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TO: Forrest Yount, Chair TC 8.2, forrest.yount@carrier.utc.com

FROM: Michael R. Vaughn
Manager of Research and Technical Services

CC: Peter Armstrong, Research Liaison 8.0, parmstr@mit.edu
Curtis Eichelberger, RPS Chair, curtis.eichelberger@jci.com
Mark Adams, Research Subcommittee Chair TC 8.2, mark.a.adams@jci.com
Justin Kauffman, Philip Johnson, Work Statement Author(s), justin.p.kauffman@jci.com; phillip.johnson@daikinapplied.com

DATE: September 19, 2018

SUBJECT: Work Statement (1716-WS), "Oil Concentration of Field Installed Liquid Chillers with Flooded Type Evaporators"

During their recent fall meeting, the Research Administration Committee (RAC) reviewed the subject Work Statement (WS) and voted 10-1-1, CNV to conditionally accept it for bid provided that the RAC approval conditions are addressed to the satisfaction of your Research Liaison in either written responses or revisions to the work statement.

1. Work statement is not biddable in present format.
2. The budget is not adequate. Approximately eight person-months of the Principal Investigator and sixteen person-months of a research assistant are estimated.
3. The scope and tasks need to be better defined. Work statement refers to one compressor, when several different compressors are listed.
4. Does the TC have committed organization? Obtaining commitments from OEM/service organization will be critical to support this project since sampling and shipping costs will be their responsibility and not funded by the project.

See the bottom of the attached WS review summary for the approval conditions.

The WS review summary also contains comments from individual members of RAC that the TC may or may not choose to also consider when revising the WS; some of these comments may indicate areas of the WS where readers require additional information or rewording for clarification.

If PES roster changes are required, please review them with your RL, Peter Armstrong for approval.

Lastly, please provide ASHRAE staff with the final names and contact information for the Proposal Evaluation Subcommittee (PES) roster, and the Technical Contact that will respond to questions from prospective bidders during the bid posting period (typically this is a WS author or PES member). The technical contact and all members of the PES must also agree to not bid on this project.

Please coordinate changes to this Work Statement with your Research Liaison, Peter Armstrong, or RL8@ashrae.net, or Curtis Eichelberger, Curtis.eichelberger@jci.com. Once he is satisfied that the approval conditions have been met, the project will be ready to bid.

The first opportunity that you will have for this project to possibly bid is winter 2019. To be eligible for this bid cycle, a revised work statement that has been approved for bid by your research liaison should be sent (electronically) to Mike Vaughn, Manager of Research and Technical Services, mvaughn@ashrae.org or morts@ashrae.net, before December 15, 2018. The next opportunity for bid after that will be spring 2019.

Project ID	**1716**	
Project Title	**Oil Concentration of Field Installed Liquid Chillers with Flooded Type Evaporators**	
Sponsoring TC	TC 8.2 (Centrifugal Machines)	
Cost / Duration	$135,000 / 12 Months	
Submission History	**2nd Submission, 1st WS Returned S18, RTAR Accepted W14, 1st Submission returned Nov. 2013**	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC 2018 Fall Meeting Review	**RTAR STAGE FOLLOWED**	
Check List Criteria	**Voted NO**	**Comments & Suggestions**
State-of-the-Art (Background): The WS should include some level of literature review that documents the importance/magnitude of a problem. If not, then the WS should be returned for revision. **RTAR Review Criterion**		
Advancement to the State-of-the-Art Is there enough justification for the need of the proposed research. Will this research significantly contribute to the advancement of the State-of-the-Art. **RTAR Review Criterion**		
Relevance and Benefits to ASHRAE: Evaluate whether relevance and benefits are clearly explained in terms of: a. Leading to innovations in the field of HVAC & Refrigeration b. Valuable addition to the missing information which will lead to new design guidelines and valuable modifications to handbooks and standards.		
IF THE THREE CRITERIA ABOVE ARE NOT ALL SATISFIED - MARK "REJECT" BELOW BUT ADDRESS THE FOLLOWING CRITERIA AS APPROPRIATE		
Detailed Bidders List Provided? The contact information in the bidder list should be complete so that each potential bidder can be contacted without difficulty.		**11** - 6 identified. Need email for Imagination Resources.
Proposed Project Description Correct? Are there technical errors and/or technical omissions that the WS has that prevents it from correctly describing the project? If there are, than the WS needs major revision.		**11** - However, this study is focused only on centrifugal chillers and omits screw chillers with flooded evaporators.
Task Breakdown Reasonable? Is the project divided into tasks that make technical and practical sense? Are the results of each task such that the results of the former naturally flow into the latter? If not, then major revisions are needed to the WS that would include: adding tasks, removing tasks, and re-structuring tasks among others.		**11** - The study includes only 2 technical tasks plus a final report task. Task 2 needs to be broken down in subtasks or into more 2 tasks. There is a considerable amount of important info included in the introduction to the Scope. These should be folded into the tasks.
Adequate Intermediate Deliverables? The project should include the review of intermediate results by the PMS at logical milestone points during the project. Before project work continues, the PMS must approve the intermediate results.		**7** - Can this be broken down into 4 or 5 intermediate deliverables? Perhaps the sampling program, methods/procedures and feedback?
Proposed Project Doable? Can the project as described in the WS be accomplished? If difficulties exist in the project's WS that prevent a successful conclusion of the project, then the project is not doable. In this situation, major revision of the WS is needed to resolve the issues that cause the difficulty.		**6** - Obtaining commitments from OEM/service organization will be critical to support project since sampling and shipping costs will be their responsibility and not funded by the project. Does the TC have committed organization? **11** - While the objectives and the summary refer to different compressor types, the WBS addresses only centrifugal chillers.
Time and Cost Estimate Reasonable? The time duration and total cost of the project should be reasonable so that the project can be as it is described in the WS.		**6**- Not sure, the time to analyze a refrigerant oil sample is about 2-3 hours of lab time with 200 samples is about 400 to 600 hours. Coordination may take the most time on obtaining samples and processing them. $110K seems high for this task. Maybe $60-80K?
Proposed Project Biddable? Examining the WS as a whole, is the project described in the WS of sufficient clarity and detail such a potential bidder can actually understand and develop a proposal for the project? This criterion combines the previous three criteria into an overall question concerning the usefulness of the WS. If the WS is considered to not be biddable, then either major revisions are in order or the WS should be rejected.		**6-** Only if they have committed OEMs/service organization lined up by the TC. **11** - After making the changes listed above in the Task descriptions
Decision Options	**Initial Decision**	**Final Approval Conditions**
ACCEPT		**12** - 'I think the WS is well written and suitable for bidding. My only concern is the statement "Approximately eight person-months of the Principal Investigator and sixteen person-months of a research assistant are estimated. The estimated costs include $110,000 for personnel (PI, research assistant, technicians, etc.), $15,000 for equipment and test fluids, and $10,000 for administrative and other miscellaneous costs." I don't know where you can find a bidder that can have a PI working for 8 months and a research assistant for 16 months for only $110,000! Also, as mentioned before - not mentioning the number of chillers to be checked makes its trick point since some bidders may be able to leverage external support and others won't! **6** - Obtaining commitments from OEM/service organization will be critical to support project since sampling and shipping costs will be their responsibility and not funded by the project. Does the TC have committed organization? **7** - See comments for intermediate deliverables. **13 -** In Exec Summary, what are "favorable" or "unfavorable" results and what are "normal" oil concentrations? The handbook chapters that are referred to currently have no references to oil concentration regarding maintenance issues. I also saw no reference to taking samples to measure oil concentration, so it would seem that monitoring of oil concentration in the system is not a currently accepted maintenance practice. On p 3, you don't mention the range of lubricants found in RP 601, so I presume that is of no significance? Is there any reason to describe the equipment, etc. if the oil concentration results are of no significance? Is it really true as you say on page 4 that there are limited data of any kind on chillers that run with R23 and 134a? Since oil and refrigerant mix but oil is not dissolved into the refrigerant, there is no reason to think that the oil concentration will be uniform in a flooded evaporator. There will likely be significant differences in oil concentrations from the bottom of the cooler to the refrigerant free liquid surface and from the inlet to the outlet of the cooler. Since oil return depends on refrigerant flow rate, the oil concentration will likely also change significantly with load. The ASTM and API standards you reference address measuring petroleum products, not drawing a sample of a refrigerant/oil mixture taken from an operating flooded evaporator. How is the person to easily determine the system load of an operating chiller? The field sampling program will be critical to the success of the project. Is the researcher to define the field sampling program and include that in the proposal, or come up with one that satisfies the PMS after they have been selected for the project? If developed later, how will the PES know how good the sampling program will be when they decide which bidder gets the contract? How will the researcher know that anything they come up with will ever be approved by the PMS? Samples taken for free by third parties and shipped to researcher have a high probability of inconsistent sampling technique and uncertain chain of custody, likely producing widely varying results. A project that requires 200 samples will require nearly twice as much effort to conduct as one with 100 samples, so a researcher will not know how to bid their time requirement without knowing in advance the number of samples that the PMS will require them to take. Using 2 refrigerants, 4 age ranges, 5 size ranges, 3 maintenance groups, 2 documentation types, and only 3 test conditions results in 720 different system/test combinations. A sample size of 200 won't come close to providing a valid statistical result. What is required for Task 1 and Task 2 seems to be completely subject to the decision of the PMS during the project. It is doubtful that anyone would bid on the project without a very large contingency factored in without knowing what will be expected of them in terms of both time and effort. There could be considerable differences between a final report, a design guide, and a manual, and the researcher would not know which will be required by Society. How would you charge for 16 months of one research assistant's time in a 12 month project period? Even if the researcher can write up the final report in one month, they rarely are accepted as is by the PMS, so usually require additional time for revisions, not counting the time to write the ASHRAE paper. One month to conclude everything after the last sample has been received is VERY tight. Nine months to identify, contact, and vet 100 to 200 potential pieces of equipment and tech samplers is also very tight. In summary, the scope of the tasks are not well defined, the final results are uncertain, it is unclear how any data will actually be interpreted (normal, favorable, unfavorable??) and the PES would have difficulty determining how any given bidder may perform in completing Task 1.
COND. ACCEPT	**X**	
RETURN		
REJECT		

ACCEPT Vote - Work statement(WS) ready to bid as-is
CONDITIONAL ACCEPT Vote - Minor Revision Required - RL can approve WS for bid without going back to RAC once TC satisfies RAC's approval condition(s) to his/her satisfaction
RETURN Vote - WS requires major revision before it can bid
REJECT Vote - Topic is no longer considered acceptable for the ASHRAE Research Program due to duplication of work by another project or because the work statement has a fatal flaw(s) that makes it unbiddable

WORK STATEMENT COVER SHEET

Date: 22-Jan-2018 - Revised 25-Jun-2018

(Please Check to Insure the Following Information is in the Work Statement)

A. Title	✔
B Executive Summary	✔
C. Applicability to ASHRAE Research Strategic Plan	✔
D. Application of the Results	✔
E. State-of-the-Art (background)	✔
F. Advancement to State-of-the-Art	✔
G. Justification and Value to ASHRAE	✔
H. Objective	✔
I. Scope	✔
J. Deliverables/Where Results will be Published	✔
K. Level of Effort	
Project Duration in Months	✔
Professional-Months: Principal Investigator	✔
Professional-Months: Total	✔
Estimated $ Value	✔
L Proposal Evaluation Criteria & Weighting Factors	✔
M. References	✔
N. Other Information to Bidders (Optional)	✔

