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David V Quirk, Research Subcommittee Chair TC 9.9, dquirk@dlbassociates.com
Paolo Tronville, Research Liaison 9.0, paolo.tronville@polito.it

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

DATE: November 6, 2018

SUBJECT: Research Topic Acceptance Request (1867-RTAR), "Development and validation of a model for assessing the corrosion risk of Datacom equipment under different pollution and thermal environmental conditions"

During their fall meeting, the Research Administration Committee (RAC) reviewed the subject Research Topic Acceptance Request (RTAR) and voted 5-0-0 to reject it. The following list summarizes the consensus review comments and questions on this RTAR:

1. The RTAR only provides a weak link to the ASHRAE Research Strategic Plan.
2. There are numerous negative votes requesting results from 1755 RP.
3. The need for the additional research is unclear and a more detailed explanation of what additionality there will be.
4. It is not clear what ASHRAE 1755-RP "Impact of Gaseous Contamination and High Humidity on the Reliable Operation of Information Technology Equipment in Data Centers" will accomplish and what will still be missing.

By rejecting this RTAR, RAC is strongly suggesting to the TC that this particular topic be dropped from the TC research plan based on the information that has been provided.

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.

If the TC wishes to pursue this topic further, please incorporate the above information into the RTAR with the help of your Research Liaison, Paolo Tronville, paolo.tronville@polito.it, prior to submitting 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 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.

The next realistic submission deadline for RTARs and WSs is May 15, 2019 for consideration at the Society's 2019 annual meeting. The submission deadline after that is August 15, 2019 for the RAC fall meeting.

Project ID	1867	
Project Title	**Development and validation of a model for assessing the corrosion risk of Datacom equipment under different pollution and thermal environmental conditions**	
Sponsoring TC	TC 9.9, Mission Critical Facilities, Data Centers	
Cost / Duration	$250,000 / 24 Months	
Submission History	**1st Submission**	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC 2018 Fall 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.		**2** - The RTAR stated that numerous studies have focused on the temperature, relative humidity, and gas contamination effects on metal corrosion. However, most of them have been based on extremely high concentrations of gas pollutants, much higher than concentrations expected indoors. The phenomena with high concentration however mean the accelerated tests and it would be question why the accelerated test cannot be applied at the low concentration situation. **7** - The proposal only presents a weak link between the gas contaminants and failure of electronic equipment in Data Centers. **9** - Developing a model for corrosion prediction of electronic components as a result of thermal and pollution environments
Research Need: Based on the background provided is the need for additional research clearly identified? If not, then the RTAR should be rejected.		**9** - Mentions an existing RP 1755, but need for the additional research is unclear and needs more detailed explanation of what additionality there will be. In fact the co-sponsoring TC2.3 had a number of votes against for this reason. This is issue should be made clear. **10** - It is not clear what ASHRAE 1755-RP "Impact of Gaseous Contamination and High Humidity on the Reliable Operation of Information Technology Equipment in Data Centers" will accomplish and what will still be missing. The RTAR author is PI of ASHRAE 1755-RP.
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.		**7** -The RTAR only provides a weak link to the ASHRAE Research Strategic Plan. I don't see a strong relationship between building energy efficiency (free-cooling) and the concentration of the gas contaminants mentioned in the proposal. If you are proposing direct free-cooling, then the application is not in the domain of ASHRAE interests. The Data Center industry should be funding this project. **9** - Will support new guidelines…fundamental model at surface science level. **10** - The added value of the research proposed by this RTAR is not clear until we have the final report for 1755-RP. Data and conclusions from this study are needed before moving on to a similar study. **8** - not sure that this lines up with ASHRAE research plan
IF ABOVE THREE CRITERION ARE NOT ALL 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.		**2** - The RTAR requires the development of a mechanistic model based on the fundamentals at a surface science level (e.g. adsorption of pollutants, transport of pollutants, chemistry at the surface) and it seems to be outrange of ASHRAE scope. **9** - Clear objectives, but clarify the meaning of validate with limited data - does that mean across the extremes of a range? $250k over 24 months is expensive, a and the breakdown could be more detailed. **10** - Not clear whether the experimental data provided by this project would provide additional value compared to ASHRAE RP-1755. Calculation of energy savings should include some minimum number of typical applications.
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:		**4** - What are the risks that the model cannot be developed? **9** - Clear and step by step approach given. **10** - The budget seems high if we take in consideration that ASHRAE RP-1755 was funded with approximately 250k. The overall amount for the two projects would be half a million dollars.
References: Are the references provided?		
Decision Options	**Initial Decision?**	**Final Approval Conditions**
ACCEPT AS-IS		**2 -** State why the accelerated test with high concentration cannot be applied at the low concentration situation with the same conditions of temperature and humidity. **4 - A**re there any risks that a mechanistic model cannot be developed? Are there any similar models that can be used for this purpose? The proposed work is quite expensive. There are numerous negative votes requesting results from 1755 RP. Have this been addressed in the version of the RTAR that has been submitted? **7 -** The data center or computer electronics industry should be funding this project. **9** - Either: Reject and invite re-submission pending the results of 1755 RP; Or clarify in detail the additionality this will bring beyond 1755 RP. This appears as quite fundamental science. Would other funding sources such as NSF be more appropriate than ASHRAE in the first instance? If the additionality can be identified and justified, then I'd vote to accept with comments. Can the RL help out here? **10 -** Wait till ASHRAE 1755-RP completion or final report submittal to propose the follow up of that project. All other comments could be addressed after that. Since the final report is due before next winter conference that should not delay very much the effort proposed here. **12** - If 1755-RP does not cover this information, then it is needed. Will concede to your TC members to approve. **8** - research need is not compelling
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: August 14, 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:

