INVITATION TO SUBMIT A RESEARCH PROPOSAL ON AN ASHRAE RESEARCH PROJECT

1830-TRP, Experimental Characterization of Aircraft Bleed Air Particulate Contamination

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 9.3, Transportation Air-Conditioning
Co-sponsored by: SSPC 161, Air Quality within Commercial Aircraft

Budget Range: $150,000 may be more or less as determined by value of proposal and competing proposals.

Scheduled Project Start Date: **April 1, 2019** or later.

All proposals must be received at ASHRAE Headquarters by 8:00 AM, EST, December 17, 2018. 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: 1830-TRP, Experimental Characterization of Aircraft Bleed Air Particulate Contamination", 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
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Contractors intending to submit a proposal should so notify, by mail or e-mail, the Manager of Research and Technical Services, (MORTS) by December 3, 2018 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 and mvaughn@ashrae.org. Hardcopy submissions are not permitted. **In all cases, the proposal must be submitted to ASHRAE by 8:00 AM, EST, December 17, 2018. 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)

Engine bleed air is the source of ventilation for the cockpit and cabin on nearly all commercial aircraft. A key provision of Standard 161 is sensing to detect oil and hydraulic fluid contamination of bleed air used for ventilation (1). The Federal Aviation Administration has also identified the need for such contaminant sensing (2). There is currently no demonstrated, market ready technology available to meet these needs. Recent research has shown that ultra-fine particles are generated when engine oil and, likely, other fluid contaminants are present and therefore detection of these particles has potential to meet these needs (3-5). Other potential markers, such as various gaseous contaminants will not be addressed in this research. The NASA VIPR program provided a unique opportunity to verify these findings on a large aircraft engine under actual operating conditions (6). It also provided an opportunity to compare particle sensing to other potential forms of contaminant sensing.

The above research shows that ultrafine particulates are generated and measurement of these particles provides good potential for meeting the requirements of Standard 161. The signal-to-noise ratios are in the range of 100 to 10,000 when substantial oil contamination is present as compared to background values (5). Given this high signal to noise ratio, particulate sensing has the potential to be a sensitive indicator of oil contamination with low false alarm rates which is critical for aircraft applications. This research also indicates that particle size decreases at low contamination levels, which actually increases the sensitivity (more particles per unit of mass) at low concentrations.

Justification and Value to ASHRAE

ASHRAE Standard 161 was designated as a policy level standard by ASHRAE and its development demonstrates ASHRAE's international leadership in aircraft cabin air quality, an area of increasing national and international interest. The requirement for bleed air contaminant monitoring is an important provision of the standard and played a major role in bringing divergent interests to a consensus that allowed the standard to be broadly supported. The lack of a viable option to implement a key provision is a significant hurdle for widespread adoption. The requested research will provide the missing information that allows us to know if ultra-fine particle sensing is a viable option for meeting this requirement in the standard.

The requested research is well aligned with ASHRAE's Strategic Plan, Sections 3A, 3C, and 4A. This research will provide the knowledge required to effectively use the appropriate technology for meeting requirements of Standard 161 (3A). It will provide the information needed to substantially improve the usability of Standard 161, a prominent national and international standard (3C). Standard 161 is recognized globally and providing information to make it more effective serves the global community (4A). This research is aligned with ASHRAE Research Strategic Plan, Goal 9, as it directly addresses a significant health and safety concern associated with aircraft environmental control system components.

The research requested is not intended for sensor development. Rather, it will define precisely what a sensor utilizing ultra-fine particle detection will need to sense to be useful for meeting the Standard 161 requirements. This information can then be used to identify appropriate existing sensors or develop new sensors as needed. Ultra-fine particle detection is not the only potential means for meeting this requirement. Various types of chemical detection also have potential. However, the need to measure very low chemical concentrations and the sophistication of the required sensors create significant challenges for widespread aircraft onboard application. At the present time, ultra-fine particle detection presents a promising approach and a relatively modest investment will answer the primary outstanding questions for this approach.

Objectives

The objective of the requested research is to fill in the data gaps identified above. Specifically:

1. Determine the particulate concentrations and size distribution at representative engine operating conditions over wide a range of contamination rates including very low rates.
2. Compare the particulate concentrations and size distribution resulting from bleed air contamination from engine oil, hydraulic fluid and de-icing fluid at several representative conditions.
3. Compare particulate concentrations and size distribution between an APU and other engine types.
4. Recommend performance specifications for a particle sensing instrument as a potential option to meet the bleed air sensing requirements set forth in Standard 161.