Title:
OIL CONCENTRATION OF FIELD-INSTALLED LIQUID CHILLERS WITH FLOODED TYPE EVAPORATORS

WS# 1716
(To be assigned by MORTS - Same as RTAR #)

Results of this Project will affect the following Handbook Chapters, Special Publications, etc.:

Handbook: Volume "HVAC Systems & Equipment", Chapter 43 "Liquid-Chilling Systems"

Handbook: Volume "Refrigeration", Chapter 1 "Halocarbon Refrigeration Systems" and Chapter 46 "Refrigeration in the Chemical Industry"

Responsible TC/TG: 8.2 Centrifugal Machines

Date of Vote: 25-Jun-2018

For		8
Against	*	0
Abstaining	*	0
Absent or not returning Ballot	*	1
Total Voting Members		9

This W/S has been coordinated with TC/TG/SSPC (give vote and date):

No

Has RTAR been submitted?
Strategic Plan
Theme/Goals

Yes

Work Statement Authors: **

Justin Kauffman
Phillip Johnson

Proposal Evaluation Subcommittee:

Chair: Mark Adams (mark.a.adams@jci.com)
Members:
Rick Heiden (rheiden@trane.com)
Phillip Johnson (phillip.johnson@daikinapplied.com)
Scott MacBain (Scott.Macbain@carrier.utc.com)
Mark Rogan (markr@arcticchillergroup.com)
Dwayne Johnson (sk0rp55di@gmail.com)

Project Monitoring Subcommittee:
(If different from Proposal Evaluation Subcommittee)

Recommended Bidders (name, address, e-mail, tel. number): **

1. Hudson Technologies (JRiyaz Papar (rpapar@hudsontech.com; 281 298 0975)
2. Analysts, Inc. [Bureau Veritas] (1-800-655-4473)
3. ChillTek (310-545-7192, info@chilltek.com)
4. Creative Thermal Solutions, Inc. (217-344-7663, info@creativethermalsolutions.com)
5. National Refrigerants Inc. (Rob Yost, 856-455-4555, info@refrigerants.com)
6. Imagination Resources (614 793-1972)

(**Three qualified bidders must be recommended, not including WS authors.**)

Potential Co-funders (organization, contact person information):

Anticipate in-kind support from service organizations (chiller manufacturers or independent providers) to participate in the sampling collection program, to collect refrigerant samples per protocols and submit to the research contractor.

	Yes	No	How Long (weeks)
Is an extended bidding period needed?		✔	
Has an electronic copy been furnished to the MORTS?	✔		
Will this project result in a special publication?		✔	
Has the Research Liaison reviewed work statement?	✔		

* Reasons for negative vote(s) and abstentions

** Denotes WS author is affiliated with this recommended bidder
Use additional sheet if needed.

WORK STATEMENT# 1716

Title:

OIL CONCENTRATION OF FIELD-INSTALLED LIQUID CHILLERS WITH FLOODED TYPE EVAPORATORS

Sponsoring TC/TG/MTG/SSPC:

8.2 Centrifugal Machines

Co-Sponsoring TC/TG/MTG/SSPCs (List only TC/TG/MTG/SSPCs that have voted formal support)

Executive Summary:

This research project will survey the levels of refrigerant side oil fouling found in chillers during actual real world usage. If results are unfavorable, if showing widespread incidence rates of oil system "mis-management" or poor maintenance & service practices, then it would guide future energy conservation practices to focus on removing excess oil and fixing the root cause problems. If results are favorable and oil concentrations are at normal levels, then the project will have demonstrated that chiller energy efficiency degradation over time, if any, is not due to oil system management. This project will focus on centrifugal chillers only but once this study is complete then a follow on separate project could be conducted for screw chillers.

Applicability to the ASHRAE Research Strategic Plan:

This research directly applies to:
Goal 1. Maximize the actual operational energy performance of buildings and facilities
Objective: Sharpen the understanding of the technical, economic, institutional and human factors that contribute to the gap between potential and actual energy performance.
Technical Challenges: Available data strongly suggest that the actual energy use of buildings is often higher than design energy use
Goal 9. Support the development of improved HVAC&R components ranging from residential through commercial to provide improved system efficiency, affordability, reliability and safety
Technical Challenges: Equipment and system designers, installers and maintenance personnel face numerous trade offs and challenges in their efforts to provide efficient and long term cost effective solutions for HVAC&R. Specific shortcomings that need to be addressed include: ... 7) Heat exchanger fouling is a problem that affects the real world efficiency in almost every HVAC&R application.

Application of Results:

Provide data & information to support revisions to guidelines for best maintenance and service practices, for sustaining efficiency levels during the operating life of equipment. Update the ASHRAE Handbook Systems & Equipment Volume (2016, Chapter S43 Liquid-Chilling Systems, such as section 3.7 Operation and Maintenance and section 4.7 Maintenance). Update the ASHRAE Handbook Refrigeration Volume (2014, Chapter R1 Halocarbon Refrigeration Systems, and Chapter R46 Refrigeration in the Chemical Industry).

Provide information for technical programs at ASHRAE conferences (contractor to present technical paper, potential for future follow up with seminar or conference paper sessions on application of the research results).

Provide information for updating ASHRAE education courses, such as "Fundamentals Of Design And Control Of Central Chilled-Water Plants", or "HVAC Design And Operation Training", or "Fundamentals Of Building Operation Maintenance And Management".

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)

Advancement to the State-of-the-Art:

There is limited data available on field-installed chillers running with refrigerants that are commonly available today. The existing ASHRAE research from RP-601 contained a very small sample size and didn't include impact of compressor type, age of equipment, maintenance practices, oil return system design or other factors that may influence the oil concentration. Availability of this data will improve understanding of the value of oil-free technologies that are touted today, provide feedback to manufacturers that may be helpful in design of oil-return systems based upon the condition of field installed chillers after years of operation, and guide owners to use maintenance practices that are shown to minimize the negative impacts of excessive oil concentration.

Justification and Value to ASHRAE:

Prior ASHRAE research has demonstrated the negative effects of high oil concentration on flooded evaporator shell-side heat transfer performance. What has been lacking is an understanding of what oil concentration exists in field installed chillers operating in real world conditions and actual maintenance practices, and what factors influence the oil concentration in field-installed chillers.

The focus of this study is on the types of equipment used in larger commercial air conditioning or refrigeration applications. The equipment typical to this type of application has among the highest initial costs and the highest energy utilization of any in the HVAC&R industry. BSRIA statistics estimate the global market size for positive displacement and centrifugal chillers at approximately $7.61 billion for 2011 [JARN, 2012]. This represents a significant investment by much of the ASHRAE community, including both manufacturers who design and manufacture the equipment and by customers who purchase it. In addition, the energy costs associated with operating this type of equipment over a 20-25 year life cycle will typically be much greater than the initial capital expense. Because of the magnitude of the costs (both direct and long term energy costs) associated with this equipment, even incremental improvements in system performance can provide significant benefits. These benefits extend through ASHRAE and beyond by allowing the construction and installation of more efficient HVAC&R equipment at a constant cost or lower cost equipment at the same efficiency level.

Objectives:

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/Technical Approach:

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.

Scope/Technical Approach (Continued 2):

Scope/Technical Approach (Continued 3):

Deliverables/Where Results Will Be Published:

Progress, Financial and Final Reports, Technical Paper(s), and Data shall constitute the only 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. Unless otherwise specified, six copies of the final report shall be furnished for review by the Society's Project Monitoring Subcommittee (PMS).

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 bound copies
- One unbound copy, printed on one side only, suitable for reproduction.
- Two copies on disks; one in PDF format and one in Microsoft Word.

c. Technical Paper

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 presentation at a Society meeting. The Technical Paper(s) shall conform to the instructions posted in "Manuscript Central" for a technical paper. The technical paper title shall contain the research project number (1716-RP) at the end of the title in parentheses, e.g., (1716-RP).

d. Data

Data is defined in General Condition VI, "DATA"

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.

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

Deliverables/Where Results Will Be Published (Continued):

Level of Effort:

It is expected that this project will take 12 months with an estimated cost of $135,000. This time estimate includes approximately two months for background literature review, survey development, sampling and analysis method definition, and sample bottle definition. Six to seven months are allotted for sample collection and return to researcher. 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 $110,000 for personnel (PI, research assistant, technicians, etc.), $15,000 for equipment and test fluids, and $10,000 for administrative and other miscellaneous costs.

Proposal Evaluation Criteria:

No.	Proposal Review Criterion	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.	2
2	Data collection complete.	11
3	Submission of project report for review & approval.	12

Authors:

This work statement was prepared by Justin Kauffman (justin.p.kauffman@jci.com), staff engineer at Johnson Controls in York, PA and Phillip Johnson (phillip.johnson@daikinapplied.com), engineering director at Daikin Applied in Staunton, VA. It extends past work statement efforts by Parviz Payvar, PhD, Emeritus Professor in the Mechanical Engineering Department at Northern Illinois University, DeKalb, Illinois, and Ben Dingel, Heat Transfer/Thermal Systems Engineer at Trane in La Crosse, Wisconsin.

References:

ASHRAE RP-601 “Chemical Analysis and Recycling of Used Refrigerant from Field Systems”

ASHRAE RP-751 “Experimental Determination of the Effect of Oil on Heat Transfer with Refrigerants HCFC-123 and HFC-134a”

ASHRAE RP-1089 “Flooded Evaporation Heat Transfer Performance Investigation for Tube Bundles Including the Effects of Oil Using R410A and R507A”

ASHRAE Standard 41.4-2015 Standard Method for Measuring the Proportion of Lubricant in Liquid Refrigerant

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

ASTM D4177-16 "Standard Practice for Automatic Sampling of Petroleum and Petroleum Products"

JARN, Japan Air Conditioning, Heating & Refrigeration News, “World Chiller and Large AC Market”, 25-Nov-2012.

Westphalen and Koszalinski, Energy Consumption Characteristics of Commercial Building HVAC Systems, Volume I: Chillers, Refrigerant Compressors, and Heating Systems. April 2001.

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.

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.

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.

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.

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.

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.

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.

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.

Gupte, N. S., and R. L. Webb, 1992, "Convective Vaporization of Refrigerants in Tube Banks," ASHRAE Transactions, Vol. 98, Part 2, pp. 411-424.

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.

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.

http://www.hudsontech.com/wp-content/uploads/2015/09/ChillSMART_Example.pdf
http://www.ddpsinc.com/de-dietrich-expertise/sampling

Other Information for Bidders (Optional):

The intent of this study is to supplement and extend the work conducted in previous ASHRAE and academic studies by examining a combination of variables and refrigerants not specifically targeted by previous work. In terms of related work, the final report of RP-1089 can provide background on the need for the work. ASHRAE Standard 41.4-2015, Standard Method for Measurement of Proportion of Lubricant in Liquid Refrigerant, shall be reviewed.

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

1. Statements describing facilities, equipment, capabilities, procedures, methods, etc., to be used to meet the objectives defined in this work statement.
2. Statements indicating experience in conducting research related to fluid concentration measurement and statistical data analysis.
3. Resumes of the principal investigator and others involved in the study.
4. Planned schedule and length of time for the project to be completed.
5. Budget information.

Feedback to RAC and Suggested Improvements to Work Statement Process

Now that you have completed the work statement process, RAC is interested in getting your feedback and suggestions here on how we can improve the process.

ASHRAE Inc • 1791 Tullie Circle, NE • Atlanta, Georgia 30329-2305 ☎404-636-8400 • Fax 404-321-5478

T.C. 8.2 CENTRIFUGAL MACHINES
TC 8.2 Research Subcommittee August 6, 2018

Subject: **WS - 1716 - Oil concentration of field-installed liquid chillers with flooded type evaporators.**

To: **Michael Vaughn & Research Administration Committee (RAC)**

From: **Mark Adams**

Response from TC 8.2 to comments on our WS. We have revised the WS, reviewed it with our RL, and it was re-voted to approve it at the Houston meeting.

