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Kimberly Barker, Research Subcommittee Chair TC 1.4, kimberly.barker@siemens.com
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FROM: Michael R. Vaughn, Manager of Research and Technical Services (MORTS)

CC: Shinsuke Kato, Research Liaison 1.0, kato@iis.u-tokyo.ac.jp
Ahmed Kashef, Incoming Research Liaison 1.0, ahmed.kashef@nrc-cnrc.gc.ca

DATE: July 16, 2019

SUBJECT: Work Statement (1865-WS), "Optimizing Supply Air Temperature Control for Dedicated Outdoor Air Systems"

During their recent annual meeting, the Research Administration Committee (RAC) reviewed the subject Work Statement (WS) and voted 11-0-0 to conditionally accept it for bid provided that the RAC approval conditions below are addressed to the satisfaction of your Research Liaison in either written responses or revisions to the work statement.

See the approval conditions below.

1. Justification required why the duration was doubled, and the budget tripled from the RTAR values.
2. The proposal evaluation criteria does not add up to 100%.
3. The project milestones don't align with the stated scope and deliverables.
4. Update project milestone section with more descriptive content.

The WS review summary also contains comments from individual members of RAC that the TC may or may not choose to also consider when revising the WS; some of these comments may indicate areas of the WS where readers require additional information or rewording for clarification.

Lastly, please provide ASHRAE staff with the final names and contact information for the Proposal Evaluation Subcommittee (PES) roster, and the Technical Contact that will respond to questions from prospective bidders during the bid posting period (typically this is a WS author or PES member). The technical contact and all members of the PES must also agree to not bid on this project directly or through their employer as the primary contractor or a subcontractor.

Please coordinate changes to this Work Statement with your Research Liaison, Ahmed Kashef RL1@ashrae.net or ahmed.kashef@nrc-cnrc.gc.ca. Once he is satisfied that the approval conditions have been met, the project will be ready to bid.

The first opportunity that you will have for this project to possibly bid is fall 2019. To be eligible for this bid cycle, a revised work statement that has been approved for bid by your research liaison should be sent (electronically) to Michael Vaughn, Manager of Research and Technical Services, mvaughn@ashrae.org or morts@ashrae.net, by **September 1, 2019**. The next opportunity for bid after that will be spring 2020.

Project ID	**1865 NEW**	
Project Title	**Optimizing Supply Air Temperature Control for Dedicated Outdoor Air Systems**	
Sponsoring TC	TC 1.4 Control Theory and Application	
Cost / Duration	$180,000 / 24 Months	
Submission History	**1st WS Submission, RTAR Accepted F18**	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC 2019 Annual Meeting Review	**COMPLETE RTAR CHECK LIST CRITERIA BELOW IF RTAR STAGE WAS SKIPPED BY TC**	
RTAR Check List Criteria	**Voted NO**	**Comments & Suggestions**
State-of-the-Art (Background): The WS should include some level of literature review that documents the importance/magnitude of a problem. If not, then the WS should be returned for revision. **RTAR Review Criterion**		
Advancement to the State-of-the-Art Is there enough justification for the need of the proposed research. Will this research significantly contribute to the advancement of the State-of-the-Art. **RTAR Review Criterion**		
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. **RTAR Review Criterion**		
IF THE THREE CRITERIA ABOVE ARE NOT ALL SATISFIED - MARK "REJECT" BELOW BUT ADDRESS THE FOLLOWING CRITERIA AS APPROPRIATE		
		RTAR STAGE FOLLOWED
WS Check List Criteria - START HERE		**Comments & Suggestions**
Detailed Bidders List Provided? The contact information in the bidder list should be complete so that each potential bidder can be contacted without difficulty.		
Proposed Project Description Correct? Are there technical errors and/or technical omissions that the WS has that prevents it from correctly describing the project? If there are, than the WS needs major revision.		
Task Breakdown Reasonable? Is the project divided into tasks that make technical and practical sense? Are the results of each task such that the results of the former naturally flow into the latter? If not, then major revisions are needed to the WS that would include: adding tasks, removing tasks, and re-structuring tasks among others.		**#8** - Good details provided
Adequate Intermediate Deliverables? The project should include the review of intermediate results by the PMS at logical milestone points during the project. Before project work continues, the PMS must approve the intermediate results.		
Proposed Project Doable? Can the project as described in the WS be accomplished? If difficulties exist in the project's WS that prevent a successful conclusion of the project, then the project is not doable. In this situation, major revision of the WS is needed to resolve the issues that cause the difficulty.		
Time and Cost Estimate Reasonable? The time duration and total cost of the project should be reasonable so that the project can be as it is described in the WS.		**#9** - The work statement follows directly from the RTAR. It is not clear why the duration was doubled and the budget tripled from the RTAR values.
Proposed Project Biddable? Examining the WS as a whole, is the project described in the WS of sufficient clarity and detail such a potential bidder can actually understand and develop a proposal for the project? This criterion combines the previous three criteria into an overall question concerning the usefulness of the WS. If the WS is considered to not be biddable, then either major revisions are in order or the WS should be rejected.		**#8** - The proposal evaluation criteria don't add to 100%! The project milestones don't align with the stated scope and deliverables (12 months vs. 24 months!)
Decision Options	**Initial Decision**	**Suggested Approval Conditions**
ACCEPT		
COND. ACCEPT	X	**#8 -** WS: on top of page 2, the title states "outside air" when it should be "outdoor air"! The proposal evaluation criteria don't add to 100%! The project milestones don't align with the stated scope and deliverables (12 months vs. 24 months!). **#9 -** Needs some justification for tripling the budget that was proposed in the RTAR. It would seem that setting up the system models to run in multiple climate zones should be somewhat repetitious and not nearly as time intensive as is now suggested. **#6 =** Please update project milestone section with more descriptive content than "Task 1" -- include a few more breakdowns in tasks schedule that is to be completed during the task
RETURN		
REJECT		

ACCEPT Vote - Work statement(WS) ready to bid as-is
CONDITIONAL ACCEPT Vote - Minor Revision Required - RL can approve WS for bid without going back to RAC once TC satisfies RAC's approval condition(s) to his/her satisfaction
RETURN Vote - WS requires major revision before it can bid
REJECT Vote - Topic is no longer considered acceptable for the ASHRAE Research Program due to duplication of work by another project or because the work statement has a fatal flaw(s) that makes it unbiddable

WORK STATEMENT COVER SHEET 05-12-2019

(Please Check to Insure the Following Information is in the Work Statement)

A. Title	X
B Executive Summary	X
C. Applicability to ASHRAE Research Strategic Plan	X
D. Application of the Results	X
E. State-of-the-Art (background)	X
F. Advancement to State-of-the-Art	X
G. Justification and Value to ASHRAE	X
H. Objective	X
I. Scope	X
J. Deliverables/Where Results will be Published	X
K. Level of Effort	
Project Duration in Months	X
Professional-Months: Principal	X
Professional-Months: Total	X
Estimated $ Value	X
L Proposal Evaluation Criteria & Weighting	X
M. References	X
N. Other Information to Bidders (Optional)	X

