2018 ASHRAE Annual Conference
June 23rd – June 27th, 2018

www.ashrae.org/houston

The Technical Program along with Committee meetings, Registration, Bookstore, and Speakers Lounge will be held at the Hilton Americas hotel and the George R. Brown Convention Center.

Updated June 20, 2018
Sunday, June 24

Sunday, June 24, 8:00 a.m. - 9:00 a.m.

Conference Paper Session 1 (Intermediate)

Identifying Energy and Cost Saving Measures for Combined Heat and Power Applications
Track: District Energy and Cogeneration Plants
Room: 370CF

Chair: Hyojin Kim, Ph.D, The Catholic University of America, Washington, D.C.

Various approaches are taken to determine best fit technologies for CHP investments. This session outlines methods of assessment and case histories to illustrate the application of the cost and energy reducing measures.

Salvador Acha, Ph.D., Member, Niccolo Le Brun, Christos N. Markides, Member, Nilay Shah, Romain Lambert, Ph.D., Imperial College London, London, United Kingdom

Designing and scheduling combined heat and power (CHP) units for commercial or industrial applications is not a straightforward task. Careful consideration of multiple parameters is required covering technical, financial and environmental metrics. But even a thorough analysis cannot guarantee an attractive return on the investment. One of the reasons is the presence of uncertainties during the project which can significantly affect the financials. This study proposes to assess the impact of uncertainties on CHP projects and offers guidelines on how to select and operate CHP unit under such variable conditions.

2. Fuel Cells as CHP Systems in Commercial Buildings: a Case Study for the Food Retail Sector (HO-18-C002)
Salvador Acha, Ph.D., Romain Lambert, Niccolo Le Brun, Christos N. Markides, Member, Nilay Shah, Imperial College London, London, United Kingdom

Designing and scheduling combined heat and power (CHP) units for commercial or industrial applications is not a straightforward task. Careful consideration of multiple parameters is required covering technical, financial and environmental metrics. But even a thorough analysis cannot guarantee an attractive return on the investment. One of the reasons is the presence of uncertainties during the project which can significantly affect the financials. This study proposes to assess the impact of uncertainties on CHP projects and offers guidelines on how to select and operate CHP unit under such variable conditions.

Sunday, June 24, 8:00 a.m. - 9:00 a.m.

Seminar 1 (Intermediate)

Division 25 Challenges! When Integrated Automation Isn’t!
Track: HVAC&R Control Freaks
Room: 370ABDE

Sponsors: 1.4 - Control Theory and Application and 7.1 - Integrated Building Design
Chair: Ron Bernstein, RBCG Consulting, Encinitas, CA

- Understand the basics of integrated automation for building design
- Understand the scope of the CSI master format and how the Division 25 specification is defined
- Identify the benefits of well-designed integrated building automation systems and the integration requirements for electrical, mechanical and other equipment into a whole-building design
Understand industry direction for achieving better BMS/BAS designs that have reduced silos, achieve greater efficiency and provide improved value for the owner through open interoperable system architecture and design.

Integrated building automation systems require broad understanding of the various subsystems and components that make up the building including HVAC, Lighting, Elevators, Power, Fire, Life Safety and many more. The CSI Master Format provides guidance for how to design and specify project requirements. The CSI Division 25 Integrated Automation section lays out the key areas for integration, but provides no details, examples or guidance. This session discusses key industry efforts to harmonize CSI and ASHRAE specification development examples and provides the audience concepts and direction for achieving better system design, specification and integration of open, interoperable building control systems.

1. Division 25 Challenges! When Integrated Automation Isn’t! (1)
Ron Bernstein, Member, RBCG Consulting, Encinitas, CA
Developing a control standards for large end user organizations requires multi-discipline knowledge. Challenges included gaining trust and buy-in from the various stakeholders. This session discusses the successful process achieved by several large end users and how these efforts are driving the industry towards better integrated automation for building controls.

2. Division 25 Challenges! When Integrated Automation Isn’t! (2)
David Wilts, Member, Arup Engineering, Chicago, IL
Leveraging integrated building controls and data to transform the operations model and user experience. Developing a control topology for different market segments requires multi-discipline knowledge. Challenges included gaining trust and buy-in from the various stakeholders and the client’s IT group. This session discusses the successful process achieved by several large end users and how these efforts are driving the industry towards better integrated automation for building controls.