Scope:
Engine Facilities

The engine bleed air data must be collected using bleed air from an actual turbine engine or an externally driven turbine engine compressors operated at speed representative of engine operation. Simulated bleed air is not acceptable. Due to cost constraints, the need to operate over a wide range of conditions, and the need for extended run times to enable the collection of reliable data, it is anticipated that a small gas turbine engine will be used for collecting experimental data rather than a full-size airliner propulsion engine. The engine used should be capable of producing bleed air with temperatures over the range of at least 200C to 310C at the extraction location without any supplemental heating. This range is needed to allow data to be collected for range of conditions that is representative of most aircraft engine operation. Additional information about the range of typical bleed air conditions is provided by The National Academy (7), Table 2-2 “Typical Conditions of Bleed Air from Engine.” The engine used must have been validated to yield particulate size distributions representative of a typical high bypass airliner engine. Size distribution information is available in references 5 and 6. There is no requirement, other than economics, to use a smaller engine and experiments may be conducted on an actual high bypass airliner engine provided adequate operation time will be available to collect data for the required conditions. Regardless of the engine used, the rate at which the contaminant is injected and the engine airflow rate must be measured. The contaminant may be introduced as an aerosol in the compressor intake air or injected directly into the compressor. In the latter case, it must be injected upstream of the first stage.

Auxiliary power units (APUs) typically provide electrical power and pressurized air to the aircraft when it is not connected to ground sources and the propulsion engines are not operating or are not operating at sufficiently high power to meet aircraft requirements. There are two basic types of APUs: single compressor and dual compressor. In both cases, they consist of a gas turbine engine. In the single compressor design, compressed air is drawn off as bleed air from the engine compressor. In the dual compressor design, the compressor used to supply air to the aircraft is separate from the engine compressor. A dual compressor APU should be used for the experiments as there is no reason to believe that a single compressor APU would yield results significantly different from other turbine engines. Alternatively, an externally driven APU compressor run at speeds representative of APU operation may be employed.

Particle Sizing Equipment Requirements

Refer to Reference 5 for the expected nature of particle sizes. As a minimum, particle measurement equipment must be used which can determine particle numbers and size distribution for the full range of 10 nm to 1000 nm. For a given condition, data collection can focus on narrower ranges if other data indicate there is no reason to include larger particle sizes. The 10 nm to 200 nm range is particularly important. The applicant shall ensure and demonstrate that the sampling system has minimal effect on the sample particulate signature and that the collected data is representative of the contaminated bleed air.

In Tasks 1 through 3 below, measurements shall be made using the engine bleed air facility and particulate measuring equipment described above to determine particle size distributions for each bleed air temperature and contamination rate specified. For each condition, the bleed air facility shall be operated for a period sufficient to achieve steady state operation before collecting size distribution data. A minimum of five distributions distributed over a minimum time period of 10 minutes shall be measured for each condition. Additionally, background ambient particle size distributions shall be measured at the engine compressor air inlet with the compressor in operation, as a minimum, before and after a series of tests. Similarly, bleed air particle size distributions shall be measured with the engine compressor in operation without oil injection, as a minimum, before and after a series of tests.

In Task 4 the APU facility and particulate measuring equipment described above shall be used to determine particulate size distributions for each operating conditions and contamination rate specified. Measurement procedures are the same as for Tasks 1-3.

The time line for completion of each of these tasks is not specified in this request for proposals as it may depend upon availability of equipment, test facilities, and other factors that may not be the same for each bidder. Proposals, however, should include a project time line including the timing for completion of each of the four tasks.

Task 1: Oil Contaminants in Engine Bleed Air

The oil used shall be Mobil Jet II as it is widely used in airliner engines. Additional data may be collected with other oils if desired but is not required and will not be considered in the bidder selection. As a minimum, data shall be collected at bleed air temperatures of 200C, 250C 300C and 310C at oil contamination rates of 0 1, 3, 5, and 10 ppm by mass oil to air.

Task 2: Hydraulic Fluid Contamination in Engine Bleed Air

The hydraulic fluid used shall be Skydrol LD-4 as this fluid is widely used in the aviation industry. The purpose of the hydraulic fluid experiments is to confirm that the submicron particles of contamination resulting from contamination with hydraulic fluid are similar (or not) to those measured for engine oil. It is not necessary to repeat all test conditions used for engine oil. As a minimum, experiments should be conducted with contamination rates of 0, 3 and 10 ppm with bleed air temperatures of 250C and 310C.

