New York Technical and Poster Session Papers Questions and Comments

This is a compilation of the written questions and comments submitted to authors by attendees at the 2014 ASHRAE Winter Conference in New York, New York. 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. 120, Part 1.

NY-14-001

Hydraulic Modeling as a Tool to Enable Design Resiliency for Data Center Chilled-Water Systems

Michelle R. Contri, PE
ASHRAE Member

Thomas A. Davidson, PE
Member ASHRAE

Long Fu, Senior Advanced Engineer, Ingersoll Rand, Shanghai, China: Building hydraulic system geometry is complicated. Can you explain how to manage the geometry by inputs during the modeling? Can you explain the modeling numerical robustness and complete calculation speed?

Michelle R. Contri: The program that we utilized for this modeling has a graphical user interface that makes inputs quite easy. It consists of pipelines and nodes that are laid out on a grid, and components such as pumps, heat exchangers, and chillers that are typically inserted at nodes with one input and one output pipeline. Figure 3 of this paper provides an example of how the data is presented. The program also allows for individual pipelines, nodes, and equipment to be custom labeled to allow for quick lookup of grid location.

In terms of numerical robustness, we have been very satisfied with the accuracy of the results, based on commissioning tests on many projects. The program utilizes a simultaneous path adjustment method to reach a solution. This method starts with the Hardy Cross method (see reference in NY-14-002) and switches to a linear method to complete the calculation. More detailed information could likely be obtained from the company that developed the program (see the first listed reference in this paper).

Calculation time for a grid with 300 heat exchangers and associated control valves (five parallel pumps, five parallel heat exchanges, and five parallel chillers) is less than one minute with an off-the-shelf personal computer.

NY-14-002

Hydraulic Modeling as a Tool to Quantify Pump Energy Savings in Data Center Chilled-Water Systems

Thomas A. Davidson, PE
Member ASHRAE

Michelle R. Contri, PE
Member ASHRAE

Srdjan Jankovic, Senior Energy Engineer, Optimum Energy, LLC, Seattle, WA: In quantifying simulated plant total energy consumption, was condenser water side considered and modeled? Without including condenser water side in the model, holistic plant energy consumption cannot be effectively modelled.

Thomas A. Davidson: The purpose of this paper was not to simulate total plant (or facility) energy consumption but rather to show how hydraulic modeling can be used as a tool to analyze pump energy consumption in a piping system, especially one that has redundant equipment (pumps, heat exchangers, chillers). Most commercial energy modeling programs do not have the algorithms embedded in them to analyze various mixes of redundant equipment and to assess the change in pump head and pump energy that results from various combinations of this equipment. Hydraulic modeling, however, can be used for this purpose, and the results from this analysis (i.e., specific optimized operating conditions for pump power minimization) can then be input into a broader analysis program to assess facility energy use. As you point out, the hydraulic solution to the chilled-water system with the least pumping power may not correspond to the optimal facility operating condition with full consideration of the energy consumption of chillers, condenser water pumps, and cooling towers on the heat rejection side of this heat transfer loop and rear door heat exchanger performance on the other side.

NY-14-003 (RP-1495)

Effect of Lubricant on the Distribution of Water between Vapor and Liquid Phases of Refrigerants

John Senediak
Member ASHRAE

Mirza M. Shah, Consultant, Redding, CT: Why was R-22 chosen for research as it is essentially obsolete now?

John Senediak: R-22 was chosen by ASHRAE based on its comparative physical and chemical properties. The properties of R-22 served as a good contrast to those of R-134a for a comparative study. Additionally, it allowed us to investigate mineral oil as well as synthetic lubricants. Finally, the conclusions drawn from this investigation are not tied to a specific refrigerant but rather can be applied to any refrigerant with similar chemical and structural characteristics. Though its future use is diminishing, it is still being used in a significant amount of existing systems.

NY-14-004

Investigation of Two-Phase Flow Pressure Drop in Refrigeration Systems

S. Zahid Hussain Rizvi, PhD, CEng
Member ASHRAE

Mirza M. Shah, Consultant, Redding, CT: Pressure drop is nonlinear with vapor quality. Did you use the arithmetic mean quality or the local quality for calculating pressure drop?