3. Division 25 Challenges! When Integrated Automation Isn’t! (3)
Chariti Young, Member, Automated Logic, Kennesaw, GA
What is an integrated design and how to achieve it? This presentation presents the basics of the CSI Division 25 master format, how it relates to HVAC and other sub-systems and the opportunities for the industry to create better integrated automation and control networking standards. A brief overview of ASHRAE Guideline 13: Specifying Building Automation Systems will be presented.

Sunday, June 24, 8:00 a.m. – 9:00 a.m.
Seminar 2 (Intermediate)

Energy Analytics in Virtual Energy Audits
Track: HVAC&R Analytics
Room: 372AD

Sponsors: 7.6 - Building Energy Performance and 7.5 - Smart Building Systems

• Understand the concept of virtual energy audit and its common application
• Apply useful tips to perform various energy analytical solution in energy
• Understand the common energy saving strategies
• Explain how to process the large amount of data effectively

This session covers useful energy analytical practice in different "virtual energy audit" scenario and present lessons and learned from each case. It covers wild range of buildings, including residential homes, commercial buildings and a large federal mission critical facility. It presents some useful tips/tools for practitioners on energy audits.
1. Finding Residential Water Heaters in the Data
Dane Christensen, Member, NREL, Golden, CO

As low-time-resolution data, such as smart meter data, becomes more broadly available, it can inform adoption of efficiency technology, solar photovoltaics (PV), energy storage and controls. This presentation covers a use case - identifying electric resistance water heaters from smart meter data, as well as characterizing their potential for load-shifting to offset local utility challenges from high-penetration PV adoption. The presentation discusses opportunities and limitations of utility data and what is needed to enable the desired application. This example methodology can be adapted to other grid-integrated efficient building use cases.

2. A Virtual Energy Audit for Commercial Building Energy Savings
Arash Khalilnejad, Case Western Reserve University, Cleveland, OH

A virtual energy audit that conducts a robust analysis without setting foot in the building would bring the industry significant value. Our solution, Energy Diagnostics Investigator for Efficiency Savings (EDIFES), diagnoses building characteristics and operational inefficiencies and predicts potential energy savings. With recent developments of “big data” analytics techniques (e.g. time series decomposition, clustering and filtering), EDIFES ingests, processes and analyzes 15-minute interval electricity consumption and associated weather data. Validated results on dozens of commercial buildings demonstrate its value to diagnose and predict building energy performance. Lessons learned are covered.

3. A Virtual Energy Audit Based on Historical Trending
Eric Yang, Member, Energy Systems Group, Washington, D.C.

This work presents useful resources, road blocks and several interesting findings of various virtual energy analysis based on the historical trending. This will identify current available tools for practitioners. Lessons learned will be covered as well.

Sunday, June 24, 8:00 a.m. - 9:00 a.m.
Seminar 3 (Intermediate)

New Advances in Simulating Fenestration Systems
Track: HVAC&R Systems and Equipment
Room: 372BE
Sponsor: 4.7 - Energy Calculations

Chair: Jeff S. Haberl, Ph.D., Texas A&M University, College Station, TX

• Describe the approach used to extrapolate the characters of fenestration components when only general bulk properties are available
• Explain the genetic algorithm approach used in the RP-1588 solver to do a live demonstration showing how the software can be used
• Explain the general approach used in modeling the performance of complex fenestration systems
• Describe the effects of interior shades on room cooling loads

This seminar presents new advances in the modeling of fenestration systems developed through recent ASHRAE research projects RP-1588 and RP-1311. RP-1588 developed a solver to derive detailed window fenestration properties when only bulk properties such as the U-factor, SHGC, number of panes, are known. RP-1311 developed ASHWAT a detailed fenestration model capable of simulating complex fenestration systems including interior shading systems such as blinds located within the fenestration.

1. ASHRAE Research Project RP-1588: Development of the Solver
Neal Kruis, Member, Big Ladder Software, Denver, CO

This presentation discusses ASHRAE Project RP-1588 including the development of the solver used to search for the appropriate detailed, multilayer window model given only bulk properties such as U-value and SHGC.
2. RP-1311 ASHWAT Detailed Fenestration Model
Charles S. Barnaby, Life Member, Moultonborough, NH
This presentation discusses the Research Project RP-1311 ASHWAT detailed fenestration model capable of simulating complex fenestration systems including interior shading systems such as blinds located within the fenestration.

