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Michael R. Vaughn, P.E.
Manager Research & Technical Services

TO: Bass Abushakra, Chair TC 4.7, datadigm-analytics@outlook.com

FROM: Michael R. Vaughn
Manager of Research and Technical Services

CC: Michael Pouchak, Research Liaison 4.0, mike.pouchak@honeywell.com
Jeff Haberl, Research Subcommittee Chair TC 4.7, jhaberl@tamu.edu
Anthony Fontanini, Joe Huang, Work Statement Author(s), anthony.fontanini@nrel.gov

DATE: September 19, 2018

SUBJECT: Work Statement (1748-WS), "Assess and Implement Natural and Hybrid Ventilation Models in Whole-building Energy Simulations (Phase 2)"

During their fall meeting, the Research Activities Subcommittee (RAS) of RAC reviewed the subject Work Statement (WS) and voted 5-0-1 CNV to return with comments.

Below are the main issues and concerns that must be addressed in your next submission of the WS if you choose to resubmit.

1. Update the work statement cover sheet with missing information, such as proposed PES, and recommended bidders
2. Work statement is very confusing as if reference old buildings.
3. Address items under milestones, bidders, and ability for bidder to meet requirements.
4. Is this a Phase 2 of a 2-phase study to be performed by the same contractor? Does it have to be performed by the same contractor?

A WS evaluation sheet is attached as additional information and it provides a breakdown of comments and questions from individual RAC members based on a specific review criteria. This should give you an idea of how your WS is being interpreted and understood by others. Some of these comments indicate areas of the WS where readers require additional or corrected information or rewording for clarification.

Please coordinate changes to this Work Statement with your Research Liaison Michael Pouchak, mike.pouchak@honeywell.comor RL4@ASHRAE.net prior to resubmitting it again to the Manager of Research and Technical Services for further consideration by RAC.

Also, it is necessary that you provide with your next submission a new TC vote on the revised Work Statement, and a letter describing how each of the above items were addressed in the revision.

If you wish for this work statement to be reconsidered at the next RAC meeting, the revised Work Statement must be sent (electronically) to Michael Vaughn, Manager of Research and Technical Services (morts@ashrae.net) by **December 15, 2018.** The next opportunity for consideration after this deadline is May 15, 2019.

Project ID	**1748**	
Project Title	**Assess and Implement Natural and Hybrid Ventilation Models in Whole-building Energy Simulations (Phase 2)**	
Sponsoring TC	TC 4.7 (Energy Calculations)	
Cost / Duration	$120,000 / 12M	
Submission History	**1st WS Submission, RTAR accepted F14**	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC 2018 Fall Meeting Review	**RTAR STAGE FOLLOWED**	
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**		**7** - the bidders list is empty -- is this this project attractive for bidders?
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.		**12** - the ASHRAE strategic research plan is not adequately cited or referenced. The specific goals and how this WS address them are not listed!
IF THE THREE CRITERIA ABOVE ARE NOT ALL SATISFIED - MARK "REJECT" BELOW BUT ADDRESS THE FOLLOWING CRITERIA AS APPROPRIATE		
Detailed Bidders List Provided? The contact information in the bidder list should be complete so that each potential bidder can be contacted without difficulty.		**12**- they were listed on an older version though! **6** - No bidders also no PES, PMS or potential co-funders listed. I see it on the 1st submission? From 2014? **13** - Cover Sheet check list not completed. No potential bidders or PES or PMS are listed. **11** - Is it assumed that this is to be performed by the same contractor who performed Phase 1?
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.		**11** - The work seems to be focused on multi-zone models. There is no mention in the Scope of the use of CFD or the coupling of CFD with multi-zone model, although there was a mention of this in the SoA (and other studies on the coupling of CFD nd multi-zone models since then).
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.		**11 -** 5 tasks with specific deliverables are defined.
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.		**12** -no listed! **6** - It could be clearer if the deliverables were called out specifically. I understood the formatting and what the deliverables were as presented.
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.		**7** - I have concerns about the ability for a bidder to meet all the requirements of this WS
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.		
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.		**12** -I am not sure Appendix A is required. Also, there are some grammatical errors. **7** -,Are the project milestones only to be reports of the tasks? **13** - The specifications for model validation in Task 4 places some significant and extensive restrictions on what field measurements must be made in Task 2. I don't know how many zones the "candidate building" has, but if all these measurements are taken only once every minute, Task 2 becomes a gargantuan field measurement exercise which becomes extremely complex and expensive to set up and conduct for an occupied building.
Decision Options	**Initial Decision**	**Final Approval Conditions**
ACCEPT		**12 -** see comments above. **6 -** Need to update the cover sheet with a number of items like bidders and such. For some reason it was not transferred from previous submission. Has it been too long since RP1456 that this work statement is no longer valid? I see this is part of Task 1, but is this adequate? I am not familiar with this type of work to provide much input into when this work is biddable or the $'s and time are adequate. **8 -** I feel the modeling testing and evaluation program should be defined a part of the Work Statement to allow better bidding. Bidder may develop a wide range of assumptions to address this open question. 7 - Address items under milestones, bidders, and ability for bidder to meet requirements. **13** - Cover Sheet check list not completed. No potential bidders or PES or PMS are listed. Reference for RP-1456? Should be RP, not TRP. Under Objectives, you say "…objective…is…" and it should be "objectives are" (more than one). Reference for the phase 1 work? In 4th paragraph of objectives, says "…to bring a building…" probably should be "…to use a building…". The word "bring" appears several times when "use" may be better. Be consistent referring to this effort as either Phase 2 or Phase Two, but don't flip flop terms since it suggests different things. Refers to "…database of tools that are available for naturally ventilated…". Tools for what; ventilation fans, cranks to open windows? I'm sure you mean modelling or simulation tools. Major grammar problems in the last paragraph of Objectives. You might want to quantify what you mean by "computationally intensive". Also, "software commonly used by practitioners". Is that CAD software, Excel, BIM, Word, ??? "Implemented in such tools" needs to be more specific. Should it be in C++, COBOL, FORTRAN, Excel??? You clearly have your ideas of what you mean here, but you need to be more explicit if you want all the bidders to have the same understanding of what you intend. You keep saying "tools". I think you need to adopt a more explicit term, like your "simulation tools" or "modeling tools" or "computer models". Your jargon may not be shared with international audiences or others not so active in this area. In Task 1, "…since the start of the Phase 1 project…" Give a time (year) for that just so the bidders know how far back they need to go. "…in a form to be agreed with the PMSC…" Why not spell it out here so the bidders know what they are getting into. I have seen more than one ASHRAE project get drug out for years because the PMSC kept stringing the PI on and on. Task 2 links the recommendations from Phase 1 to the "candidate building", which de facto requires the bidder to use the same Phase 1 building in their study. Have you already gotten approval from the building owner to use the building for this purpose with all the additional instrumentation, experimental traffic, and disruptions that such experimental tests entail? This will place significant travel cost and time burdens on PIs from outside the Illinois region. Task 2 again says format is to be approved by PMSC. Suggest stating the recommended format here in the WS. In Task 3, I would suggest you provide an inclusive list of building model software that is acceptable to you. Otherwise, the PI could do this in an Excel spreadsheet and technically comply with all the bullet items even if the PMSC does not like what they have done. The specifications for model validation in Task 4 places some significant and extensive restrictions on what field measurements must be made in Task 2. Zone temps, zone temp gradients, zone surface temps, zone occupancies, detailed energy use in each zone, air flow rate through every ventilation opening, every vent opening position, etc. I don't know how many zones the "candidate building" has, but if all these measurements are taken only once every minute, Task 2 becomes a gargantuan field measurement exercise which becomes extremely complex and expensive to set up and conduct for an occupied building. After looking up the building online, it is an 88,000 sq. ft. building housing a school of architecture and a library. Have you really looked at the extent of what you are asking for in Task 4? Even if the "candidate building" is a small commercial building with, say, 10 zones, the specified time, effort, and budget would not come close to covering what is needed to set up and conduct the field measurements in an occupied building as specified in Task 4. I am afraid that potential bidders will look at this and be scared off because of the extensive scope of the project and because the PMSC must approve of formats and details every step all along the way before they can proceed. I may be misinterpreting your intent, but that suggests that potential bidders might also misinterpret your intent and not bid on the project. If you require that the Phase 1 Weber building be used and leave all the decisions about format, process, etc. to be made during the project, how will you judge one bidder's proposal from another's? **11** - While the SoA and the Scope are well written, this WS has gaps (e.g., no list of potential bidders, no PES members, no check marks in the top section). Is this a Phase 2 of of a 2-phase study to be performed by the same contractor. Does it have to be performed by the same contractor? Would like some clarifications of these issues.
COND. ACCEPT		
RETURN	**X**	
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

Date: 8/15/18

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

A. Title
B Executive Summary
C. Applicability to ASHRAE Research Strategic Plan
D. Application of the Results
E. State-of-the-Art (background)
F. Advancement to State-of-the-Art
G. Justification and Value to ASHRAE
H. Objective
I. Scope
J. Deliverables/Where Results will be Published
K. Level of Effort
- Project Duration in Months
- Professional-Months: Principal Investigator
- Professional-Months: Total
- Estimated $ Value

L Proposal Evaluation Criteria & Weighting Factors
M. References
N. Other Information to Bidders (Optional)

Title:

Assess and Implement Natural and Hybrid Ventilation Models in Whole-Building Energy Simulations – Phase 2

WS# 1748
(To be assigned by MORTS - Same as RTAR #)

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

ASHRAE Handbook of Fundamentals:
Ch: 6, 17, 18, and 19

Responsible TC/TG: TC 4.7

Date of Vote: 8/15/18

For		9
Against	*	0
Abstaining	*	1
Absent or not returning Ballot	*	1
Total Voting Members	CNV	11

This W/S has been coordinated with TC/TG/SSPC (give vote and date):
TC 4.10 – 12 Yes, 0 No, 0 Abstain 07/24/2018

Has RTAR been submitted? YES, RTAR Cond. Accept. 14.10

Strategic Plan Theme/Goals: 2010 - 2018 #1, #3, #7

Work Statement Authors: **
Anthony Fontanini
Joe Huang

Proposal Evaluation Subcommittee:
Chair:
Members:

Project Monitoring Subcommittee:
(If different from Proposal Evaluation Subcommittee)

Recommended Bidders (name, address, e-mail, tel. number): **

(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?		X	
Has an electronic copy been furnished to the MORTS?	X		
Will this project result in a special publication?		X	
Has the Research Liaison reviewed work statement?	X		

* Reasons for negative vote(s) and abstentions

Chair abstained from vote

** Denotes WS author is affiliated with this recommended bidder

Use additional sheet if needed.

