INVITATION TO SUBMIT A RESEARCH PROPOSAL ON AN ASHRAE RESEARCH PROJECT

1716-TRP, "Oil Concentration of Field Installed Liquid Chillers with Flooded Type Evaporators" REBID

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, 8.02, Centrifugal Machines

Budget Range: $135,000 may be more or less as determined by value of proposal and competing proposals.

Scheduled Project Start Date: **April 1, 2023** or later.

All proposals must be received at ASHRAE Headquarters by 8:00 AM, EST, Thursday, December 15th, 2022, May 16, 2022. 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: 1716-TRP, "Oil Concentration of Field Installed Liquid Chillers with Flooded Type Evaporators", *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
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For Administrative or Procedural Matters:
Manager of Research & Technical Services (MORTS)
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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 1 2022, 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. In all cases, the proposal must be submitted to ASHRAE by 8:00 AM, EST, December 15, 2022. 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 reserves the right to reject any or all bids.

State of the Art (Background)

The majority of field-installed chillers utilize a lubricant to ensure proper operation of the compressor and other mechanical components in the system. This lubricant is often a "necessary evil", as prior ASHRAE research (RP-1089) has demonstrated that oil in the refrigerant can significantly impact the heat transfer performance of enhanced tube surfaces that are commonly used in the industry. Thome and Robinson (2004) reported the impact of oil on a Turbo-Bii flooded evaporator bundle with R-134a, R-507A and R-410A by comparing the local bundle boiling heat transfer coefficients measured with oil to those measured without oil. The authors developed a correlation to predict the heat transfer coefficient ratio, defined as the ratio of the local heat transfer coefficient with oil to the local heat transfer coefficient without oil at the same operating conditions, with local oil concentration varying from approximately 1%-10%. Chart from RP-1089 (Chapter 8, Figure 3) shows degradation of local heat transfer coefficient to as low as 25% of the baseline without oil. The reduction in heat transfer performance will lead to increased head on the compressor in a chiller, and increased power consumption. In the case of a centrifugal compressor, the increased head may also reduce the capacity of the chiller. The energy costs associated with operating this type of equipment over a 20-25 year life in a degraded state implies that even incremental changes in power consumption can be important.

While the research above begins to quantify the impact of oil concentration on flooded evaporator heat transfer performance, literature regarding the oil concentration in field-installed chillers is scarce. Many product literature documents cite ASHRAE RP-601 (April 1990) "Chemical Analysis and Recycling of Used Refrigerant from Field Systems." The project was performed to "identify and quantify typical contaminant levels", one of which was oil in the refrigerant. The project used refrigerant samples obtained from R-11 chillers, from R-12 commercial heat pumps, and from R-502 low temperature frozen food cases. The operating conditions of the sampled systems ranged from normal operating systems (minimal refrigerant contamination) to systems requiring minimal repair (average refrigerant contamination) to systems experiencing motor burnouts (severe refrigerant contamination). While the RP-601 study included a wide range of systems (heat pumps, small air-conditioners, commercial refrigeration, and some chillers), the study had several significant shortcomings.

· The refrigerants studied were not representative of current commercially available equipment, with all ten centrifugal chillers using low-pressure refrigerant R-11. More common today are R-134a and R-123.
· All chillers were located on a single university campus, with one set of operation and maintenance practices.
· The R-11 chillers covered the narrow range of 200-500 tons.
· One medium-pressure R-12 chiller was tested, but it was a very small instrument process chiller rated for 0.75 hp.

Objective

The objective of the research defined by this work statement is to conduct a field survey of oil concentration in field-installed chillers. The survey will include compressor type, age of equipment, maintenance practices, oil return system design, or other factors as determined by the researcher. The results of the field study can be used to recommend best design practices for oil-return system design, best maintenance practices for minimizing oil concentration, and provide information necessary to quantify the potential benefits (if any) of oil-free systems.

[Note that the intent is NOT to conduct field testing of chillers to determine before and after performance changes due to a change in oil concentration. The impact of oil on heat transfer performance has been characterized in the literature and can be propagated to an estimate of the overall impact on chiller energy consumption by chiller manufacturers, with varying level of uncertainty in that estimate. However that estimate cannot be made without knowing what oil concentration levels exist in actual operating equipment.]

