Shaping Tomorrow's Built Environment Today

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TO: Joe Huang, Chair TC 4.2, yjhuang@whiteboxtechnologies.com
Drury Crawley, Research Subcommittee Chair TC 4.2, dbcrawley@gmail.com

CC: Michael Pouchak, Research Liaison Section4.0, mike.pouchak@honeywell.com

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

DATE: January 23, 2019

SUBJECT: Research Topic Acceptance Request (1874-RTAR), "Climatic Design Conditions for Roof Top HVAC Equipment"

During their winter meeting, the Research Administration Committee (RAC) reviewed the subject Research Topic Acceptance Request (RTAR) and voted to accept it with comments for further development into a work statement (WS) provided that the key comment(s) and question(s) below are addressed to the satisfaction of your Research Liaison, Michael Pouchak, mike.pouchak@honeywell.com, or RL4@ashrae.net, in the work statement draft.

1. The expected approach should be more detailed and clearly indicate whether the experimental validation is required.

The work statement draft 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 first draft of the work statement should be submitted to RAC no later than **December15, 2020** or it will be dropped from display on the Society's Research Implementation Plan. The next likely submission deadline for a new work statement on this topic is **March 15, 2019** for consideration at RAC's 2019 spring meeting. The submission deadline after that for work statements is May 15, 2019 for consideration at the RAC's 2019 annual meeting.

Project ID	**1874**	
Project Title	**Climatic Design Conditions for Roof Top HVAC Equipment**	
Sponsoring TC	TC 4.2, (Climatic Information)	
Cost / Duration	$75,000 - 12M	
Submission History	**1st Submission**	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC 2018 Winter Meeting Review		
Essential Criteria	**Voted NO**	**Comments & Suggestions**
Background: The RTAR should describe current state of the art with some level of literature review that documents the importance/magnitude of a problem. References should be provided. If not, then note it in your comments.		**9** - Good background, references cited, and some indication of the magnitude of the air heating effect is given, as it might affect HVAC rooftop equipment.
Research Need: Based on the background provided is the need for additional research clearly identified? If not, then the RTAR should be rejected.		**9** - The need is clear….namely, for better design data for the 'microclimate' region on roofs for evaluating potential effects on HVAC plant. **3** - Many relevant studies were already done. **12-** Having justification to promote CO2 or any other refrigerant is not necessary. The relevance is in getting an accurate air inlet temperature and enhance system efficiency through design? Looking online at 3 different manufacturers, it seems that RTU are sold on cooling load and not selected based on climatic data or geographic location. Looking at EU rating standard, RTUs are rated at 35C cooling and 7C heating there doesn't seem to be what-ifs (roof color, texture, etc.) in the rating scale.
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.		**9** - Clearly relevant. **4** - Connection to ASHRAE's Strategic Plan would be useful.
IF ABOVE THREE CRITERION ARE NOT <u>ALL</u> SATISFIED - MARK "REJECT" BELOW & CONTINUE REVIEW BELOW		
Other Criteria	**Voted NO**	**Comments & Suggestions**
Project Objectives: Based on the background and need, evaluate whether the project objectives are: 1. Aligned with the need 2. Specific 3. Clear without ambiguity 4. Achievable If not, then appropriate feedback should be provided.		**9** - These are clear, but the challenge of developing what are termed 'simple' relationships (between the broader local climate and the rooftop microclimate) should not be underestimated. It may be necessary to restrict the evaluation to particular representative typical geometries, and to consider the local wind profile as influenced by local terrain factors and height. **3** - There are many relevant studies, and the project objectives seems to be almost similar and are not distinct. **6** - this may require further definition to reduce ambiguity on 2,3,4.
Expected Approach and Budget: 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. Anticipated funding level and duration:		**2** - If more testing is needed, the funding may not be sufficient. **9** - This is broadly ok, but note the comments above under 'objectives'. Allowance of time and resource might have to be made for sufficient monitoring and measurements in practical situations. For that reason, I think the current funding range is low, and the duration is short. Be prepared to adjust these. **7** - The expected approach should be more detailed and clearly indicate whether the experimental validation is required. **6** - concerns about enough budget
References: Are the references provided?		
Decision Options	**Initial Decision?**	**Final Approval Conditions**
ACCEPT AS-IS		**2** - Need is well established, objectives and approach are clear. If more testing is needed, the funding may not be sufficient. **9** - Clearly-explained RTAR, proposing useful research. Work with RL to develop the WS with sufficient detail, and taking into account comments above, namely: i) the challenge of developing what are termed 'simple' relationships (between the broader local climate and the rooftop microclimate) should not be underestimated. It may be necessary to restrict the evaluation to particular representative typical geometries, and to consider the local wind profile as influenced by local terrain factors and height; ii) Allowance of time and resource might have to be made for sufficient monitoring and measurements in practical situations. For that reason, I think the current funding range is low, and the duration is short. Be prepared to adjust these. **4** - Connection to ASHRAE Strategic Plan. **7** - Clarify the expected approach. **3** - There are many relevant studies, and the project objectives seems to be almost similar and are not distinct. **6** - I like the concept; see comments above for refinements. **12** - I think it would be nice to have data for industrial design purposes, but link to refrigerant needs to be broken all systems (controller logic) could benefit. I worry that to the manufacturers of RTUs, this knowledge is well known and is already built in to existing controller logic designs allowing for product differentiation.
ACCEPT W/COMMENTS		
REJECT		