WORK STATEMENT# 1748

Title:

Assess and Implement Natural and Hybrid Ventilation Models in Whole-Building Energy Simulations – Phase 2

Sponsoring TC/TG/MTG/SSPC:

TC 4.7

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

TC 4.10

Executive Summary:

Natural and hybrid ventilation have a large potential for minimizing the need for mechanical cooling. However, engineers need reliable and easy-to-use modeling tools before they can incorporate such systems into their HVAC designs. However, in order to model the complex air flows and thermal conditions, engineers need reliable and easy-to-use modeling tools to be able to adopt such designs. The current modeling strategies of natural and hybrid ventilation systems have been shown to have some major limitations, which limits their applicability to widespread usage. This phase-2 project builds on the understanding phase 1 developed about the capabilities of the tools available to model natural and hybrid ventilation systems. Phase 2 addresses the questions "How do current modeling strategies perform?" and prompts action toward areas of future research. Phase 2 uses a data set from a full-scale building. This project helps provide a consensus method for modeling natural and hybrid ventilation systems, and provides tools and strategies to better understand the impact of these passive strategies on whole-building energy usage.

Applicability to the ASHRAE Research Strategic Plan:

There is a need to assess the accuracy of these models or modeling methods, as well as their usability in whole-building energy simulations. Measured data on the three air flow/thermal processes (ventilation rate, stratification, and thermal coupling) have been gathered at various universities and research institutions, but vary greatly in their quantity or resolution. Preliminary enquiries have indicated numerous studies of bulk ventilation rates, but few of temperature stratification within a naturally ventilated space, and even fewer of the thermal coupling between the spaces with the ventilation air. Furthermore, while modeled air flow rates can be validated on a stand-alone basis, validation of stratification and thermal coupling requires that the modeling methods be implemented within at least a room, and preferably a whole-building, simulation model.

The need for this research is corroborated by ASHRAE Research Strategic Plan coving a number of the goals and needed research topics. This project aims to establish techniques to improve the energy efficiency of HVAC system by utilizing passive strategies. The end product of this research should provide a better understanding of the airflow network models and how they can be coupled with building energy simulation software. A consensus method will be established for designing and evaluating these systems.

Application of Results:

This project will provide ASHRAE members with a more reliable consensus method for modeling the effects of natural and hybrid ventilation on the HVAC designs. General guidance for setting up the simulations and analyzing the results can be added to the ASHRAE Handbook chapters 16, 17, 18, and 19 of the Fundamentals. The insight gained from the analysis helps ensure that the performance of natural ventilation and hybrid systems achieve their design values while saving energy by utilizing passive strategies.

State-of-the-Art (Background):

Natural ventilation of buildings has received more attention in recent decades because it is a cooling strategy that requires no energy use. However, since it is generally difficult for natural ventilation to maintain indoor comfort under all conditions, it is frequently supplemented with mechanical cooling in what has now become known as "hybrid ventilation" or "mixed mode" operations.

Modeling natural ventilation involves complex air flows that are highly dependent on varying external and internal conditions, as well as the building geometry and local site conditions. The modeling needs for hybrid ventilation also include an additional control component. The three primary modeling issues for natural ventilation are: (1) determining the amount of air flow from the outside and from zone to zone, (2) stratification within natural ventilated spaces, and (3) thermal coupling between the spaces and building fabric with the ventilation air.

To address the first issue, various energy simulation programs such as EnergyPlus, ESPr, and TRNSYS have linked multi-zone air flow network solutions to their thermal calculations, typically in a "ping-pong" fashion between the two (Hensen 1991, Huang 1999). There have also been efforts to link thermal programs to CFD models (Beausoleil-Morrison 2000, Zhai et al. 2002).

To address the latter two issues, there have been efforts to extend stratified-room models originally developed for displacement ventilation to simulate stratified interior spaces resulting from buoyancy-driven ventilation (Linden 1999, Rees and Haves 1999, Carrilho da Graca & Linden 2002).

Since these efforts, ASHRAE has supported the phase 1 part of this project (TRP-1456) that assessed the ability of thermal-ventilation models (up to 2010) to model natural and hybrid ventilation systems. The models identified by phase 1 were compared against published experimental data. The comparisons had some major limitations, as there were some missing data and non-standard control strategies in the buildings. Phase 1 did provide recommendations for improving the energy models along with details explaining a more "ideal" naturally ventilated building, measurement parameters, and monitoring conditions. To address these limitations of the Phase 1 project, a benchmark case for a heavily instrumented building is needed to (1) evaluate the performance of airflow network and energy modeling strategies, (2) establish the minimum data necessary to calibrate, validate, and accurately predict the airflows, thermal response, and energy requirements of buildings, (3) identify the aspects of the state-of-the-art methods that could use improvement, and (4) for future comparative testing between different models and modeling strategies.

Advancement to the State-of-the-Art:

The simulation techniques and models that have been developed for natural and hybrid ventilation make various assumptions and simplifications about air flows, boundary conditions, and thermal distributions within the building. To illustrate, Appendix A lists those assumptions related to just the air flow aspects of network models. The impact of such assumptions on the accuracy of the models is unclear, nor is there any consensus on which method best suits the needs of the engineer, or what improvements are needed for the models to be used in standard engineering applications. Therefore, there is a need to evaluate currently available methods for modeling natural and hybrid ventilation, assess their usability and accuracy for practical design applications, and identify areas where future work is needed.

This project builds off the efforts of the phase 1 project in the identification and evaluation of potential tools for modeling natural and hybrid ventilation systems in a whole-building energy simulation. This phase-2 project has two major goals. 1) Provide a usable dataset for researchers, engineers, and architects to use in benchmarking their naturally ventilated and mixed mode buildings, and 2) Evaluate the current capabilities of modeling techniques that will identify future avenues of research. The objectives of the project are designed to provide a roadmap towards better analyzing the impact of natural and hybrid ventilation systems all over the world.

Justification and Value to ASHRAE:

Natural and hybrid ventilation have a large potential for minimizing the need for mechanical cooling. However, engineers need reliable and easy-to-use and computationally efficient modeling tools before they can incorporate such systems into their HVAC designs.

Objectives:

The overall objective of this project is to provide ASHRAE members with an objective assessment of the applicability of current modeling methods for natural and hybrid ventilation systems, give guidance on how to use of these tools in the design or evaluation of naturally-ventilated buildings, and identify conditions under which the models are deficient and need improvement. Because of the complexity of the topic and the amount of work, this has been conceived as a two-phase project, with phase 1 having been carried out in 2005-2007.

The phase 1 project compiled an inventory of existing measured data sets, and obtained data sets for several small-scale test cases, and one full-scale building that used natural ventilation. Corresponding simulation models were developed, first using a stand-alone air flow network program, and then with a thermal simulation program coupled to an air flow network. Simulations were then done to evaluate the programs' ability to model different ventilation regimes, e.g., wind-driven and stack-driven ventilation etc. The results compared well for the test cases, but were inconclusive for the full-scale building due to how the building was controlled.

Phase 1 has also summarized areas of limitations in modeling naturally ventilated buildings. These major areas are atrium ventilation, large horizontal openings, thermal mass, and vent control. More information on these limitations are outlined in Appendix B. Although there has been some improvement to energy models and airflow network modeling since Phase 1, these areas have been prioritized by the task group of this work statement. The contractors should prioritize the accuracy of their experimental and simulation campaign in these areas in the following order: thermal mass response of the building, vent control, atrium ventilation, and large horizontal openings.

As part of the evaluation criteria of the phase 2 project, contractors are required to bring a building that is suitable for this project. The task group for the work statement have identified that there are buildings available for such analysis. One potential candidate building identified by the task group is the Harm A. Weber academic center building on the Judson University campus in Elgin, Illinois, USA. This building is a mixed mode naturally ventilated building that data has been collected since 2009. The multistory building is approximately 88,000 ft^2 LEED Gold certified building. For information about this building please refer to the following references: Kaiser and D.M. Ogoli 2005, C.A. Short and K.J. Lomas 2007, K.J. Lomas et al. 2007, K.J. Lomas 2007, Kaiser et al. 2009. The phase 2 project is not limited to using only the Judson University building, but contractors are welcomed to bring other buildings as potential candidates for monitoring for this project. The goal of this project is to use a building similar to the characteristics of the Judson University building. The building brought as a candidate by the contractor is called the "candidate building" through the rest of the work statement.

The objectives for Phase Two are to (1) update the database of tools that are available for naturally ventilated and mixed mode buildings since the phase 1 project, (2) evaluate and enhance the available data from the candidate building (3) create an energy model to that has potential to simulate the the energy and thermal response of the candidate building, (4) evaluate the energy and thermal model with the experimental campaigns, and (5) provide guidance of the use of simulations for modeling hybrid and natural ventilation.

Scope/Technical Approach:

It is intended that the project be concerned with models of natural and hybrid ventilation that can practically be applied in annual simulations, i.e. are not computationally intensive. Value is placed on models that are implemented in software commonly used by practitioners, or could conceivably be implemented in such tools without substantial modification. It is not intended that CFD modeling methods be in the scope of this work.

Task 1: Update the database of tools available for natural and hybrid ventilation

Phase 1 of the project identified four tools that have some ability to simulate natural and hybrid ventilations systems for whole building energy simulations (e.g. COMIS, CONTAM, ESP-r, and EnergyPlus). A literature search is to be performed on these four simulation tools identified by phase 1 on documented changes or improvements of these models, along with new tools that have been developed since the start of the phase 1 project. The literature is to be reviewed with a view to establishing what models of natural and hybrid ventilation have been developed. After the literature review of the current tools, an assessment of an itemized list of strengths and weaknesses are to be developed. Documentation summarizing the findings of these reviews, in a form to be agreed with the PMSC and presented as a milestone before the project moves forward, is to be prepared which will record the following.