Title:
Optimizing Supply Air Temperature Control for Dedicated Outdoor Air Systems

WS# 1865
(To be assigned by MORTS - Same as RTAR #)

Results of this Project will affect the following Handbook Chapters, Special Publications, etc.:
ASHRAE Guideline 36 High Performance Sequences of Operation for HVAC Systems
ASHRAE Design Guide for Dedicated Outdoor Air Systems

Responsible TC/TG: TC 1.4 Control Theory and Application

Date of Vote: 05/13/2019

For		9
Against	*	0
Abstaining	*	0
Absent or not returning	*	
Total Voting Members		

This W/S has been coordinated with TC/TG/SSPC (give vote and date):
TC 8.10: 8/0/0 (Chair Voting) on 4/27/2019

Has RTAR been submitted? Yes

Strategic Plan Theme/Goals

Work Statement Authors: **
Jingjuan (Dove) Feng
Steve Taylor
Hwakong Cheng
John Murphy

Proposal Evaluation Subcommittee:
Chair: Jingjuan (Dove) Feng
Members: John Murphy
Jayson Bursill
Edward Gutowski

Project Monitoring
(If different from Proposal Evaluation Subcommittee)

Recommended Bidders (name, address, e-mail, tel. number): **
1.Center for the Built Environment/UC Berkeley, Paul Raftery, p.raftery@berkeley.edu, (510) 642-9322
2. HGA, Svein Morner, smorner@hga.com, (608)554.5342
3. University of Nebraska-Lincoln, Josephine Lau, jlau@unl.edu
4. University of Alabama, Zheng O'Neill, zoneill@eng.ua.edu
5. Cx Associates, Rick Stehmeyer, rick@cx-associates.com, 802.861.2717

(Three qualified bidders must be recommended, not including WS authors.)

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

	Yes	No	How Long (weeks)
Is an extended bidding period needed?			
Has an electronic copy been furnished to the MORTS?			
Will this project result in a special publication?			
Has the Research Liaison reviewed work statement?			

* Reasons for negative vote(s) and abstentions

** Denotes WS author is affiliated with this recommended bidder

Use additional sheet if needed.

WORK STATEMENT# 1865

Title:

Optimizing Supply Air Temperature Control for Dedicated Outside Air Systems

Sponsoring TC/TG/MTG/SSPC:

TC 1.4 Control Theory and Application

Co-Sponsoring TC/TG/MTG/SSPCs (List only TC/TG/MTG/SSPCs that have voted formal support)

TC 8.10 Mechanical Dehumidification Equipment and Heat Pipes

Executive Summary:

The growing use of distributed HVAC systems that decouple the space sensible conditioning from ventilation latent conditioning is giving rise to dedicated outdoor air systems (DOAS). The control of these systems must be optimized with the local heating and cooling systems they serve, or significant amounts of energy can be wasted. While there are design guides that offer general considerations and principles to control DOAS supply air dry bulb and dew point temperature, it is difficult for designers to translate principles into concrete control sequences that will function in practice. We are not aware of any literature that offers detailed annual operational sequences aiming to achieve both energy efficiency and the basic psychrometric functions.

This research proposes to conduct energy simulations to develop near-optimal sequences for supply air temperature control of DOASs to be used in different design applications and climates. It involves control of leaving air temperature from each temperature control component in the DOAS, which may include a latent heat recovery wheel, a chilled water cooling coil, a sensible heat recovery wheel after the cooling coil and/or a hot water heating coil after the cooling coil. The three most common DOAS configurations will be analyzed. Design parameters to be evaluated include, but are not limited to representative ASHRAE climate zones, different zonal system types with a focus on chilled beams, four-pipe fan coils and water source heat pumps, and two building types with different ventilation requirements. The goal is to provide designers with detailed control sequences that achieve the near optimal energy and comfort performance for their design applications and are ready for implementation. The results may also be used to improve DOAS design approaches. For simplicity, the cooling and heating source (plant) for the DOAS will be the same for the zonal system.

The results of the research will be used to improve ASHRAE's Advanced Energy Design Guides Series (ASHRAE), and potentially to be included in the ASHRAE Guideline 36 (ASHRAE 2018) and ASHRAE Design Guide for Dedicated Outdoor Air Systems (ASHRAE, 2017).

Applicability to the ASHRAE Research Strategic Plan:

This research addresses the following goals listed in the ASHRAE Research Strategic Plan 2010-2018.

Goal 1: Maximize the actual operational energy performance of buildings and facilities.

Goal 2: Progress toward Advanced Energy Design Guides (AEDG) and cost-effective net-zero-energy (NZE) buildings.

Goal 7: Support development of tools, procedures and methods suitable for designing low-energy buildings.

Goal 9: Support the development of improved HVAC&R components ranging from residential through commercial to provide improved system efficiency, affordability, reliability and safety.

Application of Results:

The results of the research will be used to improve ASHRAE's Advanced Energy Design Guides Series and will be submitted to ASHRAE Guideline Project Committee 36 "High Performance Sequences of Operation for HVAC Systems". This will allow direct digital control (DDC) system manufacturers to preprogram the sequences in their controllers to reduce the cost and improve the reliability of implementation.

It is expected the SAT logic developed will also become a prescriptive requirement of ASHRAE Standard 90.1.

State-of-the-Art (Background):

Dedicated outdoor air systems (DOASs) usually have heating, cooling, and dehumidification capability, and often have outdoor air energy recovery and possibly run-around heat recovery systems. They typically serve local (zonal) space temperature control systems such as variable refrigerant flow (VRF) fan-coils, 4-pipe fan-coils, water-source heat pumps, chilled beams, and radiant systems. The amount of ventilation air delivered by a DOAS also varies if there are high-occupancy areas in the building and demand-controlled ventilation (DCV) is required by Standard 90.1 or building codes. Advocates of DOASs argue that the systems can save energy by eliminating (or nearly eliminating) simultaneous cooling and reheat that would otherwise be needed to provide adequate dehumidification in humid climates (ASHRAE, 2017). However, the overall energy performance of a DOAS depends highly on the actual control sequences implemented (Feng and Cheng, 2018).

The primary functions of DOASs are to deliver ventilation air and to remove latent load in the ventilation air and the space, and at the same time it provides sensible cooling as air is cooled due to dehumidification. Depending on the terminal system type that is coupled with the DOAS, the basic psychrometric purposes of the DOAS, and consequently the control strategies, could be quite different, especially when they operate at part load conditions.

- Four pipe fan-coils, zonal heat pumps or Variable Refrigerant Flow (VRF) units usually have some capability to dehumidify supply air. In particular, under part load conditions when the zonal units' design capacity is larger than space sensible load, they can remove space latent load or even ventilation air latent load. The DOAS supply air could be dehumidified just enough for ventilation air latent load removal, overcooled to provide supplemental cooling

(Shank and Mumma 2001), or cooled and heated back to a neutral air temperature (e.g. using heating coils or energy recovery) as some practitioners do for simplicity.