3. ASHRAE Research Project RP-1588: Application of the Solver
Joe Huang, Member, Whitebox Technologies, Berkeley, CA
This presentation discusses the new advances in the modeling of fenestration systems developed through ASHRAE research projects RP-1588 to develop a solver to derive detailed window fenestration properties when only bulk properties such as the U-factor, SHGC, and the number of panes. The presentation discusses how the new solver can be used to provide more accurate window thermal models.

Sunday, June 24, 8:00 a.m. - 9:00 a.m.
Seminar 4 (Basic)

Positive-Displacement Compressors: Back to Basics
Track: HVAC&R Systems and Equipment
Room: 372CF
Sponsor: 8.1 - Positive Displacement Compressors
Chair: Rick Heiden, Trane - Ingersoll Rand, LaCrosse, WI
• Differentiate between positive displacement compressors in terms of types and typical efficiencies
• Identify HVAC&R applications which are best suited to positive displacement compressors
• Describe how positive displacement compressors unload capacity and modulate volume ratio for a given application
• Identify industry standards for machine performance and certification programs

Positive displacement compressors are the workhorse of vapor compressor refrigeration systems used in both residential and commercial HVAC&R equipment. This seminar provides an overview of the different types of positive displacement compressors, functional differentiators along with test methods and certification programs.

1. Compressor Types
Craig Robert Bradshaw, Member, Oklahoma State University, Stillwater, OK
Positive displacement compressors used to meet specific application conditions vary widely in form and efficiency. This seminar provides an equipment overview with an emphasis on the compression elements along with typical operating range, efficiency and footprint.

2. Typical Applications, Capacity Unloading and Volume Ratio
David Halbrooks, Student Member, Purdue University, West Lafayette, IN
This seminar covers the typical applications and refrigeration cycles positive displacement compressors are applied to along with an overview of the mechanics by which each compressor type achieves capacity unloading and pressure ratio modulation. This includes economizer cycles, variable volume ratio and variable speed drives.

3. Test Methods and Rating Programs
Connor Hayes, Associate Member, La Crosse, WISA
Standard test methods and certified rating programs exist for positive displacement compressors. This seminar provides an overview of ASHRAE Standard 23.1 and 23.2 which covers methods of testing for rating positive displacement refrigerant compressors and condensing units and the AHRI 540 and 545 which cover performance rating of positive displacement refrigerant compressors. Typical test facilities used in industry are also discussed.
Trials and Tribulations of Dishroom HVAC Design, Comfort and IAQ (Part 1)

Track: Fundamentals and Applications
Room: 371DE
Sponsor: 5.10 - Kitchen Ventilation
Chair: Derek Schrock, Halton Company, Scottsville, KY

- State the typical dishroom temperature and humidity range observed the ASHRAE RP-1469 field study
- Determine the sensible and latent loads from various warewashers and the dishes that are cleaned by those systems
- Understand the real-world challenges encountered in actual restaurant operation
- Optимальly design a dishroom so that the design conditions are properly met

This seminar presents the current state of the environment in Dishrooms in restaurants. If they are designed on paper to meet a design criteria, why are those conditions not being met in real restaurants? What are the sensible and latent loads from the warewashers and the dishes that are being cleaned? The seminar also presents what the challengers are for chain operators in their restaurants? From an HVAC system design point what is currently working and what does not work?

1. Dishroom HVAC: More than Just Dishwasher Exhaust!
Vernon Smith, Member, Smith Energy Engineers, LLC, Niwot, CO

While ASHRAE has dramatically raised the bar with respect to commercial kitchen ventilation and HVAC design, little advancement has been made with respect to guidelines for dishrooms. This presentation outlines the design challenges for dishroom HVAC in context with data from the ASHRAE RP-1469 field study. Simply stated, the design of an effective HVAC system involves more than specifying an exhaust hood for the dishwasher. Furthermore, the exhaust airflows required for complete capture and containment often exceed manufacturers’ specifications. Improving thermal comfort in commercial dishrooms has become a priority for ASHRAE TC 5.10’s research and handbook efforts.