- The characteristics and intended application of each model.
- The capabilities and limitations of each model.
- The input/output data and parameter requirements.
- The extent of prior verification and validation.
- Current model implementations (if any).
- Recommendations for the most promising model available

Task 2: Evaluate and enhance available data from the identified building

Phase 1 identified 3 buildings for the project. Each of these buildings had limitations with the data that has been taken during the project. Based on these limitations, recommendations for future experimental campaigns have been stated in Appendix B from Phase 1. Using the recommendations from Phase 1 and the current data being taken in the candidate building, the contractor are required to comment on the currently available data in the building along with enhancements needed to the data to perform this project. The purpose of this task is to provide the necessary information such that the analysis can be reproducible by (1) documenting the building and existing data being taken in the building, (2) increasing the sensors if needed or obtain information about the candidate building that is missing to perform the rest of the project, and (3) ensuring that the data for creating the energy model, setting conditions and controls of the building, and evaluating the performance of the model is available. Documentation summarizing the building information, prior experiments in the candidate building, and current measurement campaign of the candidate building (the first three bullets below) is to be submitted as the 1st intermediate milestone for Task 2 to the PMSC.

- Building information
    - The layout of the candidate building and the natural ventilation circuit(s).
    - Basic information about the candidate building location, size, orientation, and climate

Scope/Technical Approach (Continued 2):

- Prior experiments in the candidate building
  - Geometry. A description of the geometric configuration of the experiments including dimensions and any details of air inlets/outlets etc.
  - Flow regime. For example, whether the flow is buoyancy, wind or mechanically driven and whether stratified or mixed.
  - Key variables measured
  - Number of data sets recorded and experimental conditions
  - Estimated measurement error limits
- Current measurement campaign of the candidate building
  - Measurements currently being taken in the candidate building
  - Measurement methods currently being taken in the candidate building
  - A detailed account of the length of time data has been collected in the candidate building

The enhancement experimental campaign will be submitted as the 2nd intermediate milestone of Task 2 in an agreed upon format by the PMSC based on the results of 1st intermediate milestone.

- Enhancement program for the phase 2 project
  - Enhanced measurements and measurement methods needed to satisfy this phase 2 project in the candidate building
  - Time duration that the enhanced measurement scheme is needed to properly evaluate the other objectives in the work statement
  - Measurement uncertainty

The format of the documentation is to be agreed with the PMSC. Authors and laboratories associated with the experiments should be approached to obtain such information and wherever possible provide copies and explanatory documents. Consent for use of the data in this, phase 2 of the work, and further distribution of the data by ASHRAE should be obtained where possible. The experimental data sets are to be collated and organized by the contractor and will become part of the final project data/documentation delivered to ASHRAE.

Task 3: Create an Energy Model for the Candidate Building

Based on the candidate building the contractor will create a model or models with capabilities to simulate the energy usage and thermal response of the candidate building during the experimental campaigns of the building. In creating the model, the contractor should state the following in a format of documentation to be agreed with the PMSC and presented as a milestone before the project moves forward.

- The tools used for the simulation process. Examples of these tools are but are not limited to (EnergyPlus, ESP-r, CONTAM, COMIS, etc…)
- Implementation details on how the tools are used to run the simulations for reproducibility
- Uncertainty in the modeling approach, coupling approach, unknown factors of the experimental dataset
- Limitations to the current approaches towards modeling specific aspects of the candidate building
- Temporal convergence of the numerical solution
- Reporting initial calibration and or initial validation results to show model should be acceptable to move forward in the project.

Scope/Technical Approach (Continued 3):

Task 4: Model Testing and Evaluation

The contractor will, on the basis of this information, establish a model testing and evaluation program following consultation with the PMSC. The contractor will attempt to validate the selected models/tools, by way of seeking to reproduce experimental measurements using applicable input and model parameter data. Although some degree of validation and optimization of the model parameters should be possible the focus of this task is to identify the shortcomings of the models, deficiencies in the experimental data and usability of the models/tools. Where a number of models can be tested using a given data set, inter-model comparisons should be undertaken. The results of the simulation are to be better than the phase 1 project of 35% for the predicted airflow quantities of interest. The contractor is expected to report a comparison of the experimental data and the numerical simulations for the following quantities of interest, and will be evaluated by the PMSC as an intermediate milestone before the project moves forward. These quantities are based on the recommendations of Phase 1 in appendix B:

Zone Conditions
- Zone temperatures.
- Temperature gradient in the zone(s) with high ceilings (ex: atriums) where buoyancy dominants the airflow dynamics.
- Surface temperature of thermal mass in each zone.
- Energy use for lighting & plug loads
- Occupancy

Ventilation Conditions
- Vent status, including open/closed and % open if the building vents modulate.
- Air flow through every building vent, both inlets and outlets.
- Fan speed, exhaust rate, and energy consumption, if hybrid ventilation is in use.
- Inlet air temperature is also desirable

Error Quantification
- Quantify errors of numerical simulation for each of the quantities above.

In reporting this task emphasis is to be placed on providing practical guidance to ASHRAE members on the capabilities of each model or type of model, range of applicability and usability in a design context. Consideration should be given as to whether the required parameter data is likely to be available to designers, the sensitivity of the models to particular parameters and the uncertainty that can be expected in any model predictions.

Task 5: Recommend Further Work

Following competition of tasks 1, 2, 3, and 4 the contractor will establish and report the following and will be evaluated by the PMSC before the completion of the project:

- What additional experimental data is required for satisfactory validation or model development?
- What is the minimum data required for accurate airflow and energy modeling results?
- What situations do the models work well?
- What models are needed but not yet developed?
- What and how current models need to be extended or developed further?
- What existing models should be considered for immediate implementation?
- What model assumptions need to be addressed?

Deliverables/Where Results Will Be Published:

Progress, Financial and Final Reports, Technical Paper(s), and Data shall constitute the 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. Interim Reports

An interim report at the completion of Task 2 and an interim report at the completion of Task 4 shall be prepared by the Institution and submitted to the Society's Manager of Research and Technical Services. An electronic copy of each report in Microsoft Word or PDF format shall be furnished for review by the Society's Project Monitoring Subcommittee (PMS). Each report must be approved by the PMS prior to subsequent work.

c. 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, including a summary of the control strategy and savings guidelines. Unless otherwise specified, the final draft report shall be furnished, electronically for review by the Society's Project Monitoring Subcommittee (PMS).

Tabulated values for all measurements shall be provided as an appendix to the final report (for measurements which are adjusted by correction factors, also tabulate the corrected results and clearly show the method used for correction).

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 copies; one in PDF format and one in Microsoft Word.

d. Science & Technology for the Built Environment or ASHRAE Transactions Technical Papers

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 HVAC&R Research 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

Deliverables/Where Results Will Be Published (Continued 2):

"Manuscript Central" for an ASHRAE Transactions Technical or HVAC&R Research papers. The paper title shall contain the research project number (1748-RP) at the end of the title in parentheses, e.g., (1748-RP).

All papers or articles prepared in connection with an ASHRAE research project, which are being submitted for inclusion in any ASHRAE publication, shall be submitted through the Manager of Research and Technical Services first and not to the publication's editor or Program Committee.

e. Data

Data is defined in General Condition VI, "DATA"

f. Project Synopsis

A written synopsis totaling approximately 100 words in length and written for a broad technical audience, which documents 1. Main findings of 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. 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 is planned to have 18-month duration (spread over 4 society meetings) with an approximate budget of $140,000 - $150,000. It is expected that 6 person-months of Principle Investigator and 18 person-months of researcher effort are required to complete the project.

Proposal Evaluation Criteria:

No.	Proposal Review Criterion	Weighting Factor
1	Contractor understanding of the Work Statement for conducting research	15%
2	Probability of contractor's research plan meeting the objectives of the Work Statement	30%
3	Quality of methodology proposed for conducting research	25%
4	Contractors past capability to evaluate experimental data, evaluate software and attempt model validation	15%
5	Likelihood of the contractor effectively communicating with other institutions and obtaining the required data	10%

6	Performance of contractor on prior ASHRAE projects or related projects – no penalty for new contractors	**5%**

Project Milestones:

No.	**Major Project Completion Milestone**	**Deadline Month**
1	**Task 1: Report**	**3**
2	**Task 2: Report**	**9**
3	**Task 3: Report**	**15**
4	**Task 4: Report**	**16**
5	**Final Report**	**18**

Authors:

Anthony Fontanini
Joe Huang

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Other Information for Bidders (Optional):

APPENDIX A: Comments on Natural Ventilation RTAR

from: George Walton
To: Joe Huang
Date : June 26 2005
Re: problems with current airflow network methods:

***Wind assumptions*:**

1a. *wind pressure*: $\rho\ (V^2/2)$ assumes the wind velocity is reduced to zero at the building surface. This assumption is okay for infiltration through small openings, but is it okay for large openings that may have significant velocities ?

1b. *one-sided ventilation*, e.g., rooms with two openings on one wall. An oversimplified wind pressure model will assign the same pressure to both openings resulting in no ventilation flow. A similar situation exists for a single wide opening.

1c. *stochastic wind conditions*: wind speed and direction are variable, sometimes rapidly variable. Using average values over a long time step can be problematic, especially when flow directions can change.

1d. *flow control or enhancement devices are not adequately dealt with:*

a. passive flow limiters
b. chimney enhancement

2. *momentum effects are ignored*. At higher velocities the position of openings relative to the flow direction can become important, i.e., air jets.

3. *node pressure losses*: As velocity increases, there is a pressure loss through the zone, although I suspect this is usually not significant.

Air flow network assumptions:

all pressure losses occur in the links between nodes, i.e.,

links:	openings	ducts
nodes:	rooms	junctions

the above assumption implies that all nodes can be characterized by a single pressure value (but with hydrostatic variation) air velocities within the node are negligible (no ΔP driving flow within the node)

(3) In the links: $\Delta P\ =\ f(\dot{m})$ non-linear function

(4) In the nodes: $\sum \dot{m}\ =\ 0$ steady-state with some additions for transient and non-transient contaminants

3. and 4. has lead to our standard solution method to solve simultaneous non-linear equations

APPENDIX B: Summary and Recommended Future Work from ASHRAE TRP-1456

1. Summary of Phase-One Study Results

Network modeling:

- Single-sided wind driven NV cannot be modeled.
- Network model is generally able to predict airflow within 35%.
- The tools are very dependent on ambiguous coefficients, especially the discharge coefficient.
- Four models tested (COMIS, CONTAM, ESP-r, and EnergyPlus) are essentially identical with respect to underlying principles of network modeling.

