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1791 Tullie Circle NE ▪ Atlanta, Georgia 30329-2305 ▪ Tel 678.539.1211 ▪ Fax 678.539.2211 ▪ http://www.ashrae.org

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

mvaughn@ashrae.org

TO: Brian Fricke, Chair TC 10.7, frickeba@ornl.gov

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

CC: John Shonder, Research Liaison 10.0,
Daryl G Erbs, Research Subcommittee Chair TC 10.7, daryl.erbs@manitowoc.com

DATE: July 25, 2013

SUBJECT: Research Topic Acceptance Request (1706-RTAR), "Minimum Refrigerant Charge Attainment for Commercial Refrigeration Systems"

During their Annual 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. The 2012 paper by Pega Hrnjak describes how to evaluate charge reduction options in heat exchangers, and uses the methods in a condenser example. Other components are also discussed. I don't believe that this RTAR, as written, will advance from what has already been done.
2. RTAR needs to have much tighter focus in scope. Need to have clearer objectives that add to the current knowledge base.
3. Strongly recommended that co-funding opportunities, including from equipment manufacturers who might benefit from this research, be sought for this project.

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

Project ID	**1706**	
Project Title	**Minimum Refrigerant Charge Attainment for Commercial Refrigeration Systems**	
Sponsoring TC	TC 10.7 Commercial Food and Beverage Display and Storage Equipment	
Cost / Duration	$180,000/ 18M	
Submission History	**1st submission**	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC SPRING 2013	**REVIEW SUMMARY**	
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.	**#15**	**#15** - I think that there is a well established need, but I don't think that this RTAR will properly address them. Need to have clearer objectives that add to the current knowledge base. **#8** - Seems that there is a need to find ways to minimize charge in systems using hydrocarbons and ammonia and other such potentially hazardous fluids
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.		
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.	**#15, #8**	**#8** - The RTAR is not well thought out. While the issue is clear, they list a myriad of working fluids, and essentially list out a laundry list of possibilities, system types, components, oil dissolved refrigerant fractions, and so on. Then they simply state that simulations and experiments should be conducted. This could easily be a 10-15 year long research program. The RTAR should focus on a manageable and well defined scope.
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.	**#15, #8**	**#15** - Hard to tell, it looks like most of the objectives have been accomplished in a recent publication. **#8** - The scope could be anything based on how the RTAR is written, and it is impossible to assess the cost.
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.		

Decision Options	**Initial Decision**	**Approval Conditions**
ACCEPT		**#10** - Strongly recommended to find co-funding opportunities including from equipment manufacturers who might benefit from this research. **#15** - The 2012 paper by Pega Hrnjak describes how to evaluate charge reduction options in heat exchangers, and uses the methods in a condenser example. Other components are also discussed. I don't believe that this RTAR, as written, will advance from what has already been done. **#4**- RTAR is well written and clearly establishes the need and benefit. Recommend they proceed to a WS. **#8 -** While the topic is interesting, the authors do not seem to have actually visualized someone doing this work. It just lists everything that may be worth studying. The RTAR needs to have much tighter focus in scope.
COND. ACCEPT		
RETURN	**X**	
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: May 14, 2013

(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 Cost	X
I. Estimated Duration	X
J. Estimated Cost	X
K. Estimated Duration	
	X
L. References	*
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Title: Minimum Refrigerant Charge Attainment for Commercial Refrigeration Systems

RTAR# **1706**
(To be assigned by MORTS)

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

Handbook chapters 46 and 47

Responsible TC/TG: TC 10.7

Date of Vote: May 13, 2013

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

Co-sponsoring TC/TG/MTG/SSPCs (give vote and date):
TC 8.4 has expressed support to co-sponsor, but was unable to complete vote in time for submission deadline

RTAR Lead Author:
Daryl Erbs

Potential Co-funders (organization):
AHRI

	Yes	No
Has the Research Liaison reviewed the RTAR?	X	

* Reasons for negative vote(s) and abstentions

- - - -
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- - - - - - - -

Unique Tracking Number Assigned by MORTS _1706_

RESEARCH TOPIC ACCEPTANCE REQUEST (RTAR) FORM

Sponsoring TC/TG/SSPC: TC 10.7 Commercial Food and Beverage Display and Storage Equipment

Title: Minimum Refrigerant Charge Attainment for Commercial Refrigeration Systems

Applicability to ASHRAE Research Strategic Plan:

The objective of this project is to identify design options and guidelines to reach the minimum possible refrigerant charge in commercial refrigeration systems. This will directly support the ASHRAE Strategic Plan 2010-2015 Goal 8 to facilitate use of low GWP refrigerants and seek methods to reduce charge and Goal 9 to develop improved HVAC&R components for use with low GWP refrigerants. The design guidelines and system configurations developed through this project can be used to improve the information provided in the ASHRAE Handbook for systems employing flammable and toxic refrigerants.

