

INVITATION TO SUBMIT A RESEARCH PROPOSAL ON AN ASHRAE RESEARCH PROJECT

2008-TRP, Evaluating the Influence of Challenge Gas Composition, Mixture Composition and Concentration on Gas-Phase Clean Air Delivery Rate Measurements in Chamber Testing of Various Air Cleaner Technologies

Attached is a Request-for-Proposal (RFP) for a project dealing with a subject in which you, or your institution have expressed interest. Should you decide not to submit a proposal, please circulate it to any colleague who might have interest in this subject.

Sponsoring Committee: TC 02.03 -Gaseous Air Contaminants and Gas Contaminant removal Equipment
Co-sponsors: SSPC 145 – Test Method for Assessing the Performance of Gas-Phase Air Cleaning Equipment;
TG2.RAST, TG2 Reactive Air and Surface Treatment; SPC 234, Methods of Testing HVAC-Duct Mounted Devices and Systems and In-room Devices for Particle and Microorganism Removal or Inactivation in a Chamber with a recirculating Duct System

Budget Range: \$350,000 may be more or less as determined by value of proposal and competing proposals.

Scheduled Project Start Date: **April 1, 2027**, or later.

All proposals must be received at ASHRAE Headquarters by 8:00 AM, EST, Tuesday, December 15th, 2026. NO EXCEPTIONS. Electronic copies must be sent to rpbids@ashrae.org. Electronic signatures must be scanned and added to the file before submitting. The submission title line should read: 2008-TRP, Evaluating the Influence of Challenge Gas Composition, Mixture Composition and Concentration on Gas-Phase Clean Air Delivery Rate Measurements in Chamber Testing of Various Air Cleaner Technologies, and “*Bidding Institutions Name*” (electronic pdf format, ASHRAE’s server will accept up to 10MB)

If you have questions concerning the Project, we suggest you contact one of the individuals listed below:

For Technical Matters

Technical Contact
Caitlin Naske
9008 Martime Court
Springfield, VA 22153-1625
Phone: 518 281-3178
E-Mail: cnaske@dynamicqs.com

For Administrative or Procedural Matters:

Manager of Research & Technical Services (MORTS)
Steve Hammerling
ASHRAE, Inc.
180 Technology Parkway, NW
Peachtree Corners, GA 30092
Phone: 404-636-8400
Fax: 678-539-2111
E-Mail: MORTS@ashrae.net

Contractors who plan to submit a proposal must notify the Manager of Research and Technical Services (MORTS) via email by December 1st. This will ensure that they receive any late or additional information regarding the RFP before the bid due date. The deadline for submitting technical questions is also Tuesday, December 1st, 2026.

All proposals must be submitted electronically.
Electronic submissions require a PDF file containing the complete proposal preceded by signed copies of the two forms listed below in the order listed below.
ALL electronic proposals are to be sent to rpbids@ashrae.org.

All other correspondence must be sent to ddaniel@ashrae.org and shammerling@ashrae.org. In all cases, the proposal must be submitted to ASHRAE by 8:00 AM, EST, Tuesday, December 15th, 2026. NO EXCEPTIONS.

The following forms (Application for Grant of Funds and the Additional Information form have been combined) must accompany the proposal:

- (1) ASHRAE Application for Grant of Funds (electronic signature required) and
- (2) Additional Information for Contractors (electronic signature required) ASHRAE Application for Grant of Funds (signed) and

ASHRAE reserves the right to reject any or all bids.

State of the Art (Background)

In recent years, there has been an increased emphasis on indoor air quality (IAQ) leading to a need for performance measurements for all air cleaners. Awareness of IAQ often focuses on PM_{2.5} or small particles in the air, but in recent years the influence of gas-phase contaminants has been increasingly recognized. ASHRAE Standards 62.1 and 62.2 recognize the need to have acceptable maximum limits for both particulate and gas-phase contaminants in the air through their indoor air quality procedures (IAQP). IAQP is based on reducing outdoor air (saves on heating/cooling) when maintaining air quality goals for acceptable levels of particles and multiple gaseous contaminants. Air cleaners are often essential to meeting these requirements. Other organizations including LEED and WELL also have indoor air quality strategies that often require air cleaning.