- For four-pipe chilled beams or radiant panel systems that cannot handle any latent load, the DOAS must be adequately dehumidified to avoid condensation. A common conservative strategy is to cool air down to the chilled water supply temperature feeding the chilled beams, but this can cause excessive energy use at the DOAS to sub-cool the air and then reheat it back up either at the DOAS or at the local systems (Taylor 2018). More efficient strategies include using outdoor and space relative humidity sensors or condensate sensors mounted to piping such that the air temperature leaving the DOAS cooling coil can reset based on zone and ventilation latent load.

DOAS's supply air dew-point and dry-bulb temperature control could also vary depending on climate and zone loads. Since a DOAS is a 100% outdoor air unit typically sized for design ventilation air flow rate, it cannot economize by increasing outdoor air flow rate. This is more significant in drier climates where, for much of the year, 100% outdoor air can be used for economizing without the concern of raising indoor humidity levels. But the DOAS can still provide some level of economizer by not operating cooling or heating components when free-cooling is available. Supplying neutral air during those economizer hours could result in significant heating and cooling energy waste, both at the DOAS and at local units, if local systems are predominantly in cooling mode. Accordingly, Standard 90.1 includes this prescriptive requirement:

6.5.2.6 Ventilation Air Heating Control

> Units that provide *ventilation* air to multiple zones and operate in conjunction with zone heating and cooling *systems* shall not use heating or heat recovery to warm supply air above 60°F when representative *building* loads or *outdoor air* temperature indicate that the majority of zones require cooling.

However, this requirement lacks enough detail to readily implement in real control systems.

DOAS control approach could also vary depending on the amount of ventilation air required for different building types. In buildings with high-occupancy areas such as schools, the DOAS is usually sized for the peak ventilation flow rate which can be much higher than the minimum ventilation rate as DCV requires reduction of outdoor air intake below design rates when the actual occupancy of spaces is less than design occupancy. In these buildings, it is possible to increase the DOAS air flow rates to be above the minimum requirement to provide free-cooling if the outdoor air condition is favorable. With LED lighting and effective plug load management, actual internal heating gains in modern buildings now are usually dramatically lower such that supplying sub-cooled ventilation air, as suggested by the ASHRAE DOAS Design Guide (ASHRAE, 2017), may be adequate for meeting the cooling load. On the other hand, with low building loads, supplying minimum ventilation air at low temperature may also cause significant reheat energy waste.

While DOASs need to achieve their primary functions of cooling, heating, and dehumidification, conservatively conditioning the outdoor air to achieve those functions may result in significant energy waste. In the design industry, one simple and common approach is to supply neutral air temperature from the DOAS, which involves dehumidifying the air through sub-cooling, and then heating it back to neutral temperature (Paliaga, Farahmand, Raftery, & Woolley, 2017). The literature that has studied DOAS supply air temperature control is very limited. The ASHRAE DOAS Design Guide provides some general control considerations focusing on achieving the basic psychrometric functions (ASHRAE, 2017). It presents two example control sequences - both use a constant low temperature setpoint for air leaving the cooling coil when outside air temperature is higher than 55°F and then reheat the cold air to avoid overcooling the spaces. There is no evaluation of the energy impacts or suggestion on setpoint ranges for different climates. Another study (Shank & Mumma, 2001) suggests the supply air temperature leaving the DOAS should be no higher than 55°F, and the supply air dew-point temperature should be kept at 44°F. However, this conclusion was based on simulations using Atlanta weather data, which is relatively humid and hot. In addition, it assumes the internal loads are at 3-5 W/ft^2, which are much higher than typical given current lighting code minimum requirements. For buildings in drier or cooler climate zones with reasonable load management measures, these control approaches could potentially cause a significant amount of cooling and heating energy waste.

Advancement to the State-of-the-Art:

While there are design guides that offer general considerations and principles to control DOAS supply air dry bulb and dew point temperature, it is difficult for designers to translate principles into concrete control sequences that will function in practice. We are not aware of any literature that offers detailed operational sequences that aim to achieve both energy efficiency and the basic psychometric functions. The scope of this research includes the documentation and systematic evaluation of these DOAS supply air control sequences and the development of new near-optimal control sequences for different design applications. It involves controls of the temperature leaving each temperature modulating component in the DOAS, including, for example, temperature leaving the cooling coil and the temperature leaving a heating coil or heat recovery system downstream of the cooling coil. For simplicity, the cooling and heating source (plant) for the DOAS will be the same for the zonal system. Even though the research focuses on DOAS with chilled water cooling, the control sequences developed from this research should be generally applicable to DOAS unit with DX cooling.

The goal is a near-optimal control sequence for different applications that could be easily adopted into Guideline 36 and that is straightforward for designers to apply on their projects.

Justification and Value to ASHRAE:

The ASHRAE Advanced Energy Design Guides Series (ASHRAE.) has recommended DOASs as part of the HVAC design strategy for most climate zones and building types evaluated, including K-12 schools, hospital and healthcare facilities, small to medium offices buildings, retail buildings, etc. This project will recommend new near-optimal control sequences for DOAS systems and improve ASHRAE's Advanced Energy Design Guides Series. The control sequences generated from the research will be submitted to ASHRAE Guideline Project Committee 36 "High Performance Sequences of Operation for HVAC Systems". The results of the project can also improve the recently published ASHRAE Design Guide for Dedicated Outdoor Air Systems (ASHRAE, 2017).

This research addresses the following goals listed in the ASHRAE Research Strategic Plan 2010-2018.

- Goal 1: Maximize the actual operational energy performance of buildings and facilities.
- Goal 2: Progress toward Advanced Energy Design Guides (AEDG) and cost-effective net-zero-energy (NZE) buildings.
- Goal 7: Support development of tools, procedures and methods suitable for designing low-energy buildings.
- Goal 9: Support the development of improved HVAC&R components ranging from residential through commercial to provide improved system efficiency, affordability, reliability and safety.

