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TO: David Skelton, Chair TC 2.9, DavidSkelton@EvergreenUV.com
Richard Vincent, Research Subcommittee Chair TC 2.9, vincentrl777@gmail.com
CC: Pawel Wargocki, Research Liaison Section 2.0, paw@byg.dtu.dk

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

DATE: January 23, 2019

SUBJECT: Research Topic Acceptance Request (1873-RTAR), "Upper-Air Ultraviolet Germicidal Irradiation (UVGI) for Tall Spaces"

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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, Pawel Wargocki, paw@byg.dtu.dk, or RL2@ashrae.net, in the work statement draft.

1. Work with RL to develop a suitably detailed WS.
2. The research term and the budget can be reduced since the study will be conducted only by computation.
3. Detail how this work is different from other projects on upper UV systems.
4. Make clear whether the proposed work is only an experimental work and whether it includes also modelling.
5. Since there is a lot of projects on UV systems, add more references to the most relevant ones, specifically addressing the main objective of the proposed, which is upper UV systems in tall spaces.

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** | **1873** | |
| **Project Title** | **Upper-Air Ultraviolet Germicidal Irradiation (UVGI) for Tall Spaces** | |
| **Sponsoring TC** | TC 2.9, (Ultraviolet Air and Surface Treatment) | |
| **Cost / Duration** | $150,00 -$200,000 - 12 to 18 M | |
| **Submission History** | **1st Submission** | |
| **Classification: Research or Technology Transfer** | Basic/Applied Research | |
| **RAC 2019 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. | | **DL** - Background clearly defines the background to the problem. |
| **Research Need:** Based on the background provided is the need for additional research clearly identified? If not, then the RTAR should be rejected. | | **DL** - There is a clear need for evaluating two differing approaches to UV treatment of room air in high ceiling rooms. The RTAR explains the problem very clearly. |
| **Relevance and Benefits to ASHRAE:**<br>Evaluate whether relevance and benefits are clearly explained in terms of:<br>a. Leading to innovations in the field of HVAC & Refrigeration<br>b. Valuable addition to the missing information which will lead to new design guidelines and valuable modifications to handbooks and standards.<br>Is this research topic appropriate for ASHRAE funding? If not, Reject. | | **9** - There is a very clear benefit to ASHRAE. The work will provide a definitive answer to two differing approaches…which one is right? |
| **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:<br>1. Aligned with the need<br>2. Specific<br>3. Clear without ambiguity<br>4. Achievable<br>If not, then appropriate feedback should be provided. | | **9**- The objectives are clear…a carefully designed comparison. |
| **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.<br>Anticipated funding level and duration: | | **9** - A clear experimental approach, with appropriate funding and timescale. Make clear whether the 'research space' is to be funded as part of the requested funds, or should be an existing facility to be offered by a bidder (albeit with some modifications required). **7 -** Clarify whether the expected approach is just experimental or it involves some kind of modeling. **3 -** The research term and the budget can be reduced science the study will be conducted only by computation. **6** - budget seems high |
| **References:** Are the references provided? | | |
| **Decision Options** | **Initial Decision?** | **Final Approval Conditions** |
| ACCEPT AS-IS | | **2** - AR is well written and need, objectives and approach are clear. **9** - Good proposal, clearly written, addressing a specific question. Work with RL to develop a suitably detailed WS. **4** - This RTAR reads very well.. The proposed study will provide important input to ASHRAE guides and will experimentally examine different approaches used for designing UVGI in spaces with tall ceilings. As I understand no such research have been performed in the past. **7** - Clarify whether the expected approach is just experimental or it involves some kind of modeling. **3-** The research term and the budget can be reduced since the study will be conducted only by computation. **6** - overall would like better justification of cost. |
| 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: December 3, 2018

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

Title: Upper-Air Ultraviolet Germicidal Irradiation (UVGI) for Tall Spaces

| | |
|---|---|
| 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 |

RTAR # 1873
(To be assigned by MORTS)

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

HVAC Design Manual for Hospitals and Clinics
Chapter 8 Applications
Chapter 60 Applications
Chapter 17 Systems and Equipment

Research Classification:

| | |
|---|---|
| Basic/Applied Research | x |
| Advanced Concepts | |
| Technology Transfer | |

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Responsible Committee: TC 2.9 Ultraviolet Air and Surface Treatment

Date of Vote: 12/03/2018

| | | |
|---|---|---|
| For | | 7 |
| Against | * | 0 |
| Abstaining | * | 0 |
| Absent or not returning Ballot | * | 3 |
| Total Voting Members | | 10 |