1. The project will be hard to execute (relies on OEMs to provide in kind access to equipment) and the samples reliability is suspect because of running conditions, application conditions and climate zone differences) to name a few. – We understand your concerns and have discussed this among the committee but we believe we can manage this. Our proposal is that the investigator will be provided lists of chillers to choose from and using DOA or other method to select a sampling list that can address this variability. As part of the scope of the project the investigator will establish the rules for taking the samples to control the conditions and provide statistical valid set of conditions to cover the range of typical chiller applications.
2. Not clear to me if all the bidder had detailed information enough to bid the project. We have enhanced the Scope/Technical Approach section of the WS to provide additional information to allow someone to bid this project.
3. Need further clarity on selection criteria for chiller samples. We have removed Screw Chillers from the scope of this project to shrink the scope. The plan is to give much of this to the investigator. Since the chiller manufactures are providing the samples we deliberately wanted this selection to be completed by the investigator such that the selection is based on statistical analysis to avoid any appearance of bias by the chiller manufacturers.
4. The WS as written does not provide enough detail about the scope and scale of the testing to support good comparative bidding. More detail about the sampling/testing and the number of test required (range of equipment) needs to be provided. Needs selection criteria and milestones. We have enhanced the Scope/Technical Approach section of the WS to provide additional information to allow someone to bid this project. We have removed Screw Chillers to limit the scope. We have added a range of the number of samples to be analyzed. We have added additional instructions to the investigator to further define their scope to give them more information to bid this project.

Respectfully submitted,
Mark Adams
Research Subcommittee Chair

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Michael R. Vaughn, P.E.
Manager
Research & Technical Services

mvaughn@ashrae.org

TO: Forrest Yount, Chair TC 8.2, forrest.yount@carrier.utc.com
Mark Adams, Research Subcommittee Chair TC 8.2, mark.a.adams@jci.com
Curtis Eichelberger, Research Liaison Section 8.0, Curtis.eichelberger@jci.com

FROM: Michael Vaughn, MORTS, MORTS@ASHRAE.net

DATE: April 18, 2018

SUBJECT: Work Statement (1716-WS), "Oil Concentration of Field Installed Liquid Chillers wit Flooded Type Evaporators"

During their recent spring meeting, the Research Administration Committee (RAC) reviewed the subject Work Statement (WS) and voted to return with comments.

Below are the issues, concerns, and questions that must be addressed in your next submission of the WS if you choose to resubmit.

1. The project will be hard to execute (relies on OEMs to provide in kind access to equipment) and the samples reliability is suspect because of running conditions, application conditions and climate zone differences) to name a few.
2. Not clear to me if all the bidder had detailed information enough to bid the project.
3. Need further clarity on selection criteria for chiller samples.
4. The WS as written does not provide enough detail about the scope and scale of the testing to support good comparative bidding. More detail about the sampling/testing and the number of test required (range of equipment) needs to be provided. Needs selection criteria and milestones.

Please coordinate changes to this Work Statement with your Research Liaison Curtis Eichelberger, Curtis.eichelberger@jci.com or RL8@ashrae.org prior to resubmitting it to the Manager of Research and Technical Services for further consideration by RAC.

Also, it is necessary that you provide a new TC vote on the revised Work Statement, and a letter describing how each of the above items were addressed in the revision.

If you wish for this work statement to be reconsidered at the next RAC meeting, the revised Work Statement must be sent (electronically) to Mike Vaughn, Manager of Research and Technical Services (morts@ashrae.net) by **May 15, 2018**. The next opportunity for consideration after this deadline is August 15, 2018.

Project ID	**1716**	
Project Title	**OIL CONCENTRATION OF FIELD-INSTALLED LIQUID CHILLERS WITH FLOODED TYPE EVAPORATORS**	
Sponsoring TC	TC 08.02, (Centrifugal Machines)	
Cost / Duration	$135,000 / 12 Months	
Submission History	**1st WS Submission, RTAR Accepted W14, 1st Submission returned Nov. 2013**	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC 2018 Spring Meeting Review	**RTAR STAGE FOLLOWED**	
Check List Criteria	**Voted NO**	**Comments & Suggestions**
State-of-the-Art (Background): The WS should include some level of literature review that documents the importance/magnitude of a problem. If not, then the WS should be returned for revision. **RTAR Review Criterion**		
Advancement to the State-of-the-Art Is there enough justification for the need of the proposed research. Will this research significantly contribute to the advancement of the State-of-the-Art. **RTAR Review Criterion**		
Relevance and Benefits to ASHRAE: Evaluate whether relevance and benefits are clearly explained in terms of: a. Leading to innovations in the field of HVAC & Refrigeration b. Valuable addition to the missing information which will lead to new design guidelines and valuable modifications to handbooks and standards. Is this research topic appropriate for ASHRAE funding? If not, Reject. **RTAR Review Criterion**		**#6**- This appears to be a very worthwhile project
IF THE THREE CRITERIA ABOVE ARE NOT ALL SATISFIED - MARK "REJECT" BELOW BUT ADDRESS THE FOLLOWING CRITERIA AS APPROPRIATE		
Detailed Bidders List Provided? The contact information in the bidder list should be complete so that each potential bidder can be contacted without difficulty.		**#11**- 6 potential bidders identified
Proposed Project Description Correct? Are there technical errors and/or technical omissions that the WS has that prevents it from correctly describing the project? If there are, than the WS needs major revision.		**#11**- While the results of this proposed project, if successfully implemented, will be valuable, the number of possible combinations of the tested compressor types - screw (oil-flooded with separators) & centrifugal; semi-hermitic & open-drive, manufacturers, refrigerants, ages, capacities, etc. is very large and it is doubtful that sufficient data will be obtained to derive meaningful statistical inferences and recommendations in a 12 month study of such a wide range of alternative combinations. We may end up with another set of anecdotal results that cannot be generalized in a list of useful recommendations. Will chiller manufacturers modify their designs based on the recommendations of this project? Will HCFC R123 continue to be used in the future? Also, will the results and recommendations of such a project be applicable to new low-GWP refrigerants such as R1233zd?
Task Breakdown Reasonable? Is the project divided into tasks that make technical and practical sense? Are the results of each task such that the results of the former naturally flow into the latter? If not, then major revisions are needed to the WS that would include: adding tasks, removing tasks, and re-structuring tasks among others.		**#6** - I would like to see task 1 broken down in more detail. The bidders should be given specifics requirements. The WS states " The researcher will define a field sampling program, with requirements for site & chiller selection, data collection requirements, sampling methods, and participant qualifications." which is fine once the project is awarded but the WS should be give more specific guidelines to the bidders. Would the bidder know what the PES is looking for? **#11** - The WBS includes 3 Tasks. Task 2 is described with reasonable detail, however, Task 1 lacks detail and needs to be amplified to include some of the information provided in the Guidelines listed above the list of Tasks, i.e., the information provided as guidelines in part or in full should be included in Task descriptions (tasks could be divided into subtasks to facilitate this).
Adequate Intermediate Deliverables? The project should include the review of intermediate results by the PMS at logical milestone points during the project. Before project work continues, the PMS must approve the intermediate results.		**#8** - Seems to be a need for more definition of who and how the samples will be collected and solicited. Will this be region specific or brand specific?
Proposed Project Doable? Can the project as described in the WS be accomplished? If difficulties exist in the project's WS that prevent a successful conclusion of the project, then the project is not doable. In this situation, major revision of the WS is needed to resolve the issues that cause the difficulty.		**#11**- It is doubtful that sufficient data will be collected within 12 months that will encompass in a statistically meaningful manner the scope of this work given the potentially large number of possible combinations of chiller configurations and maintenance practices. It may be more useful if the range of combinations is reduced, e.g., focus on centrifugal chillers only
Time and Cost Estimate Reasonable? The time duration and total cost of the project should be reasonable so that the project can be as it is described in the WS.		**#11**- Too low given the potentially large number of combinations.
Proposed Project Biddable? Examining the WS as a whole, is the project described in the WS of sufficient clarity and detail such a potential bidder can actually understand and develop a proposal for the project? This criterion combines the previous three criteria into an overall question concerning the usefulness of the WS. If the WS is considered to not be biddable, then either major revisions are in order or the WS should be rejected.		**#8** - Without clarity on the selection of the "field sampling program", It can be difficult for bidder to identify a wide and valid sampling to candidate chillers.
Decision Options	**Initial Decision**	**Final Approval Conditions**
ACCEPT		**#5** - I conditional accept because I think the project will be hard to execute (relies on OEMs to provide in kind access to equipment) and the samples reliability is suspect because of running conditions, application conditions and climate zone differences) to name a few. The previous study had it faults and this study would be beneficial in expanding the industry knowledge, Wondering why AHRI doesn't have an ARTI project in this area to gain industry involvement more easily. We would need the OEM's to line up before sending this proposal out for bid and identify the job sites to know that their is a represented sampling .plan. **#6-** This is a well written WS. The reason for return is that it was not clear to me if all the bidder had detailed information enough to bid the project. **#8** - Need further clarity on selection criteria for chiller samples. **#12** - this is a well written WS and covers all the required elements nicely. Suggest to accept it as is. **#13** - The justification for the work verifies that this work should produce useful results. The WS as written does not provide enough detail about the scope and scale of the testing to support good comparative bidding. More detail about the sampling/testing and the number of test required (range of equipment) needs to be provided. Needs selection criteria and milestones.
COND. ACCEPT		
RETURN		
REJECT		

ACCEPT Vote - Work statement(WS) ready to bid as-is
CONDITIONAL ACCEPT Vote - Minor Revision Required - RL can approve WS for bid without going back to RAC once TC satisfies RAC's approval condition(s) to his/her satisfaction
RETURN Vote - WS requires major revision before it can bid
REJECT Vote - Topic is no longer considered acceptable for the ASHRAE Research Program due to duplication of work by another project or because the work statement has a fatal flaw(s) that makes it unbiddable

WORK STATEMENT COVER SHEET

Date: 22-Jan-2018 - Revised 25-Jun-2018

(Please Check to Insure the Following Information is in the Work Statement)

A. Title	✔
B Executive Summary	✔
C. Applicability to ASHRAE Research Strategic Plan	✔
D. Application of the Results	✔
E. State-of-the-Art (background)	✔
F. Advancement to State-of-the-Art	✔
G. Justification and Value to ASHRAE	✔
H. Objective	✔
I. Scope	✔
J. Deliverables/Where Results will be Published	✔
K. Level of Effort	
Project Duration in Months	✔
Professional-Months: Principal Investigator	✔
Professional-Months: Total	✔
Estimated $ Value	✔
L Proposal Evaluation Criteria & Weighting Factors	✔
M. References	✔
N. Other Information to Bidders (Optional)	✔

Title:
OIL CONCENTRATION OF FIELD-INSTALLED LIQUID CHILLERS WITH FLOODED TYPE EVAPORATORS

WS# 1716
(To be assigned by MORTS - Same as RTAR #)

Results of this Project will affect the following Handbook Chapters, Special Publications, etc.:

Handbook: Volume "HVAC Systems & Equipment", Chapter 43 "Liquid-Chilling Systems"

Handbook: Volume "Refrigeration", Chapter 1 "Halocarbon Refrigeration Systems" and Chapter 46 "Refrigeration in the Chemical Industry"