        - Minor differences in naming conventions, etc. exist between the tools
        - COMIS's has an additional capacity to model density gradients, but testing did not show any major benefit from this capability.
- Desirable network model improvements include:
    - A relationship for bi-directional flow in horizontal openings
    - A relationship for wind-driven single-sided ventilation

Coupled thermal-airflow modeling

- EnergyPlus's Airflow Network is an acceptable tool for modeling simple NV buildings.
- EnergyPlus deficiencies:
    - Venting control and exhaust fan control is very limited. Conversely, many NV building rely on very complex control schemes.
    - The parameters for defining operable window area do not function. This capability would be beneficial to prevent users from having to manually resize windows.
    - Relationships are needed for:
        - Roof-level horizontal openings
        - Atrium-type openings
- A more complete dataset is required to more fully evaluate the airflow-thermal coupling.

2. Recommended Energy Model Improvements

Atrium Ventilation

Results from the two buildings utilizing atriums indicate that the model may be overestimating buoyancy-driven induced in the areas with high ceilings. While the airflow network model performed well for both buoyancy- and combined-driven atrium ventilation in the laboratory testing, neither of these lab tests were conducted on real full-size geometries. Thus, data from a controlled experiment performed on a full-size atrium would be very valuable towards further refinement of this portion of the network model.

Horizontal Openings

Prior to the release of EnergyPlus v4.0, there was no incorporated model for horizontal openings. In version 4.0, a new relationship for horizontal stairway-type openings was added, based on limited experimental data. However, further refinement is still recommended. First, this opening type remains unavailable for roof-level openings. Second, comparison testing between this new component and the v3.0 component did not reveal any major difference in result. Since naturally ventilated buildings often have roof-level horizontal openings, this addition is desirable.

Thermal Mass

For both the Bang&Olufsen Building and Houghton Hall, increasing the level of thermal mass improved the predicted temperature performance of the building. Though the increase needed to impact the model was well beyond reality, this may indicate that the EnergyPlus model is underpredicting the effect of thermal mass. Further investigation using a dataset with airflow measurements is needed in order to more fully evaluate this portion of the model.

3. Recommended Experimental Campaign

(1) Ideal Naturally Ventilated Building to be Monitored

Characteristics of the best naturally ventilated building for monitoring include:

Automatically control vents: Though most naturally ventilated buildings allow for occupant control of windows and other vents, the ideal building would have only automatic venting. With manual vents, it becomes necessary to monitor airflow at every opening since each can be operated independently of the others.

Areas using single-sided and cross ventilation: The building should ideally have separate areas where single-sided and cross ventilation are in use. This will allow for more thorough testing of the model's capability to model each scenario. An atrium area is also desirable.

Detailed building construction information: As when constructing any building model, accurate information about the building envelope must be available. The relatively high window area associated with most naturally ventilated buildings means that glazing properties are especially critical.

High level of thermal mass: For more in-depth understanding of the coupling between the airflow network and thermal mass calculations in EnergyPlus, the building should be designed with a high level of internal thermal mass. Many naturally ventilated buildings are designed around night cooling of this thermal mass.

Wind pressure coefficient data: If a study on wind pressure coefficients was not conducted during the design stages of the building, such a study should be included in the monitoring campaign.

Vent effective area and discharge coefficients: Given the network model's sensitivity to vent area, it is critical that testing on the effective area and discharge coefficients be conducted specifically for the vents in the buildings. It is desirable therefore that the building utilize only type of inlet vent for simplicity.

(2) Measurement Parameters

Zone Conditions

The following parameters should be measured on an hourly basis:

- Zone temperatures for every zone in the building. An array of measurements should be taken in spaces with high ceilings to measure temperature gradient in the zone.
- Surface temperature of thermal mass in each zone.
- Energy use for lighting & plug loads
- Occupancy

Ventilation Conditions

The following parameters should be measured on an hourly basis:

- Vent status, including open/closed and % open if the building vents modulate.
- Air flow through every building vent, both inlets and outlets. This is the primary deficiency among currently available datasets. Without measured volume flow rate data, only temperature response can be compared, which is a secondary calculation and is also influenced by other zone and envelope loads.
- Fan speed, exhaust rate, and energy consumption, if hybrid ventilation is in use.
- Inlet air temperature is also desirable.

Ambient Conditions

The following parameters should be measured on an hourly basis in close proximity to the building, in order to create an accurate weather file:

- Outdoor air dry bulb temperature

(3) Monitoring Campaign Conditions
The ideal monitoring campaign would incorporate all of the above listed measurements in the building for a variety of conditions:

Infiltration only: In order to ensure that the building's internal loads and infiltration are correctly modeled, data should be collected during a period where the natural ventilation system is not in use.

Natural Ventilation only: Most naturally ventilated buildings have heating systems that preheat the outdoor air during winter. Many ventilation systems also include a fan for backup in case natural ventilation is not sufficient. Data should be collected when these types of system and any other auxiliary space conditioning systems are not in use.

Hybrid Ventilation only: If the building does have fan assistance, monitoring of ventilation rate while the fans are running is also important.

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.

Reply to RAC's Comments

WS-1748L Assess and Implement Natural and Hybrid Ventilation Models in While-Building Energy Simulations – Phase 2

We thank RAC for the constructive comments and generally positive review. In particular, we are grateful for the RAC's advice for clarifying the applicability of this work statement. We have incorporated or addressed all the suggestions and concerns of RAC in an updated work statement. This document details each point below:

Detailed Bidders List Provided? The contact information in the bidder list should be complete, so that each potential bidder can be contacted without difficulty.

#3 – *4 bidders provided.*

Reply: *We would like to thank the reviewer for the information provided in their comment.*

#6 – *Whoa! How does this relate to 1744, which seems to play in the same world?*

Reply: This is a good observation by the reviewer. The authors of both WS-1748 and WS-1744 are working together to better address current issues in naturally ventilated buildings. These two work statements are not conflicting, but both are complimentary and essential to the success of better understanding the complex dynamics in naturally ventilated buildings. The two work statements attack separate issues in the predicted performance of natural ventilation. WS-1748 investigates the performance of energy modeling and airflow network strategies in predicting the thermal conditions of the zones, airflows between zones, and energy consumption predictions in a heavily instrumented building. These strategies in WS-1748 makes specific assumptions about the thermal zones that are created, this is where WS-1744 comes in to address the space air physics and dynamics. WS-1744 determines the boundary conditions, methodology for modeling turbulence, and discretization requirements to resolve the flow physics within thermal zones. While the result of WS-1748 may methods and new capabilities to simulate large complex commercial buildings, WS-1744 helps understand the complex nonlinear physics and establish applicability and improvements of the underlying assumptions in energy modeling and airflow network modeling.

#14 – *4 identified including a member of the PES!!!!*

Reply: We would like to thank the reviewer for this positive comment and the information provided in their comment.

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, then the WS needs major revision.

#6 – *Looks good, particularly strong on tying to prior work and on the detailed description of Task 4.*

> ***Reply:*** We would like to thank the reviewer for this positive comment.

#14 – *I do not see the justification for doing a research study for a specific building. There are so many different types of buildings and configurations and doing a study like this may not be broadly applicable. This study looks like a validation of a general approach for a specific building.*

> ***Reply:*** It is a good point by the reviewer that the justification for a specific building is not explicit in the work statement. This topic has been a concern when work statement was being developed by TC 4.7 and obtaining co-sponsorship by TC 4.10. The justification for a specific building is based on the recommendations and problems seen in Phase 1 of the project and budgetary constraints. One of the main limiting factors of the Phase 1 project was that there was not enough data in a single building to properly make important aspects of the assessment in Phase 1. The TCs believes that although buildings may be vastly different even between building types, it is important to establish a benchmark test case that will test important aspects of the energy modeling and airflow network modeling capabilities. Members of TC 4.7 have also identified at least one building (explained in the "OBJECTIVE" section) that would satisfy the data requirements necessary for the success of the work statement. Modifications to the "STATE-OF-THE-ART (BACKGROUND)" and "Task 5: Recommend Further Work" sections have been made to better explain the motivation for a specific building and the generalization of the results.

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.

#3 – *Unclear what is being done in Task 2.*

> ***Reply:*** This is a good point by the reviewer, as the purpose is not explicitly stated in the work statement. The purpose of this task is to provide the necessary information such that the analysis can be reproducible by (1) documenting the building and existing data being taken in the building, (2) increasing the sensors if needed or obtain information about the candidate building that is missing to perform the rest of the project, and (3) ensuring that the data for creating the energy model, setting conditions and controls of the building, and evaluating the performance of the model is available. This language has been added to Task 2 in the updated work statement.

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.

#6 – *TBD.*

> ***Reply:*** To make this point more clear, explicit language in each task was added in the work statement to state to the contractor that there will be a review by the PMS committee to approve each task.

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.

#7 – *Lack of whole building experimental data still appears to be an issue. Phase 1 identified that there is a deficiency in available data but this was not resolved based on my read of the WS.*

> ***Reply:*** The reviewer is correct in that Phase 1 identified that there was a deficiency in the available data at the time of the Phase 1 project. Since the conclusion of the project, the members of TC 4.7 and TC 4.10 have searched for a potentially acceptable building and have identified at least one building (explained in the "OBJECTIVE" section) that could fit this project. Also, Task 2 in the work statement (which has been updated as part of this review by RAC) is specifically for documentation of the building, evaluating the data that is available, and enhancing the data if the data is not sufficient to perform the analysis. This is a major milestone for the project and is to be evaluated by the PMSC before the project moves forward. With these improvements TC 4.7 and TC 4.10 have determined that there would be buildings available for this project.

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.

#3 – *Apparently; experienced WS team.*

> ***Reply:*** We would like to thank the reviewer for this positive comment and the information provided in their comment.

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.

#7 – *I think there could be bidding issue due to the ambiguity around the availability of experimental data. It is not clear if the work should include additional experimentation/data collection or if there is the expectation that additional data will be available.*

> ***Reply:*** As part of the bid evaluation process, the contractor's responsibility to explain the building and the data that they have available, and whether they believe that additional data is required. The PMSC will use their explanation to determine which contractor is best suited for the project. In Task 2 of the work statement, after a review of the current modeling capabilities, there may need to be more data experimentation or data collection. This part of the work statement has gone through some modification based on other RAC's other comments. We have tried to better address these issues.

#6 – *Project milestones are "TBD", which I assume means to be negotiated with contractor. WS still uses obsolete "Final Report" Section. How do we fix this?*

> ***Reply:*** We would like to thank the reviewer for pointing out the obsolete version and the work statement format has been updated. The milestones have also been updated to reports after each completion of each task with the expected timeline.