Research Classification:
Basic/Applied

TC/TG Priority:
1

TC/TG/SSPC Vote:
10-0-0 (Chair not voting)

Reasons for Negative Votes and Abstentions:

Estimated Cost: $180,000

Estimated Duration: 18 months

RTAR Lead Author
Daryl Erbs

Expected Work Statement Lead Author
Daryl Erbs

Co-sponsoring TC/TG/SSPCs and votes:
TC 8.4 has expressed interest to co-sponsor

Possible Co-funding Organizations:
AHRI

Application of Results:

- The results of this research will help determine the potential range of system size for low GWP refrigerants that are flammable, toxic, or a combination of the two.
- The potential reduction in LCCP for all refrigerants as the result of charge reduction can be estimated more accurately.
- The study will provide a better understanding of how each component in a commercial refrigeration system contributes to the overall charge, and the range of options available for each type of component to reduce charge.
- Manufacturers of commercial refrigeration equipment will be able to use the findings to determine the best strategy for refrigerants for each equipment segment and region.
- Manufacturers of commercial refrigeration components will be able to use the findings to determine the market opportunities for components that minimize charge in systems.
- Regulatory, code, and safety standards organizations will have an improved understanding of the potential application of flammable and toxic refrigerants in the commercial sector.
- ASHRAE Refrigeration Handbook Chapters 46 – Retail Food Store Refrigeration and Equipment, and 47 – Food Service and General Commercial Refrigeration Equipment, can be enhanced and expanded with the findings from this study.

State-of-the-Art (Background):

The development of microchannel tubes for use in air-to-refrigerant heat exchangers, which feature small parallel passages for the flow of refrigerant, led to a number of research studies investigating the potential charge reduction resulting from microchannel condenser and evaporator coils. A number of refrigerant and system combinations were investigated, including ammonia in a chiller (Litch and Hrnjak, 1999) and hydrocarbons (Hoehne and Hrnjak, 2004.) Significant reduction in charge was demonstrated through the use of microchannel heat exchangers.

Additional work on microchannel heat exchangers focused on optimum circuit design for charge reduction (Traeger and Hrnjak, 2005) and characterizing the heat transfer and pressure drop correlations for microchannel heat exchangers employed in reduced charge systems (Tarawneh, 2004.) More recent studies include charge reduction in heat pump systems using both plate and microchannel heat exchangers (Fernando, 2007),a review of charge distribution and charge reduction options for commercial refrigeration systems (Poggi et. al., 2008.), and charge optimization in microchannel condensers for a range of refrigerant options without reduction in system COP (Hrnjak, 2012.)

The studies on minimizing refrigerant charge have demonstrated the potential for significant charge reduction through the use of microchannel technology in the heat exchangers. The charge inventories in each of the components has been reported in a number of the studies, but there has been limited work on the potential for reducing the charge in components beyond the condenser and evaporator. For example, it is well known that significant mass of refrigerant can be dissolved in the lubricating oil of a compressor, but the opportunity for charge reduction by oil selection or reduction in oil volume has not been studied as a charge minimization objective. An excellent summary of the available strategies for charge reduction is outlined by Hrnjak (2012), but only the condenser opportunity is quantified. Many of the studies have not included the full range of low GWP candidates.

Advancement to the State-of-the-Art:

In the case of hydrocarbons and ammonia, charge limits have been established that place significant restrictions on the allowable system size, or alternately require restrictions on the physical volume, ventilation provisions, and use category for the space in which the system is employed. Hydrocarbons and ammonia have some of the most desirable attributes for a low GWP refrigerant – they are natural, have excellent thermodynamic and transport properties, are compatible with the most desirable compressor lubricants, and are readily available at reasonable cost.

The least restrictive application limits for hydrocarbons set a maximum charge amount of 150 g. While this allows for the use of hydrocarbons in fractional hp refrigeration systems found in reach-in refrigerators and freezers, small ice machines, and small walk-in refrigeration, the full range of product sizes in these commercial refrigeration segments cannot be accommodated within the 150 g limit. Further reduction in charge volume in not only the heat exchangers, but in other components such as compressors, refrigerant lines, expansion devices and distributors, and filter-driers has the potential to significantly extend the range of application of hydrocarbons to self-contained commercial refrigeration systems.

The addition of the A2L flammability classification to ASHRAE Standard 34 is expected to enable significantly higher charge limits for low GWP refrigerant candidates that are flammable, but with much lower flame speed and heat of combustion. For large commercial refrigeration systems and systems with remote condensers or condensing units employing field installed liquid and suction piping, A2L refrigerants represent an important option for reduction in refrigerant GWP. For large systems, there will still be an upper limit to the acceptable charge based on reasonable risk levels established within the applicable safety standards and codes. The potential cost of some of the A2L candidates may create additional emphasis on charge minimization. The different types of heat exchangers, compressors, and the requirement for receivers, accumulators, and extensive refrigerant line lengths create a need for investigation into charge reduction opportunities for large commercial refrigeration systems. While secondary loop systems can result in significant charge reductions in large commercial systems, this work seeks to evaluate opportunities at the component-by-component level.