Responsible TC/TG: 8.2 Centrifugal Machines

Date of Vote: 25-Jun-2018

For		8
Against	*	0
Abstaining	*	0
Absent or not returning Ballot	*	1
Total Voting Members		9

This W/S has been coordinated with TC/TG/SSPC (give vote and date):

No

Has RTAR been submitted?
Strategic Plan
Theme/Goals

Yes

Work Statement Authors: **

Justin Kauffman
Phillip Johnson

Proposal Evaluation Subcommittee:

Chair: Mark Adams (mark.a.adams@jci.com)
Members:
Rick Heiden (rheiden@trane.com)
Phillip Johnson (phillip.johnson@daikinapplied.com)
Scott MacBain (Scott.Macbain@carrier.utc.com)
Mark Rogan (markr@arcticchillergroup.com)
Dwayne Johnson (sk0rp55di@gmail.com)

Project Monitoring Subcommittee:
(If different from Proposal Evaluation Subcommittee)

Recommended Bidders (name, address, e-mail, tel. number): **

1. Hudson Technologies (JRiyaz Papar (rpapar@hudsontech.com; 281 298 0975)
2. Analysts, Inc. [Bureau Veritas] (1-800-655-4473)
3. ChillTek (310-545-7192, info@chilltek.com)
4. Creative Thermal Solutions, Inc. (217-344-7663, info@creativethermalsolutions.com)
5. National Refrigerants Inc. (Rob Yost, 856-455-4555, info@refrigerants.com)
6. Imagination Resources (614 793-1972)

(**Three qualified bidders must be recommended, not including WS authors.**)

Potential Co-funders (organization, contact person information):

Anticipate in-kind support from service organizations (chiller manufacturers or independent providers) to participate in the sampling collection program, to collect refrigerant samples per protocols and submit to the research contractor.

	Yes	No	How Long (weeks)
Is an extended bidding period needed?		✔	
Has an electronic copy been furnished to the MORTS?	✔		
Will this project result in a special publication?		✔	
Has the Research Liaison reviewed work statement?	✔		

* Reasons for negative vote(s) and abstentions

** Denotes WS author is affiliated with this recommended bidder
Use additional sheet if needed.

WORK STATEMENT# 1716

Title:

OIL CONCENTRATION OF FIELD-INSTALLED LIQUID CHILLERS WITH FLOODED TYPE EVAPORATORS

Sponsoring TC/TG/MTG/SSPC:

8.2 Centrifugal Machines

Co-Sponsoring TC/TG/MTG/SSPCs (List only TC/TG/MTG/SSPCs that have voted formal support)

Executive Summary:

This research project will survey the levels of refrigerant side oil fouling found in chillers during actual real world usage. If results are unfavorable, if showing widespread incidence rates of oil system "mis-management" or poor maintenance & service practices, then it would guide future energy conservation practices to focus on removing excess oil and fixing the root cause problems. If results are favorable and oil concentrations are at normal levels, then the project will have demonstrated that chiller energy efficiency degradation over time, if any, is not due to oil system management. This project will focus on centrifugal chillers only but once this study is complete then a follow on separate project could be conducted for screw chillers.

Applicability to the ASHRAE Research Strategic Plan:

This research directly applies to:
Goal 1. Maximize the actual operational energy performance of buildings and facilities
Objective: Sharpen the understanding of the technical, economic, institutional and human factors that contribute to the gap between potential and actual energy performance.
Technical Challenges: Available data strongly suggest that the actual energy use of buildings is often higher than design energy use
Goal 9. Support the development of improved HVAC&R components ranging from residential through commercial to provide improved system efficiency, affordability, reliability and safety
Technical Challenges: Equipment and system designers, installers and maintenance personnel face numerous trade offs and challenges in their efforts to provide efficient and long term cost effective solutions for HVAC&R. Specific shortcomings that need to be addressed include: ... 7) Heat exchanger fouling is a problem that affects the real world efficiency in almost every HVAC&R application.

Application of Results:

Provide data & information to support revisions to guidelines for best maintenance and service practices, for sustaining efficiency levels during the operating life of equipment. Update the ASHRAE Handbook Systems & Equipment Volume (2016, Chapter S43 Liquid-Chilling Systems, such as section 3.7 Operation and Maintenance and section 4.7 Maintenance). Update the ASHRAE Handbook Refrigeration Volume (2014, Chapter R1 Halocarbon Refrigeration Systems, and Chapter R46 Refrigeration in the Chemical Industry).

Provide information for technical programs at ASHRAE conferences (contractor to present technical paper, potential for future follow up with seminar or conference paper sessions on application of the research results).

Provide information for updating ASHRAE education courses, such as "Fundamentals Of Design And Control Of Central Chilled-Water Plants", or "HVAC Design And Operation Training", or "Fundamentals Of Building Operation Maintenance And Management".

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)

Advancement to the State-of-the-Art:

There is limited data available on field-installed chillers running with refrigerants that are commonly available today. The existing ASHRAE research from RP-601 contained a very small sample size and didn't include impact of compressor type, age of equipment, maintenance practices, oil return system design or other factors that may influence the oil concentration. Availability of this data will improve understanding of the value of oil-free technologies that are touted today, provide feedback to manufacturers that may be helpful in design of oil-return systems based upon the condition of field installed chillers after years of operation, and guide owners to use maintenance practices that are shown to minimize the negative impacts of excessive oil concentration.

Justification and Value to ASHRAE:

Prior ASHRAE research has demonstrated the negative effects of high oil concentration on flooded evaporator shell-side heat transfer performance. What has been lacking is an understanding of what oil concentration exists in field installed chillers operating in real world conditions and actual maintenance practices, and what factors influence the oil concentration in field-installed chillers.

The focus of this study is on the types of equipment used in larger commercial air conditioning or refrigeration applications. The equipment typical to this type of application has among the highest initial costs and the highest energy utilization of any in the HVAC&R industry. BSRIA statistics estimate the global market size for positive displacement and centrifugal chillers at approximately $7.61 billion for 2011 [JARN, 2012]. This represents a significant investment by much of the ASHRAE community, including both manufacturers who design and manufacture the equipment and by customers who purchase it. In addition, the energy costs associated with operating this type of equipment over a 20-25 year life cycle will typically be much greater than the initial capital expense. Because of the magnitude of the costs (both direct and long term energy costs) associated with this equipment, even incremental improvements in system performance can provide significant benefits. These benefits extend through ASHRAE and beyond by allowing the construction and installation of more efficient HVAC&R equipment at a constant cost or lower cost equipment at the same efficiency level.

Objectives:

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/Technical Approach:

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.

Scope/Technical Approach (Continued 2):

Scope/Technical Approach (Continued 3):

Deliverables/Where Results Will Be Published:

Progress, Financial and Final Reports, Technical Paper(s), and Data shall constitute the only 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. Unless otherwise specified, six copies of the final report shall be furnished for review by the Society's Project Monitoring Subcommittee (PMS).

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 bound copies
- One unbound copy, printed on one side only, suitable for reproduction.
- Two copies on disks; one in PDF format and one in Microsoft Word.

c. Technical Paper

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 presentation at a Society meeting. The Technical Paper(s) shall conform to the instructions posted in "Manuscript Central" for a technical paper. The technical paper title shall contain the research project number (1716-RP) at the end of the title in parentheses, e.g., (1716-RP).

d. Data

Data is defined in General Condition VI, "DATA"

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.

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

Deliverables/Where Results Will Be Published (Continued):

Level of Effort:

It is expected that this project will take 12 months with an estimated cost of $135,000. This time estimate includes approximately two months for background literature review, survey development, sampling and analysis method definition, and sample bottle definition. Six to seven months are allotted for sample collection and return to researcher. 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 $110,000 for personnel (PI, research assistant, technicians, etc.), $15,000 for equipment and test fluids, and $10,000 for administrative and other miscellaneous costs.

Proposal Evaluation Criteria:

No.	Proposal Review Criterion	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.	2
2	Data collection complete.	11
3	Submission of project report for review & approval.	12

Authors:

This work statement was prepared by Justin Kauffman (justin.p.kauffman@jci.com), staff engineer at Johnson Controls in York, PA and Phillip Johnson (phillip.johnson@daikinapplied.com), engineering director at Daikin Applied in Staunton, VA. It extends past work statement efforts by Parviz Payvar, PhD, Emeritus Professor in the Mechanical Engineering Department at Northern Illinois University, DeKalb, Illinois, and Ben Dingel, Heat Transfer/Thermal Systems Engineer at Trane in La Crosse, Wisconsin.

References:

ASHRAE RP-601 “Chemical Analysis and Recycling of Used Refrigerant from Field Systems”

ASHRAE RP-751 “Experimental Determination of the Effect of Oil on Heat Transfer with Refrigerants HCFC-123 and HFC-134a”

ASHRAE RP-1089 “Flooded Evaporation Heat Transfer Performance Investigation for Tube Bundles Including the Effects of Oil Using R410A and R507A”

ASHRAE Standard 41.4-2015 Standard Method for Measuring the Proportion of Lubricant in Liquid Refrigerant

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

ASTM D4177-16 "Standard Practice for Automatic Sampling of Petroleum and Petroleum Products"

JARN, Japan Air Conditioning, Heating & Refrigeration News, “World Chiller and Large AC Market”, 25-Nov-2012.

Westphalen and Koszalinski, Energy Consumption Characteristics of Commercial Building HVAC Systems, Volume I: Chillers, Refrigerant Compressors, and Heating Systems. April 2001.

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.

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.

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.

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.

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.

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.

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.

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.

Gupte, N. S., and R. L. Webb, 1992, "Convective Vaporization of Refrigerants in Tube Banks," ASHRAE Transactions, Vol. 98, Part 2, pp. 411-424.

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.

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.

http://www.hudsontech.com/wp-content/uploads/2015/09/ChillSMART_Example.pdf
http://www.ddpsinc.com/de-dietrich-expertise/sampling

Other Information for Bidders (Optional):

The intent of this study is to supplement and extend the work conducted in previous ASHRAE and academic studies by examining a combination of variables and refrigerants not specifically targeted by previous work. In terms of related work, the final report of RP-1089 can provide background on the need for the work. ASHRAE Standard 41.4-2015, Standard Method for Measurement of Proportion of Lubricant in Liquid Refrigerant, shall be reviewed.

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

1. Statements describing facilities, equipment, capabilities, procedures, methods, etc., to be used to meet the objectives defined in this work statement.
2. Statements indicating experience in conducting research related to fluid concentration measurement and statistical data analysis.
3. Resumes of the principal investigator and others involved in the study.
4. Planned schedule and length of time for the project to be completed.
5. Budget information.

Feedback to RAC and Suggested Improvements to Work Statement Process

Now that you have completed the work statement process, RAC is interested in getting your feedback and suggestions here on how we can improve the process.

Shaping Tomorrow's Built Environment Today

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Manager Research & Technical Services

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TO: Rick Heiden, Chair TC 8.2, rheiden@trane.com
Mark Adams, Research Subcommittee Chair TC 8.2, mark.a.adams@jci.com
David Yashar, Research Liaison Section 8.0, david.yashar@nist.gov

FROM: Michael Vaughn, MORTS, mvaughn@ashrae.org

DATE: February 12, 2014

SUBJECT: Research Topic Acceptance Request (1716-RTAR), "Oil Concentration of Field-installed Liquid Chillers with Flooded Type Evaporators"

At their winter meeting, the Research Administration Committee (RAC) reviewed the subject Research Topic Acceptance Request (RTAR) and voted to accept it for further development into a work statement (WS).