Approval Conditions

#3 – *This WS needs some work. Task descriptions need more definition, and intermediate milestones should be developed for each task.*

> ***Reply:*** The intermediate milestones are a good suggestion by the reviewer. Task 2 (being the most important task for the success of the project) has been modified to include 2 intermediate milestones to be evaluated by the PMSC. Through the other comments supplied by the reviewers, the Tasks have been slightly expanded for better definition.

#5 – *The authors of this WS need to communicate with the WS 1744 authors and come up with a common project. Also need to get a TC involved that covers computer modeling (4.7). Much more reasonable cost compared to 1744.*

> ***Reply:*** This is a good comment by the reviewer. The authors have tried to address this topic in a previous comment (Detailed Bidders List Provided? #6). We refer this reviewer's comment to that response for discussion on the topic. The work statement is championed by TC 4.7 and co-sponsored by TC 4.10 (the champion of WS 1744). The authors of each work statement have been collaborating on both WS 1744 and WS 1748.

#6 – *This strikes me as a better bet than 1744, and I haven't seen a need for both to be funded. 1748 needs some admin details resolved.*

> ***Reply:*** The authors have tried to address this topic in a previous comment (Detailed

Bidders List Provided? #6) for the WS 1744 and WS 1748 discussion. We refer this reviewer's comment to that response for discussion on the topic. The work statement is championed by TC 4.7 and co-sponsored by TC 4.10 (the champion of WS 1744). The authors of each work statement have been collaborating on both WS 1744 and WS 1748.

#7 – *I feel this is potentially good research but that the work statement requires additional clarity. It may not be possible to address all of the issues with whole building simulation all at once. I would recommend focusing on one part such as the thermal coupling/stratification as figuring out how to deal with variable wind conditions seems like a daunting undertaking.*

Reply: We thank the reviewer for the comment. Through the other comments addressed in this document, the authors have tried to better clarify the mentioned comments from RAC. The physics behind stratification is better suited for WS 1744 as that work statement specifically deals with the modeling and fluid physics within the thermal zones. Over the past couple of years (since the end of Phase 1), substantial advancements have been made by whole building energy simulation programs to simulate natural ventilation. Although these advancements are important, a consensus methodology,

#14 – *The WS lacks some inputs (looks like it was rushed). 5 of 12 members of the TC did not vole.*

Reply: Based on all the other comments the work statement was updated to address the comments and concerns of the reviewers. The work statement was re-voted in Houston.

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Michael R. Vaughn, P.E.
Manager Research & Technical Services

TO: Bass Abushakra, TC 4.7, abushakr@msoe.edu
Jeff S Haberl, Research Subcommittee Chair TC 4.7, jhaberl@tamu.edu
Xudong Yang, Research Liaison 4.0, xyang@tsinghua.edu.cn

FROM: Michael Vaughn, MORTS, MORTS@ASHRAE.net

DATE: October 28 2016

SUBJECT: Work Statement (1748-WS), "Assess and Implement Natural and Hybrid Ventilation Models in Whole-Building Energy Simulations - Phase 2"

During their fall meeting, the Research Activities Subcommittee (RAS) of RAC reviewed the subject Work Statement (WS) and voted 3-0-1-2 (6) CNV to return with comments.

Below are the main issues and concerns that must be addressed in your next submission of the WS if you choose to resubmit.

1. Milestones must be specific, cannot read "TBD".
2. There are many factors and a lot of experimental data involved. How to ensure chance of success?
3. Task descriptions need more definition. For example, collect what data, in what type of buildings? Intermediate milestones should be developed for each task.
4. The work statement lacks some inputs (looks like it was rushed). Five of 12 members of the TC did not vote.

A WS evaluation sheet is attached as additional information and it provides a breakdown of comments and questions from individual RAC members based on a specific review criteria. This should give you an idea of how your WS is being interpreted and understood by others. Some of these comments indicate areas of the WS where readers require additional or corrected information or rewording for clarification.

Please coordinate changes to this Work Statement with your Research Liaison, Xudong Yang, xyang@tsinghua.edu.cn or RL4@ASHRAE.net prior to resubmitting it again to the Manager of Research and Technical Services for further consideration by RAC.

Also, it is necessary that you provide with your next submission a new TC vote on the revised Work Statement, and a letter describing how each of the above items were addressed in the revision.

If you wish for this work statement to be reconsidered at the next RAC meeting, the revised Work Statement must be sent (electronically) to Michael Vaughn, Manager of Research and Technical Services (morts@ashrae.net) by **December 15, 2016.** The next opportunity for consideration after this deadline is May 15, 2017.

Project ID	**1748**	
Project Title	**Assess and Implement Natural and Hybrid Ventilation Models in Whole-Building Energy Simulations - Phase 2**	
Sponsoring TC	TC 4.7, Energy Calculation; Co-Sponsor: TC 4.10 (Indoor Environmental Modeling)	
Cost / Duration	$180,000 / 18 months	
Submission History	**1st WS Submission, RTAR Accepted F14**	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC 2016 Fall Meeting Review	**RTAR STAGE FOLLOWED**	
Check List Criteria	**VOTED NO**	**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.		**#3**- 4 bidders provided. **#6** - Whoa! How does this relate to 1744, which seems to play in the same world? **#14** - 4 identified including a member of the PES!!!!
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.	**#14**	**#6** - Looks good, particularly strong on tying to prior work and on the detailed description of Task 4. **#14** - I do not see the justification for doing a research study for a specific building. There are so many different types of buildings and configurations and doing a study like this may not be broadly applicable. This study looks like a validation of a general approach for a specific building.
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.		**#3** - Unclear what is being done in Task 2.
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.	**#6**	**#6** - TBD
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.	**#3**	**#7** - Lack of whole building experimental data still appears to be an issue. Phase 1 identified that there is a deficiency in available data but this was not resolved based on my read of the WS.
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.		**#3** - Apparently; experienced WS team.
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.	**#7**	**#7** - I think there could be bidding issue due to the ambiguity around the availability of experimental data. It is not clear if the work should include additional experimentation/data collection or if there is the expectation that additional data will be available. **#6** - Project milestones are "TBD", which I assume means to be negotiated with contractor. WS still uses obsolete "Final Report" Section. How do we fix this?

Decision Options	**Initial Decision**	**Approval Conditions**
ACCEPT		**#7** - I feel this is potentially good research but that the work statement requires additional clarity. It may not be possible to address all of the issues with whole building simulation all at once. I would recommend focusing on one part such as the thermal coupling/stratification as figuring out how to deal with variable wind conditions seems like a daunting undertaking. **#3** - This WS needs some work. Task descriptions need more definition, and intermediate milestones should be developed for each task. **#6** - This strikes me as a better bet than 1744, and I haven't seen a need for both to be funded. 1748 needs some admin details resolved. **#5** - The authors of this WS need to communicate with the WS 1744 authors and come up with a common project. Also need to get a TC involved that covers computer modeling (4.7). Much more reasonable cost compared to 1744. **#14** - The WS lacks some inputs (looks like it was rushed). 5 of 12 members of the TC did not vole.
COND. ACCEPT		
RETURN		
REJECT		

RETURN Vote - Topic is probably acceptable for ASHRAE research, but RTAR is not quite ready.
REJECT Vote - Topic is not acceptable for the ASHRAE Research Program

WORK STATEMENT COVER SHEET

Date: July 29, 2014

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

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

Title:
Assess and implement natural and hybrid ventilation models in whole-building energy simulations

WS# 1748
(To be assigned by MORTS - Same as RTAR #)

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

Chapters 16, 17, 18, and 19 ASHRAE Handbook of Fundamentals

Responsible TC/TG: TC 4.7

Date of Vote: August 6,2014

For		7
Against	*	0
Abstaining	*	0
Absent or not returning Ballot	*	5
Total Voting Members		12

This W/S has been coordinated with TC/TG/SSPC (give vote and date):
TC 4.10 -8-0-0 (13) - June 27, 2016

Has RTAR been submitted? YES - Cond. Accept 10/16/14

Strategic Plan Theme/Goals: Goals #1, #3, and #7

Work Statement Authors: **
Anthony Fontanini, Joe Huang, Malcolm Cook

Proposal Evaluation Subcommittee:
Chair: 10
Members:
Kamal Haddad, TC 4.7
Malcolm Cook, TC 4.7
TBD, TC 4.10

Project Monitoring Subcommittee:
(If different from Proposal Evaluation Subcommittee)
TBD

Recommended Bidders (name, address, e-mail, tel. number): **
John Zhai, Univ. of Colorado Boulder CO, john.zhai@colorado.edu, 303-492-4699
Paul Linden, Univ. of Cambridge UK, p.f.linden@damtp.cam.ac.uk, 01223337890
Jelena Srebric, Univ. of Maryland College Park MD, jsrebric@umd.edu, 301-405-7276
Simon Rees, Univ. of Leeds UK, S.J.Rees@leeds.ac.uk 441162577974
** Malcolm Cook, Loughborough University UK, malcolm.cook@lboro.ac.uk 01509222816

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

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

	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# 1748

Title:

Assess and Implement Natural and Hybrid Ventilation Models in Whole-Building Energy Simulations - Phase 2

Sponsoring TC/TG/MTG/SSPC:

TC 4.7 (Energy Calculations)

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

TC 4.10 (Indoor Environmental Modeling)

Executive Summary:

Natural and hybrid ventilation have a large potential for minimizing the need for mechanical cooling. However, engineers need reliable and easy-to-use modeling tools before they can incorporate such systems into their HVAC designs. The current modeling strategies for natural and hybrid ventilation systems have been shown to have some major limitations, which limits their applicability to widespread usage. This Phase 2 project builds on the understanding Phase 1 developed about the capabilities of the tools available to model natural and hybrid ventilation systems. Phase 2 addresses the question "Why do the models have deficiencies?" and prompts action toward improving the accuracy of the most advanced modeling techniques through the use of benchmarks. The improved approach is compared to data sets from full-scale buildings and analytical models. This project helps provide a consensus method for modeling natural and hybrid ventilation systems, and provides tools and strategies to better understand the impact of these passive strategies on whole-building energy usage.

Applicability to the ASHRAE Research Strategic Plan:

There is a need to assess the accuracy of numerical methods for predicting hybrid and natural ventilation, as well as their usability in whole-building energy simulations. Measured data on air flow/thermal processes such as ventilation rate, stratification, and thermal coupling, have been gathered at various universities and research institutions, but vary greatly in their quantity or resolution. Preliminary enquiries have indicated numerous studies of bulk ventilation rates, but few of temperature stratification within a naturally ventilated space, and even fewer of the thermal coupling between the building fabric and the ventilation air. Furthermore, while modeled air flow rates can be validated on a stand-alone basis, validation of stratification and thermal coupling requires that the modeling methods be implemented within at least a room, and preferably a whole-building, simulation model.