2. That’s A Lot of Heat: Sensible and Latent Loads
Richard T. Swierczyna, Associate Member, Food Service Technology Center, San Ramon, CA

Commercial kitchens and dishrooms contain the equipment and appliances that generate the most intensive concentrations of sensible heat, latent heat and moisture loads in the commercial sector. This seminar presents recent ASHRAE and industry heat load data from dishwashers (standard, low temp and heat recovery models) and unhooded appliances and recommend HVAC design criteria.
• Advocate for HVACR by actively promoting the HVACR Industry in their communities
• Advocate for HVACR by engaging in STEM activities in their communities
• Advocate for local Higher Ed programs to participate in the ASHRAE-APPA MOU
• Recognize that Status quo is not acceptable for the HVACR industry in recruiting tomorrow’s employees

Roughly 10,000 baby boomers will exit the workforce daily between now and the end of the next decade. Social Security Administration estimates 22% of U.S. workforce will retire over next eight years. HVACR will likely be hit harder with an estimated 115,000 new workers to be trained by 2022. Status quo is no longer an option. Solving the looming challenge of the graying of industry employees across the board, and hiring A-list talents to replace them. So who is Generation Z? And welcome to the HVACR industry of tomorrow. Universities provide a unique perspective.

1. Generation Z: Ready or Not, Our Industry’s Future Depends on Them and It's Sooner Than You Might Think
David Palty¹, Member, Jeffrey Benjamin², (1) AEMEP Group, Phoenix, AZ, (2), University of Houston, Houston, TX

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Sunday, June 24, 8:00 a.m. - 9:00 a.m.

Workshop 2 (Intermediate)

Writing Scientific Journal Research Papers
Track: Research Summit
Room: 371CF

Sponsor: Publication and Education Council

Chair: Reinhard Radermacher, Ph.D., University of Maryland, College Park, MD

• Become familiar with the required sections of a scientific research papers, the purpose of each, and how to write a compelling abstract
• Learn how to meet the publication requirements of a journal and avoid being flagged in plagiarism scan
• Gain tips on productively addressing reviewers' comments and avoid unnecessary rounds of reviews
• Understand the different levels of open access, the costs and benefits associated with it, and determine if it is right for their work

Understanding journal author requirements and knowing how to find the right journal match for your research is important to know for a smooth submission process. This workshop explains the required sections of scientific papers, how to write an abstract, the publication requirements of a journal and gain tips on productively addressing reviewers' comments for a smooth submission and review process. Learn if Open Access can help make your paper available to a broader audience, the ins and outs of costs and repositories use and most of all, if OA is right for you.

1. Tips for Manuscript Formatting, Finding the Right Journal and Negotiating the Review Process
Mary Baugher, University of Maryland, College Park, MD

Whether you are new to writing scientific papers or you are an old pro who would like to go through less revisions, being current on research journal author requirements and knowing how to find the right journal match for your research is important to know for a smooth submission process. This workshop covers the required sections of scientific papers and the purpose of each, how to write a compelling abstract, understand the publication requirements of a journal and gain tips on productively addressing reviewers' comments for a smooth submission and review process.
2. Publishing Open Access: Is It Right for You?
Stephanie Loeh, Taylor and Francis, Abingdon, United Kingdom

Open access refers to online research outputs (manuscripts, research and databases) that are free of all restrictions on access - such as needing a subscription - and are free of many restrictions on use. Learn about the multiple ways authors can provide open access to their work – such as a repository where it can be accessed for free. Become familiar with terms such as open access embargo, the difference between 'gold' and 'green' open access, and article processing fees. Discover how all of this relates to copyright and how open access may lead to higher citation rates and a wider audience for your work.

Sunday, June 24, 9:45 a.m. - 10:45 a.m.
Conference Paper Session 2 (Intermediate)

HVAC Applications in Transportation
Track: Fundamentals and Applications
Room: 371CF

Chair: Jaya Mukhopadhyay, Montana State University, Bozeman, MT

Designing for transportation systems, like cars, trains and planes have their own unique considerations. Engineers designing in this field will learn new and exciting ways to increase thermal comfort and decrease health concerns for passengers in these somewhat confined spaces.