In the past, ASHRAE air cleaner test standards were applicable to air cleaning equipment integrated into HVAC systems, and air cleaning test standards included ASHRAE Standards 52.2 and 145.2, which are in-duct single-pass tests that compare upstream and downstream concentrations to determine an efficiency value. With a growing demand for good IAQ and air cleaning, there is a wider range of air cleaning technologies and many air cleaners are considered in-room air cleaners or work on the air in rooms. For in-room air cleaners (IRAC), upstream and downstream values are difficult or impossible to determine, especially since the IRAC changes the value in the room in which it is placed. Thus, a standard way to test IRAC is to determine a clean air delivery rate (CADR), a parameter based on the change in concentration over time in a test chamber. These tests, in the form of AHAM AC-1, have been performed on particle removal air cleaners for decades.

Without an in-room air cleaner test, the need for expanded test standards resulted in the development of ASHRAE chamber plus duct tests: 234P for particulates and bioaerosols and 145.4P for gas phase contaminants. In parallel, AHAM and ASTM also developed in-room air cleaner testing standards. AHAM AC-4 specifies evaluating air cleaning equipment in a chamber using a fixed list of single gases resulting in a c-CADR (chemical CADR) at somewhat elevated concentrations (143-1004 ppb). The AC-4 scope does not include byproducts. ASTM developed ASTM D8625-2025, including a multi-gas mixture test at low concentrations (3-18 ppb) to examine indoor chemistry between the gas mixture, particles and air cleaner performance resulting in multiple gas CADRs and byproduct emissions rates. In comparison, proposed concentrations in ASHRAE 145.4P are 100-200 ppb.

With these three new gas-phase standards (AHAM AC-4, ASTM D8625-2025 and ASHRAE 145.4P), one of the differences is in the initial challenge concentration for the tests. It is well known for sorbents (such as carbons) that the challenge concentration of a test will change the performance of the air cleaner. This may mean that initial efficiency is different or that the time for a contaminant to start exiting the sorbent bed (breakthrough time) changes. The Wheeler (or Wheeler-Jonas) and Dubinin-Radushkevich (DR) equations (Lodewyckx, 2004) give predictions for sorbent performance at different concentrations, and ASHRAE projects 792-RP (VanOsdell et al. 1996) and 1557-RP (Kwanghoon et al. 2013) give many examples of these phenomena. Competitive adsorption is also a well-studied phenomena in sorbents where individual gases will compete for space and one gas can impact another's adsorption [Lillo-Ródenas 2006, Vizhemehr 2015, Lara-Ibeas 2020]. Reactive air cleaners, non-sorbent based, usually work based on intentional reactions or introduced reactive species with the contaminants; this reaction may be dependent on the concentrations of chemical in ways different from sorbent air cleaners. Also, unlike particles, gases in gas mixtures also have the potential to react with each other especially in the presence of ozone, which alters the air cleaner performance [Fan et al. 2003].

However, little is known about whether the initial concentration in a chamber test will change the resulting CADR, especially for reactive air cleaners using technologies such as ultraviolet photocatalytic oxidation (UV-PCO) and ionizers [Xiang et al. 2025, Borelli et al. 2024]. In addition, the published test methods AHAM AC-4 and ASTM 8625 are relatively new, and there is little public data available on the results [Link et al. 2024]. It is also unclear whether one test on a mixture of challenge gases will give the same results as multiple tests on individual gases. There is some data supporting each possibility. Clearly, testing many individual gases for many air cleaners can be prohibitively expensive and may limit the useful data available for these air cleaners. If testing with mixtures can give similar results to single-gas tests, a single test could replace multiple tests.

The aim of this project is to answer these questions: For a range of air cleaner technologies, does the initial concentration impact the resulting CADR, does performance change if gases are testing in mixtures, and can gas mixtures be used to reduce testing costs while providing the same results?

Justification and Value to ASHRAE

Clean air is essential for health and productivity and ensuring that performance testing of air cleaning equipment is performed accurately will assist the HVAC industry to deliver products that benefit consumers. It is important that the HVAC community trust standardized test results. This project will increase the number of accurately tested devices, provide better input to the IAQP of ASHRAE Standard 62.1 and has the potential to be used in ASHRAE Standard 241 (safety test). It will also improve IAQ/IEQ with more reliable test results that yield better IAQ.