Scope:

The study will follow the general guidelines given below:

1. The researcher will develop appropriate sampling methods that minimize or eliminate permanent modifications to the chiller, by adapting piping sampling techniques and best practices from other industries (such as ASTM D4177-16, API MPMS CHAPTER 8.2-2016, or others proposed by the researcher), and applying to refrigerant oil mixtures with consideration given to methods in ASHRAE Standard 41.4-2015. Input from chiller

manufacturers will be solicited regarding appropriate sampling locations according to different system designs, and chiller operating requirements (such as cooling load or running time since last start-up) to obtain representative oil concentration measurements.

2. The researcher will define a field sampling program, with requirements for site & chiller selection, data collection requirements, sampling methods, and participant qualifications. The proposal from the committee is that Manufacturers/Service Organizations would provide information on a list of chillers available to sample. The researcher using DOE or other method would select which chillers should be sampled. The Manufacturers/Service Organizations would collect the samples and forward to the researcher. The rational why the researcher is responsible for this selection is to avoid any bias from the Manufacturers/Service Organizations on this selection.
3. Refrigerant samples shall be provided to the sampling program by the Manufacturers/Service Organizations at their own expense. Researcher to provide participants with any special hardware required by the sampling method, with samples returned to the researcher or designated laboratory for analysis. Such shipments of refrigerant sample par bomb cylinders shall comply with applicable DOT regulations.
4. The researcher shall prepare a survey to be completed for each chiller sampled, documenting the chiller model number, refrigerant, age, design conditions, and maintenance practices, and other pertinent information defined by the researcher and the project monitoring subcommittee (PMS) that can be used to correlate the results of the oil sample analysis.
5. The number of samples required to properly correlate each of the variables with statistical significance shall be agreed upon by the researcher and the PMS. The committee expects this will be in the range of 100 to 200 chillers as determined by the researcher to meet a target statistical significance.
6. The variables to investigate and suggested ranges for each are listed below. Other variables or ranges may be proposed with justification provided in the researcher's bid.

Compressor type:	Centrifugal
Refrigerant:	R-134a, R-123
Age:	0-20 years
Design Capacity:	100-3000 Tons
Maintenance organization:	OEM service, 3rd party service, owner internal service
Service records documentation:	well documented, poorly documented
Operating conditions:	as-tested conditions, design conditions minimum acceptable chiller load run time since last start

The project work content is expected to be divided into the following three main tasks and deliverables. The project bid proposal may add other tasks or create further detailed breakdown of the project work content.

Task 1. An written interim report with the sampling program defined with methods & procedures, submittal to PMS for review & approval prior to proceeding to Task 2.

Task 2. Implement the program defined in Task 1, provide guidance to the service organizations during their collection of the samples, survey info, and perform sample analysis. When sufficient data is available, analyze the data set to characterize the results and determine correlations to the factors (variables). If the initial analysis determines that more data is needed from certain ranges of the variables, to reach some level of statistical significance, then initiate requests for more samples from the necessary target population. Continue updating the analysis as more samples are collected. When results are determined to be meaningful, communicate or announce an end to the sampling program. The contractor shall conduct one or more meetings with the PMS to provide an update on the interim results after the initial analysis is conducted. Another PMS meeting shall be held after the final analysis, prior to announcing the end of sampling program, for review & approval prior to proceeding to Task 3.

Task 3. Create a final written report for the project, including the data and the analysis. Submit report to PMS for review & approval.

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.

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).

The Final Report shall include:
- Background/Literature Survey
- Sampling Uncertainty Analysis
- Appropriate results as described in the Scope of this work statement.
- All experimental data in tabular form, published in a way that is manufacturer agnostic
- All experimental data for a particular manufacturer to be provided to that manufacturer

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 *Science & Technology for the Built Environment* or *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 (1716-RP) at the end of the title in parentheses, e.g., (1716-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 documenting: (i) the main findings of the research project, (ii) why the findings are significant, and (iii) how the findings benefit ASHRAE membership and/or society in general.

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

It is expected that this project will take 13 months with an estimated cost of $135,000. This time estimate includes approximately three months for background literature review, survey development, sampling and analysis method definition, and sample bottle definition. Six to seven months are allotted for chiller manufacturers to collect samples and return to researcher. This includes sample collection procedure support. Data analysis will be on-going as samples are received but concluding around the eleventh month, then one month for final analysis and report documentation. Approximately eight person-months of the Principal Investigator and sixteen person-months of a research assistant are estimated. The estimated costs include $100,000 for personnel (PI, research assistant, technicians, etc.), $25,000 for equipment and test fluids, and $10,000 for administrative and other miscellaneous costs.