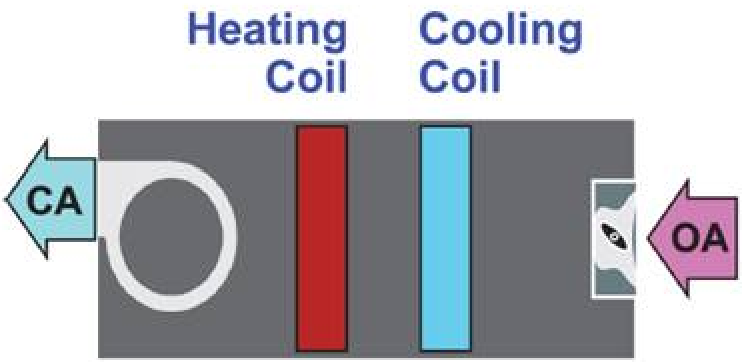
Objectives:

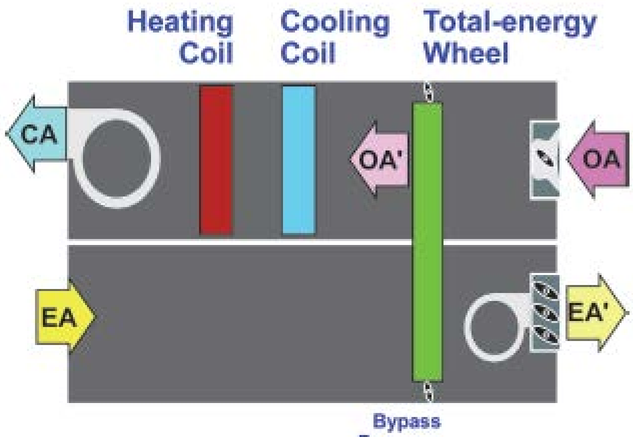
This research project will:

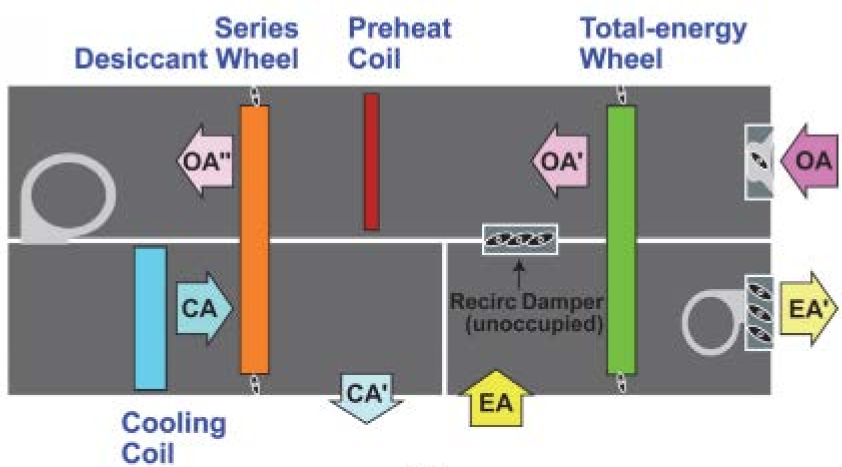
- Provide ASHRAE members guidance on determining the DOAS supply air temperature control sequences that can achieve both the basic psychrometric functions and energy efficiency for different system configurations and various climates.
- Develop near optimal and practical supply air temperature control sequences for the dedicated outdoor air system applications evaluated in the study, articulated in English and ready to be adopted into ASHRAE Guideline 36 and programmed into a commercial Direct Digital Control (DDC) system.

Scope/Technical Approach:

Research will include and be limited to the following three DOAS systems as defined in the ASHRAE Design Guide for Dedicated Outdoor Air Systems (ASHRAE, 2017):

1. 

2. 

3. 

Feedback from industry groups indicated these were the most common designs. Option 2 may have sensible-only or total energy recovery.

The DOAS shall be modeled with separate supply diffusers from the zonal systems (described below). There are many other common configurations, as described in the Design Guide for Dedicated Outdoor Air Systems, but they need not be modeled for simplicity and because optimized control logic is not expected to vary from one configuration to the others.

The DOAS shall be sized in two ways:

1. Standard 62.1-minimum
2. 30% higher than Standard 62.1, reflecting the LEED V4 Enhanced Indoor Air Quality Increased Ventilation credit. This rate is also close to California Title 24 ventilation rates and is compliant with Standard 90.1 Section 6.5.3.7.

The DOAS will each be applied to three zonal systems:

1. Variable speed 4-pipe fan-coils, which represents those systems that have dehumidification capability at the zone level. The system shall be modeled with the same cooling and heating source (plant) as the DOAS so tradeoffs in where heating and cooling are used (zone vs. DOAS) are not complicated by having different cooling/heating plant efficiencies.
2. Active chilled beams (ACBs), which represent systems that do not have zonal dehumidification capability and must have humidity limited to avoid condensation at the zone levels. For simplicity, heating and cooling for both the ACBs and DOAS will be the same plant (not dual temperature plants). Sequences from this
3. Water-source heat pumps, which represent systems that transfer energy between zones that are in different heat/cool modes. Sequences from this analysis are also applicable to heat recovery type variable refrigerant system. The DOAS heating and cooling shall also be from water-source heat pumps, again for simplicity.

The systems shall be applied to these two applications:

1. Offices including a mixture of offices and conference rooms
2. Schools including mostly classrooms

In both cases, the DOAS will have zone demand controlled ventilation (DCV) where Standard 90.1 requires it, and all zones must be pressure independent. Outdoor air supply fan speed must be controlled with static pressure setpoint reset off damper position per Standard 90.1. These two prototype buildings were used for RP-1547 (ASHRAE 2013) and RP-1747 (ASHRAE (2017a)) using EnergyPlus as the modeling engine. The same basic architectural models should be used for consistency and to reduce development costs. The models have randomized internal load schedules to provide realistic load profiles. (If these prototypes are not used, bidders shall identify and describe in detail the buildings they plan to use.)

At a minimum, DOAS designs listed above shall be analyzed in these ASHRAE Climate Zones (ASHRAE 2013a).

DOAS Design:	1	2	3
Weather Zones:	2A, 3A, 3B, 3C, 4A, 4C, 5A, 5B, 6A, 6B	Total: 2A, 3A, 4A, 5A, 6A Sensible: 3B, 4C, 5B, 6B	2A, 3A, 4A, 5A, 6A

If modeling and optimization can be automated, bidders are encouraged to do all permutations of DOAS designs and all 19 Climate Zones, except eliminating energy recovery where not required by Standard 90.1. For all cases, DOAS shall be modeled with all permutations of zonal types and building types.

Task 1. Detailed Model Development

The prescribed DOAS and zonal system types are generally described above but many details are lacking such as:

1. Cooling, heating, and fan equipment type and efficiency
2. Heat recovery system efficiency and pressure drop
3. Pump heads and fan pressures
4. Zonal control logic
5. Control points and sensors in DOAS and zonal systems
6. Energy cost rate schedules
7. And many other details