The project results will be applied to the appropriate situations: if there are different results at different concentrations testing may need to be done at low and high concentrations; if the same, less testing will be needed. The results may be different for different gases and different technologies. The results can also aid in harmonization in standards across industry (ASTM, AHAM) where different gas concentrations are used.

The results could also help save money, help make the outputs used in modeling more accurate and relevant, and make sure that the test results are collected properly. The results of the gas mixture testing could allow for a more efficient testing process compared to single gas testing. If the results show that a multiple gases test provides the same results as single gas this could save time and money for the manufacturers but is also more representative of what air cleaners will actually see in the real world.

Objectives

The overall objectives of the project are 1) to determine whether testing at different initial concentrations of a challenge gas will give the same clean air delivery rates (CADRs) such that one test will give useful data across varied indoor contaminant conditions and 2) to determine if testing of challenge gas in mixtures instead of singly will give the same CADRs for each gas. This will be looked at for a non-reactive mixture and one containing ozone to be able to include mixture reactivity with its own constituents as a complicating variable. To achieve these overarching objectives, we require that the project meets these testing specific objectives:

- 1) Choose in-room air cleaners (IRAC) representing at least 3 different technologies (including one of: adsorption based, UV-PCO, and ionizer) that do remove gases from the air.
- 2) Develop a test plan and test matrix to cover the objectives below and include consultation with the PMS in developing this plan.
- 3) Using a test rig composed of a chamber of at least 1000 cubic feet:
 - a. Use formaldehyde as a screening gas to verify the chosen IRAC performance.
 - b. Measure CADR for single gas challenges for at least 4 gases each at 3 different concentrations within the chamber for the selected various air cleaning devices. The gases must include ozone, formaldehyde, toluene and limonene. The PI may choose a fifth gas, but it is not required. Present results to PMS before moving to mixture testing.
 - c. Evaluate impact of concentration on the single gas CADR.
 - d. Measure CADR for multiple-gas challenge of the same gases used in the single gas testing for at least two set of concentrations with and without the ozone and same air cleaning devices. The PI should use their single gas experience to suggest options.
 - e. Evaluate impact of ozone in mixture gas on CADR.
 - f. Evaluate impact of multiple gas challenge CADR vs single gas CADR.
 - g. Examine the data for possible correlations such as whether one concentration's CADR may be able to predict that for the other concentrations. It is not a goal to prove that this is true, rather that it could be possible.

Prepare the data in a format that can be digested easily by groups writing or revising chamber test methods and present to the PMS and research committee during the project. The goal is to allow these groups to use the basic conclusions of the project to move forward with their work even before a full final report or paper is published.

Scope:

This scope is intended to cover the required work and an acceptable order of priorities. Bidding PIs are welcome to revise the order or grouping to make the project more efficient or simple to run as long as all the points are covered.

Task 1: Preparation

- a) Upgrade chamber and/or equipment as needed. Items included in this could be significant chamber changes if needed to test gas-phase air cleaners such as improving air tightness, adding ports, buying analytical equipment, and developing lab SOPs if this work is not covered. The assumption is that a lab will have strong related capabilities and not need extensive spending in both areas but that improvements to existing capabilities are likely to be needed.
- b) In conjunction with the PMS, choose in-room air cleaners (IRAC) representing at least 3 different technologies (including one of: adsorption based, UV-PCO, and ionization,) that produce a measurable reduction in challenge gas concentration(s) from the air (Objective 1). PI should produce a list of possible air cleaners to discuss with the PMS. Purchase of air cleaners and replacement parts is expected unless acceptable donations are arranged.
- c) Propose chamber validation and QA/QC tests based on similar available tests or lab standards. Present to PMS and get their approval. Run this required chamber validation testing and gather data from the test setup to prove that the test setup (generators, analyzers, chamber, etc.) meets the agreed upon requirements. Present the result to the PMS with at least one virtual meeting with the PMS. Chamber validation will require at least leak testing, mixing verification, temperature and humidity stability, and any validation that has not been done in the lab immediately preceding this testing. This may include developing lab SOPs or acquiring needed parts and equipment.
- d) Develop and document a test plan for the individual runs including a lab plan for chamber cleaning, challenge injection, decay monitoring, and use of with and without the air cleaner testing to be approved by the PMS. Individual runs should not exceed 1 hour for the drawdown portion of the test. Total test time including chamber cleanup, chemical injection and mixing, as well as test prep. Include needed QA tests, calibrations, sampling, and analysis. Obtain agreement on the test plan document from the PMS prior to proceeding (Objective 2).
- e) Develop the overall test matrix including devices, challenge gases, three concentrations, test lengths to allow enough samples to give the CADR, and number of replicates. When choosing single gas concentrations, use values in existing standards as a guide. The three single concentrations should include a low value (similar to ASTM 8625), a high value (similar to AHAM AC-4) and a third middle value in the range of 100-200 ppb.

