INVITATION TO SUBMIT A RESEARCH PROPOSAL ON AN ASHRAE RESEARCH PROJECT

1825-TRP, Effects of Locally Provided Makeup Air on Commercial Kitchens

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 5.10 Kitchen Ventilation
Co-sponsored by: TC 5.3 Air Room Distributions & TC 2.1 Physiology^&Human Environment

Budget Range: $287,470 may be more or less as determined by value of proposal and competing proposals.

Scheduled Project Start Date: **September 1, 2025** or later.

All proposals must be received at ASHRAE Headquarters by 8:00 AM, EDT, May 30, 2025. NO EXCEPTIONS, NO EXTENSIONS. 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: 1825-TRP, Effects of Locally Provided Makeup Air on Commercial Kitchens, 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
Greg DuChane
Trane Technologies
2213 S. 20th Street
LaCrosse, WI 54601
Phone: 614-404-0468
E-Mail: greg.duchane@trane.com

For Administrative or Procedural Matters:
Manager Research & Technical Service
Steve Hammerling
ASHRAE, Inc.
180 Technology Parkway, NW
Peachtree Corners, GA 30092
Phone: 404-636-8400
E-Mail: Shammerling@ashrae.org

Contractors intending to submit a proposal should notify, by mail or e-mail, the Research Administrator by May 1st, 2025 in order that any late or additional information on the RFP may be furnished to them prior to the bid due date.

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. Hardcopy submissions are not permitted. **In all cases, the proposal must be submitted to ASHRAE by 8:00 AM, EDT, May 30, 2025.**
NO EXCEPTIONS, NO EXTENSIONS.

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 commercial kitchens, exhaust hoods are required to remove the heat, smoke and grease generated from the cooking process in order to provide a safe and clean working environment. The International Mechanical Code [1] requires that replacement air be brought into the kitchen to maintain the air balance. This replacement air can come through several means: makeup air, transfer air or through air conditioning units. For this study, we are focusing on the makeup air portion since it is either unconditioned or partially conditioned outside air.

In an effort to save energy, design engineers quite often use unconditioned air as the makeup air in the summer in kitchens and use air that is heated to 62°F (13°C) as the makeup air in the winter. It is commonly believed that if this air is brought into a kitchen adjacent to a hood, it is immediately exhausted and has no impact on the load or thermal comfort in the space. But operational experience has shown otherwise. ASHRAE project 1469-RP [3] monitored temperatures in 39 kitchens during summer conditions and found that the operative temperature in the cooking zone at a height of 43 inches (1.7 m) ranged from 83 to 94°F (30.4 to 37.9°C) which far exceeded the typical design space temperature of 74°F (23.3°C). The fact that the HVAC systems are not able to maintain the space design temperature anecdotally indicates that some of the makeup air are not exhausted and the actual heating/cooling loads brought in by the makeup air to the space are unknown.

ASHRAE 1480-RP [4] analyzed the impact of makeup air configuration on hood performance for island hood configurations but the supply air temperature was at a nominal 75 F (23.9 C) so the impact of extreme temperature conditions was not evaluated in that study.

The authors of another ASHRAE paper [5] performed computational fluid dynamics modeling and physical measurements to ascertain that if the makeup air introduced near a hood is hotter or colder than space temperature, it will not all be captured by the exhaust hoods and it can also cause the hoods to spill.

An ASHRAE seminar [6] also used modeling to predict how much makeup air would enter the kitchen space at various supply air temperatures.

Justification

Historically, engineers have assumed that all the makeup air coming through the supply plenum is immediately exhausted through the hood and thus would result in no additional heating/cooling load to the kitchen space. However, in actual practice, an unknown percentage of makeup air would enter the space and hence result in additional heating/cooling load and unsatisfactory indoor temperature/humidity affecting occupant/worker comfort, health, and productivity. Additionally, field experience has suggested that the amount of air which goes into the hood differs depending upon the supply temperature and velocity (or airflow rate).

The basic justification of ASHRAE funding this research is to ensure that engineers, who design the HVAC system for a kitchen space, have a means to accurately estimate the unintended load introduced by the unconditioned makeup air that is not exhausted, and hence to adequately size the system in order to properly achieve the desired space temperature and humidity.

Having these data available could supplement the HVAC load calculations shown in the ASHRAE Fundaments Non-Residential Heating and Cooling Load Chapter procedures, providing the tools for a more sustainable CKV design.

Objectives

The project objectives include, for a typical commercial kitchen exhaust air system:

1. Determine the percentage of makeup air that enters the exhaust hood versus enters the space for the following testing conditions:
    a. Makeup air at three temperature conditions: 62 °F (17 C), 75 °F (23.5 C), and 95 °F (35 C).

    b. A range of airflows (40 to 100 percent of the exhaust airflow)

c. Both ceiling supply and front-face discharge systems (refer to Figure 3 for a graphical description of these systems). The front-face discharge is being utilized as a control system since all the air mixes with the room air before entering the hood.