Development and validation of a model for assessing the corrosion risk of Datacom equipment under different pollution and thermal environmental conditions

RTAR # 1867
(To be assigned by MORTS)

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

- Chapter 17 Handbook HVAC Applications
- SP: Thermal Guidelines for Data Processing Env.
- SP: Particulate and Gaseous Contamination in Datacom Env.
- ASHRAE / ANSI Standard 90.1 and 90.4

Research Classification:

Basic/Applied Research	X
Advanced Concepts	
Technology Transfer	

Responsible Committee: TC 9.9 Mission Critical Facilities, Data Centers...

Date of Vote: July 31, 2018

For		10
Against	*	1
Abstaining	*	2
Absent or not returning Ballot	*	0
Total Voting Members		13

RTAR Authors

Lead:	Jensen Zhang, Syracuse University
Others:	Dustin W. Demetriou, Vice Chair, ASHRAE TC9.9
	Rui Zhang
	Roger Schmidt
	Jon Fitch, Voting Member, ASHRAE TC9.9

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

TC2.3 Gaseous Air Contaminants and Gas Contaminant Removal Equp.
- For: 9
- Against: 4
- Abstain: 1
- Absent: 1
- Total: 15

Expected Work Statement Authors

Lead: Dustin W. Demetriou, Vice Chair, ASHRAE TC9.9

Others:
Jon Fitch, Voting Member, ASHRAE TC9.9

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

TC 9.9 negative vote comments:
Results are needed from 1755-RP before voting on a follow-on project.
TC9.9 abstaining votes were from voting members who had a part in authoring the RTAR.

TC 2.3 negative vote comments:
Results are needed from 1755-RP before voting on a follow on research effort
Outside the scope of TC 2.3
Price is too high (comment by Abstaining voter, research liaison for TC 9.9)

RTAR # 1867

Title:

Development and validation of a model for assessing the corrosion risk of Datacom equipment under different pollution and thermal environmental conditions.

Executive Summary

Describe in summary form the proposed research topic, including what is proposed, why this research is important, how it will be conducted, and why ASHRAE should fund it (50 words maximum)

The reliability of electronic equipment is affected by the environment's thermal and air quality conditions. This research will develop and validate a mechanistic model for predicting the corrosion level in these environments to enable the risk assessment of the equipment and allow for greater energy savings under wider environmental conditions.

