TC 08.05 Research Report – Jun 2010 / Albuquerque

Active Projects

1316-RP: Experimental Evaluation of the Heat Transfer Impacts of Tube Pitch on a Highly Enhanced Surface Tube Bundle. *PI: Steve Eckels, Kansas State Univ. PMS: Petur Thors (chair), Ben Dingel, Satheesh Kulankara, Axel Kriegsmann. Status: active (start date: Jan-2006. original target completion date: Jul-2008. extension #1 granted Salt Lake City mtg, Jun08: Jul-2009. extension #2 granted Louisville mtg, Jun09: Jul-2010.* ***extension #3 granted Albuquerque mtg, Jun10: Apr-2011.****)*

A durable design for the in-tube thermistors has finally been achieved. The original plastic thermistors were cracking and failing under the stress of the high water pressure. The thermistors are now embedded in a hollowed-out set screw. With this problem solved, data collection is now proceeding at a good pace.

Data has been collected on the bundles with *P/D* ratios of 1.167 and 1.33 using R134a. Local heat transfer coefficients (HTC) have been computed and plots created. Heat flux is the dominant factor in HTC. Mass flux has some influence at low heat fluxes. HTC decreases with quality at higher heat fluxes.

Local HTC's increase to a peak around a local heat flux of 10 kW/m^2 (3000 Btu/hr-ft^2) and then decrease to a plateau. For *P/D* = 1.167, the plateau is well below the pool boiling curve. Curiously, bundle performance appears to increase for *P/D* = 1.33; both the peak and the plateau are higher than for *P/D* = 1.167.

The endplates for the bundle with *P/D* = 1.5 are being prepared. Data collection should take several weeks. Following this, testing with R123 will commence. Analysis of the data will continue with a draft final report expected to be submitted for review prior to the Las Vegas meeting in Jan11.

A paper on "Pool Boiling of R-134a and R-123 on Smooth and Enhanced Tubes, Average Heat Transfer Coefficient Analysis" has been approved for publication in *HVAC&R Research*. A paper describing the local heat transfer measurements on water heated tubes undergoing pool boiling is in development.

The PI proposed holding monthly meetings *via* electronic means to keep the PMS (and others as interested) updated on progress and results. The PI will initiate the meeting invitations.

1345-RP: Waterside Fouling Performance of Brazed-Plate Type Condensers in Cooling Tower Applications. *PI: Lorenzo Cremaschi & Jeffrey Spitler, Oklahoma State Univ. PMS: Jim Bogart (chair), Art Fovargue, Axel Kriegsmann, Ken Schultz, Xudong Wang (ARTI cofunding). Status: active (start date: May-2008. original target completion date: Oct-2010.* ***extension #1 granted Albuquerque mtg, Jun10: Oct-2011.****)*

Tests have been completed on the first three BPHE's (A1, A2, and A3) with the high fouling potential water at 105°F refrigerant saturation temperature. The fourth BPHE (A4) has been under test for about 30 days. The A1 BPHE with the "soft" chevron angle (30°) had a fouling resistance that steadily increased to a value of ~0.002 hr-ft^2-°F/Btu. The fouling resistances in the A2 and A3 BPHE's with the "hard" chevron angle (60°) were roughly an order of magnitude less than this. The A4 BPHE is showing about the same fouling as the A2 and A3, but with more oscillatory behavior. The A3 BPHE (long, narrow aspect) experienced a very large increase in pressure drop, as much as 3.5 times the clean value. Speculation continues that localized buildup of precipitate is occurring near the exit ports.

The test matrix calls for testing two of the geometries at a higher saturation temperature (120°F) with the high fouling potential water and one of the geometries with a medium fouling potential water at 105°F. In addition, it is proposed to run a test of a smooth tube in an attempt to provide a means of comparing fouling between BPHE's and tubes in the same physical and chemical setup. Testing is now projected to run through next summer. A one-year no-cost extension to Oct 2011 was granted at this meeting.