S. Zahid Hussain Rizvi: The two-phase flow pressure drop is analyzed with respect to the dynamic viscosity and specific volume throughout the heat exchangers. These elements are integrated with respect to vapor quality from the inlet to the outlet of the heat exchangers and are outlined in the paper as Equations 8 and 9 (Cicchitti equation) and Equations 10 and 11 (McAdams equations). The final calculations are carried out with Equations 13 (Gosney) and 15 (Blasius), which take into account the tube diameter, flow length, frictional coefficient, etc. The third author correlation analyzed was Lockhart and Martinelli, which is based on comparing the pressure drop term with that which would be found for one of the phases flowing alone. It envisages the flow regime as separated, with each phase occupying a fraction of the tube cross-sectional area.

NY-14-005

Two-Phase VOF Model for the Refrigerant Flow through Adiabatic Capillary Tube

Yogesh Prajapati

Mohd Kaleem Khan, PhD
Associate Member ASHRAE

Manabendra Pathak, PhD

Mirza M. Shah, Consultant, Redding, CT: Your model does not take into account heat transfer. Typically, capillary tube is soldered to suction line. What impact will heat transfer have?

Mohd Kaleem Khan: The proposed model has been developed solely for the adiabatic capillary tube, which is thermally insulated. The question is related to another category of capillary tube known as nonadiabatic (or diabatic) capillary tube, where the capillary tube is partly soldered to cool the suction line. In such a case, the heat transfer from the capillary tube to the suction line has the following effects:

- The vapor in the suction line will become superheated, which in turn protects the compressor valves from getting damaged, and the lubricating film remains intact.

- The subcooled liquid refrigerant near the inlet of the capillary tube further cools, causing the flashing point to move downstream and the refrigerant to enter the evaporator with lower quality (dryness fraction), resulting in an increased refrigerating effect.

NY-14-011

A Computational Framework for Low-Energy Community Analysis and Optimization

Michael Case, PhD
Associate Member ASHRAE

Richard J. Liesen, PhD
Member ASHRAE

Alexander Zhivov, PhD
Member ASHRAE

Matthew Swanson, PhD

Benjamin Barnes
Associate Member ASHRAE

James Stinson, PhD

Lawrence Markel, Principal, SRA, Knoxville, TN: You have discussed facility requirements and needs, but have you incorporated mission-oriented resource use yet? For example, in consolidating data center servers and utilizing the cloud, you can compare energy use from multiple data centers (original) with energy used by fewer data centers (after consolidation).

In your case, if an air base is expanding with more aircraft operations, can you look at the trade-off of constructing more electricity-intensive simulators versus the mission-oriented aviation fuel you save by replacing some training flights with simulator use? Do you have plans to combine mission-oriented options and resource use with facility-related resource planning?

Michael Case: The computational framework represents mission-oriented resource usage as energy density for lighting, information technology, major equipment, and other plug loads. For instance, if data centers were consolidated, the energy density would decrease in some buildings and increase in others. The framework does not currently consider trade-offs with mission-oriented fuels, although this is an excellent suggestion. Non-mission transportation fuel is scheduled to be included in 2015.

NY-14-012

Community-Scale Energy Supply and Distribution Optimization Using Mixed-Integer Linear Programming

Matthew Swanson, PhD

Benjamin Barnes
Associate Member ASHRAE

Richard J. Liesen, PhD
Member ASHRAE

Michael Case, PhD
Associate Member ASHRAE

Alexander Zhivov, PhD
Member ASHRAE

David Baylon, President, Ecotope, Inc, Seattle, WA: Did you use discount rates to present value energy cost, capital cost? If so, what rates?

PV calculation seems appropriate although it assumes no changes in future fuel costs or value. Were capital discount rates deemed so we avoided that question?

Matthew Swanson: The capital recovery factor method was used to annualize the cost of equipment. This formula takes the interest rate and equipment lifetime into account when calculating the annual cost of ownership. This method allows us to specify a specific interest rate for each potential piece of equipment depending on the type of financing (government or commercial).

We are currently using existing fuel prices without any type of forecasting (escalation, etc.). However, we often perform a fuel-based sensitivity analysis by varying the energy prices and looking for any changes to the equipment that is selected. This type of analysis can be done using fuel prices, weather, and even the number of buildings included in the study to ensure the solution is robust.

Dominick Chirico, Director of Engineering, Columbia University Facilities, New York, NY: 1) How many integer variables are there? 2) Which algorithms for integer solution were used?