Background

Provide the state of the art with key references (at the end of this document) substantiating it (300 words maximum)

Numerous studies have focused on the temperature, relative humidity, and gas contamination effects on metal corrosion. However, most of them have been based on extremely high concentrations of gas pollutants, much higher than concentrations expected indoors. Recent results from ASHRAE 1755-RP show that even at relatively low concentrations (e.g., 10ppb H_2S, 80 ppb NO_2, 40 ppb SO_2, 2 ppb Cl_2 and 60 ppb O_3), the synergistic effects of O_3, NO_2, SO_2 and/or H_2S/Cl_2 can cause high corrosion levels that are much higher than the limits set for data center operation, namely, 300 angstroms per month for copper and 200 angstroms per month for silver. Currently there is no simulation model that is capable of predicting the synergistic effect of the different contaminants, relative humidity, and temperature. J. Tidblad et. al used the multi-layer GILDES (gas, interface, liquid, deposition, electrodic regime and solid) to simulate the corrosion of copper with Stumm's concept of proton- and ligand-promoted dissolution. Richard S. Larson studied the physical and mathematical model for the atmospheric sulfidation of copper by H_2S. It made use of the type-p semiconductor characteristic of Cu_2S to simulate the electrochemical process as the transport of electrons and vacancies. However, it was only for Cu_2S and did not include the variation of pollutants and thermal conditions. Results from ASHRAE 1755-RP showed differences in corrosion level due to various combinations of gas pollutants and thermal environments. A more comprehensive and capable corrosion model is needed to predict the corrosion levels under different pollution and thermal environmental conditions in supporting the design and operation of data centers in an energy efficient manner while reduce the risk of pre-mature failure of datacom equipment due to corrosion. Environments that can enable wider temperature and humidity conditions enable the application of free-cooling technologies for more months of the year. Applying free-cooling technologies has been shown to reduce energy consumption by as much as 8.5% for every 2°C increase in allowable temperature.

Research Need

Use the state of the art described above as a basis to specify the need for the proposed effort (250 words maximum)

In order to design efficient and reliable electronic equipment, owners and operators need to understand the impact of the synergistic effects of temperature, humidity and gas concentrations. Experimentally determining all combinations of conditions and their impact is unrealistic. Prior research efforts have showed the challenge of communicating the mechanism of corrosion to the industry and the limitations of experimental methods for characterizing corrosion. Therefore, there is an industry need for:

1. A validated model based on the surface science of corrosion accounting for the synergistic effects of different pollutants, humidity and temperature on corrosion levels.
2. Corrosion measurements under realistic conditions in an indoor environment for the validation of the mechanistic model.
3. An easy-to-use method and procedure for assessing the relative risk of electronic equipment failure due to corrosion, based on the validated mechanistic model, and the energy savings due to the extended environment for free-cooling operation.

Project Objectives

Based on the identified research need(s), specify the objectives of the solicited effort that will address all or part of these needs (150 words maximum)

To meet the research needs this project will undertake the following objectives:

1. Develop a mechanistic model with an emphasis on an understanding of the fundamentals at a surface science level (e.g. adsorption of pollutants, transport of pollutants, chemistry at the surface) of corrosion accounting for the synergistic effects of pollution and thermal environment.
2. Validate the model using limited laboratory experimental data under realistic pollution levels to understand the behaviors seen in prior mixed-flowing gas experiments.
3. Develop a risk assessment procedure for evaluating electronic equipment failure due to the combined effect of temperature, humidity, and gaseous pollution. The procedure should be easy-to-use by the industry and provide a clear series of steps to follow.
4. Develop a procedure to enable the calculation of the energy savings potential and relative risk trade-off of expanding the temperature and humidity environment on electronic equipment reliability under realistic gaseous contamination mixtures.