The need for this research is corroborated by ASHRAE Research Strategic Plan covering a number of the goals and needed research topics, e.g. GOAL #3 - “better building simulation ventilation models” and GOAL #7 - “development of tools, procedures and methods suitable for designing low energy buildings”. This project aims to establish techniques to improve the energy efficiency of HVAC systems by utilizing passive strategies - GOAL #1. The end product of this research should provide a better understanding of the airflow network models and how they can be coupled with building energy

Application of Results:

This project will provide ASHRAE members with a more reliable consensus method for modeling the effects of natural and hybrid ventilation on HVAC designs. General guidance for setting up the simulations and analyzing the results can be added to the ASHRAE Handbook (Chapters 16, 17, 18, and 19 of the Fundamentals). The insight gained from the analysis will help to ensure that the performance of natural ventilation and hybrid systems achieve their design values while saving energy by utilizing passive strategies.

State-of-the-Art (Background):

Natural ventilation of buildings has received more attention in recent decades because it is a cooling strategy that requires no energy use. However, since it is generally difficult for natural ventilation to maintain indoor comfort under all conditions, it is frequently supplemented with mechanical cooling in what has now become known as "hybrid ventilation" or "mixed mode" operations.

Modeling natural ventilation involves complex air flows that are highly dependent on varying external and internal conditions, as well as the building geometry and local site conditions. The modeling needs for hybrid ventilation also include an additional control component. The three primary modeling issues for natural ventilation are: (1) determining the amount of air flow from the outside and from zone to zone, (2) stratification within natural ventilated spaces, and (3) thermal coupling between the spaces and building fabric with the ventilation air.

To address the first issue, various energy simulation programs such as EnergyPlus, ESPr, and TRNSYS have linked multi-zone air flow network solutions to their thermal calculations, typically in a "ping-pong" fashion between the two (Hensen 1991, Huang 1999). There have also been efforts to link thermal programs to CFD models (Beausoleil-Morrison 2000, Zhai et al. 2002).

To address the latter two issues, there have been efforts to extend stratified-room models originally developed for displacement ventilation to simulate stratified interior spaces resulting from buoyancy-driven ventilation (Linden 1999, Rees and Haves 1999, Carrilho da Graca & Linden 2002).

ASHRAE has supported the phase 1 part of this project (TRP-1456) that assessed the ability of thermal-ventilation models

Advancement to the State-of-the-Art:

The simulation techniques and models that have been developed for natural and hybrid ventilation make various assumptions and simplifications about air flows, boundary conditions, and thermal distributions within the building. To illustrate, Appendix A lists those assumptions related to just the air flow aspects of network models. The impact of such assumptions on the accuracy of the models is unclear and there is no consensus on which method best suits the needs of the engineer or what improvements are needed for the models to be used in standard engineering applications. Therefore, there is a need to evaluate currently available methods for modeling natural and hybrid ventilation, assess their usability and accuracy for practical design applications, and identify areas where future work is needed.

This project builds off the efforts of the phase 1 project which identified and evaluated the potential tools for modeling natural and hybrid ventilation systems in a whole-building energy simulation. This phase-2 project has two major goals. 1) Identify what is causing the deficiencies in the current models. 2) Improve the accuracy of the models using benchmark solutions and full scale validation. The objectives of the project are designed to provide a roadmap towards better analyzing the impact of natural and hybrid ventilation systems all over the world.

Justification and Value to ASHRAE:

Natural and hybrid ventilation have significant potential for minimizing the need for mechanical cooling. However, engineers need reliable, easy-to-use and computationally efficient modeling tools before they can incorporate such systems into their HVAC designs.

Objectives:

The overall aims of this project is to provide ASHRAE members with an objective assessment of the applicability of current modeling methods for natural and hybrid ventilation systems, give guidance on how to use of these tools in the design or evaluation of naturally-ventilated buildings, and identify conditions under which the models are deficient and need improvement. Because of the complexity of the topic and the amount of work, this has been conceived as a two-phase project, with phase 1 having been carried out in 2005-2007.

The phase 1 project compiled an inventory of existing measured data sets, and obtained data sets for several small-scale test cases, and one full-scale building that used natural ventilation. Corresponding simulation models were developed, first using a stand-alone air flow network program, and then with a thermal simulation program coupled to an air flow network. Simulations were then conducted to evaluate the ability of the programs to model different ventilation regimes, e.g. wind-driven and stack-driven ventilation. The results compared well for the test cases, but were inconclusive for the full-scale building due to how the building was controlled.

Phase 1 has also summarized areas of limitations in modeling naturally ventilated buildings. These include atrium ventilation, large horizontal openings, thermal mass, and vent control. More information on these limitations is given in Appendix B. Although there have been some improvements made to energy and airflow network models since Phase 1, these areas have been prioritized by the task group of this work statement. The contractors should prioritize the accuracy of their experimental and simulation campaign in these areas in the following order: thermal mass response of the building, vent control, atrium ventilation, and large horizontal openings.

As part of the evaluation criteria of the phase 2 project, contractors are required to propose a building that is suitable for supporting the validation of this project. The task group for the work statement have identified that there are buildings available for such analysis. One potential candidate building is the Harm A. Weber Academic Center building on the Judson University campus in Elgin, Illinois, USA. This building is a mixed mode building for which some validation data is available. The multistory building is approximately 88,000 ft2 and LEED Gold certified. For information about this building and the monitoring data available, please refer to the following references: Kaiser and Ogoli (2005), Short and Lomas (2007), Lomas et al. (2007), K.J. Lomas (2007), and Kaiser et al. (2009). The phase 2 project is not dependent on using the Judson University building and contractors are welcome to propose other buildings as potential candidates. The goal of this project is to use a building similar to the characteristics of the Judson University building. The building brought as a candidate by the contractor is called the ¡°candidate building¡± throughout the rest of the work statement.

The objectives for Phase Two are to (1) update the database of tools available for natural and hybrid ventilation modeling since the end of the phase 1 project and summarize the strengths and weaknesses of these tools (2) determine a set of benchmark or analytical problems to assess the accuracy of the most promising model, and if necessary, to make adjustments to increase accuracy (3) obtain a data set for a full-scale building, ideally under controlled conditions based on the recommendations from phase 1, (4) model the full-scale building using the updated model and compare with the field data, and (5) provide guidance to the users of simulation tools on modeling hybrid and natural ventilation

Scope/Technical Approach:

It is intended that the project be concerned with models of natural and hybrid ventilation that can practically be applied in annual simulations, i.e. are not computationally intensive. Value is placed on models that are implemented in software commonly used by practitioners, or could conceivably be implemented in such tools without substantial modification. It is not intended that CFD modeling methods be in the scope of this work.

Task 1: Update the database of tools available for natural and hybrid ventilation modeling

Phase 1 of the project identified four tools that have some ability to simulate natural and hybrid ventilation systems for whole building energy simulations (COMIS, CONTAM, ESP-r, and EnergyPlus). A review of these four simulation tools is to be performed, covering changes or improvements of these models or methods, as well as a review of new tools that have been developed since the start of the phase 1 project. After the literature review of the current tools, an assessment of an itemized list of strengths and weaknesses is to be provided. Documentation summarizing the findings of these reviews, in a form to be agreed with the PMSC, is to be prepared which will record the following.

- The characteristics and intended application of each model.
- The capabilities and limitations of each model.
- The input/output data and parameter requirements.
- The extent of prior verification and validation.
- Current model implementations (if any).
- Recommendations for the most promising model available

Task 2: Evaluate and enhance validation data from the candidate building or other sources

Phase 1 identified 3 buildings for the project. Each of these buildings had limitations with the data that has been taken during the project. Based on these limitations, recommendations for future experimental campaigns have been stated in Appendix B from Phase 1. Based on the recommendations from Phase 1 and the existing data recorded in the candidate building, the contractor is required to comment on the available data along with enhancements needed to perform this project. Documentation summarizing the findings of these reviews, in a form to be agreed with the PMSC, is to be prepared which will record the following.

- Building information
    - Basic information about the candidate building, including location, size, orientation, and ventilation strategy
    - Climate data for the building location, suitable for use in energy simulations
- Previous and current experiments in the candidate building
    - Geometry. A description of the geometric configuration of the experiments including dimensions and any details of air inlets/outlets etc.
    - Flow regime. For example, whether the flow is buoyancy, wind or mechanically driven and whether stratified or mixed.
    - Key variables measured
    - Number of data sets recorded and experimental conditions
    - Estimated measurement error limits

Scope/Technical Approach (Continued 2):

- Enhanced measurement program for the phase 2 project
  - Enhanced measurements and measurement methods needed to satisfy this phase 2 project in the candidate building
  - Time duration that the enhanced measurement scheme is needed to fully evaluate the other objectives in the work statement
  - Measurement uncertainty

As well as full-scale field measurements, there are many examples of analytical models covering the thermal and air flow phenomena relevant to this project. Contractors should consider these when deciding which validation datasets to put forward.

The format of the documentation is to be agreed with the PMSC.

Task 3: Collect data set from candidate building

It is likely that additional data will be required from the candidate building to complete the validation data set necessary. This may include: energy consumption, temperatures, relative humidity and ventilation rates. Given the detailed nature of validation work, the contractor may wish to concentrate some of this measurement work in one or two key zones of the candidate building.

Authors, laboratories and building owners associated with the data should be approached to obtain such information and wherever possible provide copies and explanatory documents. Consent for use of the data in this, phase 2 of the work, and further distribution of the data by ASHRAE should be obtained where possible. The experimental data sets are to be collated and organized by the contractor and will become part of the final project data/documentation delivered to ASHRAE.

Task 4: Model the full-scale building using the updated model and compare with the field data

Based on the candidate building the contractor will create a model or models with capabilities to simulate the energy usage and thermal response of the candidate building during the experimental campaigns of the building. In creating the model, the contractor should state the following in a format of documentation to be agreed with the PMSC.