1394-RP: Study of Carbon Dioxide Condensation in a Chevron Angle Plate Geometry Exchanger. *PI: Amir Jokar, (ex-)Washington State Univ - Vancouver. PMS: Zahid Ayub (chair), Joe Huber, Jim Bogart.* ***Status: final report accepted and project closed*** *(start date: Sep-2007. original target completion date: Aug-2009. extension granted Louisville mtg, Jun09: Jan-2010.)*

The PI worked with the PMS to address questions about the draft final report. The PMS recommended approval of the final report on 01-May. The committee approved the final report by email ballot with the resulting vote (9 approve / 0 reject / 1 abstain / 1 no response) submitted to Donna Daniel on 11-May-2010.

ASHRAE still needs the "Disposition of ASHRAE Sponsored Research Results" form – Zahid will complete this.

FUTURE RESEARCH TOPICS

1556-WS: Characterization of Liquid Refrigerant Flow Emerging from a Flooded Evaporator Tube Bundle. *author: Jon Hartfield*

This project is being led by TC 1.3, with TC 8.5 as a cosponsor. The work statement was approved by RAC at the Louisville meeting (Jun09). This project is likely to go out for bid in Spring 2011; see below.

TC 3.6 (Water Treatment): How Mechanical Filtration of Cooling Loops Affects Efficiency of Equipment with Enhanced Tubes. *RTAR being drafted(?)*

Ken provided some background/bibliography on fouling to Scott Mayes following the previous meeting, but has not heard anything more. Ken will follow up to learn status of this project idea. TC 3.6 might also be interested in cosponsoring the fouling projects listed below.

Research Project Ideas

- "Fouling of Tube-in-Tube Type Condensers" This would continue our line of projects attempting to quantify the impact of fouling on heat transfer performance in various types of exchangers. It appears that 1345-RP has determined a procedure for successfully running (precipitation) fouling tests. The consensus during the TC 8.5 meeting was that it is time to start working on an RTAR. (But did anyone volunteer to lead the draft of an RTAR?) In the past, AHRI has indicated cofunding might be available for this project; Ken will contact AHRI to determine interest at this time. HTRI has expressed interest in doing this project.

- There was also consensus that the timing is right for resubmission of the fouling in enhanced tubes WS. A new WS should account for the fact that low fouling potential water did not produce any measurable fouling effect. It has also been suggested that we consider adding a modeling aspect – how should fouling be described (ie, is "β_2·FF" the correct/best description)? This topic has also been raised in TC 8.2. Joe, Ben, and Ken volunteered to draft an RTAR.

- "Enhancement of Internal Flow Heat Transfer Coefficient with Micro-Encapsulated Phase Change Material" No champion has stepped forward for this project idea and so it will be dropped.

- "Characteristics of new low GWP refrigerants in heat transfer equipment" The interest in this topic continues to increase. Some concern was expressed that thermodynamic properties are not yet well enough established to do exacting heat transfer performance calculations. It was suggested that attention at this point could be placed on performance of the new refrigerants relative to today's refrigerants. It was noted that DOE and it's contractor Navigant Consulting are preparing a report on or roadmap for alternate refrigerants.[1] **Post-meeting, Joe initiated contact with TC's 1.3, 3.1, 8.4, and 8.5, along with Sam Yanna Motta and Jon Hartfield, to begin a coordinated effort to address this topic.**

- "New Technologies for Reducing Refrigerant Charge" This topic was proposed by Samuel Yana Motta as a corollary to the project on low GWP refrigerants because of their main drawbacks (many of them are flammable or toxic to some degree and some will be expensive). One comment made was that this topic might be difficult to pursue from a pre-competitive position.

- "CO_2 in Secondary Loops" This topic was raised by Omar Abdelaziz at previous meetings, but not discussed specifically this time. The rationale is that the flammable and/or toxic nature of the natural and new low GWP refrigerants might require use of secondary loops to separate these fluids from occupied spaces.

