

Discussions for the Technical Papers from the 2015 ASHRAE Winter Conference in Chicago, Illinois

This is a compilation of the written questions and comments submitted to authors by attendees at the 2015 ASHRAE Winter Conference in Chicago, Illinois. All authors were given the opportunity to respond.

The questions/comments and authors' responses are published with the papers in the hardbound volume of *ASHRAE Transactions*, Vol. 121, Part 1.

CH-15-001

CFD Analysis of Turbulence Development in Flat-Oval Ducts for Various Entrances

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Reza Ghias, Director of Advanced Simulation Center, Southland Industry, Rockville, MD: What is γt in the study? Also, The transition from laminar to turbulent was not considered.

Devendra Kulkarni: The present CFD model was validated against experimental results, as it does not handle the near-wall region well. Numerical values of friction factor over the prescribed range of Reynolds number were compared with experimental data and were in good agreement.

H.E. Khalifa, Distinguished Professor, Syracuse University, Syracuse, NY: 1) Shouldn't your inlet BC be a velocity or flow BC instead of having pressure BC at both inlet and outlet? 2) When you assumed a surface roughness, how did

you account for that in your CFD model? 3) When you stated that the entrance length is $> 20 D_h$, was this based on velocity and TKE? Which quantity took the longest to reach full development? 4) Did you compare some of your CFD results with experiments?

Devendra Kulkarni: 1) Yes, flow was initiated by targeting mass flow rate at the inlet. 2) Surface roughness was accounted for by specifying a roughness value at each solid boundary. 3) The recommendation of entrance length $> 20 D_h$ was based on TKE. Velocity profiles took even longer to reach full development. 4) Yes. The CFD model was validated against published experimental results and was then used for comparative study of eight cases.

CH-15-002

Effect of CFD Grid Resolution and Turbulent Quantities on the Jet Flow Prediction

Waleed A. Abdelmaksoud, PhD

Reza Ghias, Director of Advanced Simulation Center, Southland Industry, Rockville, MD: Did you consider the velocity profile at the inlet boundary condition?

Use of Random Forest Algorithm to Evaluate Model-Based EUI Benchmarks from CBECS Database

Apoorva Kaskhedikar Student Member ASHRAE **T. Agami Reddy, PhD, PE** Fellow ASHRAE **George Runger, PhD**

Kashif Nardaz, PhD, Senior Heat Transfer Engineer, Johnson Controls, Norman, OK: How do you compare the proposed technique to some of the existing methods? What are the major advantages?

T. Agami Reddy: The paper contains a section that describes the random forest (RF) algorithm and gives suitable references. RF is a natural extension of classification and regression trees (CART), which is a conceptually simple, yet powerful, nonlinear method that works by successively splitting the input feature space into smaller and smaller subregions. CART can be visualized as a tree (called a decision tree) that originates from a root node and splits into successively smaller branches terminating in leaf nodes. Each branch represents a subregion of the input variable ranges, and the leaves contain data that “traverse” from the root node down the branches based on optimum splitting values of selected attributes. The tree grows until a certain stopping criterion has been met or the data in a node are completely homogenous. The tree is able to process both numerical and

categorical variables and perform classification and prediction tasks rapidly. A major advantage of the decision tree over other modeling techniques is that it produces a visual model that may represent interpretable rules or logic statements.

A single decision tree, however, is susceptible to noise (overfitting) and is considered a high-variance model. A natural extension of CART is random forests (RFs), which is simply a collection, or ensemble, of many trees using bootstrapped samples generated from the original training data. It has the desirable ability of promoting the most important input variables toward predicting the output variable and is effective for complex response functions because it capitalizes on very flexible fitting procedures that can respond to highly local features of the data. Such flexibility is desirable because it can substantially reduce the bias in the fitted values compared to the fitted values from parametric regression. The flexibility in RF comes in part from individual trees that can find nonlinear relationships and interactions. The RF algorithm has been found to work extremely well in many diverse applications