1. Effect of Gasper Jets on Human Thermal Comfort in Aircraft Cabins (HO-18-C003)
Essam E. Khalil, Ph.D., P.E., Fellow ASHRAE, Alaa Abdullah, P.E., Eslam S. Abdelghany, Ph.D., P.E., Taher Abou Dief, Ph.D., P.E., Cairo, Egypt

Providing thermal comfort and good air quality are important factors to create a healthy and comfortable environment for passengers in airplane. The current ventilation system is the mixed one, 50% of air is fresh air from outside and the other 50% is recirculated air from the cabin. Personalized systems are introduced to improve those two factors. In this research the air distribution system is a combined system between the mixed ventilation system and the gaspers, the effect of the gaspers are investigated on the whole cabin of the economy section of BOEING 777 commercial aircraft. Temperature and velocity distributions are discussed; also PMV and PPD are used to predict the thermal sensation of passengers.

2. Viral Particle Dispersion and Viability in Commercial Aircraft Cabins (HO-18-C004)
John Lynch, Fellow ASHRAE, James S. Bennett, Byron Jones, M.H. Hosni., Kansas State University., Manhattan, Kansas

Public health interest remains high for infectious disease exposure during air travel, considering transmission risks of MERS, XDR-TB, measles and the potential for an influenza pandemic. Dispersion of aerosolized viral particles under experimental conditions was examined within Boeing 737 and 767 aircraft cabin mock-ups. Viral particles were introduced under controlled conditions and collected by standard air sampling techniques, in parallel throughout the cabin, over defined periods. This paper presents findings regarding distribution and viability of dispersed viral particles, using established microbiological methods. Data analysis will include the relationship between viral point of origin, time, spatial distribution and retained viability.

3. Air Flow Regimes and Thermal Comfort in Passengers' Car Cabin (HO-18-C005)
Essam E. E Khalil, Ph.D., P.E., Fellow ASHRAE, Ahmed ElDewgy, Ph.D., Cairo University, Cairo, Egypt

Thermal comfort in vehicle cabin can affect drivers' and passengers' health, performance and comfort. Due to spatial and temporal variations of state variables and boundary conditions in the vehicle cabin, the heating, ventilating and air-conditioning (HVAC) do not have to be designed to provide a uniform environment, especially because of individual differences regarding physiological and psychological response, clothing insulation, activity, air temperature and air movement preference, etc. This paper investigates the air flow regimes and thermal comfort in vehicle cabin using computational fluid dynamics (CFD) software.
Challenges Venting High Efficiency Appliances

Track: HVAC&R Systems and Equipment
Room: 370ABDE
Sponsor: 6.10 - Fuels and Combustion
Chair: Cory Weiss, Field Controls, LLC, Warren, MI

- Explain safety and operational issues associated with sidewall venting of high efficiency appliances
- Design acceptable sidewall venting installations for high efficiency equipment
- Describe the technical issues which can occur with common venting of high efficiency appliances
- Apply the design guidance to plan safe installations and inspect installations in the field

As we strive to achieve the highest levels of efficiency with fuel-fired boilers, furnaces and water heaters the low buoyancy creates challenges in the safe venting of flue gas. This seminar addresses these challenges specifically for sidewall and common venting.

1. Sidewall Venting of High Efficiency Equipment: How Close is Too Close?
Larry Brand, Gas Technology Institute, Davis, CA

High efficiency gas fired furnaces, boilers and water heaters are generally installed with Category IV venting systems – positive pressure and condensing. In many retrofit cases, especially in multistory systems, the access to the roof for vent termination is not possible – an existing B vent may be installed in the chase or existing chimney and common-venting is not permitted. A sidewall vent is the only option, but there are restrictions. This presentation reviews the restrictions on sidewall venting in several national and local codes and investigates the potential for ice formation on sidewalls.

2. Common Venting High Efficiency Equipment
Tim McNulty, U.S. Draft Co., Fort Worth, TX

This presentation reviews the practice of common venting condensing or near condensing gas-fired appliances with respect to current ASHRAE guidelines, appliance manufacturers’ recommendations and code requirements. Although national guidelines have been developed for common venting Category I and draft hood-equipped appliances, there is no national standard for common venting condensing or near condensing appliances such as Category II and IV appliances. This presentation focuses on the current chimney design methodology along with the limitations as well as good practices related to common venting Category II and IV appliances.