2. Determine the impact of different supply air temperatures and the accumulation of moisture in the space and resulting impacts on hood performance under the following testing conditions:

   a. Use the ASTM F1704 mixed line to determine impacts on hood performance

   b. Use the ceiling supply system

   c. Repeat one of the test configurations with 4-way diffusers

   d. Introduce makeup air at two temperature conditions: 62°F (17 C) and 95 °F (35 C). This is to simulate how makeup air is typically introduced during summer and winter months. During summer months, it is believed that the hot/humid air remains near the ceiling while in winter months, the colder incoming air will drop vertically downward with increasing velocity, potentially causing the exhaust hoods to spill (which is a failure to capture all of the heat and smoke from the cooking operations).

Scope:
The scope of the project will include laboratory measurements to determine the amount of makeup air that is exhausted by a commercial kitchen ventilation system when introduced in four-way, front-face and perforated perimeter configurations at a range of supply temperatures. In addition, the impact of makeup air temperature on hood capture and containment performance, when introduced in the four-way diffuser and perforated perimeter configurations, will be evaluated.

Specific tasks of this project include:

- Task 1: Construct and/or instrument laboratory space to meet ASTM 1704 [7] test standards for all test configurations, exempting space temperature and humidity control.
- Task 2: Conduct tests to determine how much makeup air is exhausted by the commercial kitchen hood, as defined in ASTM 1704, in ceiling, front face and perforated perimeter supply configurations at a range of makeup supply temperatures using tracer gas.
- Task 3: Determine the impact of makeup air supply temperature on hood capture and containment performance for the four-way diffuser and perforated perimeter supply configurations.

Task 1: Construct and/or Instrument Laboratory Space
The purpose of this task is to define the minimum requirements for a laboratory space to conduct test measurements. Refer to ASTM 1704 [7] for room specifications. An airtight room configuration is preferred for all tests.

A suggested room configuration is shown below in Figure 1. Figures 2 and 3 detail the front face and perforated perimeter makeup air plenum configurations to be tested.

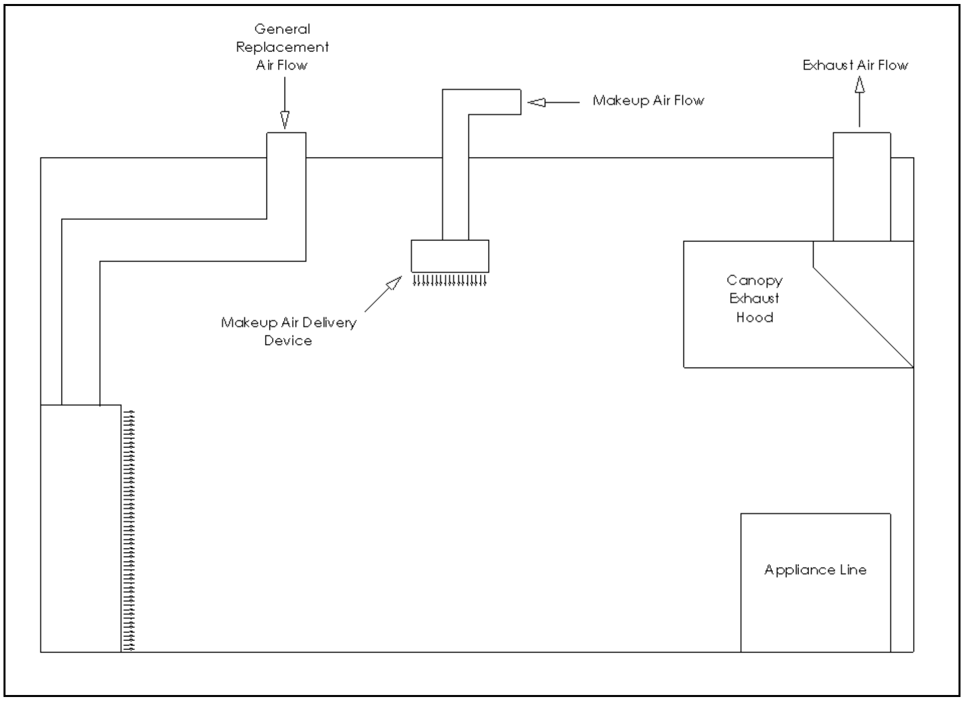

Figure 1: Laboratory Setup according to ASTM 1704, Ceiling Supply Makeup Air Device Installed

The scope of the project will include laboratory measurements to determine the amount of makeup air that is exhausted by a commercial kitchen ventilation system when introduced in four-way, front-face and perforated perimeter configurations at a range of supply temperatures. In addition, the impact of makeup air temperature on hood capture and containment performance, when introduced in the four-way diffuser and perforated perimeter configurations, will be evaluated.