CH-15-018 (RP-1504)

A Database of Static Clothing Thermal Insulation and Vapor Permeability Values of Non-Western Ensembles for Use in ASHRAE Standard 55, ISO 7730, and ISO 9920

George Havenith, PhD **Kalev Kuklane, PhD** **Jintu Fan, PhD** **Simon Hodder, PhD**

Yacine Ouzzahra, PhD **Karin Lundgren** **Yuhan Au, PhD** **Dennis Loveday, PhD**
Member ASHRAE

Hashem Akbari, Professor, Concordia University, Montreal, QC, Canada: Typically, the clothing data are presented as the physical properties of clothing and do not include film coefficient (convection coefficient). Is there a reason that you included film coefficient in your data for clothing?

George Havenith: Indeed, in our slide presentation I presented the data only as “total insulation,” which is composed of the intrinsic clothing insulation and the surface air layer insulation (corrected for the increase in outer surface area due to clothing). The surface air layer insulation consists of the inverse of the sum of the convective and radiative heat transfer coefficients of the air layer, as you indicate.

In the actual publication, however, you will also find the separate data for intrinsic clothing insulation and for the outer

surface air layer and for the correction factor for surface area “ f_{cl} .” This matches the conventional presentation.

For reasons of presentation time limits, I could not show this breakdown in components and chose to show the overall effects on the total insulation only in the presentation.

Ahmad Al-Sahhaf, PhD, Ministry of Electricity and Water, Nuzha, Kuwait: 1) Have you considered using infrared thermography in the study? 2) The presentation shows emphasis of the effect of convection heat transfer without the effect of radiation. The color of the clothing has a strong effect on thermal comfort. Is this aspect taken into account in the study?

George Havenith: 1) We tend to use infrared (IR) thermography in our research, but have not done so in this study. IR pictures would have provided us with the outer surface

temperatures of the clothing, which has no direct role in the application of the standard. The average outer surface temperature can also be deduced in a different way, by knowing the intrinsic insulation and the outer air layer insulation—the ratio of the two links to the ratio of the temperature gradient between skin, the clothing, and environment.

2) The main application of ANSI/ASHRAE Standard 55-2013 is in indoor environments. As we have shown before for indoor and for solar radiation (Bröde et al, 2010. Heat gain

from thermal radiation through protective clothing with different insulation, reflectivity and vapour permeability, *International Journal of Occupational Safety and Ergonomics* 16(2):231–44.), clothing color is irrelevant in the absence of direct solar radiation but does affect heat transfer in the visible solar spectrum. Thus, given the focus of this project on indoor conditions and the limits to the funding, the effect of solar radiation was not studied.

CH-15-019

Stairwell Pressurization and the Movement of Smoke during a High-Rise Fire

W. Z. Black, PhD, PE

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Jae-Hun Jo, Professor, Inha University, Incheon, South Korea: This is meaningful research about stairwell pressurization. 1) Tall buildings have various and complicated elevator shaft planning and thus having complicated pressure distribution. That must affect the pressure control of the stairwell. What is your opinion on these cases? 2) Could you explain more about the software COSMO?

W.Z. Black: The movement of smoke during a fire is influenced by a complex interaction of numerous factors including the fire location, fire intensity, atmospheric conditions, and building geometry. Seemly small changes in these factors can have a significant influence on the paths that smoke can take during a fire. The movement of smoke is primarily driven by buoyancy forces that move it upward and pressure forces, even if they are extremely small, that force smoke into low-pressure regions. The task of crafting a fire safety plan is particularly complicated in tall buildings in which the stack effect often dominates smoke movement. Therefore, temperature and pressure distributions throughout the entire building must be accurately determined if a smoke movement model is to be incorporated into a life safety plan.