Matthew Swanson: 1) We are using one integer variable for every piece of equipment or option that is considered by the optimization. We currently have models for about 20 different technologies and each technology has about 5 sizes to capture economies of scale (~100 total integer variables). 2) The mixed integer linear program problem is written so that it can be interpreted by open source Generic Mathematical Programming Language (GMPL) or proprietary A Mathematical Programming Language (AMPL). This formulation allows the problem to be solved by a number of different mixed integer linear programming solvers. We are currently using open source Generic Linear Programming solver (GLPSol) and proprietary CPLEX. This parallel formulation provides benefits of computation speed and ease of distribution depending on the current needs. It also aligns with the overall Net Zero Planner goals to provide a computational framework to solve the greater community planning problem while allowing the user to swap analogous software components throughout the tool.

NY-14-017

Energy Optimization for Fort Carson Combat Aviation Brigade Complex

A. Zhivov, PhD *Member ASHRAE* | **D. Herron** *Member ASHRAE* | **R.J. Liesen, PhD** *Member ASHRAE* | **K. Budde** | **S. Richter, PhD** | **S. Ochse**

S. Schad | **L. Fiedler** *Associate Member ASHRAE* | **P. Steitz** | **V. Guthrie** | **S. Turner** | **N. Shepherd**

Robert Besant, Professor, University of Saskatchewan, Saskatoon, SK, Canada: How did you select the most accurate air infiltration rate for the buildings you used in your study?

R.J. Liesen: Since the Army Corps has an air sealing requirement of 0.25 cfm/ft^2 at 75 Pa and a leakage test at the end of construction, this requirement is selected as the air infiltration rate once the value has been converted to EnergyPlus inputs. The requirement and the air leakage testing procedure can be found in engineering construction bulletins at the following websites:

- http://www.wbdg.org/ccb/ARMYCOE/COEECB /ecb_2012_16.pdf
- http://www.wbdg.org/ccb/ARMYCOE/COEECB /ARCHIVES/ecb_2009_29.pdf

NY-14-018

Multi-Objective Optimal Design of a Near Net Zero Energy Solar House

Scott Bucking *Student Member ASHRAE* | **Andreas Athienitis, PE, PhD** *Member ASHRAE* | **Radu Zmeureanu, PE, PhD** *Member ASHRAE*

Matthew Swanson, Researcher, USACE, ERDC-CERL, Champaign, IL: How much time would be required to “optimize” additional buildings (besides the passive house work done for PhD)?

Scott Bucking: Ultimately, the answer to this depends on the size of the building, the number of design variables being optimized, and the computational infrastructure being used. For this research, around 350 unique energy simulations were required per optimization study. Using multicore processors, ten energy simulations could be conducted at the same time, meaning that 35 time-equivalent simulations were required per optimization study. Since each simulation took approximately two minutes, a little over one hour is required. Note that this estimate does not include time for modelling the building or setting up life-cycle economic studies—this can take weeks.

For a large building with hundreds of zones, each simulation can take 20–35 minutes, requiring significantly more time to conduct an optimization study. Much of my previous and on-going research is finding opportunities to reduce time requirements of optimization studies.

Robert Besant, Professor, University of Saskatchewan, Saskatoon, SK, Canada: How did you select the most accurate air infiltration rate for the buildings you used in your study?

Scott Bucking: Infiltration was included as an optimization variable. A building could be more airtight but required a higher cost premium. The added cost of airtightness was based on the experience of net zero energy home builders in Canada. The selected infiltration rate was a trade-off of energy savings and added cost.

NY-14-032 (RP-1360)

How Do Pressure Drop, Efficiency, Weight Gain, and Loaded Dust Composition Change Throughout Filter Lifetime?

Kathleen Owen
Member ASHRAE

Roger Pope

James Hanley
Member ASHRAE

John McKernan, Environmental Engineer, U.S. Environmental Protection Agency, Cincinnati, OH: Exceptional presentation on filtration and MERV ratings.

Kathleen Owen: Thank you.

Paolo Tronville, Associate Professor, Politecnico Di Torino, Torino, Italy: Could you please specify the final pressure drop of the air filters examined in the six-city study? Could you also indicate how long they had been in service before being dismounted? Any indication on the total volume of air that each of them had filtered during its service life?

Congratulations for the very interesting and useful data collected during the research project.

Kathleen Owen: Thank you. Most of the data you would like to see is in the full RP-1360 report. Additionally, some is in the *Transactions* paper.

NY-14-038

Reducing Energy Consumption in Grocery Stores: Evaluation of Energy Efficiency Measures

Jaya Mukhopadhyay
Student Member ASHRAE

Jeff Haberl, PhD, PE
Fellow ASHRAE

Larry Degelman, Professor, Texas A&M University, College Station, TX: Have you quantified the food case spillover contribution to the reducing of cooling loads of the grocery store?