Specific tasks of this project include:

- Task 1: Construct and/or instrument laboratory space to meet ASTM 1704 [7] test standards for all test configurations, exempting space temperature and humidity control.
- Task 2: Conduct tests to determine how much makeup air is exhausted by the commercial kitchen hood, as defined in ASTM 1704, in ceiling, front face and perforated perimeter supply configurations at a range of makeup supply temperatures using tracer gas.
- Task 3: Determine the impact of makeup air supply temperature on hood capture and containment performance for the four-way diffuser and perforated perimeter supply configurations.

Task 1: Construct and/or Instrument Laboratory Space
The purpose of this task is to define the minimum requirements for a laboratory space to conduct test measurements. Refer to ASTM 1704 [7] for room specifications. An airtight room configuration is preferred for all tests.

A suggested room configuration is shown below in Figure 1. Figures 2 and 3 detail the front face and perforated perimeter makeup air plenum configurations to be tested.

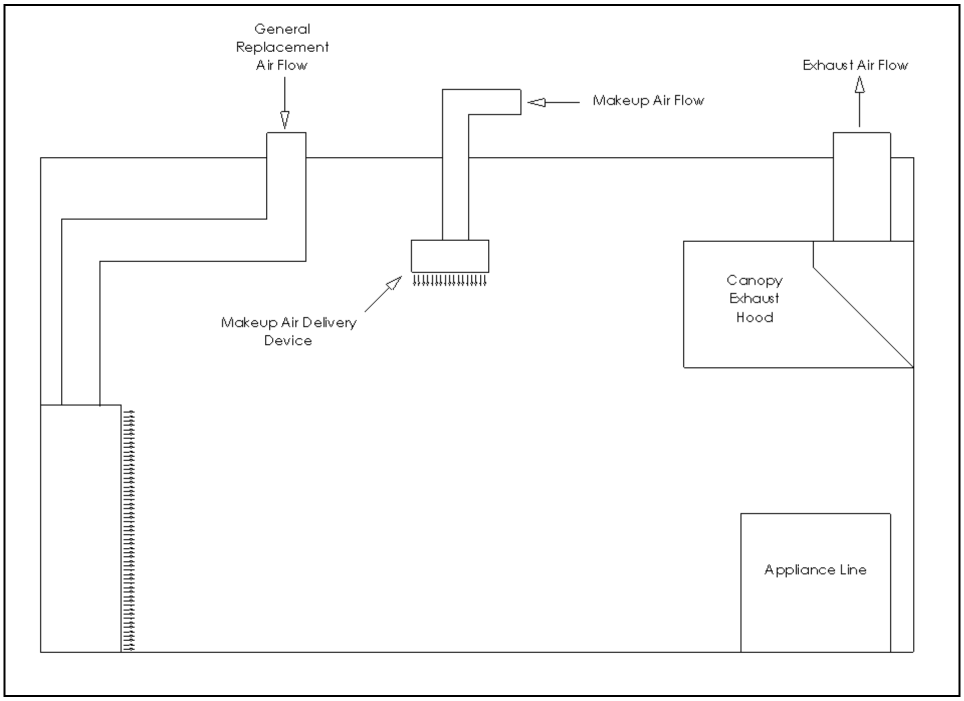

Figure 1: Laboratory Setup according to ASTM 1704, Ceiling Supply Makeup Air Device Installed

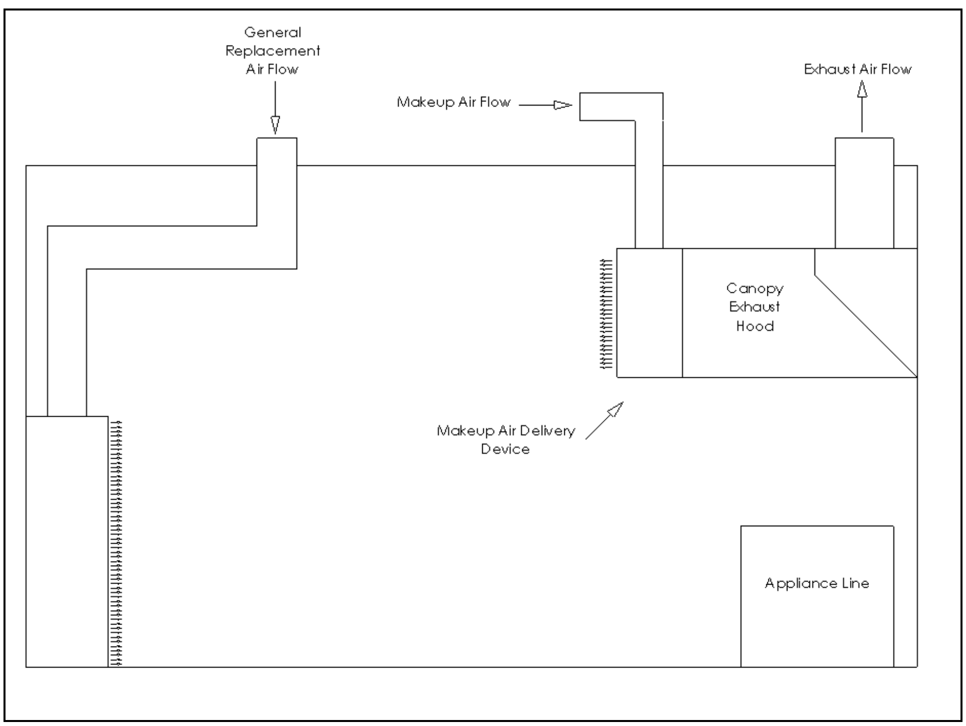

Figure 2: Laboratory Setup according to ASTM 1704, Front Face Makeup Air Device Installed