If stairwells are pressurized in an attempt to maintain them as smoke-free areas during the fire, the movement of smoke in other remote areas of the building is affected. Air leakage from the pressurized stairwells causes a slight pressure increase on all floors, which forces smoke to enter the elevator shafts and to leave through openings in the exterior skin of the building. The opposite effect is also important to recognize. Any change in the smoke movement in the elevator shafts and on the floors will influence the movement of smoke in the stairwells and affect the pressurization rate needed to keep smoke from entering the stairs. The COSMO program determines the conditions on the floors, in the elevator shafts, and in the stairwells, and can therefore calculate the influence

that changes in one shaft can have on other areas in the building.

These complex interactions between various areas in the building are difficult to predict without the use of a computer model that allows the determination of pressure and temperature distributions within the building. Once a model based on fundamental principles of heat transfer, fluid mechanics, and thermodynamics is verified by experimental measurements, then the routes that smoke will take during a fire can be reliably determined. However, limitations of analytical models for smoke movement must be recognized. Due to the fact that simplifying assumptions are always necessary to reduce a complicated physical system to a solvable set of mathematical equations, the results predicted by models will always be limited by those assumptions. Therefore, it is more important to rely on the trends suggested by the model rather than the quantitative output information provided by the program.

The focus of the paper was on stairwell pressurization. A detailed description of the mathematics was not included because it has been outlined in previous papers that are listed in the reference section. COSMO output has been compared with a NIST model and the results from the two programs compare within 10% for a simplified building geometry. Output has also been compared with results from CFD models, and again, there were reasonable differences. Future work is underway to compare COSMO output with experimental results from scale-model tests.

The COSMO program requires input of 50 variables, and the output provides detailed information including the pressure, temperature, and smoke flow rates throughout the building. Repeated executions of the program permit examination of how changes in building geometry, fire heat release rate, and other relevant parameters influence the movement of smoke. The execution time of the program for a tall building is less than 10 s when run on a laptop computer.

Energy Savings and Thermal Comfort Optimization in Office Cubicle Environment

Waleed A. Abdelmaksoud, PhD

Essam E. Khalil, PhD

Fellow ASHRAE

George Havenith, Professor of Environmental Physiology, Loughborough University, Loughborough, UK: 1) I noticed that the value for metabolic rate that you used (44 W/m^2) is lower than the lowest value in the standard (58 W/m^2). 2) You use an inlet humidity of 83%. Does that give a risk of

condensation in the building when moisture is added by people? 3) PMV/PPD was not designed to measure local comfort (front versus back). Do you feel this is a reliable way to look at local comfort?

Analysis and Monitoring of Energy Consumption and Indoor Climate in a School Before and After Deep Energy Renovation

Jørgen Rose, PhD Kirsten Engelund Thomsen

Niels C. Bergsøe Ove Christen Mørck, PhD

Barry Bridges, Mechanical Engineer, CxA, Sebasta Blomberg & Associates, St. Paul, MN: In addition to energy you also measured CO_2 . The change in ACH rate showed as a change in CO_2 . Were there any anecdotal benefits that suggest additional value for making those changes?

Kirsten Engelund Thomsen: The question, as we understand it, is about whether the observed change in air change rates and, consequently, CO_2 concentrations implies benefits that suggest additional value.

It is a well-known fact that poor indoor air quality in schools has a major impact on students' performance. In this

study, the students' performance was not measured. However, from the questionnaires that were distributed among the students before and after the renovation, it is noted that during winter conditions, in room 58, the students' assessments of the indoor air quality shifted toward "fresh" from before to after the renovation. In room 40, no significant changes are noted. During summer conditions the students' assessments of the indoor air quality show only small changes from before the renovation to after the renovation.

Extending the Reach of Campus Renovation Through Combined Financing

Mark "Dusty" Wheeler, PE, BEMP

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Lawrence Markel, Principal, SRA, Knoxville, TN: Combining renovation money and operating money is difficult. You are to be commended for accomplishing this. Please give some details on how you resolved legal, scope, and liability issues and worked with government contracting officers. Were there specific checklists, agreements, contracts, etc. designed for this? It would help if you documented this and had a future session just focusing in depth on this aspect.

