often found in the home. The performance of an air cleaner is given for each of these particle ranges as a separate CADR number and the performance can be compared if your family is concerned with one or more of these particle pollutants. As a comparison, the diameter of the smallest human hairs is about 50 micrometers and it becomes very difficult for humans to see objects smaller than 40 micrometers without lenses. A 0.1-micrometer particle measured by Method AC-1 is 500 times smaller than the smallest human hairs
For the future, methods for testing the reduction of gases by air cleaners are important. Many standards development bodies are testing methods now to help compare the performance but there is no universal test method yet accepted for measuring performance of air cleaners to clean gases or volatile organic compounds.

Air Flow Rate

Some methods, such as AC-1, use stirring or mixing fans during test? What is their purpose?

For AC-1, test chambers use a ceiling fan mounted in the center of the ceiling to stir or mix the pollutants before testing. In the AC-1 test, this fan is shut off during the test. A continuously operating recirculation fan assures uniform mixing of the contaminants during the entire set of tests. The recirculation fan is mounted out of the air stream against a wall to reduce the chance of contaminants gathering in a corner. The recirculation fan runs for all tests whether the air cleaner is operating or not. This recirculation fan does not contribute to the measured performance of the air cleaner but creates a fair and comparable environment for small, medium and large air cleaners.

How does Airflow relate to CADR performance and room size?

CADR is based on the highest fan speed as a uniform standard condition. If you run the air cleaner on a lower fan speed, it is understood that both efficacy and the room coverage will also decrease. At slower speeds, the amount of clean air delivered is at least proportional to the speed reduction. Airflow and CADR should not be confused between themselves although both are measured in cubic feet per minute (cfm). CADR is the contribution of clean air to the room, while airflow is just a measure of how much air is moved