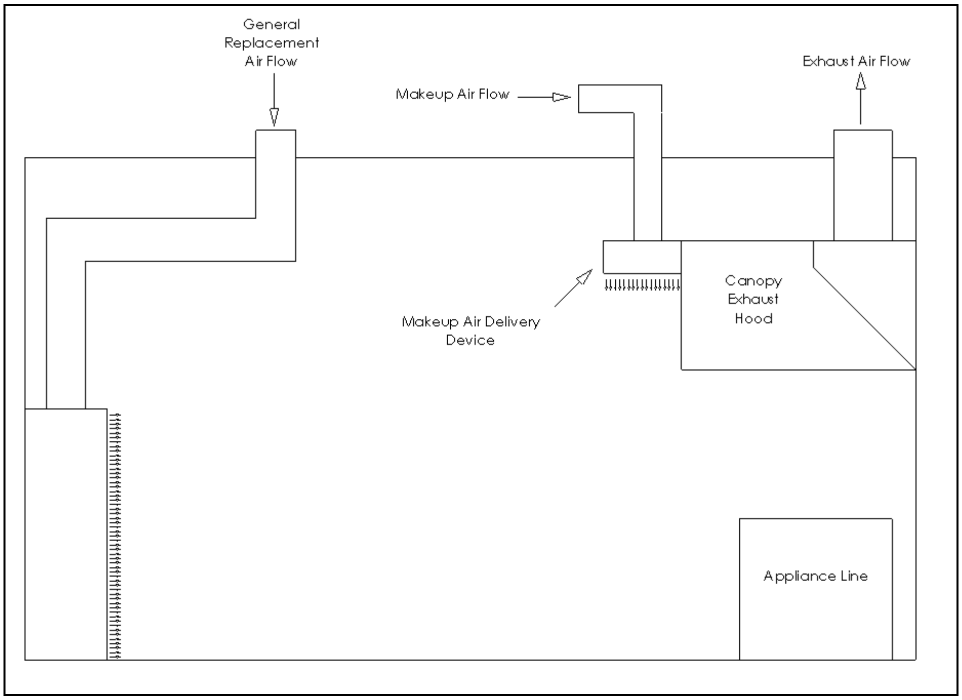

Figure 3: Laboratory Setup according to ASTM 1704, Perforated Perimeter Makeup Air Device Installed

A generic canopy exhaust hood measuring 120 inches (3.05m) in length, 54 inches (1.37m) in depth and 24 inches (0.61m) in height is to be installed in the laboratory and 78 inches (1.98m) above finished floor. The mixed appliance lineup noted in ASTM 1704 [7] is to be used for all test configurations. The appliances shall be a full-size oven, underfired broiler and 2-Vat fryer as specified in ASTM 1704 [7], operating during full-load cooking conditions or during simulated cooking condition as described in ASTM F1704 [7] Appendix X1 *Procedure for Determining the Capture and Containment Exhaust Rate for a Standard Appliance Line Challenge.* Exhaust and supply fans are to be appropriately sized and capable of adjustment to maintain space balance within the room. Variable frequency drives are recommended on all devices. The bidder shall specify how the exhaust and supply fans will be sized for this project.

The laboratory should be capable of maintaining 74-76°F (23-24°C) space conditions for all tests. The bidder shall specify how to achieve such requirement.

Baseline capture and containment performance of the generic canopy hood will need to be determined and maintained in all test configurations. The hood design, general supply and makeup air delivery devices are to be reviewed and approved by the Project Evaluation Subcommittee to ensure design compliance with ASHRAE and industry norms.

All exhaust, makeup and supply air volumetric flow rates are to be measured per AMCA 210/ASHRAE 51[10] or approved equivalent measures. A laminar flow element on general supply and/or makeup air devices is acceptable. Temperatures of exhaust, makeup and supply airflow are to be measured with a grid composed of evenly distributed points with a minimum of 9 points. The face velocity of the supply air diffuser should be measured using a device such as a vane-anemometer measuring in a grid with points placed 6 inches apart along the entire surface of the diffuser. Alternatively, the bidder may propose another device such as a vel-grid which can measure a larger surface area in a single measurement.

Task 2: Makeup Air Entering Hood Testing

The purpose of this task is to determine the quantity of makeup air that enters the exhaust hood by introducing tracer gas in the supply air system and measuring the concentration of the tracer gas in the supply air system and in the ductwork after the exhaust hood. Continuous sampling will be accomplished by measuring the concentration of the tracer gas in the exhaust air, the laboratory space, and the air entering the laboratory through the makeup air devices are measured and used to determine the fraction of the makeup air that is entering the hood under steady-state conditions. Four-way ceiling supply and front face makeup air devices are considered control devices as all air delivered enters the space prior to being exhausted by the room.