- "Nanofluids for HVAC" This topic also being considered by TC 1.3. As part of his New Investigator project, Amir Jokar has compiled an extensive bibliography of work in this area. Ken Schultz reported the results of a benchmarking exercise recently conducted on measurements of the thermal conductivity of various nanofluids. "Nan et al.'s theory[2] was found to accurately reproduce the [exercise's] experimental data, thus suggesting that no anomalous enhancement of thermal conductivity was observed in the nanofluids tested in" the benchmarking exercise. [3] Published reports in the area of boiling/evaporation using nanofluids, although agreeing that critical heat flux can be increased, are inconsistent with regard to improved or degraded heat transfer coefficients and remain uncertain as to the fundamental phenomena occurring. The consensus was that this field remains too young and uncertain for us to play an effective role, at least in the short term.

[1] Navigant Consulting led a forum at the Purdue Conferences on 13-Jul-2010 with the objective to seek input on how DOE could facilitate the implementation and market acceptance of next-generation low GWP and low LCCP refrigerants. The summary report is appended to this document. Additional input will be sought over the coming months. The goal is to outline a roadmap by early 2011 for work that could progress over the next five years. So, maybe by next year there could be opportunities to seek co-funding from DOE for ASHRAE projects in this area?

[2] Generalization of Maxwell's "effective medium theory" from 1881.

[3] J Boungiorno, 2010, "Letter to the Editor – The international nanofluid property benchmark exercise", *International Journal of Heat and Fluid Flow*, vol 31, issue 2, pp 246-247. link to abstract See also, "J Boungiorno et al., 2009, "A benchmark study on the thermal conductivity of nanofluids", *Journal of Applied Physics*, vol 106, 094312. link to abstract

SUMMARY FROM RESEARCH CHAIR BREAKFAST

The Research Strategic Plan 2010-2015 has been published; http://www.ashrae.org/technology/page/39. "The plan identifies key HVAC&R research needs and provides that information to ASHRAE members and technical committees as guidance while they develop research projects and to the Research Administration Committee as it approves and funds research proposals. The Research Plan is not meant to take the initiative for research design from the cognizant committees, but rather to use input from ASHRAE members to identify strategic research needs that are appropriate for many committees to collaborate on, that may require larger budgets, and for which additional outside funding may be available to supplement ASHRAE's budget." RTAR's don't need to explicitly fit into the RSP. They do need to describe how the project will benefit ASHRAE and society. "If it's good research, it will get funded."

RAC is consulting with the following organizations as it reviews, prioritizes, and selects research projects: AHRI, CIBSE, CEC (California Energy Commission), and USGBC.

Some budget numbers:

	FY 2010-2011	FY 2011-2012
current commitments	$2,616,000	$802,000
additional commitments	310,000	1.7M-2.2M
total commitments	$2,926,000	for Spring 2011

About 15 projects were awarded at Louisville; these consumed a good share of the available funds. The remaining funds may allow 1-3 projects to be awarded this fall. The remaining (~20) TRP's in the queue are expected to be awarded in Spring 2011. So, it is a good time to submit new RTAR's.

The Research Manual has been updated. Existing RTAR's can continue to refer to the old Research Strategic Plan (2005-1010), new RTAR's should refer to the new Plan (2010-2015). Again, research proposals do have to directly address the plan, but those that do will likely be given higher priority.

New forms have been created for RTAR and WS evaluations. The forms attempt to categorize the evaluation criteria and responses by RAC members. Criteria include well established need, appropriateness for ASHRAE, reasonable budget, etc. The forms are meant to provide a means for documenting RAC comments/questions and transmitting them back to the TC's more consistently and clearly.

As a project deliverable, only papers submitted to the HVAC&R Research journal and as Transactions Technical paper are acceptable; "Conference" papers are not acceptable (not as rigorously reviewed). PMS members will be invited to review these papers (through Manuscript Central). There is expectation that the PMS will have already reviewed an papers prior to submission. Papers need only be submitted to meet the project deliverable, not necessarily accepted. This prevents final payment to the PI being impacted by potential tardiness in or length of the review process.