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 (X), Computations (X), Surveys ( ), Field tests ( ), Analyses and modeling (X), Validation efforts (X), Other (specify) ( )

The project will be a comprehensive numerical / experimental research plan to utilize the following techniques and tools for accomplishing the stated objectives:

1. Develop a mechanistic simulation model with an emphasis on an understanding of the fundamentals at a surface science level (e.g. adsorption of pollutants, transport of pollutants, chemistry at the surface). A mechanistic understanding will allow the research to build a predictive model that explains/models the experimental corrosion rate results and is able to evaluate the relative risk of corrosion.
2. Laboratory testing using mixed-flow gas testing (ASTM B927) with control of temperature, humidity, and velocity and gas concentration with a focus on validation of the model. Copper and silver coupons and bare PCBs as the samples.
3. Coulometric reduction (ASTM B835) will be used to measure the corrosion thickness of the coupons.
4. SEM/EDS, AFM and XPS to do the chemical analysis and detect the geographical and chemical composition characteristics of the corrosion surface.

Relevance and Benefits to ASHRAE

Describe why this effort is of specific interest to ASHRAE, its impact, and how it will benefit ASHRAE and the society. How does it align with ASHRAE Strategic Plans and Initiatives? How does it advance the state of the art in this area in general? Are there other stakeholders that should be approached to obtain relevant information or co-funding? (350 words maximum)

The results of this research proposal will help support both ASHRAE's Strategic Plan and Research Priorities. The research will support the development of new guideline for controlling the thermal environment for electronic equipment (e.g. data centers) around the world. The corrosion model will enable and provide a good reference for designers and operators of buildings to reduce energy consumption through the expanded use of free-cooling solutions while maintain high reliability of the electronic equipment. The scientific models developed through this effort will be turned into practical tools that help owners and operator is assessing their building designs and support the easier development of solutions to meet ASHRAE Standard 90.1 and 90.4. These practical tools will be most valuable in global, emerging markets and expand the influence of ASHRAE publications and standards in these markets. Although the research has a focus on data centers, the applicability of this research extends to any and all electronics that could be impacted by corrosion due to gaseous contamination – for example, HVAC control systems, telecom rooms, PCs and laptops, to name a few.

Anticipated Funding Level and Duration

Funding Amount Range: $250,000 total

Mechanistic corrosion model development $100,000

Model validation experiments $100,000

Characterization of the corrosion products $50,000

Duration in Months: 24 months

References

List the key references cited in this RTAR

ASHRAE (2005). Design Considerations for Datacom Equipment Centers. ASHRAE Datacom Series, Book 3.

ASHRAE (2014). Particulate and Gaseous Contamination in Datacom Environments, 2nd Edition. ASHRAE Datacom Series, Book 8.

ASHRAE (2015). Thermal Guidelines for Data Processing Environments, 4th Edition. ASHRAE Datacom Series, Book 1.

ASHRAE (2016). IT Equipment Design Impact on Data Center Solutions. ASHRAE Datacom Series, Book 12.

Hainan Zhang, Shuangquan Shao, Hongbo Xu, Huiming Zou, Changqing Tian (2014). Free Cooling of Data Centers: A Review. *Renewable and Sustainable Energy Reviews*, 35(2014), 171-182

Intel Information Technology (2008). Reducing Data Center Cost with an Air Economizer.

J. Tidblad, T.E. (1996). GILDES Model Studies of Aqueous Chemistry. III. Initial SO2-Induced Atmospheric Corrosion of Copper. *Corrosion Science*, 38 (12), 2201 – 224.

Kuei-Peng Lee, Hsiang-Lun Chen (2013). Analysis of Energy Saving Potential of Air-Side Free Cooling for Data Centers in Worldwide Climate Zones. *Energy and Buildings*, 64 (2013), 103-112

Larson, R.S. (2002). A Physical and Mathematical Model for the Atmospheric Sulfidation of Coppery by Hydrogen Sulfide. *Journal of the Electrochemical Society*, 149 (2), B40 – B46.

Revie, R.W. Uhlig's Corrosion Handbook, 3rd Edition.

Feedback to RAC and Suggested Improvements to RTAR Process

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