Testing will be conducted with the hood operating at capture and containment airflow rates with the ceiling supply, front face makeup air and perforated perimeter makeup air devices. Each device will be tested at the following makeup air temperatures:

- Cooling Mode 62 +/-2°F (17°C)
- Space Neutral, 75°F +/-2°F (23.5°C)
- Heating Mode 95 +/-2°F (35°C)

Airflow rate through the selected devices should be varied at 40, 60, 80 and 100% of capture and containment airflow rate for each temperature condition noted above. Table 1 shows the proposed test matrix. The Xs mark the minimum test points but the bidder may desire to propose more tests.

Makeup Air Fraction	Air Temperature Condition								
	Cooling Mode			Space Neutral			Heating Mode		
	Front Face Supply	Four-Way Ceiling Supply	Perforated Perimeter Supply	Front Face Supply	Four-Way Ceiling Supply	Perforated Perimeter Supply	Front Face Supply	Four-Way Ceiling Supply	Perforated Perimeter Supply
40%			X			X			X
60%			X			X			X
80%	X	X	X	X	X	X	X	X	X
100%			X			X			X

Table 1: Makeup Air Testing Matrix

A tracer gas that is non-toxic, non-flammable, such as Sulfur Hexafluoride (SF_6) shall be used to determine representative concentrations at the locations noted in Figure 4 for all tested configurations. SF_6 is readily available through gas suppliers and can be measured using instrumentation such as the following device in Figure 5.