- The tools used for the simulation process. Examples of these tools are but are not limited to (EnergyPlus, ESP-r, CONTAM, COMIS, etc…)
- Implementation details on how the tools are used to run the simulations for reproducibility
- Uncertainty in the modeling approach, coupling approach, unknown factors of the experimental dataset
- Limitations to the current approaches towards modeling specific aspects of the candidate building
- Temporal convergence of the numerical solution

The contractor will be required to validate the selected models/methods, by way of seeking to reproduce experimental measurements using applicable input and model parameter data. It is unlikely that this validation work will use the entire candidate building. Rather, it will be more practical to select single spaces or recognized analytical benchmark test cases identified in Task 2. Notwithstanding the validation work, the focus of this task is to identify the shortcomings of the models, deficiencies in the experimental data and usability of the models/tools. Where a number of models can be tested using a given data set, inter-model comparisons should be undertaken. The results of the simulation are to be better than the phase 1 project of 35% for the predicted airflow quantities of interest. The contractor is expected to report a comparison of the experimental data and the numerical simulations for the following quantities of interest. These quantities are based on the

Scope/Technical Approach (Continued 3):

Zone Conditions

· Zone temperatures.

· Temperature gradient in the zone(s) with high ceilings (excluding atria) where buoyancy dominates the airflow dynamics.

· Surface temperature of thermal mass in each zone.

· Energy use for lighting & plug loads

· Occupancy

Ventilation Conditions

· Vent status, including open/closed and % open if the building vents modulate.

· Air flow through every building vent, both inlets and outlets.

· Fan speed, exhaust rate, and energy consumption, if hybrid ventilation is in use.

· Inlet air temperature is also desirable

Error Quantification

· Quantify errors of numerical simulation for each of the quantities above.

In reporting this task emphasis is to be placed on providing practical guidance to ASHRAE members on the capabilities of each model or method, its range of applicability and usability in a design context. Consideration should be given to whether the required parameter data is likely to be available to designers, the sensitivity of the models to particular parameters and the uncertainty that can be expected in any model predictions.

Task 5: Recommend Further Work

Following competition of tasks 1, 2, 3, and 4 the contractor will establish and report:

The accuracy that can be expected from energy models used to predict the performance of natural and hybrid ventilation systems

Indications of situations for which the models work well

Details of any additional modeling capability not currently available.

Which modeling assumptions need to be improved

Deliverables/Where Results Will Be Published:

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. 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 presentation at a Society meeting. The Technical Paper(s) shall conform to the instructions posted in "Manuscript Central" for a technical paper. The technical paper title shall contain the research project number (xx-xxxx-xxxxx-RP) at the end of the title in parentheses, e.g., (99-9999-99999-RP).

d. Data

Data is defined in General Condition VI, "DATA"

All papers or articles prepared in connection with an ASHRAE research project, which are being submitted for inclusion in any ASHRAE publication, shall be submitted through the Manager of Research and Technical Services first and not to the publication's editor or Program Committee.

Deliverables/Where Results Will Be Published (Continued):

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 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. 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 is planned to have an 18 month duration (spread over 3 society meetings) with an approximate budget of $180,000. It is expected that 2 person-months of Principle Investigator and 18 person-months of researcher effort are required to complete the project.

Proposal Evaluation Criteria:

No.	Proposal Review Criterion	Weighting Factor
1.	Contractor understanding of the Work Statement for conducting research	15%
2.	Probability of contractor's ontractor's research plan meeting the objectives of the Work Statement	30%
3.	Quality of methodology proposed for conducting research	25%
4.	Contractors past capability to evaluate experimental data, evaluate software and attempt model validation	15%
5.	Likelihood of the contractor effectively communicating with other institutions and obtaining the required data	10%
6.	Performance of contractor on prior ASHRAE projects or related projects - no penalty for new contractors	5%

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
1.	TBD	
2.	TBD	
3.	TBD	

Authors:

Anthony D. Fontanini, Joe Huang, Malcolm Cook

References:

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Other Information for Bidders (Optional):

APPENDIX A: Comments on Natural Ventilation RTAR

From: George Walton
To: Joe Huang
Date : June 26 2005
Re: problems with current airflow network methods:
Wind assumptions:
1a. wind pressure: ρ (V2/2) assumes the wind velocity is reduced to zero at the building surface. This assumption is okay for infiltration through small openings, but is it okay for large openings that may have significant velocities ?
1b. one-sided ventilation, e.g., rooms with two openings on one wall. An oversimplified wind pressure model will assign the same pressure to both openings resulting in no ventilation flow. A similar situation exists for a single wide opening.
1c. stochastic wind conditions: wind speed and direction are variable, sometimes rapidly variable. Using average values over a long time step can be problematic, especially when flow directions can change.
1d. flow control or enhancement devices are not adequately dealt with:
a. passive flow limiters
b. chimney enhancement
2. momentum effects are ignored. At higher velocities the position of openings relative to the flow direction can become important, i.e., air jets.
3. node pressure losses: As velocity increases, there is a pressure loss through the zone, although I suspect this is usually not significant.
Air flow network assumptions:
all pressure losses occur in the links between nodes, i.e.,
links: openings ducts
nodes: rooms junctions
the above assumption implies that all nodes can be characterized by a single pressure value (but with hydrostatic variation) air velocities within the node are negligible (no ΔP driving flow within the node)
(3) In the links: $\Delta P = f(m)$ non-linear function
(4) In the nodes: $\Sigma m?? = 0$ steady-state with some additions for transient and non-transient contaminants. 3. and 4. has lead to our standard solution method to solve simultaneous non- linear equations

APPENDIX B: Summary and Recommended Future Work from ASHRAE TRP-1456

1. Summary of Phase-One Study Results
Network modeling:
• Single-sided wind driven NV cannot be modeled.
• Network model is generally able to predict airflow within 35%.
• The tools are very dependent on ambiguous coefficients, especially the discharge coefficient.
• Four models tested (COMIS, CONTAM, ESP-r, and EnergyPlus) are essentially identical with respect to underlying principles of network modeling.
o Minor differences in naming conventions, etc. exist between the tools
o COMIS's has an additional capacity to model density gradients, but testing did not show any major benefit from this capability.
• Desirable network model improvements include:
o A relationship for bi-directional flow in horizontal openings
o A relationship for wind-driven single-sided ventilation
Coupled thermal-airflow modeling
• EnergyPlus's Airflow Network is an acceptable tool for modeling simple NV buildings.
• EnergyPlus deficiencies:
o Venting control and exhaust fan control is very limited. Conversely, many NV building rely on very complex control schemes.
o The parameters for defining operable window area do not function. This capability would be beneficial to prevent users from having to manually resize windows.
o Relationships are needed for:
Roof-level horizontal openings
Atrium-type openings

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.

Shaping Tomorrow's
Built Environment Today

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TO: Yu Joe Huang, Chair 4.7, yjhuang@whiteboxtechnologies.com
Jeff Haberl, Research Subcommittee Chair, TC 4.7, jhaberl@tamu.edu
Xudong Yang, Research Liaison Section 4.0, xyang@tsinghua.edu.cn

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

DATE: October 16, 2014

SUBJECT: Research Topic Acceptance Request (1748-RTAR), "Assess and Implement Natural and Hybrid Ventilation Models in Whole-building Energy Simulations (Phase 2)"

During their recent fall meeting, the Research Administration Committee (RAC) reviewed the subject Research Topic Acceptance Request (RTAR) and voted to conditionally accept it for further development into a work statement (WS) provided that the RAC approval condition(s) below are addressed to the satisfaction of your Research Liaison in a revision to the RTAR first.

1. Technical approach needs to be well established.
2. Cite and use the most recent ASHRAE Research Strategic Plan.

Please coordinate changes to the RTAR with the help of your Research Liaison, Xudong Yang xyang@tsinghua.edu.cn or RL4@ashrae.net, in response to the approval condition(s) only so that it can be submitted to the Manager of Research and Technical Services and posted by ASHRAE as part of the Society's Research Implementation Plan.

Once the revised RTAR is posted, please develop a work statement also with the help of your Research Liaison prior to submitting it to the Manager of Research and Technical Services for consideration by RAC. The work statement 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 **August 15, 2016** 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, 2015** for consideration at RAC's 2014 annual meeting. The submission deadline after that for work statements is **August 15, 2015** for consideration at RAC's 2015 fall meeting.

Project ID	**1748**
Project Title	**Assess and Implement Natural and Hybrid Ventilation Models in Whole-building Energy Simulations (Phase 2)**
Sponsoring TC	TC 4.7, Energy Calculations
Cost / Duration	$120,000 / 12M
Submission History	**1st Submission**
Classification: Research or Technology Transfer	Basic/Applied Research - Advanced Concepts

RAC 2014 Fall Meeting Review		
Check List Criteria	**VOTED NO**	**Comments & Suggestions**
Is there a well-established need? The RTAR should include some level of literature review that documents the importance/magnitude of a problem. If not, then the RTAR should be returned for revision.		**6** - CF 1744, fromTC 4.10. This one looks sound, but highly dependent on finding the right building with the right data set. One wonders if Continental experience (e.g., CIBSE), since Europe seems to be doing more with natural ventilation. **8** - But the write up is a little stale. Looks like a lot of information was recycled from the phase 1 portion of the project, references are old and there has been a lot of work in this area recently. **5** - Can we perform this modeling if the CFD is not done from 1744 first (if it needs to be developed)
Is this appropriate for ASHRAE funding? If not, then the RTAR should be rejected. Examples of projects that are not appropriate for ASHRAE funding would include: 1) research that is more appropriately performed by industry, 2) topics outside the scope of ASHRAE activities.		
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.	4	**4** - Not clear where and who conducted Phase I research. Who funded the Phase I research? The third aspect of research - thermal coupling - is not well explained. It should be noted like displacement ventilation that thermal stratification is desirable in naturally ventilated spaces. However, estimation of the occupied zone temperature is essential as stated in the RTAR.
Is the budget reasonable for the project scope? If not, then RTAR could be returned for revision or conditionally accepted with a note that the budget should be revised for the WS.	4	**4** - Technical approach needs to be well established - Technical approach needs to be well established. **6** - Note promise (?) of CEC co-funding
Have the proper administrative procedures been followed? This includes recording of the TC vote, coordination with other TCs, proper citing of the Research Strategic Plan, etc. If not, then the RTAR could be returned for revision or possibly conditionally accepted based on adequately resolving these issues.		**6** - all boxes are checked. **1** - Was the citing of the Research Strategic Plan adequate? **5** - RAL should coordinate between 1744 and this effort.