RTAR Authors

Lead: Steve Martin

Others: Ken Mead

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

TC 9.6 Healthcare Facilities
vote 12/3/2018
8 for, 0 against, 0 abstaining, 7 not returning ballot, 15 total

Expected Work Statement Authors

Lead: Steve Martin

Others: Ken Mead

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 # ____1873_____**

**Title:**

**Upper-Air Ultraviolet Germicidal Irradiation (UVGI) for Tall Spaces**

**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)

Currently 49

Upper air ultraviolet germicidal irradiation is effective at controlling airborne infectious diseases. However, disagreement on the best UV dosing strategy exists, particularly in spaces with tall ceilings. This research will address the issues leading to disagreement and allow ASHRAE to provide conclusive design guidance for reliable, effective, energy-efficient systems.

**Background**

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

Currently 300

Upper-air ultraviolet germicidal irradiation (UVGI) is an effective means to reduce or eliminate the transmission of airborne infectious diseases. While performance efficacy is unquestioned, design approaches are challenging. Typical upper-air UVGI fixtures are installed a minimum of 7 feet above the floor. They incorporate horizontal baffles to direct the UV energy across the upper irradiated zone while limiting direct or reflected UV exposures to the lower occupied zone. The result is usually a relatively narrow horizontal irradiation zone operating directly above the occupied space. In 2009, the CDC's National Institute for Occupational Safety and Health (NIOSH) published *Environmental Control for Tuberculosis: Basic Upper-Room Ultraviolet Germicidal Irradiation Guidelines for Healthcare Settings*. The guidance resulted from a 2-year research effort to evaluate the ability of a well-designed and thoroughly characterized upper-air UVGI system to inactivate airborne mycobacteria. The NIOSH guidelines recommend a uniform UVGI distribution with an average UV irradiance of 30–50 $\mu W/cm^2$ applied across the upper room's horizontal cross-section. One limitation of the NIOSH guidance is that system designers cannot easily determine the average UV irradiance until after fixture selection and installation. This uncertainty leads to some ineffective and/or inefficient (i.e. over-designed) systems. Recently, researchers proposed a new strategy for upper-air system design based on total room volume, as opposed to horizontal room cross-section. Mphaphlele et al. stated that properly designed upper-air systems should provide a total UV fixture output of 15–20 $mW/m^3$ of total room volume, or an average whole-room UV irradiance level of 5–7 $\mu W/cm^2$, as calculated by a computer-assisted design program modified for UV use. There is desire to evaluate and include this new design strategy into *Guidelines for the Application of Upper-Air (Upper Room) Ultraviolet Germicidal (UV-C) Devices to Control the Transmission of Airborne Pathogens* currently being developed by ASHRAE GPC 37, if appropriate.

**Research Need**

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

Currently 247

Research is necessary to address issues precluding consensus design guidelines for upper-air UVGI systems installed in tall spaces. Mphaphlele's volume-based approach to system design is met with apprehension from some system designers due to perceived penalties on initial equipment and energy costs when the strategy is applied to tall spaces. Under the room volume design strategy, a given room requires a certain number of UV fixtures to adequately dose the space with UV energy. However, that same room footprint with the ceiling height doubled requires twice as many fixtures and twice the energy use. There is significant debate on whether these additional fixtures are actually needed in tall spaces or whether some other modification to current system design is appropriate for such spaces. The prevailing argument against the room volume method is that if a 12-inch horizontal irradiated zone with an adequate irradiance level adequately protects room occupants in a room with 8-foot ceilings, that same irradiated zone should remain protective to occupants in that same room with higher ceilings. After all, the volume of the occupied space and the associated pathogen generation rate is unchanged, and any viable airborne contaminants existing above the irradiated zone in a tall space would have to travel through the irradiated zone prior to exposing occupants. While this prevailing hypothesis seems plausible, no published research studies have investigated the concentration of viable microorganisms in the occupied zone for upper-air systems and the effect that ceiling height has on the system performance.

**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) –

Currently 147

The objective of this research is to identify improved ASHRAE design guidance for upper-air UVGI systems in spaces with tall ceilings. This research will determine if spaces with tall ceilings require more ultraviolet energy in the irradiated zone than spaces with typical 8-10 feet ceilings. The determination will be based on the ability of the UVGI systems to control the concentration of viable surrogate microorganisms in the occupied zone. The findings will scientifically validate competing methods for upper-air system design in tall spaces, comparing: 1.) existing NIOSH design criteria, which are currently used by ASHRAE in the 2015 HVAC Applications (Chapter 60) and 2016 HVAC Systems and Equipment (Chapter 17) Handbooks and 2.) recently proposed criterion suggesting total UV fixture output of 15–20 $mW/m^3$ of total room volume [Mphaphlele et al.]. The result may also be a new research-based design approach that adequately addresses tall spaces.