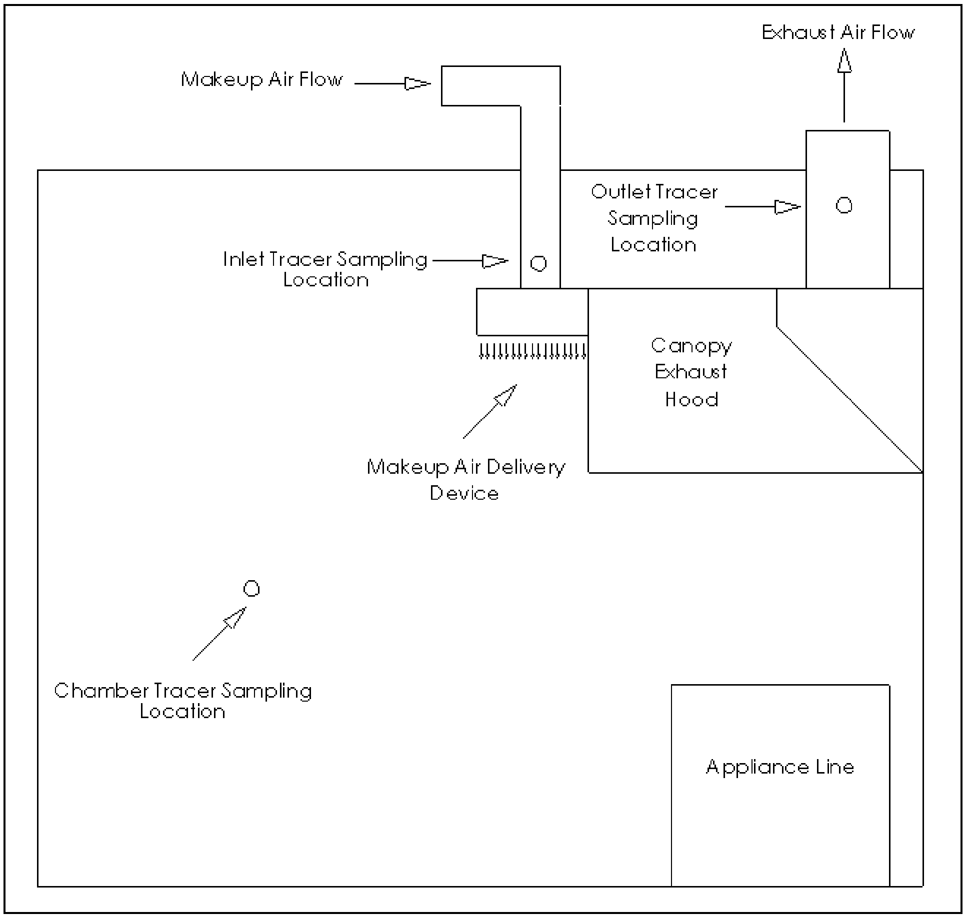

Figure 4: Tracer Gas Sampling Locations

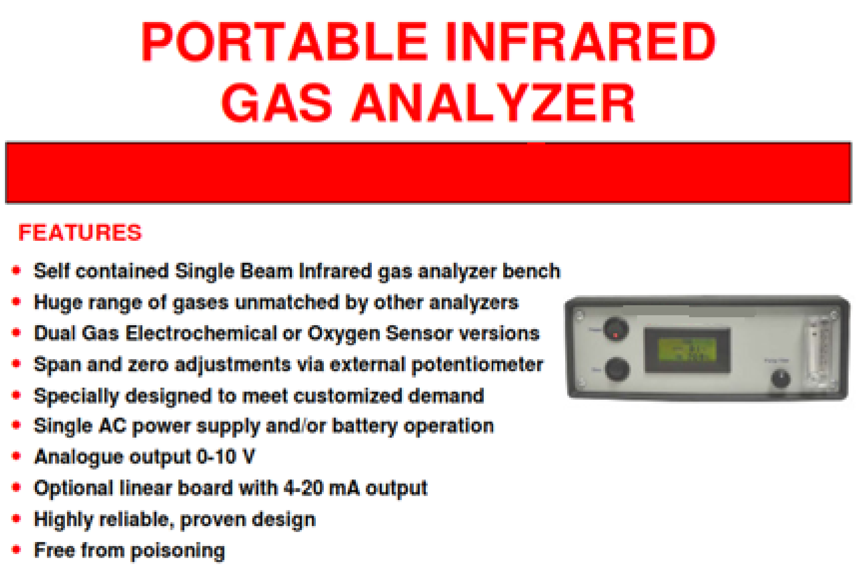

Figure 5: Tracer Gas Sampling Equipment Example

The system shall be allowed to reach steady state by waiting until at least four air changes of the test chamber have been completed. The bidder should describe how to ensure steady state status during the tests. After attaining steady state, the concentrations shall be averaged over at least a 10-min period with a minimum of 10 tracer gas measurements at each location. The bidder may wish to propose additional measurement points which could provide data for developing and validating relevant CFD and other simulation models in the future.

For each tested configuration, the makeup air fraction is to be reported using the equation below:

$$CE = \frac{C_{exhaust} - C_{chamber}}{C_{exhaust} - C_{ambient}}$$

[REF 11]

Task 3: Capture and Containment Impacts

The purpose of this task is to determine the impact of makeup air temperature on hood capture and containment performance. The evaluation should follow the procedure outlined in ASTM 1704-17, *Standard Test Method for Capture and Containment Performance of Commercial Kitchen Exhaust Ventilation Systems*. The threshold of capture and containment will be evaluated for a baseline case and compared to hood exhaust flow rates while introducing makeup from two other devices at three different temperatures each.

The baseline exhaust flow rate will be determined for the test hood and a standard appliance line challenge.

The stand appliance line challenge shall consist of a the full-size oven, underfired broiler and 2-Vat fryer specified in ASTM 1704-17 operating during full-load cooking conditions or during simulated cooking condition as described in ASTM F1704-17 Appendix X1 *Procedure for Determining the Capture and Containment Exhaust Rate for a Standard Appliance Line Challenge*.

The makeup air supplied through floor mounted displacement diffusers or other apparatus that represents transfer air from an adjacent zone. It will be introduced at a neutral temperature of 74-76°F (23.3 to 24.4 C)

Table 2 details the proposed test matrix for capture and containment evaluation. The X's mark the minimum tests required but the bidders may wish to propose additional testing.

Air Temperature Condition	Displacement Ventilation Baseline	Four-Way Ceiling Supply	Perforated Perimeter Supply
Cooling Mode		X	X
Space Neutral	X	X	X
Heating Mode		X	X

Table 2: Capture and Containment Test Matrix

The following evaluation will be conduct using 4-way diffusers mounted 3 feet away from the hood, as shown in Figure 6

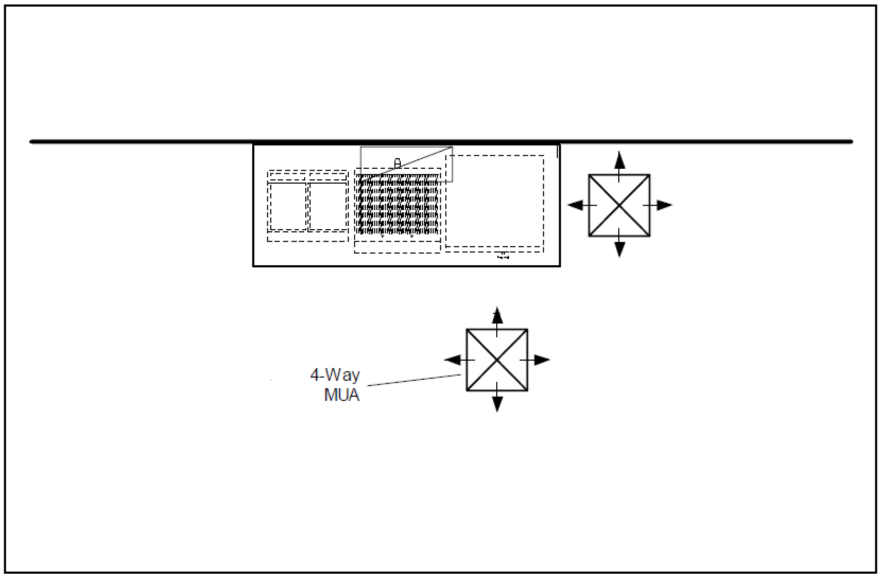

Figure 6: Four-Way Diffuser Set Up

The exhaust airflow rate will be determined for 1000 cfm of makeup air (1699 cmh) introduced via 4-way diffusers at the side or front of the hood. The temperature of the makeup air supplied via 4-way diffusers shall be 62 +/- 2°F (16.7 +/ 1.1 C), neutral -- 74 to 76 °F (23.3 to 24.4 C), and 95 +/- 2°F (35 +/ 1.1 C).