Field vs. Factory Programmed Controls

Track: HVAC&R Control Freaks
Room: 370CF
Sponsor: 1.4 - Control Theory and Application
Chair: Charitii Young, Automated Logic Corp., Kennesaw, GA

- Understand the differences between factory and field programmed control systems
• Understand how to select equipment with the appropriate controls options to meet an owner’s needs, and avoid the cost of misapplication

• Identify all required field and factory controls installation on design documents

• Explain network protocols and interface options to equipment with factory mounted controls

Which is better - field or factory programmed controls? The answer is...it depends! This session discusses the different options available, the applications where one may be preferred over the other and the benefits of each. Regardless of the chosen option, how does an end user ensure appropriate integration into a central automation front end or reporting system? The session also addresses the requirements to include in design documents and specifications to ensure that a customer's expectations are met, regardless of how the controls are provided.

1. Choose Wisely

Gaylen Atkinson, Member, Atkinson Electronics, Salt Lake City, UT

Control hardware may be either factory designed and mounted on HVAC equipment before arriving at the jobsite or field installed. Field installed controls may be either locally engineered and supplied by a local controls contractor or integrator or the local integrator field installs the factory supplied and engineered control system. All of the above require integrating into a central automation or reporting system. This presentation discusses how to make the best choice for your application and shares stories to illustrate the issues that can result from a choice that is less than wise.

2. Ask Well

Larry Scholl, Member, Automated Logic, Kennesaw, GA

This presentation discusses the differences between factory mounted and field installed controls and the applications where field or factory controls may be preferred and the benefits of each. Once you know the best fit for your application, how do you ask well? The presentation explains what the design documents must include to ensure that the controls are specified and provided correctly and outline the options for interfacing factory provided controls with an on-site building management system.

Sunday, June 24, 9:45 a.m. - 10:45 a.m.

Seminar 8 (Intermediate)

Optimization for Intelligent Building Controls

Track: HVAC&R Control Freaks

Room: 372BE

Sponsors: 1.13 - Optimization and 7.5 - Smart Building Systems

Chair: Zheng O’Neill, Ph.D., P.E., University of Alabama, Tuscaloosa, AL

• Understand the benefits of MPC

• Identify gaps that remain for wide-scale industry deployment

• Describe the advantages and tradeoffs from using MPC for low-level equipment control

• Understand the control tradeoff between utility cost savings and battery degradation

Efficient and automatic building control algorithms could help improve the energy efficiency of HVAC systems and thus reduce the overall energy consumption in buildings. Recently, optimization based control has been investigated for the control of full scale (or partially) HVAC systems and thermal mass in buildings because of significant potential for energy consumption and/or energy cost savings. This session discusses model predictive control (MPC), an optimization-based control strategy. MPC utilizes dynamic building and HVAC equipment models and input forecasts to estimate future energy usage and employs optimization to minimize an integrated cost function for a specified prediction horizon.
1. Gaps to Fill for Widespread Deployment of Model Predictive Control from Experience with Multiple Applications
David H. Blum, Associate Member, Lawrence Berkeley National Laboratory, Berkeley, CA
Model predictive control (MPC) for HVAC has been studied for almost 30 years. It is suggested as a control technique that can meet many of the current and future challenges of HVAC control, including energy and cost reductions, grid integration, and occupant responsiveness. Despite these benefits, it has not been adopted to any scale within the building industry. This seminar discusses experiences of configuring MPC for multiple applications of different systems, objectives, requirements and identify the gaps that need to be filled for widespread deployment.

2. Equipment-Level Model Predictive Control for Smart Building Applications
Christopher R. Laughman, Member, Mitsubishi Electric Research Laboratories, MA
While model predictive control (MPC) has received a great deal of attention for overall building systems, there are also many benefits of applying MPC to the low-level control of equipment, such as for compressors, expansion valves or fans in reversible variable-capacity heat pumps. Modern heat pumps and VRF systems have a wealth of variable actuators that must be managed within operational constraints on temperatures and pressures, and MPC has proven to be an effective tool for providing guarantees that these constraints will be satisfied. This seminar describes some of the work and applications in this area and provides some results suggesting the benefit to integrating equipment controlled with MPC in the larger smart building context.

3. Optimized Control of Building-PV-Battery Systems: Tradeoffs Between Utility Cost and Battery Degradation
Jie Cai, University of Oklahoma, Norman, OK
Buildings have seen increasing deployment of on-site photovoltaic (PV) and batteries to reduce electricity purchase meanwhile enabling deeper demand response. Although battery costs have dropped in recent years, cost associated with battery degradation still represents a significant portion of the overall building operation cost. This presentation describes an economic model-predictive control approach that explicitly considers the tradeoffs between utility cost savings and battery capacity degradation.