An RTAR evaluation sheet is attached as additional information and it provides a breakdown of comments and questions from individual RAC members based on a specific review criteria. This should give you an idea of how your RTAR is being interpreted and understood by others. Some of these comments may indicate areas of the RTAR and subsequent WS where readers require additional information or rewording for clarification.

The first draft of the work statement should be submitted to RAC no later **December 15, 2015** or it will be dropped from display on the Society's Research Implementation Plan. The next submission deadline for work statements is **May 15, 2014** for consideration at RAC's 2014 annual meeting. The submission deadline after that for work statements is August 15, 2014 for consideration at RAC's 2014 fall meeting.

Project ID	**1716**	
Project Title	**Oil Concentration of Field-installed Liquid Chillers with Flooded Type Evaporators**	
Sponsoring TC	TC 8.2, Centrifugal Machines	
Cost / Duration	$175,000 / 12 Months	
Submission History	**RTAR 2nd Submission, 1st Submission returned Nov. 2013**	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC 2014 Winter Meeting Review		
Check List Criteria	**VOTED NO**	**Comments & Suggestions**
Is there a well-established need? The RTAR should include some level of literature review that documents the importance/magnitude of a problem. If not, then the RTAR should be returned for revision.	**#8**	**#5** - A blind study of this type will provide data useful to manufacturers and end users to allow for improvement in design and operation. **#4** - AHRTI has voted to support the project, which should indicate industry wide chiller manufacturer support. **#6** - I'm quite satisfied that they have established the need, and I feel also that there is a strong need to understand HX fouling better. The literature search is fine. **#8** - The data might be useful to chiller manufacturers, if a lot of details are provided. However, if this is an important issue and not much data are yet available, why do not the manufacturers try to collect such data for their products? Who else could benefit from this study is also not very clear. **#2** - letter of co-funding support from AHRI, and comments from 1st submission well addressed.
Is this appropriate for ASHRAE funding? If not, then the RTAR should be rejected. Examples of projects that are not appropriate for ASHRAE funding would include: 1) research that is more appropriately performed by industry, 2) topics outside the scope of ASHRAE activities.	**#8**	**#6** - Yes, if there is substantial cost-share with industry (ARTI) and if owners and maintenance organizations will do the necessary leg work to provide samples. Just for the heck of it, how can a small high-pressure refrigerant sample be shipped to a lab? How do we get a good sample? **#8** - I think the project is more appropriately performed by industry.
Is there an adequate description of the approach in order for RAC to be able to evaluate the appropriateness of the budget? If not, then the RTAR should be returned for revision.		**#4** - Would like to see more detail in the data mapping output. **#6** - The description is good. What I don't understand is how much this approach would contribute. At its heart, it seems to be a mass balance effort: From concentration of oil in refrigerant, known system volume , refrigerant and oil charges, the difference "should" be oil on the surfaces of the HX. This proposal assumes that all of these are pretty precisely known from field records and OEM specs, and that there is no surface deposition in areas like the large suction line surface, or the evaporator. Can the approach work? My other challenge is that there is no effort to look at the "power" of the experiment: Is the number of chillers to be tested even near the ball park of the number that need to tested for the statistical validity they seek, or should they restrict the study to a smaller class of chillers?
Is the budget reasonable for the project scope? If not, then RTAR could be returned for revision or conditionally accepted with a note that the budget should be revised for the WS.	**#8**	**#4** - The time duration of 12 months seems too short to pull this data together. **#6** - The budget is not expressed in terms of effort-day estimates for the tasks (field study, sample analysis, data analysis, report development, etc.), so I can't even begin to estimate whether the budget is reasonable. This ties into the concerns about statistical power -- but also into my reservations of continually ratcheting up our expectations and adding new concerns at each review round. **#8**- Cannot judge - the level of efforts to make these measurements was not elaborated.
Have the proper administrative procedures been followed? This includes recording of the TC vote, coordination with other TCs, proper citing of the Research Strategic Plan, etc. If not, then the RTAR could be returned for revision or possibly conditionally accepted based on adequately resolving these issues.	**#13**	**#4** Concerned about the 1 negative vote on the original submittal. Would like to see a new vote and whether the concerns have been addressed. **#13** - Would like to know reason for no and abstain vote for AHRI refrigerant committee. **#6**- I continue to assume that it doesn't get to me unless the list has been checked by staff.

Decision Options	**Initial Decision**	**Approval Conditions**
ACCEPT	**X**	**#5**- Move the project forward to allow review of WS. **#4** - Feel there is enough justification to go on to the WS phase. **#13** - I approve based on the condition that the following conditions are met at the work statement stage: 1. Co-funding from AHRI/AHRTI, and 2. mostly positive response and in-kind support from chiller manufacturers. **#6** -Need to understand that this approach has some chance of success, even if relatively high risk.
COND. ACCEPT		
RETURN		
REJECT		

ACCEPT Vote - Topic is ready for development into a work statement (WS).
COND. ACCEPT Vote - Minor Revision Required - RL can approve RTAR for development into WS without going back to RAC once TC satisfies RAC's approval condition(s)
RETURN Vote - Topic is probably acceptable for ASHRAE research, but RTAR is not quite ready.
REJECT Vote - Topic is not acceptable for the ASHRAE Research Program

Unique Tracking Number Assigned by MORTS 1716

RESEARCH TOPIC ACCEPTANCE REQUEST (RTAR) FORM

(Generally 2 to 6 pages, with 10 pt Times New Roman font)

Sponsoring TC/TG/MTG/SSPC/EHC/REF: TC8.2

Title:

Oil concentration survey of field-installed liquid chillers with flooded type evaporators.

Applicability to ASHRAE Research Strategic Plan:

This research topic supports Goal 9 of the 2010-2015 plan.

> Goal 9: Support the development of improved HVAC&R components ranging from residential through commercial to provide improved system efficiency, affordability, reliability and safety.

The proposed topic addresses the following technical challenges and needed areas of research for Goal 9:

- "Potential system contaminates in new refrigerants and their effects on system performance and reliability have not been fully investigated."
- "Heat exchanger fouling is a problem that affects the real world efficiency in almost every HVAC&R application."
- "Conduct studies and experiments to support development of maximum allowable levels for individual or combinations of contaminates in refrigerant systems that use newly developed refrigerants. These studies should include the impact of the contaminants on system performance and durability."
- "Conducting studies and experiments to fully optimize system performance."

Research Classification:

Basic/Applied Research

TC/TG/MTG/SSPC Vote:
(For-Against-Abstentions-Absent-Total)
8-1-1-0-10

Reasons for Negative Votes and Abstentions:
(Negative Votes) 1 - Concerned about too much variability in measurement, refrigerant sampling could be inconsistent and inconclusive.
(Abstentions) 1 - Member is not active and felt he had insufficient information to vote.

Estimated Cost:
$100k—$175k

Estimated Duration:
12 Months

RTAR Lead Author
Justin P. Kauffman, justin.p.kauffman@jci.com

Expected Work Statement Lead Author
Justin P. Kauffman, justin.p.kauffman@jci.com

Co-sponsoring TC/TG/MTG/SSPCs and votes:

None

Possible Co-funding Organizations:

1) AHRI/AHRTI refrigerant committee voted by letter ballot in support of this research proposal and to continue exploring co-funding if the RTAR is approved (R.Choski 12/11/13 vote, 9-1-4, yes-no-abstain)

2) TC 8.2 is submitting a letter of inquiry to chiller manufacturers with request for participation level to be submitted to ASHRAE by January 10th. Anticipate support to identify potential chiller locations, provide service technician support to collect refrigerant samples and submit samples to the research contractor. Manufacturers may also conduct sample analysis and submit results to the research contractor.

Application of Results:
Research results will be applied as follows:

1. Compare maintenance practices on oil management and develop best practices for the industry. This could be used by owners to maintain the efficiency of their chillers.
2. With the pressure on efficiency and the adverse effect of oil on performance this study will show manufacturers the long term effectiveness of their oil return systems. This data could be used to improve this performance.
3. Allow manufactures to understand the performance of their oil return systems in comparison to industry average and allow them to improve the designs. This is only possible with a blind cross sectional study like this.
4. Update ASHRAE handbooks broadening statements for equipment designers, owners and operators for proper equipment system design consideration and state of the art maintenance practices for maintaining oil levels that do not significantly impact chiller performance. Specific handbook chapters include HVAC Systems and Equipment Handbook Liquid Chilling Systems (Chapter 43) and Compressors (Chapter 39) and possibly Refrigeration Handbook Refrigerant System Chemistry (Chapter 6).

State-of-the-Art (Background):
In chillers with a flooded-type evaporator, oil that escapes the compressor and oil sump is a refrigerant system contaminate and has potential to negatively impact heat exchanger effectiveness and thereby chiller performance. As such oil must be carefully managed through chiller system design and maintenance practices. However, currently ASHRAE handbooks do not contain guidance for typical or acceptable levels of this contaminate in flooded evaporators nor have many works been published at ASHRAE sponsored conferences. In general, at some oil concentration level and depending on the tube surface geometry oil logging begins to negatively impact heat transfer and thereby significantly degrade chiller capacity and chiller efficiency. The extent to which depends on bundle arrangement, tube enhancement and refrigerant/oil types along with dependencies on operating conditions. Several works have been published on this topic and the state of the art is typically managed by TC 8.5 Heat Transfer. However, only one known work has been published on the amount of oil typically found in liquid chilling packages.

To manage oil in chillers, manufacture of both low and high pressure machines have designed oil recovery systems and in some cases oil free chillers to address this issue. However, very little data has been collected and published for oil concentration in field installed operating systems to determine the effectiveness of these systems and associated field maintenance practices. Although previous ASHRAE research has been conducted, and is often cited as a definitive reference source in marketing literature, the data is extremely sparse, was conducted on refrigerants that are no longer used and was statistically insignificant. Chiller manufacturers and chiller operators need factual data to determine typical in-situ oil concentrations in order to provide the operational data necessary to advance system designs to improve oil recovery system effectiveness and also advance chiller maintenance practices (i.e. oil addition guidelines). Alternatively, this data may also indicate the scope of oil loss problems is limited to a relatively small subset of the chiller population, system designs or maintenance practice. In other words,

is this "much ado about nothing", or is there a serious oil contamination problem to be solved to ensure that chillers operate as efficiently as when they left the factory.

ASHRAE RP-601, completed in April 1990, is titled "Chemical Analysis and Recycling of Used Refrigerant from Field Systems." The project was performed to "identify and quantify typical contaminant levels in used refrigerant samples obtained from R-11 systems, 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)." Residual oil in refrigerant samples was considered one of the contaminants of interest.

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
- although ten centrifugal chillers were studied:
    - all used R-11
    - all were located on one university campus, with one set of operation & maintenance practices
    - the R-11 chillers covered the narrow range of 200-500 tons
    - one R-12 chiller was tested, but it was a very small instrument process chiller rated for 0.75 hp.

The following ASHRAE research projects provide background on the need to understand actual oil concentration levels in flooded type evaporators, due to the impact on chiller efficiency and energy consumption.

ASHRAE RP-751 was motivated to provide refrigerant-side heat transfer coefficients in a bundle segment in a way that would be of direct applicability in the rational design of flooded evaporators. Integral finned (26 FPI) and Turbo-B2 (low pressure version) tube bundles were tested with refrigerant R-123 and various concentrations of mineral oil. 26FPI and Turbo-B2 (high pressure version) were tested with refrigerant R-134a and various concentrations of polyol ester oil. The study concluded that the effect of oil, whether beneficial or detrimental, is very dependent upon tube geometry. The plain finned tubes saw improved heat transfer with the addition of oil, while the highly enhanced tube saw a decrease in heat transfer with the addition of oil. It was suggested that the small nucleation sites associated with highly enhanced tubes become oil-logged and prevent the refrigerant from entering.