The threshold of capture and containment shall be determined according to the procedure outlined in ASTM F1704 *Capture and Containment Performance of Commercial Kitchen Exhaust Ventilation Systems.*

Set the initial exhaust flow rate high enough to be certain to capture and contain the thermal/effluent plume produced from the cooking appliances under cooking conditions. Turn off all test space recirculating systems.
Set the general replacement airflow rate from the displacement diffusers at approximately the difference between the exhaust airflow rate and the local makeup airflow rates. Keep room differential pressure within 0.05 in. of water.

Establish the cooking threshold capture and containment flow rate, whereby the appliance is operating to maintain a full-load cooking condition using a flow enhancement visualization system, as illustrated in ASTM F1704. While cooking, the appliances must cycle a minimum of one full-load cook cycle. The hood must show capture and containment during the full cycle period over the full hood perimeter from the hood edge to the floor level during idle or cooking conditions when using a flow enhancement visualization system.

During the test, reduce the exhaust flow rate until the hood begins to spill. Any observed leak moving beyond 3 in. (7.6 cm) from the hood face will be construed to have escaped from the hood, even if it may appear to be drawn back into the hood. If the effluent/thermal plume mixes with the local make-up air, and the local make-up air is not captured and contained by the hood, then the effluent/thermal plume will be construed to have escaped from the hood.

Gradually increase the exhaust flow rate in fine increments until full capture and containment of the thermal/effluent plume is achieved.

Calculate the mean threshold capture and containment airflow rate and uncertainty according to the Standard.

The second evaluation will be through the ceiling mounted supply plenum (used in Task 2) at 62 +/- 2°F (16.7 +/ 1.1 C), neutral - 74 to 76 °F (23.3 to 24.4 C), and 95 +/- 2°F (35 +/ 1.1 C), see Figure 7.

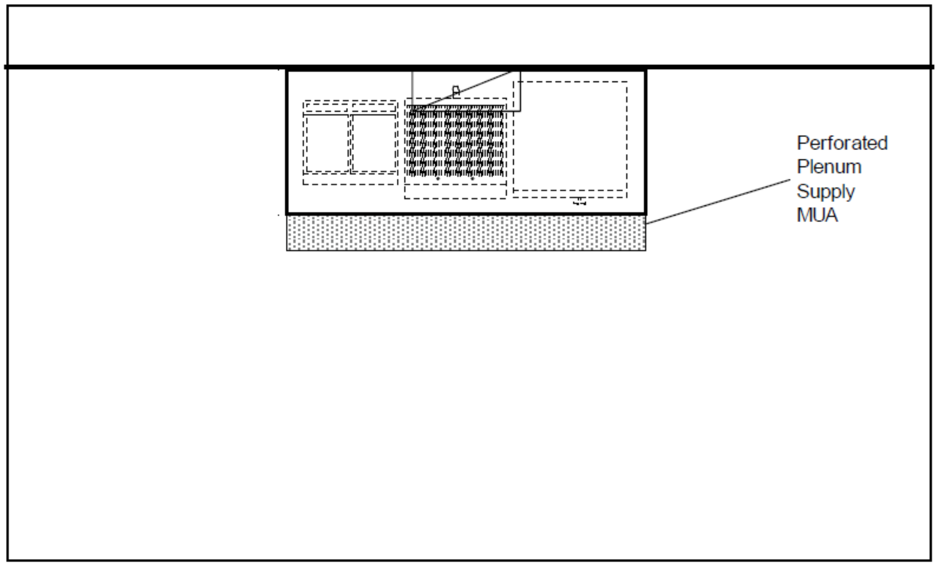

Figure 7: Ceiling Plenum Set Up

Report

Report fraction of makeup air from makeup air devices that enters the exhaust hood and that enters the room at specified airflow rates and delivery temperatures.

Report and compare threshold of capture and containment with specified makeup air devices and delivery temperatures.

Deliverables:
Items *a* through *e* below are generic ASHRAE requirements a contractor is required to provide on every ASHRAE research project. These cover:

- Quarterly progress and financial reports to MORTS (to be reviewed by the Project Monitoring Subcommittee (PMS)).
- A final report.
- A research or technical paper, submitted for peer review and publication in the ASHRAE *Transactions* or *Science and Technology for the Built Environment.*
- Any data obtained from the research.
- A project summary.