Task 2: Single Challenge Gas Testing

- b) (a) Use formaldehyde as a screening gas. Run the test agreed to above at one of the concentrations for each air cleaner. Also run at least 1 natural decay test (measuring CADR with no device in the chamber). This is to determine that the devices produce at least a CADR of 10 cfm and not more than 300 cfm (these values assume the mid-level concentration is used and may be changed to meet a goal that the devices are determined to be acceptable for this type of testing and variable concentrations). Also make sure devices have different measured CADRs (do not all have the same result from the test) so the later subsequent single concentration and mixture tests are done across a range of IRAC performance levels. During screening, measure for ozone levels to help inform that expectations for the mixture testing in Task 3. Present the selected air cleaners and results to the PMS (virtually) prior to proceeding. PowerPoint slides or documentation will also be shared. If any device fails this step, choose a different device until all 3 devices pass. (Objective 3a)
- c) (b) In addition to the four required gases (ozone, formaldehyde, toluene and limonene), the PI may choose a fifth gas but is not required. Choose the approximate concentrations to be used for single and mixture testing. See the proposed test matrix below. Obtain agreement on the test matrix with the PMS (virtually) prior to proceeding. (Objective 3b)
- (c) Proceed testing with the rest of the single gas tests from the test plan including the 3 different concentrations for each gas. Test in duplicate unless the two calculated CADRs are different by 15% or more, then a third test must be completed. Consideration should be given to replacing device consumables for each test when appropriate. The order of the tests used for a device should be tracked. (Objective 3b)
- d) Plot data. Calculate CADRs for each test and tabulate. Present results to PMS. Discuss with PMS to ensure that the data is logical and sound before proceeding to the mixture testing. Discuss with PMS to determine a plan for mixture tests including concentration of mixture and concentration of gas components of the mixture based on single concentration test results. (Objective 3c)

Task 3: Mixture Testing (Objective 3c)

- a) Run mixture tests for all device types that successfully completed testing in Task 2 for the single challenge gas at different concentrations. Perform at least two mixture concentration comparisons with and without ozone (high and low ozone conc). One example of mixture concentration is to use the concentration of the four gases tested as a single challenge for the total mixture concentration (each gas at ¼ of single gas concentration so the total gas concentration is equal to the single gas concentration).
- b) Calculate CADR for each test and tabulate. Test in duplicate unless the two calculated CADR are different by 15% or more, then a third test must be completed. Consideration should be given to replacing device consumables for each test when appropriate. The order of use of a device should be tracked. (Objective 3d)
- c) Share data with PMS after 1-3 tests have been performed to allow the PMS to give input on whether the results are useful and on how the data analysis is working toward the project goals. Also share data at least every two months including, at least, what tests are completed and the CADR.

Task 4: Reporting and Papers (Objectives 3e,3f, 4)

- a) As detailed in the ASHRAE boilerplate, prepare and submit quarterly reports.
- b) As described above, report regularly to PMS.
- c) Review relevant ASHRAE handbook chapters and suggest revisions based on project (expected 1-2 paragraphs)
- d) Include basic suggestions for chamber testing protocol revisions in at least one PMS or Research meeting with digital copy available to share with standard committee after getting ASHRAE permission.
- e) Report to or present at the research subcommittee meetings virtually or in person twice a year.
- f) Prepare final report (may be done across whole project) and share draft with PMS. Work with PMS to resolve comments. Submit report.
- g) As detailed in the ASHRAE boilerplate, prepare and submit paper. Also submit other required papers.