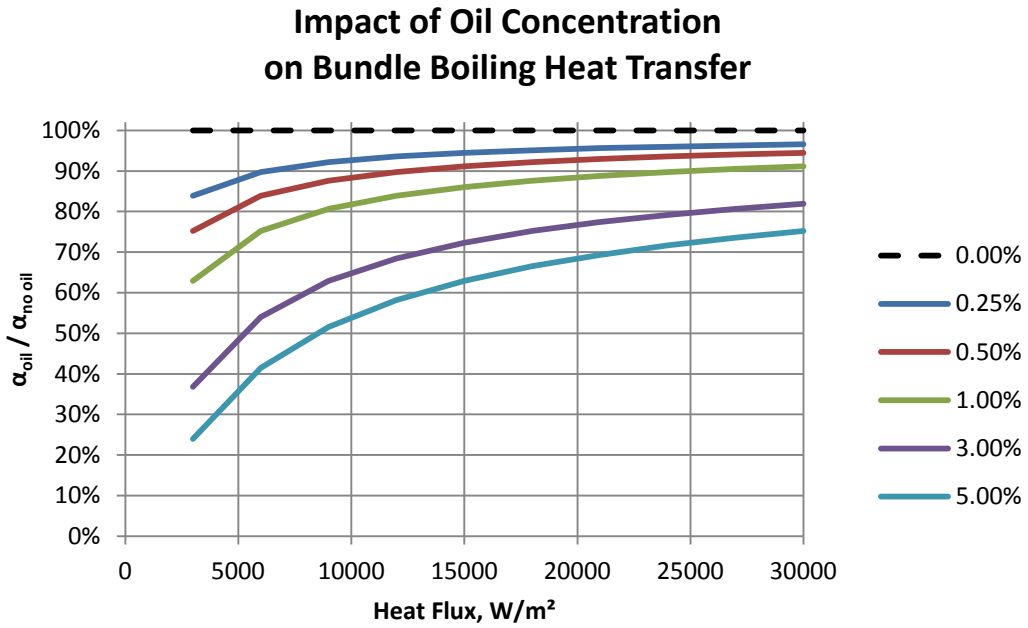
ASHRAE RP-1089 further studied the impact of oil concentration on refrigerant-side boiling in a flooded evaporator tube bundle using Turbo-BII tubes and developed a correlation that can be used to calculate the impact on the local refrigerant-side heat transfer coefficient within a tube bundle. The refrigerants studied were limited to R-410A and R-507A.

The lack of field data from actual operating equipment makes it difficult to determine the total increase in energy consumption due to high oil concentration in a tube bundle. However, RP-1089 stated that the effect of oil upon bundle boiling on Turbo-BII tubes may be related to percent oil concentration by:

$$\frac{\alpha_{oil}}{\alpha_{no\ oil}} = \frac{1}{exp\left[\left(\frac{w_{oil}\,(100\%)}{q/1000}\right)^{0.7}\right]}$$

Where:
α_{oil} is the tube bundle local heat transfer coefficient with oil
$\alpha_{no\ oil}$ is calculated at the same operating conditions without oil
w_{oil} is the local oil fraction
q is the heat flux [W/m²]

Since oil concentration data in the field is unavailable at this time, the performance impact was plotted for a range of typical heat flux at various oil concentrations. As shown below, even minimal oil concentrations can have a severe negative impact on bundle boiling performance, particularly at low heat flux.



The severity of the penalty reinforces the need to gather appropriate data on oil concentration levels in field units, such that improved designs or maintenance procedures may be prepared to increase actual operating efficiency of field units.

Advancement to the State-of-the-Art:
The current proposal is to advance the state of the art by determining typical oil concentrations in flooded evaporator liquid chillers using current fluids and technology through statistically significant sampling methods.

Justification and Value to ASHRAE:
BSRIA statistics estimate the global market size for positive displacement and centrifugal chillers at approximately $7.61 billion for 2011 [JARN]. This represents a significant investment by much of the ASHRAE community, including both manufacturers who design and manufacture the equipment and by customers who purchase it. In addition, the energy costs associated with operating this type of equipment over a 20-25 year life cycle will typically be much greater than the initial capital expense. Annual energy consumption associated with these chillers in the US was estimated to be 29% of the primary energy used

for cooling [Westphalen and Koszalinski]. Because of the magnitude of the costs associated with this equipment, both first cost and long term operating energy costs, small incremental improvements in evaporator design and oil management can provide significant benefits.

This research will determine whether the industry has a latent problem with poor chiller efficiency due to oil loss within the refrigerant system, or the industry has a few isolated oil loss incidents to be dealt with case by case using routine maintenance procedures.

If this research indicates oil loss issues occur frequently, manufacturers will make design improvements to minimize oil loss and/or increase oil recovery system effectiveness, maintenance personnel and operators will have data to justify better maintenance practices in order to enhance equipment efficiency, and owners and operators will have additional data so that they may make informed equipment selections.

There will be no intellectual property rights associated with this research project.

Objectives:
Data from the proposed research will provide operators and equipment manufacturers with additional information necessary to make informed decisions about appropriate technologies and maintenance practices for both existing and future chiller designs. To meet this objective, the following objectives are proposed:

1. **Measure oil concentration, in circulation through the liquid line and/or within the evaporator for screw chillers (R134a) and centrifugal chillers (R123 & R134a) from many different manufacturers, with different equipment age (operating hours), different capacity sizes, and different operating and maintenance practices**. The research contractor will decide whether the measurements will be made from collecting refrigerant samples for laboratory analysis, or whether to send oil concentration measuring equipment to each chiller location. The approximate scope will be 25 to 35 chillers from each of the three chiller types identified above, but the research contractor will make the final recommendation to obtain a statistically valid sample size of the current population. The work statement & the selected research contractor will define measurement methods or sample selection methods, including operating condition requirements, and surveys to collect additional data about maintenance practices. With appropriate guidelines defined to avoid bias, and procedures defined for sample collection and measurement methods, the data collection program could rely on chiller manufacturers, service providers, or chiller owner/operators to volunteer measurements collected through their daily operations (to reduce the program cost to ASHRAE). The researcher must submit a data verification plan which must include at least one gage repeatability and reproducibility exercise for each a R123 and R134a chiller.

2. **Correlate oil concentration measurements with respect to refrigerant type, oil type, evaporator bundle type, tube type, refrigerant and oil charge / ton, equipment age and operation and maintenance practices to determine trends.** Acquiring the "as-found" data will be valuable to determine the current state of the chiller population (through a statistically valid sample size).

This research proposal does not include field performance measurements on chillers. While measurements could be taken before and after oil loss problems are resolved following practices in Guideline 22 or SPC 184 to estimate the impact of oil on overall system performance, expanding the the research project in this manner would significantly raise the cost and is beyond the scope of this proposal.

Key References:

(List references cited in the state-of-the art section.)

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

ASHRAE RP-751 "Experimental Determination of the Effect of Oil on Heat Transfer with Refrigerants HCFC-123 and HFC-134a"

ASHRAE RP-1089 "Flooded Evaporation Heat Transfer Performance Investigation for Tube Bundles Including the Effects of Oil Using R410A and R507A"

JARN, Japan Air Conditioning, Heating & Refrigeration News, "World Chiller and Large AC Market", 25-Nov-2012.

Westphalen and Koszalinski, Energy Consumption Characteristics of Commercial Building HVAC Systems, Volume I: Chillers, Refrigerant Compressors, and Heating Systems. April 2001.

Method of Test for Oil Samples (specific reference to be added to Work Statement)

December n, 2013

ASHRAE Headquarters
1791 Tullie Circle, N.E.
Atlanta, GA 30329

Subject: Letter of Intent Regarding RTAR-1716

To: ASHRAE RAC Members
cc: ASHRAE TC 8.2 Research S/C Members

YourCompanyName supports the proposed research project outlined in RTAR-1716 “Oil Concentration of Field-installed Liquid Chillers with Flooded Type Evaporators”. This letter signifies our intent to provide in-kind support in the following areas:

(check all that apply, delete extra symbols and delete this line)

×✓	Provide list of available installed chillers to research contractor, to be used by the research contractor for selection of sites & chillers (including make, model, production year, nominal capacity, compressor type, refrigerant type, installed location)
×✓ ×✓	Personnel travel costs and time for collection of refrigerant samples from chillers, or for oil concentration measurements taken on site: • during routine service calls (locations chosen by our company) • to specific locations selected by the research contractor (whether randomly selected or to meet statistical requirements of the study)
×✓	Shipping cost to send samples to the research contractor selected by ASHRAE, or to analysis lab designated by the research contractor
×✓	Other: *(fill in other forms of support, or delete this table row)*

Legend:
× = not able to provide
✓ = able & willing to provide support

Yours truly,

Your Name
Your Title

David and Mike,

Attached is the revised RTAR addressing concerns from RAC (attached). This is the 2nd review by David Yashar and his comments were addressed in the attached draft (file ending in …2013-12-15.doc) to emphasize benefits to chiller maintenance practices and better clarify the tangible benefits of the research. I believe we have met all concerns and ask that this new draft be considered as TC 8.2's formal resubmission to ASHRAE Research Administration Committee meeting the December 15th deadline for re-evaluation at the January 2014 ASHRAE meeting.

I am submitting this email as the required point by point letter detailing the changes made to address the specific RAC concerns. The RAC concerns and the associated changes are as follows:

A. Lack of tangible benefits defined in RTAR
   - revised RTAR (attached) with specific benefits noted in the "Application of Results" section. Benefits are:
     1. Compare maintenance practices on oil management and develop best practices for the industry. This could be used by owners to maintain the efficiency of their chillers.
     2. With the pressure on efficiency and the adverse effect of oil on performance this study will show manufacturers the long term effectiveness of their oil return systems. This data could be used to improve this performance.
     3. Allow manufactures to understand the performance of their oil return systems in comparison to industry average and allow them to improve the designs. This is only possible with a blind cross sectional study like this.
     4. Update ASHRAE handbooks broadening statements for equipment designers, owners and operators for proper equipment system design consideration and state of the art maintenance practices for maintaining oil levels that do not significantly impact chiller performance. Specific handbook chapters include HVAC Systems and Equipment Handbook Liquid Chilling Systems (Chapter 43) and Compressors (Chapter 39) and possibly Refrigeration Handbook Refrigerant System Chemistry (Chapter 6).

B. Need for AHRI / manufacturer cosponsorship
   1. AHRI Chiller Section submitted letter ballot asking them to consider sending a letter to ASHRAE RAC indicating they would explore co-sponsoring this research if the RTAR is approved. Motion passed by letter ballot 9-1-4 (for-against-abstain) per Rupal Choski, AHRI manager.
   2. Daikan, JCI, Trane, Carrier and Smardt are being sent letters of intent (draft attached) soliciting commitment to support research. Formal responses are due to ASHRAE by January 10th

Please advise if you have any concerns or questions.