ACCEPT Vote - Topic is ready for development into a work statement (WS).
ACCEPT W/COMMENTS 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)
REJECT Vote - Topic is not acceptable for the ASHRAE Research Program

Research Topic Acceptance Request Cover Sheet

Date: Dec 3, 2018

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

A. Title	X
B Executive Summary	X
C. Background	X
D. Research Need	X
E. Project Objectives	X
F. Expected Approach	X
G. Relevance and Benefits to ASHRAE	X
H. Anticipated Funding Level and Duration	X
I. References	X

Title:

Climatic Design Conditions for Roof Top HVAC Equipment

RTAR # 1874
(To be assigned by MORTS)

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

Chapter 14 Climatic Design Information

Research Classification:

Basic/Applied Research	X
Advanced Concepts	
Technology Transfer	

Responsible Committee: TC 4.2 Climatic Information

Date of Vote: e-mail ballot, closed Dec. 3

For		7
Against	*	0
Abstaining	*	CNV
Absent or not returning Ballot	*	0
Total Voting Members		8

RTAR Authors

Lead: Niel Hayes

Others: Joe Huang
Joshua New

Co-sponsoring TC/TG/MTG/SSPCs (give vote and date)

TC 4.7 Energy Calculations (7-0-0 CNV Dec. 3)
TC 4.10 Indoor Enviironmental Modeling (9-0-1, 2NV Dec.1)

Expected Work Statement Authors

Lead: Joe Huang

Others: Niel Hayes
Joshua New
Michael Roth

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

	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

RTAR # ___1874______

Title:

Climatic Design Conditions for Roof Top HVAC Equipment

Executive Summary

The Climatic Information tables in the ASHRAE Handbook are used extensively to size HVAC&R equipment. The information in these tables is based on weather station data frequently obtained at airports and thus reflect average conditions in an open area at the outskirts of an urban environment. Often times, the actual climate conditions for various system components located on commercial rooftops, i.e., Rooftop Units (RTUs), may be significantly different than the Handbook values due to the localized air being heated as it travels over the hot roof. Neglecting this effect can lead to incorrectly sized system components and adverse system performance. The purpose of this RTAR is to study this effect combining measured data with computer modeling, with the final output either a calculation method or correction factors that allows application engineers to take this effect into account in the sizing of RTUs, thus improving their energy-efficiency and cost-effectiveness.

Background

There is a growing technical literature on microclimate variations within a city due to human-made changes to the local environment such as buildings, streets, and urban vegetation that have resulted in an "Urban Heat Island" (UHI) effect (Akbari et al. 1990; Erell et al. 2010; Williamson, Erell, and Soebarto 2009, Georgescu et al 2012). ASHRAE has sponsored two projects on this topic, one (RP-606, "Determination of Climate Variation within Metropolitan Areas", completed 1992) to characterize the UHI, and another (RP-1561,"Procedure to Adjust Observed Climatic Data for Regional or Mesoscale Climate Variations", completed 2015) to use meso-scale climate simulations to model the UHI effect. There have also been limited studies of the impact of a building itself on its own immediate environment, as when a hot roof elevates the temperature of the intake air of a Rooftop Unit (RTU). One UHI study in London reported that the UHII (UHI Intensity) for an RTU was of the order of 7°C as compared to an UHII of 2.6°C for the city (Levermore , Vandaele, and Parkinson 2017). A study comparing air temperatures at two locations (1 near and 1 far from the RTU) found a small increase of 0.3°C that was eliminated when the roof albedo was increased (Wray and Akbari 2008). Another recent study in Australia found that air temperatures within 1.5m (4.5 ft) of the roof surface were typically 0.5-4°C higher than the ambient air temperature during the middle of the day (Green, Paolini, Synnefa et al. 2018). CFD simulations were also done in parallel with the measurements, but the RMS compared to the measured data was larger than the measured temperature rise. Lastly, there are also measured data on air temperatures entering RTUs that can be made available to this proposed project (Hayes 2018).