The development of a more comprehensive understanding of the charge reduction potential for each of the components found in commercial refrigeration systems, from small self contained designs through large remote systems, combined with knowledge of how the charge reduction potential for each component type is a function of the characteristics and properties of the low GWP refrigerant options available will allow manufacturers to make more intelligent design choices and utilize the optimal low GWP refrigerant candidate for each equipment type and size.

Justification and Value to ASHRAE:

This project would provide benefits to several constituencies within ASHRAE membership and scope:

1. Introduce the widest range of potential options for low GWP refrigerants available as a result of extending the maximum refrigeration capacity limit for refrigerants that have limitations due to flammability and/or toxicity, but otherwise are highly efficient and cost effective.

2. Manufacturers and end users would be able to select commercial refrigeration equipment configurations that effectively minimize total refrigerant charge without compromise to energy efficiency or performance.

3. End users of the commercial refrigeration equipment would realize economic and environmental benefits due to higher system efficiency and lower lifecycle cost achieved by extending the range of application for refrigerants that are constrained by safety considerations.

4. Regulatory and code bodies would make better informed decisions on future options for refrigerants to attain greenhouse gas objectives.

The likelihood that extended utilization of flammable and toxic refrigerants will be adopted by industry is dependent on yet to be defined safety standards and building codes, the impact charge minimization design changes have on the individual component costs, and government policies and regulations.

It is very likely that this study will influence the design practices for commercial refrigeration systems to further reduce charge amounts in these systems whether the final refrigerant choices include those with degrees of flammability and toxicity.

The timeframe required for development of new component and system designs to minimize charge amounts for commercial refrigeration systems, and the establishment of corresponding safety standards, codes, and regulations is anticipated to be from 5 to 10 years for most countries and applications. Shorter time horizons are possible where more aggressive policies are implemented.

Objectives:

The overall objective of this project is to identify the minimum possible refrigerant charge for hydrocarbons, ammonia, R32, and HFO1234yf for common manufacturer designed and built commercial refrigeration system types. The research will not include large scale engineered systems typically employed in industrial process or storage facilities.

This study is expected to evaluate and analyze the impact of the following variables:

- Self-contained versus split systems with remote condensers/condensing units.
- Influence of refrigerant properties and characteristics on relative importance and opportunity for charge reduction for each type of refrigeration system component.
- Combined effects of changes in multiple components in typical commercial refrigeration configurations.
- Differences among the different equipment types and end use categories of commercial refrigeration systems (reach-in, walk-in, retail case, ice machine, etc.)
- Trade-off's between reduction in charge and performance of components and systems.

Advancement to the state-of-the-art is anticipated to require a combination of simulation and experimental work. Key objectives are:

1. Review of prior research to identify and categorize key findings related to design variables affecting refrigerant charge. Update to previous review of research and literature on the subject of refrigerant charge minimization to include recent publications and findings.

2. Identification of key components for charge reduction studies and appropriate simulation models and experimental tests for analysis of the relationship between component design and refrigerant charge.

3. Development of baseline simulation results to set energy efficiency levels for each system to be simulated with charge reduction design modifications.

4. Identification of the key thermo-physical property data needed for each refrigerant candidate to support both simulation and experimental studies and acquisition of the necessary property data/models.

5. Validation of relationship of key design parameters and refrigerant charge held by the primary charge containing components found in factory assembled commercial refrigeration systems.

6. Simulation or experimental determination of overall charge reduction potential for each type of commercial refrigeration system for hydrocarbons, ammonia, R32, and HFO-1234yf based refrigerants.

Key References:

Fernando, W. P. D, 2007, *Experimental Investigation of Refrigerant Charge Minimization of a Small Capacity Heat Pump*, KTH Trita REFR Report No. 07/58.

Hoehne, M. R., and P. S. Hrnjak, 2004, *Charge Minimization in Systems and Components using Hydrocarbons as a Refrigerant,* University of Illinois at Urbana-Champaign, ACRC TR-224.

Hrnjak, P.S., 2012, *Low Refrigerant Charge with a Focus on Microchannel Heat Exchangers,* 2012 ASHRAE/NIST Refrigerants Conference Proceedings.

Litch, A. D., and P. S. Hrnjak, 1999, *Condensation of Ammonia in Microchannel Heat Exchangers,* University of Illinois at Urbana-Champaign, ACRC CR-22.

Poggi, F. et. al., 2008, *Refrigerant Charge in Refrigerating Systems and Strategies of Charge Reduction*, International Journal of Refrigeration, Volume 31, Issue 3.

Tarawneh, M. S., 2004, *Refrigerant Charge Reduction in a Small Commercial Refrigeration Systems*, Journal of Applied Sciences, 4(1).

Traeger, K. M., and P. S. Hrnjak, 2005, *Charge Minimization of Microchannel Heat Exchangers,* University of Illinois at Urbana-Champaign, ACRC TR-251