Sincerely,

Rick Heiden
Chair, ASHRAE TC 8.2 Centrifugal Machines

Leader, Compressor Mechanical Design Group
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Manager Research & Technical Services
mvaughn@ashrae.org

TO: Rick Heiden, Chair TC 8.2, rheiden@trane.com

FROM: Michael Vaughn, MORTS, mvaughn@ashrae.org

CC: David Yashar, Research Liaison 8.0, david.yashar@nist.gov
Mark Adams, Research Subcommittee Chair TC 8.2, mark.a.adams@jci.com

DATE: November 19, 2013

SUBJECT: Research Topic Acceptance Request (1716-RTAR), "Oil Concentration of Field-installed Liquid Chillers with Flooded Type Evaporators"

During their fall meeting, the Research Administration Committee (RAC) reviewed the subject Research Topic Acceptance Request (RTAR) and voted to return it. The following list summarizes the mandatory comments and questions that need to be fully addressed in the RTAR re-submission:

1. A need is described, but it is not clear as to the overall benefit or the actual effect the research will have on the industry.

2. Co-funding should be available from chiller manufacturers and AHRTI if this is worthwhile.

Please address or incorporate the above information into the RTAR with the help of your Research Liaison prior to resubmitting it to the Manager of Research and Technical Services for further consideration by RAC. In addition, a separate document providing a point by point response to each of these mandatory comments and questions must be submitted with the RTAR. The response to each item should explain how the RTAR has been revised to address the comment, or a justification for why the technical committee feels a revision is unnecessary or inappropriate. The RTAR and response to these comments and questions must be approved by the Research Liaison prior to submitting it to RAC.

An RTAR evaluation sheet is attached as additional information and it provides a breakdown of comments and questions from individual RAC members based on specific review criteria. This should give you an idea of how your RTAR is being interpreted and understood by others. Some of these comments may indicate areas of the RTAR and subsequent WS where readers require additional information or rewording for clarification.

The next submission deadline for RTARs and WSs is **December 15, 2013** for consideration at the Society's 2014 winter meeting. The submission deadline after that is May15, 2014.

Project ID	**1716**	
Project Title	**Oil Concentration of Field-installed Liquid Chillers with Flooded Type Evaporators**	
Sponsoring TC	TC 8.2, Centrifugal Machines	
Cost / Duration	$175,000 / 12 Months	
Submission History	**RTAR 1st Submission**	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC 2013 Fall Meeting Review		
Check List Criteria	**VOTED NO**	**Comments & Suggestions**
Is there a well-established need? The RTAR should include some level of literature review that documents the importance/magnitude of a problem. If not, then the RTAR should be returned for revision.	**10**	**7** - A need is described, but it is not clear as to the overall benefit or the actual effect the research will have on the industry. 10 - Need is not well established.
Is this appropriate for ASHRAE funding? If not, then the RTAR should be rejected. Examples of projects that are not appropriate for ASHRAE funding would include: 1) research that is more appropriately performed by industry, 2) topics outside the scope of ASHRAE activities.	**10, 8**	**10** - This research should be conducted by the chiller manufacturers. **4** - I'd love to see a strong experimental study, followed by study of concentrations of oil in refrigerant (this study), but w/o understanding the fractionation of oil between HX surfaces and suspended, I don't see how the results of this study will be useful. I'm not sure how to address consistency in sampling location, either. 8 - I am not sure to collect oil concentration data from many chillers would benefit many ASHRAE members.
Is there an adequate description of the approach in order for RAC to be able to evaluate the appropriateness of the budget? If not, then the RTAR should be returned for revision.	**10, 4**	**7 -** The objectives are focused, but the description and benefits are vague. There is no correlation to the statement about heat-exchanger fouling which makes it confusing as to the output. **4** - Thrown off by terms: in unitary equipment, "contaminants" usually means non-condensable. Here it seems to mean the lubricating oil. More importantly, I imagine oil having two possible effects: (a) as boundary layer on HX, affecting heat transfer, or (b) as loci for boiling in the fluid. This proposal only addresses the second, but alludes to importance of the former in prior work. Even more important, I don't see anything coming out of this field work that helps me understand impacts of the combined phenomena on actual performance - which isn't and can't be evaluated with this protocol.
Is the budget reasonable for the project scope? If not, then RTAR could be returned for revision or conditionally accepted with a note that the budget should be revised for the WS.	**7, 10, 8**	**7**- Seems high for sampling oil from chillers. Co-funding should be available from chiller manufacturer's and AHRTI if this worth while. **8** - The data collection process is very laborious and cannot be exhaustive. Need strong justification why the number of chillers data collection would be sufficient to yield conclusions. Moreover, it need to show the usefulness of the data, by relating the oil concentration data with chiller performances. How to improve it if the problem exists?
Have the proper administrative procedures been followed? This includes recording of the TC vote, coordination with other TCs, proper citing of the Research Strategic Plan, etc. If not, then the RTAR could be returned for revision or possibly conditionally accepted based on adequately resolving these issues.		**4** - as far as I can tell

Decision Options	**Initial Decision**	**Approval Conditions**
ACCEPT		**7** - The project seems like it is collecting data for the sake of collecting data. Not clear on the actual deliverables to the industry. **10-** Topic and technical approach is vague. I agree with the NO vote about too many variables to reach to any conclusion. **4** - I'd be happy to have a conversation with the sponsor to understand the systems better; I have little experience with these.
COND. ACCEPT		
RETURN		
REJECT		

ACCEPT Vote - Topic is ready for development into a work statement (WS).
COND. ACCEPT Vote - Minor Revision Required - RL can approve RTAR for development into WS without going back to RAC once TC satisfies RAC's approval condition(s)
RETURN Vote - Topic is probably acceptable for ASHRAE research, but RTAR is not quite ready.
REJECT Vote - Topic is not acceptable for the ASHRAE Research Program

Research Topic Acceptance Request Cover Sheet

Date: **August 12, 2003**

(Please Check to Insure the Following Information is in the RTAR)

A. Title	x
B. Applicability to ASHRAE Research Strategic Plan	x
C. Application of the Results	x
D. State-of-the-Art (background)	x
E. Advancement to State-of-the-Art	x
F. Justification and Value to ASHRAE	x
G. Objective	x
H. Estimated Duration	x
I. References	x

Title: Oil concentration of field-installed liquid chillers with flooded type evaporators.

RTAR# **1716**
(To be assigned by MORTS)

Results of this Project will affect the following Handbook Special Publications, etc.:

Handbook Chapter 38

Responsible: Phil Johnson – TC8.2 Chair & Mark Adams – Research Chair

Date of Vote: **7/9/2013**

For	8
Against	1
Abstaining	1
Absent or not returning Ballot	0
Total Voting Members	10

Co-sponsoring TC/TG/MTG/SSPCs (give vote and date):
None

RTAR Lead Author: **Justin Kauffman**
Expected Work Statement Lead **Justin Kauffman**

Research Classification: (Basic/Applied Research; Advanced Concepts; or Technology Transfer)
Basic/Applied Research

Potential Co-funders (organization):
- Chiller Manufacturers – provide refrigerant samples from service groups

	Yes	No
Has an electronic copy been furnished to the MORTS?	X	
Has the Research Liaison reviewed the RTAR?	X	

* Reasons for negative vote(s) and abstentions

Unique Tracking Number Assigned by MORTS _____1716_____

RESEARCH TOPIC ACCEPTANCE REQUEST (RTAR) FORM

(Generally 2 to 6 pages, with 10 pt Times New Roman font)

Sponsoring TC/TG/MTG/SSPC/EHC/REF: TC8.2

Title:

Oil concentration of field-installed liquid chillers with flooded type evaporators.

Applicability to ASHRAE Research Strategic Plan:

This research topic supports Goal 9 of the 2010-2015 plan.

> Goal 9: Support the development of improved HVAC&R components ranging from residential through commercial to provide improved system efficiency, affordability, reliability and safety.

The proposed topic addresses the following technical challenges and needed areas of research for Goal 9:

- "Potential system contaminates in new refrigerants and their effects on system performance and reliability have not been fully investigated."
- "Heat exchanger fouling is a problem that affects the real world efficiency in almost every HVAC&R application."
- "Conduct studies and experiments to support development of maximum allowable levels for individual or combinations of contaminates in refrigerant systems that use newly developed refrigerants. These studies should include the impact of the contaminants on system performance and durability."
- "Conducting studies and experiments to fully optimize system performance."

Research Classification:

Basic/Applied Research

TC/TG/MTG/SSPC Vote:

(For –Against-Abstentions-Absent-Total)

8-1-1-0-10

Reasons for Negative Votes and Abstentions:

(Negative Votes) – 1- Concerned about too much variability in measurement, refrigerant sampling could be inconsistent and inconclusive.

(Abstentions) 1- Member is not active and felt he had insufficient information to vote.

Estimated Cost:

$100k—$175k

Estimated Duration:

12 Months

RTAR Lead Author

Justin P. Kauffman, justin.p.kauffman@jci.com

Expected Work Statement Lead Author

Justin P. Kauffman, justin.p.kauffman@jci.com

Co-sponsoring TC/TG/MTG/SSPCs and votes:

None

Possible Co-funding Organizations:

Anticipate in-kind support from chiller manufacturers to collect refrigerant samples, and to submit either the samples or the samples analysis results to the research contractor.

Application of Results:
The results of this research will be valuable to owners and operators as well as manufacturers by providing an accurate assessment of oil concentration in field systems. This assessment, combined with prior research, can be used to estimate the impact of oil concentration on system performance. This may provide manufacturers with data to improve system design, provide information to guide maintenance practices, and may also provide end users with information that aids in selection of appropriate equipment (oil-free, positive pressure or negative pressure systems, etc.). Additionally, the research should provide information that may be incorporated into HVAC Systems and Equipment 2012 Handbook Chapter 43 (Liquid Chilling Systems) and Chapter 39 (Compressors).

State-of-the-Art (Background):
Very little data has been collected and published for oil concentration in field installed operating systems. Although previous ASHRAE research has been conducted, and is often cited as a reference source, the data is extremely sparse and statistically insignificant.

ASHRAE RP-601, completed in April 1990, is titled "Chemical Analysis and Recycling of Used Refrigerant from Field Systems." The project was performed to "identify and quantify typical contaminant levels in used refrigerant samples obtained from R-11 systems, 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
- although ten centrifugal chillers were studied:
    - all used R-11
    - all were located on one university campus, with one set of operation & maintenance practices
- the R-11 chillers covered the narrow range of 200-500 tons
- one R-12 chiller was tested, but it was a very small instrument process chiller rated for 0.75 hp.

The following ASHRAE research projects provide background on the need to understand actual oil concentration levels in flooded type evaporators, due to the impact on chiller efficiency and energy consumption.

ASHRAE RP-751 was motivated to provide refrigerant-side heat transfer coefficients in a bundle segment in a way that would be of direct applicability in the rational design of flooded evaporators. Integral finned (26 FPI) and Turbo- B2 (low pressure version) tube bundles were tested with refrigerant R-123 and various concentrations of mineral oil. 26FPI and Turbo-B2 (high pressure version) were tested with refrigerant R-134a and various concentrations of polyol ester oil. The study concluded that the effect of oil, whether beneficial or detrimental, is very dependent upon tube geometry. The plain finned tubes saw improved heat transfer with the addition of oil, while the highly enhanced tube saw a decrease in heat transfer with the addition of oil. It was suggested that the small nucleation sites associated with highly enhanced tubes become oil-logged and prevent the refrigerant from entering.