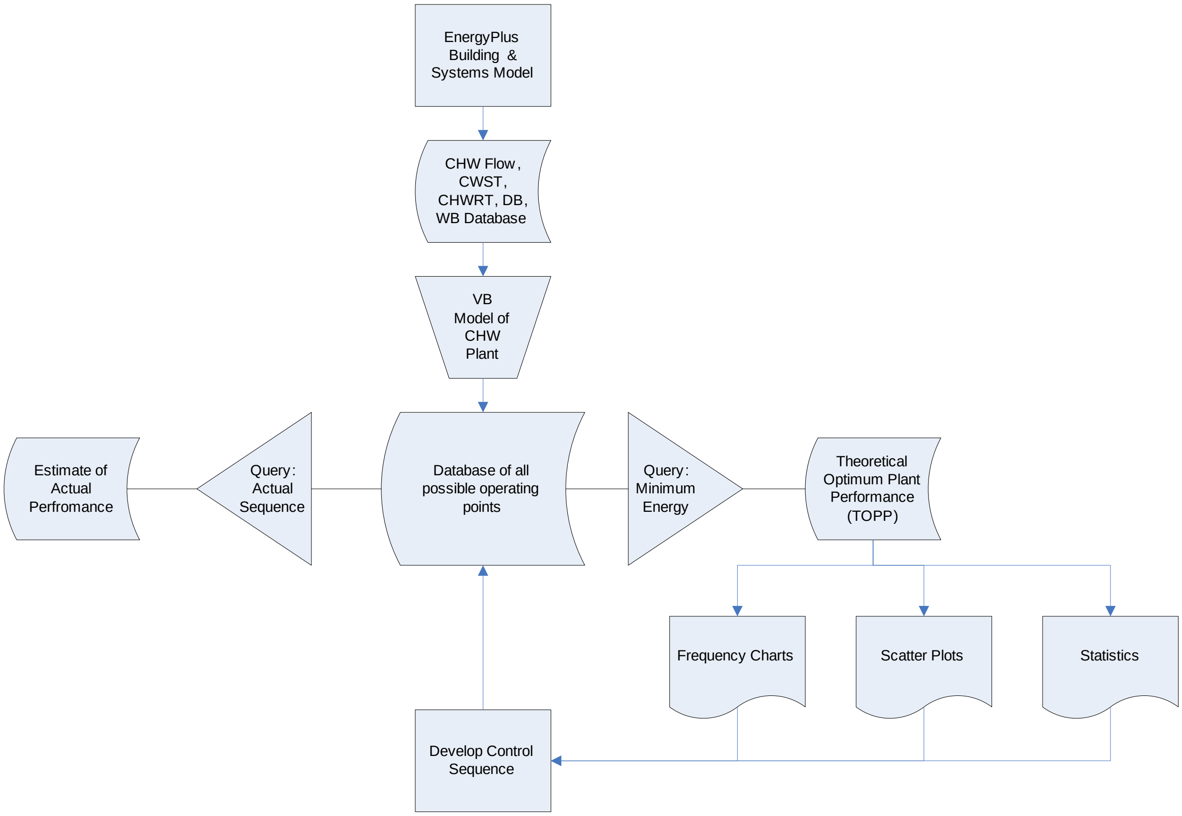
In all cases, the system designs and equipment efficiencies shall meet Standard 90.1.

Task 1 will be to fully identify all model inputs for PMS approval.

Deliverables will be in two steps: First, identify all modeling details that do not vary by climate zone. Once approved, the second deliverable will be model inputs that vary by climate zones such as cooling, heating, and fan capacity based on detailed load calculations. The energy modeling software can be used for system sizing if it provides results similar to those using the heat balance (HB) method per ASHRAE Handbook, Fundamentals, Chapter 18.

Task 2. Optimization Technique Development

To determine optimized sequences from so many model permutations will require an automated or semiautomated technique developed by the Contractor. A description of options for how this technique will be developed shall be included in Contractor proposals, but the details may be deferred to this Task. One possibility is the “brute force” optimization technique described in Hydeman 2007. It involves iterating on all valid variable setpoints (in discrete steps) and equipment staging options to generate a database of all possible operational options for each hourly timestep. The database is then queried to find the lowest energy cost for each timestep – this is the theoretical optimum performance. The various independent variables that compose this optimum are then evaluated to find trends and correlations that can be used to create sequences of operation (SOOs) that come as close as possible to the optimum. The resulting SOOs can then be tested using the database to see how close they achieve the optimum.



This is just one technique. The Contractor may propose to use any technique that can achieve the same result with similar assurances that true near-optimum SOOs can be identified.

Deliverables: Report identifying the optimization technique, including a simple example applying the technique, for PMS approval

Task 3. Sequence of Operation Development & Testing

The optimization technique shall be applied to one of the permutation options as a test. The SOOs developed must be simple enough that they can be programmed into typical direct digital control systems yet achieve near-optimal performance. Once developed, the SOOs shall be modeled to test how close to optimum performance is achieved. In addition, each run shall include a 70°F (neutral) supply air temperature run as a baseline for comparison only. (It is known that this is not an efficient strategy and disallowed by Standard 90.1 in cooling predominate applications, but it is a common practice and a reasonable baseline for comparison.)

An interim deliverable shall be a report showing how SOOs were developed for the test case and how well they perform relative to the optimum. The following shall be included:

- Overall annual energy usage
- Space dry bulb temperature and humidity in critical zones. Temperature and humidity in all zones shall meet ASHRAE Standard 55 and 62.1 requirements.
- Energy end uses by each DOAS component and the zonal units

Once the PMS has approved the interim report, the Contractor shall proceed to develop SOOs and reports for all permutations. The SOOs shall include English language sequences of operation, including critical setpoints, setpoint ranges for each application and graphs or tables that allow users to determine the setpoints.

Task 4. Guideline 36 Continuous Maintenance Proposal
The contractor shall develop a Continuous Maintenance Proposal (CMP) to ASHRAE Guideline 36 to incorporate the new control sequences, using ASHRAE CMP forms. This shall include:

- The final PMS approved sequences of operation in Guideline 36 format
- Control points list of required and optional control points in Guideline 36 format
- Control schematics showing minimum control points required to implement the sequences

Task 5. Reporting of Findings
The contractor shall produce a comprehensive Final Report detailing all the work undertaken in the project.

Deliverables/Where Results Will Be Published:

Progress, Financial and Final Reports, Research or Technical Paper(s), and Data shall constitute required deliverables ("Deliverables") under this Agreement and shall be provided as follows:

a. Progress and Financial Reports

Progress and Financial Reports, in a form approved by the Society, shall be made to the Society through its Manager of Research and Technical Services at quarterly intervals; specifically, on or before each January 1, April 1, June 10, and October 1 of the contract period.

Furthermore, the Institution's Principal Investigator, subject to the Society's approval, shall, during the period of performance and after the Final Report has been submitted, report in person to the sponsoring Technical Committee/Task Group (TC/TG) at the annual and winter meetings, and be available to answer such questions regarding the research as may arise.

b. Final Report

A written report, design guide, or manual, (collectively, "Final Report"), in a form approved by the Society, shall be prepared by the Institution and submitted to the Society's Manager of Research and Technical Services by the end of the Agreement term, containing complete details of all research carried out under this Agreement. Unless otherwise specified, six copies of the final report shall be furnished for review by the Society's Project Monitoring Subcommittee (PMS).