Jaya Mukhopadhyay: The spillover of cold air from the open-faced display cases was not quantified separately. However, the whole-building simulation program used for this analysis does take into account the effect of spillover cold air from open-faced refrigerated display cases, impacting the energy consumption for space cooling and heating. A change in the space cooling and heating energy consumption on the installation of glass doors and covers over all refrigerated display cases in the simulation model of the grocery store used for this analysis was observed and documented.

Alamelu Brooks, ICF International, Columbia, MD:

1) What is the EUI after implementing all measures? Which measure has higher impact on the EUI?
2) What was measured to create the weather file?

3) How do the EUI of the calibrated and uncalibrated models compare?

Jaya Mukhopadhyay:

1) The analysis was conducted using the metric of annual whole-building energy consumption accounted for at the site and source. The annual energy consumption of the grocery store building was reduced by 58% when accounted for at site and 56% when accounted for at source after implementing all the measures selected by this analysis. The corresponding annual energy consumption of the base case and the energy-efficient case is provided in this study.

The individual EEM that had the highest impact on reducing energy consumption in the grocery store was the installation of glass doors on all open-faced display cases in the grocery store considered for this analysis. The EEM provided site energy savings of 16.9% and source energy savings of 9.2%.

2) The weather file created for calibrating the simulation model was compiled by measuring dry-bulb and wet-bulb temperatures, solar radiation, ground temperature, and wind speed. Most of the data for this weather file was obtained from a national climatic data website. The data for the solar radiation used in the weather file was obtained from a local solar test bench.

3) A detailed calibration procedure was conducted in another section of this study. Details of the calibration procedure are documented in the dissertation titled “Reducing Energy Consumption in Grocery Stores in a Hot and Humid Climate” by Mukhopadhyay (2013) and in an ASHRAE conference paper titled “Reducing Energy Consumption in Grocery Stores: Calibration of a Grocery Store Simulation Model” by Mukhopadhyay et al. (2013).

Abdullah Abdulkarem, University of Maryland, College Park, MD: Have you performed a cost analysis and assessed payback scenarios?

Jaya Mukhopadhyay: A cost analysis and payback calculations for this section of the analysis are outside the scope of the study.

NY-14-042

Quantification of Ventilation Effectiveness for Air Quality Control in Animal Buildings

Sheryll B. Jerez, PhD **Xinlei Wang, PhD** *Member ASHRAE* **Yuanhui Zhang, PhD, PE** *Fellow ASHRAE*

Chuck Gaston, Assistant Professor, Pennsylvania State University, York, York, PA: In the Powerpoint presentation, the following “effectiveness” equation was used: $EFF = (CONC_{Exit} - CONC_{Supply})/(\langle Avg\ CONC\ Meas\rangle - CONC_{Supply})$. It seems appropriate.

I would think that a very low ventilation rate would produce a strong gradient with the highest concentration near the exhaust and therefore an effectiveness >1. Conversely, a very high ventilation rate could produce an exhaust concentration close to the supply concentration, while sampling areas outside the main flow stream could make the average concentration significantly higher than the exhaust concentration. Thus, the “effectiveness” value seems reversed.

A better measure of “effectiveness” might be related to the rate at which ventilation can reduce no-ventilation concentrations or the difference between concentrations after a certain period of no ventilation and the concentrations a certain time after ventilation is restarted.

Sheryll B. Jerez: We thank Mr. Gaston for his comment. We agree that measuring the difference in pollutant concentrations when the ventilation is off and on may be a better measure of the effectiveness of the system. However, its application in the field will necessitate intervention with the operation of the building’s ventilation system, which is not desirable for the animals housed inside.

NY-14-043 (RP-1475)

Heat and Moisture Production of Modern Swine

Tami M. Brown-Brandl *Associate Member ASHRAE* **Morgan D. Hayes** **Hongwei Xin** **John A. Nienaber**
Hong Li **Roger A. Eigenberg** **John P. Stinn** **Timothy Shepherd**

Masaya Ishihara, Azbil Corporation, Tokyo, Japan: Why did you choose a 21-hour period for continuous heat production measurement? Would 24 hours be more natural?

Tami M. Brown-Brandl: A 24-hour cycle would be the best. However, changing animals and allowing the calorimeter to equilibrate took approximately 3 hours (45–60 minutes to change animals and the remaining time to equilibrate the chamber).

So, we felt it was extremely important to start at the same time each day to ensure the pigs were moved at the same time in the diurnal cycle.