Schultz, Ken

From: Timothy Sutherland [timothy.sutherland@navigantconsulting.com]
Sent: Monday, July 19, 2010 4:00 PM
To: Timothy Sutherland
Cc: William Goetzler
Subject: Next-Generation Refrigerants Forum Summary Report
Attachments: Next-Gen Refrigerant Forum Summary Report_final_071910.docx

Dear All,

On behalf of myself and Bill Goetzler, we would like to thank you for taking the time to attend the forum on Next-Generation Refrigerants last Tuesday evening. The forum was incredibly successful and yielded crucial insights for developing and implementing a successful strategy to meet the proposed HFC phase-down requirement. Attached you will find a copy of the Forum Summary Report.

We expect to host one or more additional forums over the course of the next several months, and we welcome your continued participation.

Finally, if you are interested and would like to serve on a technical advisory panel for this effort going forward, please let me know. The commitment and responsibilities would involve reviewing a couple of reports and participating in a few web conferences.

Thanks again, and best regards,
-Tim

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July 19, 2010

Next-Generation Refrigerants Forum at Purdue University – Summary Report

On July 13, 2010, Navigant Consulting Inc. (NCI), on behalf of the United States Department of Energy (DOE) and Oak Ridge National Laboratory (ORNL), hosted a forum on next-generation refrigerants with ultra-low global warming potential (GWP). The forum was held at Purdue University, concurrent with the Compressor Engineering and Refrigeration and Air Conditioning Conferences. Forty participants attended the forum, including representatives from HVAC equipment and appliance manufacturers, refrigerant manufacturers, federal government laboratories, academia, industry trade groups, and end users. Table 1 presents a list of the attendees and their affiliations.

The forum began with a statement of DOE's objective to support the United States' stated commitment to reduce HFC consumption by 85% by the year 2033. This was followed by a brief review of DOE's historical role helping to develop HFC alternatives to CFCs and HCFCs. Finally, attendees participated in a group discussion to articulate and prioritize areas where DOE could play a role in facilitating the implementation and widespread market acceptance of next-generation low-GWP and low life cycle climate performance (LCCP) refrigerants.

During the discussion, attendees proposed numerous areas of research, development, testing, and commercialization that must be addressed in order for the United States to achieve its stated goal of phasing down the use of HFC refrigerants. At the end of the forum, each attendee was asked to identify and vote for the seven areas that should be prioritized and where DOE could play a constructive role. The results of this discussion and subsequent voting are presented in Table 2.

In addition, forum participants also voiced concern about the regulatory burden associated with meeting both efficiency regulations and refrigerant regulations. Specifically, a number of participants expressed concern that for some equipment, lower-GWP refrigerants may negatively impact energy efficiency.

At the request of the forum hosts, participants suggested venues for additional forums as well as specific stakeholder groups that should be considered for inclusion. The following potential venues were suggested:

- FMI Energy & Technical Services Conference
- AHRI Spring Meeting
- AHRI Research & Technology Committee Meeting
- ASHRAE meetings
- Insurance industry conference or meeting
- SAE meeting
- Building code official meeting
- Virtual web meeting

Forum participants suggested that the following groups be consulted for additional input:

- Insurance industry
- Building owners & operators
- Automobile industry
- Refrigeration industry
- Large national retailers
- Building code officials
- UL standards officials
- Efficiency advocates
- Policy makers

Finally, the NCI, ORNL, and DOE team wishes to thank all the participants of this forum. The suggestions, insights, and feedback provided during the forum are critically important for developing and implementing a successful strategy to meet the proposed HFC phase-down requirement. The team expects to host one or more additional forums over the course of the next several months and welcomes the continued participation of industry experts.

Please address any questions or comments to Timothy Sutherland at timothy.sutherland@navigantconsulting.com.