Research Need

While the difference of actual urban temperatures deviating from ASHRAE rural climate data has been addressed, the actual usable data that practicing application engineers need to more correctly size HVAC&R equipment that is subject to actual roof top temperatures is not readily available. Currently, the majority of customers that purchase HVAC&R equipment (grocery store retailers) do not specify the design climate conditions for equipment OEMs or manufacturers. Engineers responsible for the system design must rely on published climate data. For years, sizing HFC based HVAC&R equipment hasn't needed to be precise; if equipment was subject to temperatures greater than design temperature data, system capacity suffered but limped along during excessively hot portions of the year. With the Commercial Refrigeration industry attempting to adopt CO2, the low critical temperature and high pressures of CO2 present challenges if components are not sized correctly for the climate they will be subject to. Large amounts of (short circuited) bypassed flashgas can be produced in the system at high operating temperatures which can lead to threatening system safeties which could shut systems down rather than just "limp along." Arbitrarily increasing design temperatures by too much can lead to unnecessary increase in costs to the customer, which roadblocks the adoption of new technology. Using design temperature data that more accurately reflects what system components will be exposed to is essential to ensure that systems operate efficiently and robustly in the most cost effective manner. Research is needed to be able to properly supply more appropriate climate data in published ASHRAE materials to better assist engineers designing HVAC&R systems that will also satisfy customer's expectations.

Project Objectives

Project Objectives will include:

1. Identifying factors that influence the differences between ASHRAE design or measured ambient temperature data and urban commercial roof top temperatures (roof top surface characteristics including albedo and roughness, roof dimensions, solar radiation, wind speed, etc).
2. Observation of the temperature differences through testing and data collection.
3. Analysis of data and CFD simulations to arrive at simple equations or tables to modify ASHRAE design data to include the elevated air temperatures due to heating by the roof.
4. Update ASHRAE literature and tools to include roof top temperature data with explanation for how and when to apply the data in real world application engineering.

Expected Approach

Describe in a manner that may be used for assessment of project viability, cost, and duration, the approach that is expected to achieve the proposed objectives (200 words maximum).

Check all that apply: Lab testing ☐ Computations ☒ Surveys ☐ Field tests ☒ Analyses and modeling ☒ Validation efforts ☐ Other (specify) ( )

The project is expected to involve literature review, finding and obtaining measured data on rooftop air temperatures, preferably coupled with ambient air temperature measurements, and the use of computer simulations, e.g., Computation Fluid Dynamics (CFD), to understand the relationship between climate conditions and roof characteristics to rooftop air temperatures, which will then lead to a simple equation or look-up table in the ASHRAE Handbook to account for the heating of air entering an RTUs. If deeded necessary, limited measurements of air temperatures over a roof can also be done.

Relevance and Benefits to ASHRAE

There are many challenges that the HVAC&R industry faces with respect to its impact on climate and the environment. One of the biggest challenges is reducing the use of chemicals that contribute to global warming. CO_2 is a viable alternative to such chemicals in the commercial refrigeration sector, but its acceptance into the market has been slow outside of Europe. Some of the hesitancy to adopt CO_2 is attributed to the challenges of its low critical temperature and high working pressures, which create difficulties in designing systems to operate to the same expectations of synthetic refrigerants. Customers (grocers) are disappointed when CO_2 systems shut down in warm weather, which can occur when the temperatures that systems are being exposed to are well above the recommended design climate information currently found in the ASHRAE database.

The completion of this project will give more correct climate design information for RTUs (via a simple algorithm or look-up table) to engineers and application designers, allowing systems and components to be designed and selected appropriately for the climate conditions they will actually be exposed to. These designs will include components that won't need to be needlessly over designed, causing the first cost of the equipment to be a detriment to the acceptance and adoption of a cleaner, more environmentally friendly technology.

Anticipated Funding Level and Duration

Funding Amount Range: $ 75K

Duration in Months: 12

References

Levermore,G. , S. Vandaele and J. Parkinson (2017) "Temperature adjustments for design data for urban air condition design", Building *Services Engineering Research & Technology* (UK), 0 (0), 1-8

Erell,E., I. Eliasson, S. Grimmond, B. Offerle and T. Williamson (2010) "The effect of stability on estimated variations of advected moisture In the Canyon Air Temperature (CAT) Model, *9th Symposium on Urban Environment*, J4C.4

Green, A., R. Paolini, A. Synnefa et al. 2018. "Characterisation of the air temperature filed above large-footprint buildings – full-scale experiments and large eddy CFD simulations". *Proceedings of the 11th Australasian Heat and Mass Transfer Conference,* Melbourne Australia, July 9-10, 2018.

Hayes, N. 2018. personal information from RTAR co-author.

Williamson, t., E. Erell, and V. Soebarto (2009) "Assessing the error from failure to account for urban microclimate in computer simulation of building energy performance", *Eleventh IBPSA Conference*, Glasgow, Scotland, 497-504.

Wray, C.P. and H. Akbari (2008). "The effect of roof reflectance on air temperatures surrounding a rooftop condensing unit". *Energy and Buildings*, Vol. 40, p. 11-28.