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, including a summary of the control strategy and savings guidelines. Unless otherwise specified, the final draft report shall be furnished, electronically 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.

c. *Science & Technology for the Built Environment* or ASHRAE Transactions Technical Papers

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 as either Research Papers for HVAC&R Research or Technical Paper(s) for ASHRAE Transactions. Research papers contain generalized results of long-term archival value, whereas technical papers are appropriate for applied research of shorter-term value, ASHRAE Conference papers are not acceptable as deliverables from ASHRAE research projects. The paper(s) shall conform to the instructions posted in "Manuscript Central" for an ASHRAE Transactions Technical or HVAC&R Research papers. The paper title shall contain the research project number (1825-RP) at the end of the title in parentheses, e.g., (1825-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

The level of effort is estimated to be approximately 600 hours of a principal investigator and 1460 hours of a researcher over a 18 month period. A total cost of $287,470 is estimated. The breakdown of cost by project task and between the principal investigator and the research is shown below:

Task	Description	PI Time, hrs.	PI Cost, $	Researcher time, hrs.	Research Cost, $	Total Cost, $
1	construct/ instrument lab	240	$ 42,120	320	$ 38,400	$ 76,960
2	conduct baseline ASTM F1704 Testing	120	$ 21,060	240	$ 28,800	$ 49,860
3	Determine impact of makeup air on hood performance	300	$ 52,650	900	$ 108,000	$ 160,650
Total		660	$ 115,830	1460	$ 171,640	$ 287,470

The accepted bidder will be responsible for obtaining the supply diffusers, test equipment and testing facilities. Supply diffuser and hood manufacturers have shown interest in donating equipment to whoever the successful bidder is. Appliance requests and donations shall be coordinated by the principal investigator.

Proposal Evaluation Criteria:

No.	**Proposal Review Criterion**	**Weighting Factor**
1	Contractor's understanding of Work Statement as revealed in proposal. a) Logistical problems associated b) Technical problems associated	**20%**
2	Quality of methodology proposed for conducting research. a) Organization of project b) Management plan c) Detailed and logical work plan with major tasks and key milestones d) Reasonableness of project schedule	**25%**
3	Contractor's capability in terms of facilities. a) Laboratory/testing facilities and setup b) Data collection setup c) Measurement instrument and data acquisition system uncertainty	**20%**
4	Qualifications of personnel for this project a) Project team 'well rounded' in terms of qualifications and experience in related work b) Project manager person directly responsible, experience and corporate position c) Team members' qualifications and experience d) Time commitment of Principal Investigator	**20%**
5	Student involvement a) Extent of student participation on contractor's team b) Likelihood that involvement in project will encourage entry into HVAC&R industry	**10%**

6	Performance of contractor on prior ASHRAE or other projects (No penalty for new contractors)	**5%**

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
1	Develop draft method of test, including uncertainty analysis, and submit to PMS and TC for peer review.	1
2	PMS review of laboratory configuration and sampling locations for the tracer gas measurements, modification as needed.	3
3	Review first tests with the makeup air supplied with a perforated supply plenum configuration to ensure the tracer gas instrumentation is working at cold, hot and neutral supply air temperatures.	5
4	Review the final test results for consistency and if specific retests are needed.	9
5	Review final report	14

References

1. 2018 International Mechanical Code, International Code Council, Inc., 2017.
2. ASHRAE 90.1, Energy Standard for Buildings Except Low-Rise Buildings, ASHRAE, 2019.
3. Stoops, John, Watkins, Amber, Smythe, Ed, Adams, Mark, Simone, A., Olesen, B. W., 1469-RP: Comfort In Commercial Kitchens., KEMA Inc., 2013.
4. Swierczyna, R., Sobiski, P., and Fisher, D., 1480-RP: Island Hood Energy Consumption and Energy Consumption Strategies, 2010.
5. Livchak, A., Schrock, D., and Sun. Z., The Effect of Supply Air Systems on Kitchen Thermal Environment, ASHRAE Transactions, 2005.
6. Sandusky, J., Pageot, F., and Smith, V., Seminar 8 – Comfort Challenges in Commercial Kitchens, 2016 ASHRAE Annual Meeting, St. Louis, MO.
7. ASTM F1704, Standard Test Method for Capture and Containment Performance of Commercial Kitchen Exhaust Ventilation Systems, ASTM, 2012.
8. Swierczyna, R., Sobiski, P., Fisher, D., Cole, T. and Bramfitt, M., 1202-RP: Effect of Appliance Diversity and Position on Commercial Kitchen Hood Performance, 2005.
9. Fisher, D., Swierczyna, R., and Sobsiki, P., 1362-RP: Revised Heat Gain and Capture and Containment Exhaust Rates from Typical Commercial Cooking Appliances, 2008.
10. ANSI/AMCA Standard 210-16 / ASHRAE 51-16, Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating, AMCA/ASHRAE, 2016.
11. ASTM E Designation: E3087, Standard Test Method for Measuring Capture Efficiency of Domestic Range Hoods, ASTM, 2017.