Proposed Test Matrix			
Suggested Devices	Chemicals	Options	Replicates
Sorbent	Ozone	Single Challenge Gases (3 conc.)	2-3
Ionizer (ROS)	formaldehyde	Mixture with ozone (2 conc.)	2-3
UV-PCO	Limonene	Mixture without ozone (2 conc.)	2-3
	toluene		2-3
	Additional (PI add optional)		

Deliverables:

- a) As detailed in the ASHRAE boilerplate, prepare and submit quarterly reports.
- b) As described above, report regularly to and work with PMS. Task 1 includes suggesting and choosing air cleaners with the PMS, at least one virtual meeting with the PMS reporting on the chamber setup and validation, and delivery the test plan document to the PMS for their review and approval. Task 2 includes presenting the air cleaners and results to the PMS, working out and sharing the final test matrix with the PMS for review and approval, sharing results with PMS as testing goes forward, planning the next stage with the PMS which involves drafting their plan. Task 3 includes sharing data with the PMS both early on and as the testing progresses. Task 4 notes the regular reporting, sharing proposed Handbook revisions, sharing chamber test protocol change suggestions with the PMS, and typical PMS review of the final report.
- c) Review relevant ASHRAE handbook chapters and suggest revisions based on project (expected 1-2 paragraphs)
- d) Include basic suggestions for chamber testing protocol revisions based on the outcomes of the testing, if indicated by the results, in at least one PMS or Research meeting with digital copy available to share with standard committee after getting ASHRAE permission. These suggestions could include testing at multiple concentrations or that one concentration is sufficient and will likely need to include guidance on the use of mixture test results to extrapolate single challenge gas CADR as well as useful but unexpected outcomes.
- e) Report to or present at the research subcommittee meetings virtually or in person at least twice a year.
- f) Prepare final report (may be done across whole project) and share draft with PMS. Work with PMS to resolve comments. Submit report.

g) As detailed in the ASHRAE boilerplate, prepare and submit paper. Also submit other required papers.

Final report to include suggested input to update ASHRAE Handbook – HVAC Applications, Chapters 47 and 66, as applicable.

Final report to suggest any updates to ASHRAE Standard 145.4.

Progress, Financial and Final Reports, Technical Paper(s), and Data shall constitute the deliverables (“Deliverables”) under this Agreement and shall be provided as follows:

a. Progress and Financial Reports

Progress and Financial Reports, in a form approved by the Society, shall be made to the Society through its Manager of Research and Technical Services at quarterly intervals; specifically on or before each January 1, April 1, June 10, and October 1 of the contract period.

The following deliverables shall be provided to the Project Monitoring Subcommittee (PMS) as described in the Scope/Technical Approach section above, as they are available:

Furthermore, the Institution’s Principal Investigator, subject to the Society’s approval, shall, during the period of performance and after the Final Report has been submitted, report in person to the sponsoring Technical Committee/Task Group (TC/TG) at the annual and winter meetings, and be available to answer such questions regarding the research as may arise.

b. Final Report

A written report, design guide, or manual, (collectively, “Final Report”), in a form approved by the Society, shall be prepared by the Institution and submitted to the Society’s Manager of Research and Technical Services by the end of the Agreement term, containing complete details of all research carried out under this Agreement. Unless otherwise specified, electronic copies of the final draft report shall be furnished for review by the Society’s Project Monitoring Subcommittee (PMS).

Tabulated values for all measurements shall be provided as an appendix to the final report (for measurements which are adjusted by correction factors, also tabulate the corrected results and clearly show the method used for correction).