Following approval by the PMS and the TC/TG, in their sole discretion, final copies of the Final Report will be furnished by the Institution as follows:

- An executive summary in a form suitable for wide distribution to the industry and to the public.
- Two bound copies
- One unbound copy, printed on one side only, suitable for reproduction.
- Two copies on CD-ROM; one in PDF format and one in Microsoft Word.

c. HVAC&R Research or ASHRAE Transactions Technical Paper

One or more papers shall be submitted first to the ASHRAE Manager of Research and Technical Services (MORTS) and then to the "ASHRAE Manuscript Central" website-based manuscript review system in a form and containing such information as designated by the Society suitable for publication. Papers specified as deliverables should be submitted as either Research Papers for Science and Technology for the Built Environment (STBE) or Technical Paper(s) for ASHRAE Transactions. Research papers contain generalized results of long-term archival value, whereas technical papers are appropriate for applied research of shorter-term value, ASHRAE Conference papers are not acceptable as deliverables from ASHRAE research projects. The paper(s) shall conform to the instructions posted in "Manuscript Central" for an ASHRAE Transactions Technical or STBE Research paper. The paper title shall contain the research project number (XXXX-RP) at the end of the title in parentheses, e.g., (XXXX-RP).

Note: A research or technical paper describing the research project must be submitted after the TC has approved the Final Report. Research or technical papers may also be prepared before the project's completion, if it is desired to disseminate interim results of the project. Contractor shall submit any interim papers to MORTS and the PMS for review and approval before the papers are submitted to ASHRAE Manuscript Central for review.

d. Data

The Institution agrees to maintain true and complete books and records, including but not limited to notebooks, reports, charts, graphs, analyses, computer programs, visual representations etc., (collectively, the “Data”), generated in connection with the Services. Society representatives shall have access to all such Data for examination and review at reasonable times. The Data shall be held in strict confidence by the Institution and shall not be released to third parties without prior authorization from the Society, except as provided by GENERAL CONDITION VII, PUBLICATION. The original Data shall be kept on file by the Institution for a period of two years after receipt of the final payment and, upon request, the Institution will make a copy available to the Society upon the Society’s request.

e. Project Synopsis

A written synopsis totaling approximately 100 words in length and written for a broad technical audience, which documents 1. Main findings of the research project, 2. Why findings are significant, and 3. How the findings benefit ASHRAE membership and/or society in general shall be submitted to the Manager of Research and Technical Services by the end of the Agreement term for publication in ASHRAE *Insights*

The Society may request the Institution submit a technical article suitable for publication in the Society’s *ASHRAE JOURNAL*. This is considered a voluntary submission and not a Deliverable.

All Deliverables under this Agreement and voluntary technical articles shall be prepared using dual units; e.g., rational inch-pound with equivalent SI units shown parenthetically. SI usage shall be in accordance with IEEE/ASTM Standard SI-10.

Level of Effort:

The project anticipates a minimum of 2 principal investigators (optimization/modeling expert and HVAC/controls expert) with about 3 months total effort, with the remainder of the effort by experienced energy modelers. It is expected that this project will require a duration of 24 months to complete at a total cost of about $180,000.

Proposal Evaluation Criteria:

No.	Proposal Review Criterion	Weighting Factor
1	Energy modeling experience of complicated HVAC systems	20%
2	Experience with optimization techniques and proposed optimization plan	25%
3	Applied experience in HVAC design (especially DOAS) and writing practical control sequences	30%
4	Understanding of the work statement	20%
5	Previous ASHRAE research project experience	0%

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
1	Task 1	2
2	Task 2	4
3	Task 3	12
4	Task 4	2
5	Task 5	4

Primary Authors:

Jingjuan Feng
Steve Taylor
Hwakong Cheng

References:

ASHRAE. (2013). ASHRAE 1547-RP CO2-Based Demand Controlled Ventilation For Multiple Zone HVAC Systems

ASHRAE (2013a), ANSI/ASHRAE Standard 169-2013 Climatic Data for Building Design Standards

ASHRAE. (2017). ASHRAE Design Guide for Dedicated Outdoor Air Systems.

ASHRAE. (2017a). ASHRAE RP-1747 Implementation of RP-1547 CO2-based Demand Controlled Ventilation for Multiple Zone HVAC Systems in Direct Digital Control Systems

ASHRAE. (2018). ASHRAE Guideline36: High Performance Sequences Of Operation for HVAC Systems.

ASHRAE. (n.d.). ASHRAE Advanced Energy Design Guides.

Deng, S. (2014). *Energy Benefits of Different Dedicated Outdoor Air Systems Configurations in Various Climates.* Master Thesis, University of Nebraska, Lincoln, Architectural Engineering. Retrieved from https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1030&context=archengdiss

Frink, B. (2018, April). Life-cycle cost for DOAS with VAV. *ASHRAE Journal*, 26-32.

Feng, J., & Cheng, H. (2018). Comparison of Construction and Energy Costs for Radiant vs. VAV Systems in the California Bay Area. Deliverable for California Energy Commission Project EPIC - 14-009, Taylor Engineering. Retrieved from http://www.taylor-engineering.com/Websites/taylorengineering/images/docs/2018-11-15%20Cost%20Comparison%20of%20Radiant%20vs.%20VAV%20Systems_Final%20Report.pdf

Hydeman, M, Zhou, G. (2007, June). Optimizing Chilled Water Plant Control, ASHRAE Journal

Paliaga, G., Farahmand, F., Raftery, P., & Woolley, J. (2017). *TABS Radiant Cooling Design & Control in North America: Results from Expert Interviews.* TRC. Retrieved from http://escholarship.org/content/qt0w62k5pq/qt0w62k5pq.pdf

Raftery, P., Li, S., Jin, B., Ting, M., Paliaga, G., & Cheng, H. (2018, January). Evaluation of a cost-responsive supply air temperature reset strategy in an office building. *Energy and Buildings*, 356-370. doi:10.1016/j.enbuild.2017.10.017

Shank, K., & Mumma, S. (2001). Selecting the supply air conditions for a dedicated outdoor air system working in parallel with distributed sensible cooling terminal equipment. *ASHRAE Transactions, 107*.

Stein, J., & Taylor, S. (2013). VAV reheat versus active chilled beams & DOAS. *ASHRAE Journal*, 18-32.

Taylor S. (2018, December) 4-Pipe VAV vs. Active Chilled Beams for Labs, ASHRAE Journal

Other Information for Bidders (Optional):

The successful contractor should have a minimum of 2 principal investigators, one or more with expertise in optimization and energy modeling, and one or more with expertise in HVAC design (particularly DOAS applications) and HVAC controls.

Feedback to RAC and Suggested Improvements to Work Statement Process

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

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Kimberly A Barker, Research Subcommittee Chair TC 1.4, kimberly.barker@siemens.com
Shinsuke Kato, RL 1.0, kato@iis.u-tokyo.ac.jp

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

DATE: November 6, 2018

SUBJECT: Research Topic Acceptance Request (1865-RTAR), "Optimizing Supply Air Temperature Control for Dedicated Outdoor Air Systems"

During their fall meeting, the Research Administration Committee (RAC) reviewed the subject Research Topic Acceptance Request (RTAR) and voted to accept it for further development into a work statement (WS).