Eric James: The project was launched under the area-wide utility energy service contract (UESC) vehicle. This provided contractual ground work. The resulting study included a Basis of Design narrative (energy conservation intent), a 35% design, a design-build proposal (which utilized the 35%

design as the basis for pricing), a summary of our touch points with the SATOCC contractor, and the UET's terms and conditions.

We would agree that a future session could be focused on the contractual aspect of this project since many ways to streamline the process and lessons learned have been identified.

John Shonder, Program Manager, Oak Ridge National Laboratory, Oak Ridge, TN: What percent cost reduction resulted from combining EPC with renovation?

Eric James: At this point we are estimating the cost reduction to be around 10%.

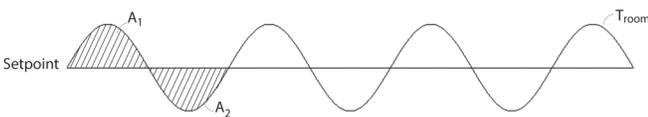
Control Accuracy and Its Impact on Building Energy Efficiency

John Q. Zhou, PhD

Associate Member ASHRAE

David Beriault, Research Development Engineer, Tekmar Control Systems, Ltd., Vernon, BC, Canada: If you are assuming a linearly proportional load, i.e., $\text{load} \propto (T_{\text{indoor}} - T_{\text{outdoor}}) \rightarrow$ (Neglecting radiative heat transfer)

Then: the relative magnitude of temperature swings about the setpoint will self-cancel by integration.



$$A_1 = A_2 \equiv \therefore \Delta T_{\text{avg}} = (T_{\text{room}} - T_{\text{outdoor}})$$

John Q. Zhou: The oscillation around the setpoint will only be evenly around the setpoint when the building load is exactly 50%. The oscillation will shift to lower temperatures in cooling when the building load is less than 50% and will shift to higher temperatures when the building load is more than 50%. This is due to system dynamic gain that is different when the HVAC equipment is on and when the equipment is off.

Continuous Building Energy Data Monitoring Using Recursive Least Squares Filter and CUSUM Change Detection: Application to Energy Balance Load Data

Hiroko Masuda David E. Claridge, PhD, PE

Member ASHRAE Fellow/Life Member ASHRAE

Fadi Alsaleem, Senior Lead Engineer, Emerson Climate Technologies, Sidney, OH: How does the model work if the system is already in fault condition? How does one separate the alarm due to fault fix from the real fault?

Hiroko Masuda: The parameters of the energy balance load model used in the present work have physical significance, and one can find some existing faults as unrealistic parameter estimates. However, it is difficult to determine realistic ranges of the parameters because (1) the accurate physical values of the parameters are difficult to obtain, especially for existing buildings, and (2) the parameter estimates have errors resulted from the estimation and model simplification. Therefore, the ability to find a fault already existing in the system by this

approach is limited. Additional techniques such as peer-comparison of parameter estimates among multiple buildings and range checks of each energy meter can be used together to improve the ability to find existing faults.

The presented method intends to find anomalies in whole-building energy data without a priori knowledge about building systems and operation. Causal analyses need to be conducted using more information to separate various types of false alarms from the real fault. Narrowing down the meters to investigate using the presented method can greatly reduce the time and cost for the causal analyses in large-scale applications such as metering for campus buildings.

Speed Optimization of Parallel-Connected Variable-Speed Pumps

Yunchuang Dai

Student Member ASHRAE

Ziyan Jiang, PhD

Peizhang Chen

Yi Jiang, PhD

Jeffrey Spitler, Regents Professor, Oklahoma State University, Stillwater, OK: Thanks for an interesting presentation. Could you please clarify how your approach would be applied to a situation where the system resistance is continually changing?

Yunchuang Dai: In real applications, continually changing system resistance would lead to the variation of measured pressure difference, which is an input variable of this algorithm. When this input variable changes, the algorithm would give a new result, including the pumps' speed and on/off status.