Task 3: Deicing Fluid Contamination in Engine Bleed Air

SAE AMS 1424 Type I propylene glycol deicing fluid shall be used as it is widely used in the aviation industry. Conditions and contamination rates are the same as for hydraulic fluids.
Task 4: APU Measurements

The purpose of the APU measurements is to verify that the particulate nature from a dedicated APU compressor is (or not) similar to particulate numbers and size distribution seen in bleed air. For this purpose, extensive data are not required. As a minimum, data must be collected for APU maximum flow conditions and at a low power level with 0, 5 ppm and 10 ppm contamination rates using engine oil.

Other Measurements

Given the objectives of this research, the focus is on the number and size distribution of particles. Other data may be collected such as potential gaseous markers (e.g. CO). However, consideration of these measurements will not be included in bidder selection.

Deliverables:
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 (1830-RP) at the end of the title in parentheses, e.g., (1830-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 anticipated level of effort is 2 professional months for the principal investigator, 2 professional months for a research technician, and 6 professional months for graduate or undergraduate students. The total cost is estimated to be $150,000. The duration is expected to be 12-18 months depending upon whether the experimental facilities are in place or must be developed for this project.

Project Milestones:

Anticipated Milestone
The following milestones are suggested. However, the appropriate milestones will depend upon how the project is organized. Proposals should state specific milestones whether the following, or alternative, milestones are used.

No.	Major Project Completion Milestone	Deadline Month
1	Experimental Engine Facility Operational	
2	Oil Contamination Data Collected on Engine	
3	Hydraulic Fluid and Deicing Fluid Contamination Data Collected on Engine	
4	APU Data Collected	
5	Final Report Submitted	

Proposal Evaluation Criteria

Proposals submitted to ASHRAE for this project should include the following minimum information:

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	15%
2	Quality of methodology proposed for conducting research. a) Organization of project b) Management plan	20%
3	Contractor's capability in terms of facilities. a) Managerial support b) Data collection c) Technical expertise	25%
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	15%
5	Probability of contractor's research plan meeting the objectives of the Work Statement. a) Detailed and logical work plan with major tasks and key milestones b) All technical and logistic factors considered c) Reasonableness of project schedule	15%
6	6a. 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%

References

1. ASHRAE, "Air Quality within Commercial Aircraft," ANSI/ASHRAE Standard 161-2013, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 2013.

2. The specific requirement referenced is in section 7.2 and is as follows: "One or more sensors intended to identify a substance or substances indicative of air supply system contamination by partly or fully pyrolyzed engine oil and hydraulic fluid shall be installed. The indicator substance(s) shall (1) be shown to be associated with the presence of partly or fully pyrolized engine oil and hydraulic fluid; (2) have a sufficiently low background level that its presence can be reliably attributed to these contaminants; and (3) be measured with sufficient sensitivity to reliably detect the occurrence of these contamination events. The sensor(s) shall sample the airstream no less frequently than once every 60 seconds."

3. G. A. Day, "Aircraft Cabin Bleed Air Contaminants: A Review" DOT/FAA/AM-15/20 Office of Aerospace Medicine, Federal Aviation Administration, November 2015.

4. S. N. Amiri, B. W. Jones, K. R. Mohan, C. P. Weisel, G. Mann, J. Roth, Study of Aldehydes, Carbon Monoxide, and Particulate Contaminants Generated in Bleed-Air Simulator, Journal of Aircraft, DOI: 10.2514/1.C034133, 2017.

5. G. W. Mann, S. J. Eckels and B. W. Jones, ”Analysis of particulate size distribution and concentrations from simulated jet engine bleed air incidents,” HVAC&R Research, 20:7, 780-789, 2014.

6. B. W. Jones, S. N. Amiri, J. W. Roth, and M. H. Hosni, The Nature of Particulates in Aircraft Bleed Air Resulting from Oil Contamination, LV-17-C047, ASHRAE 2017 Winter Conference, Las Vegas, NV.

7. D. R. Space, A. K. Salgar, D. Scheer, B. W. Jones, and S. N. Amiri, Experimental Determination of the Characteristics of Lubricating Oil Contamination in Bleed Air, LV-17-C046, ASHRAE 2017 Winter Conference, Las Vegas, NV.

8. National Academy Committee on Air Quality in Passenger Cabins of Commercial Aircraft, The Airliner Cabin Environment and the Health of Passengers and Crew, National Academy Press, 2002.