ASHRAE RP-1089 further studied the impact of oil concentration on refrigerant-side boiling in a flooded evaporator tube bundle using Turbo-BII tubes and developed a correlation that can be used to calculate

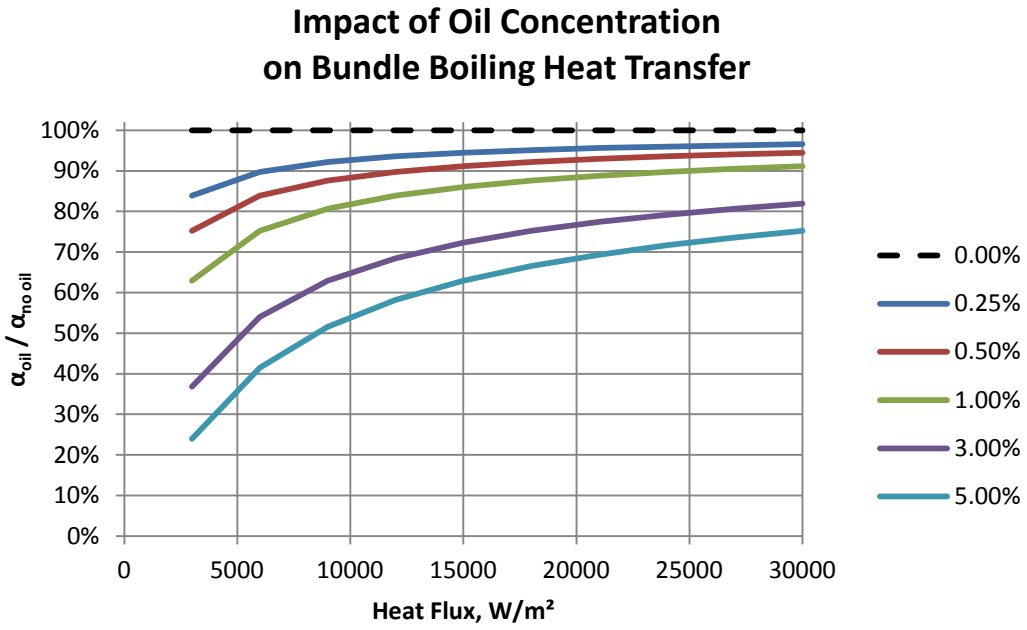
the impact on the local refrigerant-side heat transfer coefficient within a tube bundle. The refrigerants studied were limited to R-410A and R-507A.

Advancement to the State-of-the-Art:
The lack of data from operating equipment makes it difficult to determine the total increase in energy consumption due to high oil concentration in a tube bundle. However, RP-1089 stated that the effect of oil upon bundle boiling on Turbo-BII tubes may be related to percent oil concentration by:

$$\frac{\alpha_{oil}}{\alpha_{no\ oil}} = \frac{1}{exp\left[\left(\frac{w_{oil}(100\%)}{q/1000}\right)^{0.7}\right]}$$

Where α_{oil} is the tube bundle local heat transfer coefficient with oil and $\alpha_{no\ oil}$ is calculated at the same operating conditions without oil. In this expression, the local oil fraction w_{oil} is multiplied by 100% and the heat flux q is introduced in W/m².

Since oil concentration data in the field is unavailable at this time, the performance impact was plotted for a range of typical heat flux at various oil concentrations. As shown below, even minimal oil concentrations can have a severe negative impact on bundle boiling performance, particularly at low heat flux.



The severity of the penalty reinforces the need to gather appropriate data on oil concentration levels in field units, such that improved designs or maintenance procedures may be prepared to increase actual operating efficiency of field units.

Justification and Value to ASHRAE:
BSRIA statistics estimate the global market size for positive displacement and centrifugal chillers at approximately $7.61 billion for 2011 [JARN]. This represents a significant investment by much of the

ASHRAE community, including both manufacturers who design and manufacture the equipment and by customers who purchase it. In addition, the energy costs associated with operating this type of equipment over a 20-25 year life cycle will typically be much greater than the initial capital expense. Annual energy consumption associated with these chillers in the US was estimated to be 29% of the primary energy used for cooling [Westphalen and Koszalinski]. Because of the magnitude of the costs associated with this equipment, both direct and long term energy, even incremental improvements in evaporator design can provide significant benefits.

As a result, this research could provide manufacturers insight about design improvements to minimize oil and its performance effects on the system, provide maintenance personnel and operators with data to justify increased maintenance practices in order to enhance equipment efficiency, and to provide owners and operators with additional data so that they may make informed equipment selections.

There will be no intellectual property rights associated with this research project.

Objectives:

Field refrigerant samples will be acquired from screw chillers (R134a) and centrifugal chillers (R123 & R134a) from many different manufacturers, with different equipment age (operating hours), different capacity sizes, and different maintenance practices. The target will be 20 to 30 chillers from each of the three chiller types identified above. The work statement & the selected research contractor will define sample selection methods, surveys to collect additional data about maintenance practices. With appropriate guidelines defined to avoid bias, and sample collection procedures defined, the collection program could rely on chiller manufacturers, service providers, or chiller owner/operators to volunteer samples collected through their daily operations (to reduce the program cost to ASHRAE). The samples will be analyzed for oil concentrations and correlated with respect to working fluid, oil type, equipment age and maintenance practices. While simply acquiring the data will be valuable in itself, the data may be additionally be used, along with prior research, to estimate the impact of oil on overall system performance. This data will provide end users, owners and operators and equipment manufacturers with additional information necessary to make informed decisions about appropriate technologies and maintenance practices.

Key References:

(List references cited in the state-of-the art section.)

ASHRAE RP-601 “Chemical Analysis and Recycling of Used Refrigerant from Field Systems”

ASHRAE RP-751 “Experimental Determination of the Effect of Oil on Heat Transfer with Refrigerants HCFC-123 and HFC-134a”

ASHRAE RP-1089 “Flooded Evaporation Heat Transfer Performance Investigation for Tube Bundles Including the Effects of Oil Using R410A and R507A”

JARN, Japan Air Conditioning, Heating & Refrigeration News, “World Chiller and Large AC Market”, 25-Nov-2012.

Westphalen and Koszalinski, Energy Consumption Characteristics of Commercial Building HVAC Systems, Volume I: Chillers, Refrigerant Compressors, and Heating Systems. April 2001.

Method of Test for Oil Samples (specific reference to be added to Work Statement)

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TO: Rick Heiden, Chair TC 8.2, rheiden@trane.com
Mark Adams, Research Subcommittee Chair TC 8.2, mark.a.adams@jci.com
David Yashar, Research Liaison Section 8.0, david.yashar@nist.gov

FROM: Michael Vaughn, MORTS, mvaughn@ashrae.org

DATE: February 12, 2014

SUBJECT: Research Topic Acceptance Request (1716-RTAR), "Oil Concentration of Field-installed Liquid Chillers with Flooded Type Evaporators"

At their winter meeting, the Research Administration Committee (RAC) reviewed the subject Research Topic Acceptance Request (RTAR) and voted to accept it for further development into a work statement (WS).

An RTAR evaluation sheet is attached as additional information and it provides a breakdown of comments and questions from individual RAC members based on a specific review criteria. This should give you an idea of how your RTAR is being interpreted and understood by others. Some of these comments may indicate areas of the RTAR and subsequent WS where readers require additional information or rewording for clarification.

The first draft of the work statement should be submitted to RAC no later **December 15, 2015** or it will be dropped from display on the Society's Research Implementation Plan. The next submission deadline for work statements is **May 15, 2014** for consideration at RAC's 2014 annual meeting. The submission deadline after that for work statements is August 15, 2014 for consideration at RAC's 2014 fall meeting.

Project ID	**1716**	
Project Title	**Oil Concentration of Field-installed Liquid Chillers with Flooded Type Evaporators**	
Sponsoring TC	TC 8.2, Centrifugal Machines	
Cost / Duration	$175,000 / 12 Months	
Submission History	**RTAR 2nd Submission, 1st Submission returned Nov. 2013**	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC 2014 Winter Meeting Review		
Check List Criteria	**VOTED NO**	**Comments & Suggestions**
Is there a well-established need? The RTAR should include some level of literature review that documents the importance/magnitude of a problem. If not, then the RTAR should be returned for revision.	**#8**	**#5** - A blind study of this type will provide data useful to manufacturers and end users to allow for improvement in design and operation. **#4** - AHRTI has voted to support the project, which should indicate industry wide chiller manufacturer support. **#6** - I'm quite satisfied that they have established the need, and I feel also that there is a strong need to understand HX fouling better. The literature search is fine. **#8** - The data might be useful to chiller manufacturers, if a lot of details are provided. However, if this is an important issue and not much data are yet available, why do not the manufacturers try to collect such data for their products? Who else could benefit from this study is also not very clear. **#2** - letter of co-funding support from AHRI, and comments from 1st submission well addressed.
Is this appropriate for ASHRAE funding? If not, then the RTAR should be rejected. Examples of projects that are not appropriate for ASHRAE funding would include: 1) research that is more appropriately performed by industry, 2) topics outside the scope of ASHRAE activities.	**#8**	**#6** - Yes, if there is substantial cost-share with industry (ARTI) and if owners and maintenance organizations will do the necessary leg work to provide samples. Just for the heck of it, how can a small high-pressure refrigerant sample be shipped to a lab? How do we get a good sample? **#8** - I think the project is more appropriately performed by industry.
Is there an adequate description of the approach in order for RAC to be able to evaluate the appropriateness of the budget? If not, then the RTAR should be returned for revision.		**#4** - Would like to see more detail in the data mapping output. **#6** - The description is good. What I don't understand is how much this approach would contribute. At its heart, it seems to be a mass balance effort: From concentration of oil in refrigerant, known system volume , refrigerant and oil charges, the difference "should" be oil on the surfaces of the HX. This proposal assumes that all of these are pretty precisely known from field records and OEM specs, and that there is no surface deposition in areas like the large suction line surface, or the evaporator. Can the approach work? My other challenge is that there is no effort to look at the "power" of the experiment: Is the number of chillers to be tested even near the ball park of the number that need to tested for the statistical validity they seek, or should they restrict the study to a smaller class of chillers?
Is the budget reasonable for the project scope? If not, then RTAR could be returned for revision or conditionally accepted with a note that the budget should be revised for the WS.	**#8**	**#4** - The time duration of 12 months seems too short to pull this data together. **#6** - The budget is not expressed in terms of effort-day estimates for the tasks (field study, sample analysis, data analysis, report development, etc.), so I can't even begin to estimate whether the budget is reasonable. This ties into the concerns about statistical power -- but also into my reservations of continually ratcheting up our expectations and adding new concerns at each review round. **#8**- Cannot judge - the level of efforts to make these measurements was not elaborated.
Have the proper administrative procedures been followed? This includes recording of the TC vote, coordination with other TCs, proper citing of the Research Strategic Plan, etc. If not, then the RTAR could be returned for revision or possibly conditionally accepted based on adequately resolving these issues.	**#13**	**#4** Concerned about the 1 negative vote on the original submittal. Would like to see a new vote and whether the concerns have been addressed. **#13** - Would like to know reason for no and abstain vote for AHRI refrigerant committee. **#6**- I continue to assume that it doesn't get to me unless the list has been checked by staff.

Decision Options	**Initial Decision**	**Approval Conditions**
ACCEPT	**X**	**#5**- Move the project forward to allow review of WS. **#4** - Feel there is enough justification to go on to the WS phase. **#13** - I approve based on the condition that the following conditions are met at the work statement stage: 1. Co-funding from AHRI/AHRTI, and 2. mostly positive response and in-kind support from chiller manufacturers. **#6** -Need to understand that this approach has some chance of success, even if relatively high risk.
COND. ACCEPT		
RETURN		
REJECT		

ACCEPT Vote - Topic is ready for development into a work statement (WS).
COND. ACCEPT Vote - Minor Revision Required - RL can approve RTAR for development into WS without going back to RAC once TC satisfies RAC's approval condition(s)
RETURN Vote - Topic is probably acceptable for ASHRAE research, but RTAR is not quite ready.
REJECT Vote - Topic is not acceptable for the ASHRAE Research Program