Please address in the work statement the following items with the help of your Research Liaison prior to submitting the work statement to the Manager of Research and Technical Services for further consideration by RAC:

1. How relevant and useful is this research to ASHRAE?

In addition, a separate document providing a response to the above comment must be submitted with the work statement. The response to this item should explain how the work statement has been revised to address the comment, or a justification for why the Technical Committee feels a revision is unnecessary or inappropriate. The work statement and response to this comment 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 may require additional information or rewording for clarification.

The first draft of the work statement should be submitted to RAC no later August 15, 2020 or it will be dropped from display on the Society's Research Implementation Plan. The next realistic submission deadline for new work statements is May 15, 2019 for consideration at RAC's 2019 annual meeting. The submission deadline after that for work statements is August 15, 2019 for consideration at RAC's 2019 fall meeting.

Project ID	**1865**	
Project Title	**OPTIMIZING SUPPLY AIR TEMPERATURE CONTROL FOR DEDICATED OUTDOOR AIR SYSTEMS**	
Sponsoring TC	TC 1.4 Control Theory and Application	
Cost / Duration	$60,000 / 12 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** - There is a detailed explanation. But it violates the rule not to exceed 300 words. **9** - Detailed description with refs (though lengthy)
Research Need: Based on the background provided is the need for additional research clearly identified? If not, then the RTAR should be rejected.		**2** - Well described. **9**- Need to evaluate DOAS supply air control sequences
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** - Will improve ASHRAE's design guidance for DOAS. **8** - is there sufficient demand to warrant investigation on this topic?
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.		**9 -** Yes, two objectives the outcomes from which will be clear guidance
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:		**9** - Simulation-based, clear steps, hence $60k, 12 months is justified
References: Are the references provided?		
Decision Options	**Initial Decision?**	**Final Approval Conditions**
ACCEPT AS-IS		**7** - RTAR is well written. The need and objectives are clear and the budget is aligned with the approach. **9 -** Would it be appropriate to specify the ranges of conditions for simulation?
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: **08-15-2018**

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

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

Title:

OPTIMIZING SUPPLY AIR TEMPERATURE CONTROL FOR DEDICATED OUTDOOR AIR SYSTEMS

RTAR 1865

(To be assigned by MORTS)

Research Classification:

Basic/Applied	X
Advanced Concepts	
Technology Transfer	

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

Responsible **TC 1.4** Control Theory and Application

Date of Vote: **08-14-2018**

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

RTAR Authors

Lead: **Jingjuan (Dove) Feng**

Others: **Steve Taylor**

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

Expected Work Statement Authors

Lead: **Jingjuan (Dove) Feng**

Others: **Steve Taylor**

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 # _1865_

Title:

Optimizing Supply Air Temperature Control for Dedicated Outdoor Air Systems

Executive Summary

The growing use of distributed HVAC systems that decouple the space sensible conditioning from ventilation latent conditioning is giving rise to dedicated outdoor air systems (DOASs). The control of these systems must be optimized with the local heating and cooling systems they serve or significant amounts of energy can be wasted. While there are design guides that offer general considerations and principles to control DOAS supply air dry bulb and dew point temperature, it is difficult for designers to translate principles into concrete control sequences that will function in practice. We are not aware of any literature that offers detailed annual operational sequences aiming to achieve both energy efficiency and the basic psychometric functions

This research proposes to conduct energy simulations to evaluate and provide recommendations on supply air temperature control sequences for DOASs to be used in different design applications. It involves controls of temperature leaving each temperature control component in the DOAS, including, for example, temperature leaving the cooling coil and the temperature leaving a heating coil downstream of the cooling coil. It will focus on DOASs consisting of DX cooling coil. Design parameters to be evaluated include, but are not limited to, representative ASHRAE climate zones, different zonal system types with a focus on chilled beams and four-pipe fan coils, and various building types with different ventilation requirements. The goal is to provide designers guidance on which sequence works best for their design application, and to provide them with detailed control sequences that are ready for implementation.

The results of research will be used to improve ASHRAE's Advanced Energy Design Guides Series (ASHRAE) and potentially to be included in the ASHRAE Guideline 36 (ASHRAE 2018).

Background

Dedicated outdoor air systems (DOASs) usually have heating, cooling, and dehumidification capability, and often have outdoor air energy recovery and possibly run-around heat recovery systems. They typically serve local (zonal) space temperature control systems such as variable refrigerant flow (VRF) fan-coils, 4-pipe fan-coils, water-source heat pumps, chilled beams, radiant systems. The amount of ventilation air to be delivered by a DOAS also varies if there are high-occupancy areas in the building and demand-controlled ventilation (DCV) is required by Standard 90.1 of building codes. Advocates of DOASs argue that the systems can save energy by eliminating (or nearly eliminate) simultaneous cooling and reheat that would otherwise be needed to provide adequate dehumidification in humid climates (ASHRAE, 2017). However, the overall energy performance of a DOAS depends highly on the actual control sequences implemented.

The primary functions of a dedicated outdoor air systems (DOASs) are to deliver ventilation air and to remove latent load in the ventilation air and the space, and at the same time it provides sensible cooling as air is cooled due to dehumidification. Depending on the terminal system type that is coupled with the DOAS, the basic psychrometric purposes of the DOAS, and consequently the control strategies, could be quite different, especially when they operate at part load conditions.

- Four pipe fan-coils, zonal heat pumps or VRV units usually have the capability to dehumidify air. In particularly under part load conditions when the zonal units' design capacity is larger than space sensible load, they can remove space latent load or even ventilation air latent load. The DOAS supply air could be dehumidified just enough for ventilation air latent load removal, or it could be overcooled to provide supplemental cooling as suggested by (Shank and Mumma 2001), or cooled and heated back to a neutral air temperature (e.g. using heating coils or energy recovery) as a lot of practitioners do for simplicity.
- As four-pipe chilled beams or radiant panel systems cannot handle any latent load, the DOAS must be adequately dehumidified to avoid condensation. A common conservative strategy can be to cool air down to the chilled water supply temperature feeding the chilled beams, but this can cause excessive energy use at the DOAS to cool the air and to heat it back up either at the DOAS or at the local systems. More efficient strategies include using outdoor and space relative humidity sensors or condensate sensors mounted to piping such that the air temperature leaving the cooling coil can reset based on zone and ventilation latent load.

DOAS's supply air dew-point and dry-bulb temperature control also vary depends on climate. Since a DOAS is a 100% outdoor air unit typically sized for design ventilation air flowrate, it cannot economize by increasing outdoor air flow rate. This is more significant in drier climates where 100% outdoor air can be used for economizing without the concern of raising indoor humidity levels. But the DOAS can still provide some level of economizer by not operating cooling or heating components when free-cooling is available. Supplying neutral air during those economizer hours could result in significant heating and cooling energy waste, both at the DOAS and at local units, if local systems are predominantly in cooling mode. Accordingly, Standard 90.1 includes this prescriptive requirement:

6.5.2.6 Ventilation Air Heating Control

> Units that provide *ventilation* air to multiple zones and operate in conjunction with zone heating and cooling *systems* shall not use heating or heat recovery to warm supply air above 60°F when representative *building* loads or *outdoor air* temperature indicate that the majority of zones require cooling.