Following approval by the PMS and the TC/TG, in their sole discretion, final copies of the Final Report will be furnished by the Institution as follows:

- An executive summary in a form suitable for wide distribution to the industry and to the public.
- Two copies; one in PDF format and one in Microsoft Word.

a. Research Paper(s)

One or more papers shall be submitted first to the ASHRAE Manager of Research and Technical Services (MORTS) and then to the “ASHRAE Manuscript Central” website-based manuscript review system in a form and containing such information as designated by the Society suitable for publication. Papers specified as deliverables should be submitted for publication in the Science and Technology for the Built Environment (STBE). The paper(s) shall conform to the instructions posted in “Manuscript Central” for Science and Technology for the Built Environment papers. The paper title shall contain the research project number at the end of the title in parentheses, e.g., (2008-RP). ASHRAE Conference papers are **not** acceptable as deliverables from ASHRAE research projects unless explicitly approved by a vote of the PMS and TC and communicated to MORTS. Conference paper(s) shall conform to the instructions posted in “Manuscript Central” for ASHRAE Conference papers and the title shall contain the research project number at the end of the title in parentheses, e.g., (2008-RP).

All papers or articles prepared in connection with an ASHRAE research project, which are being submitted

for inclusion in any ASHRAE publication, shall be submitted through the Manager of Research and Technical Services first and not to the publication's editor or Program Committee.

d. Data

Data is defined in General Condition VI, "DATA"

e. Project Synopsis

A written synopsis totaling approximately 100 words in length and written for a broad technical audience, which documents 1. Main findings of research project, 2. Why findings are significant, and 3. How the findings benefit ASHRAE membership and/or society in general shall be submitted to the Manager of Research and Technical Services by the end of the Agreement term for publication in ASHRAE Insights

The Society may request the Institution submit a technical article suitable for publication in the Society's ASHRAE JOURNAL. This is considered a voluntary submission and not a Deliverable. Technical articles shall be prepared using dual units; e.g., rational inch-pound with equivalent SI units shown parenthetically. SI usage shall be in accordance with IEEE/ASTM Standard SI-10.

Level of Effort

24 Months/ \$350,000

No.	Proposal Review Criterion	Weighting Factor
1	Understanding of TRP	20%
2	Ability of Personnel to do the work	25%
3	Available/proposed equipment to do the work	20%
4	Scope of Work will produce required results	35%

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
1	Complete Task 1 with PMS approval	4
2	Complete Task 2	14
3	Complete Task 3	17
4	Complete Task 4	24

References

1. AHAM. 2022. ANSI/AHAM Standard AC-4-2022, Method of Assessing the Reduction Rate of Chemical Gases by a Room Air Cleaner. Washington DC: AHAM.
2. ASTM. 2025. D8625-25, Standard Test Method for Chemical Assessment of Air Cleaning Technologies. Philadelphia, PA: ASTM.

3. Borelli, Mattia, et al. "A New Laboratory Scale Methodology to Test Portable Air Cleaner (PAC) Devices: Optimization and Application." *Indoor Air* 2024.1 (2024): 7462245.
4. Fan, Zhihua, et al. "Ozone-initiated reactions with mixtures of volatile organic compounds under simulated indoor conditions." *Environmental Science & Technology* 37.9 (2003): 1811-1821.
5. Kwanghoon Han; Chuan He; Beverly Guo; and Jianshun Zhang. Laboratory Comparison of Relative Performance of Gas Phase Filtration Media at High and Low Challenge Concentrations, ASHRAE. June. 1557-RP, 2013.
6. Lara-Ibeas, Irene, et al. "Adsorbent screening for airborne BTEX analysis and removal." *Journal of Environmental Chemical Engineering* 8.2 (2020): 103563.
7. Lillo-Ródenas, M. A., et al. "Competitive adsorption of a benzene–toluene mixture on activated carbons at low concentration." *Carbon* 44.8 (2006): 1455-1463.
8. Link, Michael F., et al. "Quantification of byproduct formation from portable air cleaners using a proposed standard test method." *Environmental science & technology* 58.18 (2024): 7916-7923.
9. Lodewyckx, P., G. O. Wood, and S. K. Ryu. "The Wheeler–Jonas equation: A versatile tool for the prediction of carbon bed breakthrough times." *Carbon* 42.7 (2004): 1351-1355.
10. VanOsdell, DW, Mk Owen, and L Jaffe. Evaluation of Test Methods for Determining the Effectiveness and Capacity of Gas Phase Air Filtration Equipment for Indoor Air Applications (Phase II). ASHRAE. July. RP-792, (1996).
11. Xiang, Yiming, et al. "Assessing the performance of portable gas-phase air cleaners and Implications for their use in buildings." *Energy and Buildings* (2025): 116152.