Table 1: List of forum attendees and affiliation

Name	Affiliation
HVAC Equipment & Appliance Manufacturers:	
Qiao Lu	B/E Aerospace
Michio Moriwaki	Daikin
Hung M. Pham	Emerson
Jean-Luc Caillat	Emerson
Ken Monnier	Emerson
Gary Scheldorf	GE
Joe Bray	GE
Craig Tsai	GE Appliances
Ira Richter	Heatcraft
Shaobo Jia	Heatcraft
Ipseng Iu	Johnson Controls
Vladimir Sulc	Thermo King, IRCS
Ken Schultz	Trane
Refrigerant Manufacturers:	
Brett VanHorn	Arkema
Frank Rinne	Dupont de Nemours
Kostas Kontomaris	Dupont Fluorochemicals
Thomas Leck	Dupont Fluorochemicals
Mark Spatz	Honeywell
Samuel Yana Motta	Honeywell
Federal Government Laboratories:	
Mark McLinden	NIST
Omar Abdelaziz	ORNL
Therese Stovall	ORNL
Van Baxter	ORNL
Academia:	
Hiechan Kang	ACRC – University of Illinois
Lorenzo Cremaschi	Oklahoma State Univ
Ji Hwan	Pusan Nat'l Univ. (PNU)
Keumnam Cho	Sungkyunkwan Univ. (SKKU)
Brian Fricke	Univ of Missouri
Bryan Becker	Univ of Missouri - Kansas City
Nae-Hyun Kim	Univ. of Incheon
Reinhard Radermacher	Univ. of MD
Industry Trade Groups:	
Glenn Hourahan	ACCA
Karim Amrane	AHRI
Steven Szymurski	AHRI
Xudong Wang	AHRI
Didier Coulomb	Int'l Inst. Of Refrigeration
End Users:	
Lin Lan	Target
Others:	
Georgi Kazachki	DRS-ESI
Brian Hanhrahan	Kyowa Hakko
Qi Wang	Thermo Fisher

Table 2: Ideas proposed during next-generation refrigerant forum *{KJS: All of these ideas were deemed important to the future of low GWP/LCCP refrigerants. The prioritization reflects the attendees' thoughts on where DOE has a key role.}*

No. of Votes	Proposed Areas of Interest
29	Incorporate direct and indirect effects into models & regulations; Develop accurate LCCP models; Develop guiding criteria for assessing the feasibility of each refrigerant; Improve & standardize LCCP models, including assumptions & methodologies; Develop rigorous LCCP performance analyses & assessments
27	Measure refrigerant and system performance in real-world conditions
25	Provide refrigerant properties in the public domain, including components & blends (REFLEAK, REFPROP)
24	Test fluid properties; Assess thermo-physical/thermodynamic properties of each new fluid
22	Develop lubricants & oils for new refrigerants; Ensure material compatibility with new refrigerants
19	Promote research to support code changes & alleviate insurance concerns with respect to next-generation refrigerants
18	Promote research to deal with unique characteristics of some new refrigerants, including elevated pressures, flammability, and toxicity
17	Develop new working fluids; Screen and identify new refrigerants
17	Test system-level heat transfer properties
15	Develop accurate models of refrigerant consumption by sector that include impacts on total emissions (direct and indirect)
12	Develop sensors and tools to ensure proper charge & composition; Develop smarter systems that give feedback; Develop a common set of error codes
10	Develop equipment with low refrigerant charges
10	Support the training & education of servicers and the industry as a whole
10	Enhance cycle performance and tailor for new refrigerants
7	Create detailed system design models, and make them available in the public domain
7	Research and reassess the real-world flammability characteristics and risks of certain refrigerants
6	Demonstrate retrofit capability for low-GWP refrigerant options
5	Research other environmental, health, and safety impacts of new refrigerants
4	Design passive & active safety systems
3	Reduce leakage in semi-hermetic systems
3	Research not-in-kind technologies
2	Implement enforceable protocols and incentives for refrigerant recapture and recycling
2	Assess the decomposition or destruction of refrigerants at end-of-life
1	Research both direct-expansion and secondary loop refrigerants
1	Test and improve system reliability
1	Improve equipment insulation and sealing
1	Implement zero-leak mobile A/C systems
1	Provide better leak detection and characterization in equipment
1	Enhance air-side heat transfer technology
0	Develop marketing strategy for consumers, to make new refrigerants attractive
0	Improve in-plant production quality control
0	Articulate a common direction for all parties moving forward
0	Develop zero-leak refrigeration systems