Sunday, June 24, 9:45 a.m. - 10:45 a.m.
Seminar 9 (Basic)

The ASHRAE Conference Crash Course
Track: Professional Skills
Room: 371DE
Sponsor: YEA Committee
Chair: Stephanie Kunkel, JMT, Sparks, MD
• Understand ASHRAE's organizational structure
• Understand Standing Committees and Technical Committees
• Understand YEA
• Understand other ASHRAE events

First time at an ASHRAE Conference? Been coming for years, but still confused? What is a TC? What is a Standing Committee? Who can attend what? And why is all this happening at once? This crash course provides all attendees with an introduction to all the ASHRAE Conference activities, explains how you can get involved, and allows you to ask questions to experienced attendees.

1. The Ins and Outs of ASHRAE
Rachel Romero, Member, NREL, Golden, CO
Many of you may be familiar with ASHRAE at the Chapter level. This seminar covers the structure of Society from committees to councils and everything in between. We love our acronyms and when we’re done, you’ll finally know what they all mean and how you can get involved.
2. Make the Most of Your Conference Experience

Vanessa Freidberg, Member, Siemens Building Technologies, Austin, TX

Now that you’ve got your bearings and know the difference between a TC and a TG, this seminar tells you about the softer side of ASHRAE. You’ll find out what social events you shouldn’t miss and how to make the most of your conference experience.

Sunday, June 24, 9:45 a.m. - 10:45 a.m.

Seminar 10 (Intermediate)

Trials and Tribulations of Dishroom HVAC Design, Comfort, and IAQ (Part 2)

Track: Fundamentals and Applications

Room: 371AB

Sponsor: 5.10 - Kitchen Ventilation

Chair: Derek Schrock, Halton Company, Scottsville, KY

• State the typical dishroom temperature and humidity range observed the ASHRAE RP-1469 field study
• Determine the sensible and latent loads from various warewashers and the dishes that are cleaned by those systems
• Understand the real-world challenges encountered in actual restaurant operation
• Optimally design a dishroom so that the design conditions are properly met

This seminar presents the current state of the environment in Dishrooms in restaurants. If they are designed on paper to meet a design criteria, why are those conditions not being met in real restaurants? What are the sensible and latent loads from the warewashers and the dishes that are being cleaned? The seminar also presents what the challengers are for chain operators in their restaurants? From an HVAC system design point what is currently working and what does not work?

1. Experiences from a Restaurant Chain Perspective

Curt Sawan, Associate Member, Red Lobster Restaurants, LLC, Midlothian, VA

This presentation discusses the experiences with restaurants from a chain perspective. What is working and what doesn't work and what the impact of dishrooms are on staff in the restaurant.

2. How Can Dishmachine Manufacturers Be Part of the Solution?

Joel Hipp, Hobart, Troy, OH

This presentation discusses how manufactures be part of the solution in the dishroom providing accurate latent and sensible heat value, helping to educate customers on how equipment functions and advises on potential pitfalls.

3. Field Experiences with HVAC Design

Gregory DuChane, Member, Trane, Columbus, OH

This presentation focuses on understanding the unique needs of the dish room and impact of on local and general kitchen HVAC loads and designing the Kitchen HVAC system to meet the required dish room comfort levels.
Expanding Our Perceptions of Building Performance: Updating Standard 105

Track: HVAC&R Systems and Equipment

Room: 372CF

Sponsors: 7.6 - Building Energy Performance and 2.8 - Building Environmental Impacts and Sustainability

Chair: J. Patrick Carpenter, P.E., Facility Performance Engineers, Cinnaminson, NJ

Standard 105 which provides a method of building energy performance determination, expression and comparison was last revised in 2014. The expanding use of energy benchmarking in many parts of the country reflects the increasing awareness of the impacts of building performance on the environment. There is also growing concern about the impact of buildings on water consumption. Guidance with evaluating these impacts is important to many designs as well as potential legislation. Feedback from the industry on the current standard will help TC 7.6 begin the process of reviewing, updating or expanding this standard.