**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) ( )

Currently 200

A research space with adjustable ceiling height will be established. An 8-ft baseline ceiling height plus at least one additional height of 15 (±2) feet will be evaluated. Mechanical ventilation will provide the same air exchange rate and mixing efficiency (at breathing zone (BZ) height), regardless of ceiling height. Separate UVC upper-air systems, designed in accordance with NIOSH and Mphaphlele criteria, will be procured and properly installed for each ceiling height. Air disinfection efficiency will be determined for both the NIOSH and Mphaphlele systems by nebulizing a safe, surrogate microorganism into the test space. Multiple samples of viable microorganisms will be collected at BZ height throughout the room. Both low (8') and high 15(±2)' ceiling test conditions will be evaluated using both the NIOSH and Mphaphlele design approaches. Each ceiling height condition will also have a lamp-off control test to account for natural microorganism losses under the specific test and experimental conditions. An estimated 3-6 repetitions per test condition are anticipated, based upon variability. Fixture designs and UV output will be constant within conditions and between repetitions. Comparisons between the two design approaches will be made considering factors such as first cost, operating cost, design simplicity, and air disinfection effectiveness.

**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)

Currently 333

ASHRAE strives to provide strong design and operation guidance in the area of ultraviolet germicidal irradiation (UVGI). To that end, GPC-37 is currently finalizing the initial draft of *Guidelines for the Application of Upper-Air (Upper Room) Ultraviolet Germicidal (UV-C) Devices to Control the Transmission of Airborne Pathogens*. When it comes to upper-air UVGI systems, a key knowledge gap exists when it comes to the proper design for spaces with ceilings higher than 10 feet. The knowledge gained from this proposed research will make ASHRAE guidance stronger, increase scientific validity, and result in more cost-effective and energy-efficient upper air UV systems. In turn, these improved upper air UV systems will better protect people in the occupied zone from airborne disease transmission.

This proposed project supports multiple goals in the ASHRAE Strategic Plan. It supports Goal 1 to "Maximize the actual operational energy performance of buildings and facilities" by helping to optimize upper-air UV control strategies to improve infection control in an energy-efficient way. Upper-air UV systems designed using current guidance are often oversized and energy inefficient in spaces with tall ceilings. Describing UV system effectiveness at inactivating airborne microorganisms under various design scenarios will improve the ability of engineers to specify the most energy-efficient devices and operate them in the most effective manner. This project also supports Goal 11 to "Understand influences of HVAC&R on airborne pathogen transmission in public spaces and develop effective control strategies." In addition, Upper room UVGI strategies received the highest Application and Research Priority rankings in the ASHRAE Position Document on Airborne Infectious Diseases and it supports ASHRAE efforts to develop air cleaning and disinfection methods to reduce airborne pathogen transmission in healthcare and social assistance settings. It will also serve to blend ASHRAE, NIOSH and evolving industry guidance into overall best practice, the results of which will provide information for inclusion in the HVAC Systems and Equipment Handbook, Chapter 17: *Ultraviolet Lamp Systems* as well as in the HVAC Applications Handbook, Chapter 60: *Ultraviolet Air and Surface Treatment*.

**Anticipated Funding Level and Duration**

Funding Amount Range:

$150,000-200,000

Duration in Months: 12-18

**References**

ASHRAE [2015]. Ultraviolet air and surface treatment. In: ASHRAE handbook - HVAC applications, Chapter 60. Atlanta, GA: ASHRAE.

ASHRAE [2016]. Ultraviolet lamp systems. In: ASHRAE handbook - HVAC systems and equipment, Chapter 17. Atlanta, GA: ASHRAE.

ASHRAE [2014]. ASHRAE Position Document on Airborne Infectious Diseases (Reaffirmed by ASHRAE Technology Council in 2017), Atlanta, GA: ASHRAE.

Mphaphlele M, Dharmadhikari AS, Jensen PA, et al. [2015]. Institutional tuberculosis transmission. Controlled trial of upper room ultraviolet air disinfection: a basis for new dosing guidelines. American Journal of Respiratory and Critical Care Medicine *192*(**4**):477-484. doi:10.1164/rccm.201501-0060OC.

NIOSH [2009]. Environmental control for tuberculosis: Basic upper-room ultraviolet germicidal irradiation guidelines for healthcare settings. DHHS (NIOSH) Publication No. 2009-105. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Available at: https://www.cdc.gov/niosh/docs/2009-105/default.html.

**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.

This existing form is cumbersome to use. A more user-friendly version would be helpful.