Decision Options	**Initial Decision**	**Approval Conditions**
ACCEPT		**4** - Technical approach needs to be well established. Co-funding for this research is desirable. **1** - Contingent on proper citing of Research Strategic Plan.
COND. ACCEPT RPS: 5-0-0 RAC 11-0-0		
RETURN		
REJECT		

ACCEPT Vote - Topic is ready for development into a work statement (WS).
COND. ACCEPT 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)
RETURN Vote - Topic is probably acceptable for ASHRAE research, but RTAR is not quite ready.
REJECT Vote - Topic is not acceptable for the ASHRAE Research Program

Research Topic Acceptance Request Cover Sheet

Date: July 29, 2014

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

- A. Title ✔
- B. Applicability to ASHRAE Research Strategic Plan ✔
- C. Application of the Results ✔
- D. State-of-the-Art (background) ✔
- E. Advancement to State-of-the-Art ✔
- F. Justification and Value to ASHRAE ✔
- G. Objective ✔
- H. Estimated Duration ✔
- I. References ✔

Title:
Assess and implement natural and hybrid ventilation models in whole-building energy simulations (Phase 2)

RTAR# 1748
(To be assigned by MORTS)

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

Chapters 16, 17, 18, and 19 ASHRAE Handbook of Fundamentals

Responsible TC/TG: TC 4.7

Date of Vote: August 6,2014

For		10
Against	*	0
Abstaining	*	0
Absent or not returning Ballot	*	2
Total Voting Members		12

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

TC 4.10 (12:0:0, July 28, 2014)

RTAR Lead Author: Joe Huang and Anthony Fontanini

Expected Work Statement Lead Author: Joe Huang and Anthony Fontanini

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

The California Energy Commission has supported the development of models for low-energy cooling systems, and has indicated their intention to co-fund the multi-phase activity proposed in this RTAR.

Research Classification:
- ✔ Basic/Applied Research
- ✔ Advanced Concepts
- ☐ Technology Transfer

	Yes	No
Has an electronic copy been furnished to the MORTS?	✔	
Has the Research Liaison reviewed the RTAR?	✔	

* Reasons for negative vote(s) and abstentions

1 member did not vote, Chair non voting

DRAFT RTAR Template

Title: Assess and implement natural and hybrid ventilation models in whole-building energy simulations

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)

Natural ventilation through operable windows is probably the oldest known method to cool a building. Hybrid ventilation refers to combining natural ventilation with mechanical cooling for better environmental control while lowering energy use. These two ventilation strategies clearly have a large potential for minimizing the need for mechanical cooling. However, engineers need reliable and easy-to-use modeling tools before they can incorporate such systems into their HVAC designs.

Background

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

Natural ventilation of buildings has received more attention in recent decades because it is a cooling strategy that requires no energy use. However, since it is generally difficult for natural ventilation to maintain indoor comfort under all conditions, it is frequently supplemented with mechanical cooling in what has now become known as "hybrid ventilation" or "mixed mode" operations.

Modeling natural ventilation involves complex air flows that are highly dependent on varying external and internal conditions, as well as the building geometry and local site conditions. The modeling needs for hybrid ventilation also include an additional control component. The three primary modeling issues for natural ventilation are: (1) determining the amount of air flow from the outside and from zone to zone, (2) stratification within natural ventilated spaces, and (3) thermal coupling between the spaces and building fabric with the ventilation air.

To address the first issue, various energy simulation programs such as EnergyPlus, ESPr, and TRNSYS have linked multi-zone air flow network solutions to their thermal calculations, typically in a "ping-pong" fashion between the two (Hensen 1991, Huang 1999). There have also been efforts to link thermal programs to CFD models (Beausoleil-Morrison 2000, Zhai et al. 2002).

To address the latter two issues, there have been efforts to extend stratified-room models originally developed for displacement ventilation to simulate stratified interior spaces resulting from buoyancy-driven ventilation (Linden 1999, Rees and Haves 1999, Carrilho da Graca & Linden 2002).

Research Need

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

There is a need to assess the accuracy of these models or modeling methods, as well as their usability in whole-building energy simulations. Measured data on the three air flow/thermal processes (ventilation rate, stratification, and thermal coupling) have been gathered at various universities and research institutions, but vary greatly in their quantity or resolution. Preliminary enquiries have indicated numerous studies of bulk ventilation rates, but few of temperature stratification within a naturally ventilated space, and even fewer of the thermal coupling between the spaces with the ventilation air. Furthermore, while modeled air flow rates can be validated on a stand-alone basis, validation of stratification and thermal coupling requires that the modeling methods be implemented within at least a room, and preferably a whole-building, simulation model.

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)

The overall objective of this project is to provide ASHRAE members with an objective assessment of the applicability of current modeling methods for natural and hybrid ventilation systems, give guidance on how to use of these tools in the design or evaluation of naturally-ventilated buildings, and identify conditions under which the models are deficient and need improvement. Because of the complexity of the topic and the amount of work, this has been conceived as a two-phase project, with Phase One having been carried out in 2005-2007.

The Phase One project compiled an inventory of existing measured data sets, and obtained data sets for several small-scale test cases, and one full-scale building that used natural ventilation. Corresponding simulation models were developed, first using a stand-alone air flow network program, and then with a thermal simulation program coupled to an air flow network. Simulations were then done to evaluate the programs' ability to model different ventilation regimes, e.g., wind-driven and stack-driven ventilation etc. The results compared well for the test cases, but were inconclusive for the full-scale building due to how the building was controlled.

The objectives for Phase Two are to (1) obtained a better data set for a full-scale building, ideally under controlled conditions and including the use of operable windows as one NV mode, (2) model the building with the most promising coupled thermal/air flow program identified in Phase One, and validate the models against that measured data. Phase Two will also provide guidance of the use of simulations for modeling hybrid and natural ventilation.

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) ( )

(1) Data Collection (one or the other)
- Identify and obtain a pre-existing usable dataset
- Gather data on a pre-existing instrumented building

(2) Create a Building Model
- Model should have capability for coupling network airflow models and building thermal models

(3) Run the simulations according to the gathered dataset

(4) Assessment of the data (Direct Comparison and Analysis)
- Thermal Performance
- Airflow Dynamics
- Identify limiting functionality of the simulation methodology

(5) Give guidance
- Describe an appropriate method for setting up the simulations
- Proper analysis techniques for the output data

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 simulation techniques and models that have been developed for natural and hybrid ventilation make various assumptions and simplifications about air flows, boundary conditions, and thermal distributions within the building. To illustrate, Appendix A lists those assumptions related to just the air flow aspects of network models. The impact of such assumptions on the accuracy of the models is unclear, nor is there any consensus on which method best suits the needs of the engineer, or what improvements are needed for the models to be used in standard engineering applications. Therefore, there is a need to evaluate currently available methods for modeling natural and hybrid ventilation, assess their usability and accuracy for practical design applications, and identify areas where future work is needed.

The need for this research is corroborated by ASHRAE Research Strategic Plan coving a number of the goals and needed research topics. The end product of this research should provide a better understanding of the airflow network models and how they can be coupled with building energy simulation software. A consensus method will be established for designing and evaluating these systems. General guidance for setting up the simulations and analyzing the results can be added to the ASHRAE Handbook chapters 16, 17, 18, and 19 of the Fundamentals. The insight gained from the analysis helps ensure that the performance of natural ventilation and hybrid systems achieve their design values while saving energy by utilizing passive strategies.

Anticipated Funding Level and Duration

Funding Amount Range: $ 120,000

Duration in Months: 12 months

References

List the key references cited in this RTAR

Beausoleil-Morrison, I. 'The Adaptive Coupling of Heat and Air Flow Modelling Within Dynamic Whole-Building Simulation', Ph.D thesis, University of Strathclyde, UK, 2000.

Carrilho da Graca, G. & Linden, P.F. Simplified modeling of cross-ventilation airflow. ASHRAE Trans. 109, 1-14.

Daish, N.C., Britter, R.E., Linden, P.F., Jagger, S.F. & Carissimo, B SMEDIS:Scientific model evaluation applied to dense gas dispersion. Proc. CCPS/AICHE Conf. pp 345-371, 1999.

Hensen, J. On the Thermal Interaction of Building Structure and Heating and Ventilating System. Ph.D. thesis, TU Eindhoven, Netherlands, 1991.

Huang, Y.J., Winkelmann, F.W., Buhl, F., Pedersen, C., Fisher, D., Liesen, R., Taylor, R., Strand, R., Crawley, D and Lawrie, L. Linking the COMIS Multi-Zone Airflow Model with Energyplus, Proc. Building Simulation '99, Kyoto, September 1999

Linden, P.F. The fluid mechanics of natural ventilation. Ann. Rev. Fluid Mech., 31, 201 – 238, 1999

Rees, S.J., and Haves, P., A Nodal Model for Displacement Ventilation and Chilled Ceiling systems in Office Spaces, Proc. Building Simulation '99, Kyoto, September 1999

Zhai, Z., Chen, Q., Haves, P. and Klems, J.H., On Approaches to Couple Energy Simulation and Computational Fluid Dynamics Programs, Building and Environment, 37, pp 857-864, 2002.

Appendix A: Comments on Natural Ventilation RTAR

from: George Walton
To: Joe Huang
Date : June 26 2005
Re: problems with current airflow network methods:

***Wind assumptions*:**

1a. *wind pressure*: ρ ($V^2/2$) assumes the wind velocity is reduced to zero at the building surface. This assumption is okay for infiltration through small openings, but is it okay for large openings that may have significant velocities ?

1b. *one-sided ventilation*, e.g., rooms with two openings on one wall. An oversimplified wind pressure model will assign the same pressure to both openings resulting in no ventilation flow. A similar situation exists for a single wide opening.

1c. *stochastic wind conditions*: wind speed and direction are variable, sometimes rapidly variable. Using average values over a long time step can be problematic, especially when flow directions can change.

1d. *flow control or enhancement devices are not adequately dealt with:*

passive flow limiters

b. chimney enhancement

2. *momentum effects are ignored*. At higher velocities the position of openings relative to the flow direction can become important, i.e., air jets.

3. *node pressure losses*: As velocity increases, there is a pressure loss through the zone, although I suspect this is usually not significant.

Air flow network assumptions:

all pressure losses occur in the links between nodes, i.e.,

links: openings ducts
nodes: rooms junctions

the above assumption implies that all nodes can be characterized by a single pressure value (but with hydrostatic variation) air velocities within the node are negligible (no ΔP driving flow within the node)

(3) In the links: $\Delta P = f(\dot{m})$ non-linear function

(4) In the nodes: $\sum \dot{m} = 0$ steady-state with some additions for transient and non-transient contaminants

3. and 4. has lead to our standard solution method to solve simultaneous non-linear equations