However, this requirement lacks enough detail to readily implement in real control systems.

DOAS control approach could also vary depending on the amount of ventilation air required for different building types. In buildings with high-occupancy areas such as schools, the DOAS is usually sized for the peak ventilation flowrate which can be much higher than the minimum ventilation rate as DCV requires reduction of outdoor air intake below design rates when the actual occupancy of spaces is less than design occupancy. In these buildings, it is possible to increase the DOAS air flowrates to be above the minimum requirement to provide free-cooling if outdoor air condition is favorable. With LED lighting and effective plug load management, building design internal heating gains have decreased dramatically such that supplying colder ventilation air, as suggested by the ASHRAE DOAS Design Guide (ASHRAE, 2017), may be adequate for meeting the cooling load. On the other hand, with low building loads, supplying minimum ventilation air at low temperature may also cause significant reheat energy waste.

While DOASs need to achieve their primary functions of cooling, heating, and dehumidification, conservatively conditioning the outdoor air to achieve those functions may result in significant energy waste. In the design industry, one simple and common approach is to supply neutral air temperature from the DOAS, which involves cooling the air and then heated to back neutral (Paliaga, Farahmand, Raftery, & Woolley, 2017). Literatures that study DOAS supply air temperature control are very limited. The ASHRAE DOAS Design Guide provide some general control considerations focusing on achieving the basic psychrometric functions (ASHRAE, 2017). It presents two example control sequences both use a constant low temperature setpoint for air leaving the cooling coil when outside air is higher than 55°F and then reheat the cold air to avoid overcooling the spaces. There is no evaluation of the energy impacts or suggestion on setpoint ranges for different climates. Another study (Shank & Mumma, 2001) suggests the supply air temperature leaving the DOAS should be no higher than 55°F, and the supply air dew-point temperature should be kept at 44°F. However, this conclusion was based on simulations using Atlanta weather data, which is very humid and hot. In addition, it assumes the internal loads are at 3-5 W/ft^2, which are much higher than the current code minimum requirements. For buildings in drier or cooler climate zones with reasonable load management measures, these control approaches could potentially cause significant amount of cooling and heating energy waste.

Research Need

While there are design guides that offer general considerations and principles to control DOAS supply air dry bulb and dew point temperature, it is difficult for designers to translate principles into concrete control sequences that will function in practice. We are not aware of any literature that offers detailed annual operational sequences aiming to achieve both energy efficiency and the basic psychometric functions. The goals of this research are to document and evaluate various DOAS supply air control sequences, and if needed, develop new control sequences for different design applications. It involves controls of temperature leaving each temperature modulating component in the DOAS, including, for example, temperature leaving the cooling coil and the temperature leaving a heating coil downstream of the cooling coil.

Design parameters to be evaluated will include but not limited to the followings:

- At the minimum six ASHRAE representative climate zones
- Two building types: medium office building with densely occupied conference rooms and schools
- DOAS configurations: contractor will decide on one DOAS configuration for each climate. The DOAS may include a latent heat recovery wheel, a DX cooling coil, a sensible heat recovery wheel after the cooling coil or a heating coil after the cooling coil.
- Terminal system types: focus on four pipe fan coil and chilled beam. The results from the four-pipe fan coil will be applicable to other zonal systems that have latent load removal capability, while the results for the chilled beams will be applicable to systems that can only remove sensible heat.

Project Objectives

This research project will:

- Provide designers guidance on determining the DOAS supply air temperature control sequences that can achieve both the basic psychometric functions and energy efficiency for their specific projects.
- Develop optimal and practical supply air temperature control sequences for the dedicated outdoor air system applications evaluated in the study, articulated in English and represented in a logic flow diagrams. The sequences will be ready to be programmed into a commercial Direct Digital Control (DDC) system.

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 [x], Surveys [x], Field tests [ ], Analyses and modeling [X], Validation efforts [ ], Other (specify) ( )

To achieve the research objectives, the contractor will be required to complete the following tasks:

- Task 1: Collect and review of the existing DOAS supply air temperature sequences
- Task 2: Select, at a minimum, six representative climate zones, and determine the DOASs configuration for each climate to be studied. The DOAS may include a latent heat recovery wheel, a DX cooling coil, a sensible heat recovery wheel after the cooling coil or a heating coil after the cooling coil.
- Task 2: Develop evaluation matrix including, at the minimum, the following parameters: DOAS configurations, HVAC zonal system types, climates, building types, and conduct preliminary simulation analysis to finalize the matrix
- Task 3: Conduct full simulations to evaluate the energy performance of the selected control sequences
- Task 4: For each DOAS design configuration evaluated, develop detailed control sequences ready for implementation in a DDC system.
- Task 5. Reporting of Findings

Relevance and Benefits to ASHRAE

The ASHRAE Advanced Energy Design Guides Series (ASHRAE.) has recommended DOASs as part of the HVAC design strategy for most climate zones and building types evaluated, including K-12 schools, hospital and healthcare facilities, small to medium offices buildings, retail buildings, etc. The results of research will be used to improve ASHRAE's Advanced Energy Design Guides Series. The control sequences generated from the research will be submitted to ASHRAE Guideline Project Committee 36 "High Performance Sequences of Operation for HVAC Systems".

This research addresses the following goals listed in the ASHRAE Research Strategic Plan 2010-2018.

- *Goal 1: Maximize the actual operational energy performance of buildings and facilities.*
- *Goal 2: Progress toward Advanced Energy Design Guides (AEDG) and cost-effective net-zero-energy (NZE) buildings.*
- *Goal 7: Support development of tools, procedures and methods suitable for designing low-energy buildings.*
- *Goal 9: Support the development of improved HVAC&R components ranging from residential through commercial to provide improved system efficiency, affordability, reliability and safety.*

Anticipated Funding Level and Duration

Funding Amount Range: $60,000

Duration in Months: 12

References

ASHRAE. *ASHRAE Advanced Energy Design Guides Series*

ASHRAE. 2017. *ASHRAE Design Guide for Dedicated Outdoor Air Systems.* Altanta.

ASHRAE 2018. *ASHRAE Guideline36P: High performance sequences of operation for HVAC systems.* ASHRAE.

Frink, Brandon. 2018. "Life-cycle cost for DOAS with VAV." *ASHRAE Journal* 26-32.

Shank, Kurt, and Stanley Mumma. 2001. "Selecting the supply air conditions for a dedicated outdoor air system working in parallel with distributed sensible cooling terminal equipment." *ASHRAE Transactions* V107.

Paliaga, G., Farahmand, F., Raftery, P., & Woolley, J. (2017). "TABS Radiant Cooling Design & Control in North America: Results from Expert Interviews". TRC. Retrieved from http://escholarship.org/content/qt0w62k5pq/qt0w62k5pq.pdf

Feedback to RAC and Suggested Improvements to RTAR Process

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