Proposal Evaluation Criteria

No.	Proposal Review Criteria	Weighting Factor
1	Contractor's understanding of Work Statement as revealed in proposal.	10%
2	Quality of methodology proposed for conducting research.	25%
3	Contractor's capability in terms of facilities.	20%
4	a) Qualifications of personnel for this project. b) Student involvement.	15%, 5%
5	Probability of contractor's research plan meeting the objectives of the Work Statement.	20%
6	Performance of contractor on prior ASHRAE projects or other energy projects. (No penalty for new contractors.)	5%

Project Milestones

No.	Major Project Completion Milestone	Deadline Month
1	Sampling program defined with methods & procedures, submittal to PMS for review & approval.	3
2	Data collection complete.	12
3	Submission of project report for review & approval.	13

References

1. ASHRAE RP-601 "Chemical Analysis and Recycling of Used Refrigerant from Field Systems"

2. ASHRAE RP-751 "Experimental Determination of the Effect of Oil on Heat Transfer with Refrigerants HCFC-123 and HFC-134a"
3. ASHRAE RP-1089 "Flooded Evaporation Heat Transfer Performance Investigation for Tube Bundles Including the Effects of Oil Using R410A and R507A"
4. ASHRAE Standard 41.4-2015 Standard Method for Measuring the Proportion of Lubricant in Liquid Refrigerant

5. API MPMS CHAPTER 8.2 (2016) Standard Practice for Automatic Sampling of Petroleum and Petroleum Products, Fourth Edition

6. ASTM D4177-16 "Standard Practice for Automatic Sampling of Petroleum and Petroleum Products"
7. JARN, Japan Air Conditioning, Heating & Refrigeration News, “World Chiller and Large AC Market”, 25-Nov-2012.
8. Westphalen and Koszalinski, Energy Consumption Characteristics of Commercial Building HVAC Systems, Volume I: Chillers, Refrigerant Compressors, and Heating Systems. April 2001.
9. Robinson, D. M., and Thome, J. R., 2004a, “Local Bundle Boiling Heat Transfer Coefficients on a Plain Tube Bundle”, International Journal of HVAC&R Research, Vol. 10, No. 1, pp. 33-52.
10. Brown, M. W., and Bansal, P. K., 1999, “Heat Transfer Characteristics of Boiling Phenomenon in Flooded Refrigerant Evaporators,” Applied Thermal Engineering, Vol. 19, pp. 595-624.
11. Casciaro, S., and Thome, J. R., 2001a, “Thermal Performance of Flooded Evaporators, Part 1: Review of Boiling Heat Transfer Studies,” ASHRAE Transactions, Vol. 107, Part 1, pp. 903-918.
12. Casciaro, S., and Thome, J. R., 2001b, “Thermal Performance of Flooded Evaporators, Part 2: Review of Void Fraction, Two-Phase Pressure Drop, and Flow Pattern Studies,” ASHRAE Transactions, Vol. 107, Part 1, pp. 919-930.
13. Dowlati, R., Kawaji, M., and Chan, A. M. C., 1996, “Two-Phase Crossflow and Boiling Heat Transfer in Horizontal Tube Bundles,” Journal of Heat Transfer, Vol. 118, pp. 124-131.
14. Gorgy, E., and Eckels, S., 2011, “RP-1316 Experimental evaluation of heat transfer impacts of tube pitch on highly enhanced surface tube bundle,” ASHRAE Research Project RP-1316, Final Project Report.
15. Gupte, N. S., and R. L. Webb, 1995a, "Shell-side Boiling in Flooded Refrigerant Evaporators - Part I: Integral Finned Tubes," International Journal of HVAC&R Research, Vol. 1, No. 1, pp. 35-47.
16. Gupte, N. S., and R. L. Webb, 1995b, "Shell-side Boiling in Flooded Refrigerant Evaporators - Part II: Enhanced Tubes," International Journal of HVAC&R Research, Vol. 1, No. 1, pp. 48-60.
17. Gupte, N. S., and R. L. Webb, 1992, "Convective Vaporization of Refrigerants in Tube Banks," ASHRAE Transactions, Vol. 98, Part 2, pp. 411-424.
18. Wujek, Scott S.; Peuker, Steffen; Mai, Helena; Bower, Joseph; Koffler, Matthias; and Hrnjak, Predrag S., "Method for Measuring Oil Contained in Air-Conditioning Components" (2010). International Refrigeration and Air Conditioning Conference. Paper 1035.
19. Goth, Yvon, "Oil Content Measurement in the Liquid Line of Refrigeration Equipments with the Three Transducers Array Method" (2004). International Refrigeration and Air Conditioning Conference. Paper 635.

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