New ASHRAE Hot Climate Design Guide

Track: Residential Modern Buildings in Hot and Humid Climates

Room: 372AD

Sponsors: MTG.HCDG - Hot Climate Design Guide, 2.8 - Building Environmental Impacts and Sustainability and Publications Committee

Chairs: Melvin G Glass, EMC Engineers, El Paso, TX and Frank Mills, CEng, Frank Mills Consulting, Leyland, United Kingdom

• Understand the alternative approaches to hot climate design which take account of local climate factors, passive solar design, thermal mass, evaporative cooling and occupancy factors

• Define climate issues which affect design approach in hot humid, hot dry (arid) and hot windy locations

• Identify the principle design factors toward successful low energy buildings in hot climates

• Be aware of the design tools which can be used to assist optimum design of buildings in hot climates, particularly options for passive/air conditioned/hybrid/designs.

This presentation is a working session which invites ASHRAE members to input into the new guide and to contribute ideas and requests.

1. The New ASHRAE Hot Climate Design Guide

Melvin G Glass, Member, EMC Engineers, El Paso, TX

Outline of the new Hot Climate Design guide. Workshop session to gain input from ASHRAE members.
Testing for Change in HVAC

Track: HVAC&R Systems and Equipment

Room: 370CF

Chair: Peng Yin, University of Louisiana at Lafayette, Lafayette, LA

New concepts always require effort to determine feasibility and compare with previous methods. This session investigates new HVAC technologies and review of current design in an effort to advance the interests of ASHRAE members. Topics include cooling towers and thermal comfort.

1. Measurement of Wind Pressure for an Inflatable Fabric Evaporative Cooling Tower (HO-18-001)
   D. Kulkarni, Tennessee Tech University, Cookeville, TN

   This paper describes a test program to assess wind pressure coefficients for potential designs of various wind capture means proposed for use in a prototype fabric evaporative cooling tower. For one case, no capture device was incorporated in the scale model experiment, i.e., a simulated wind was directed normally across the open end of the duct. The second case used a five-gore elbow whose open end was oriented directly into the wind. The third case consisted of a duct with a rectangular aperture facing directly into the simulated wind. Measured wind pressure coefficients are reported for each case.

   Ali Hasan, Amanties, Doha, Qatar

   Hydrocyclone water/solids separators are widely used in the industry, known for their simplicity and virtually maintenance free. Recent experimental work on an air/solids separation separator, supplemented by CFD simulations have demonstrated that the separation of solids from air does not depend on gravity. This paper continues this investigation but with water/solids (hydrocyclone), rather than air/solids separation, with and without gravity. The outcome of this simulation should demonstrate whether hydrocyclones can play a role in possible future HVAC lunar applications requiring particle solids/water separation. It is concluded that hydrocyclones can still separate solids from water without gravity, but at a lower ratio when compared with gravity conditions.

3. Using Thermal Comfort Models in Health Care Settings (HO-18-003)
   Rodrigo Mora Ph.D, Member, British Columbia Institute of Technology, Burnaby, BC, Canada

   A fundamental challenge in assessing thermal comfort in health care settings is providing comfortable conditions for the diverse medical services and concurrent occupancy groups. Thermal comfort standards rely on thermal comfort models to predict thermal conditions in spaces that are satisfactory for human occupancy. However, thermal comfort standards and models have not been developed from experimental or field data in health care settings or with health care-specific concerns in mind, and therefore, their validity to assist in environmental health care design has been questioned. This study is motivated by the practical concerns with using thermal comfort models to assist in the design of HVAC systems for health care facilities.
Applying Analytics to Existing HVAC Systems: Benefits, Challenges and Lessons Learned

Track: HVAC&R Analytics

Room: 371DE

Sponsors: 1.4 - Control Theory and Application and 7.5 - Smart Building Systems

Chair: Chariti Young, Automated Logic Corp., Kennesaw, GA

• Describe some challenges unique to retrofitting analytics deployments to existing HVAC systems
• Describe different methods to develop and verify fault detection and diagnostics algorithms
• Understand the needs, challenges, and market gap of building energy diagnostic tools
• Describe some criteria for evaluating a smart building platform

The emergence of ubiquitous data and advanced analytics offers the promise of building system remote diagnostics that improve energy efficiency and occupant comfort. Previous work has shown that properly commissioning buildings can reduce energy consumption up to 25%. Recent studies show improved indoor air quality can double occupants' cognitive function providing a substantial additional value proposition. Delivering on these promises can be challenging, due to poor data availability and quality, insufficient knowledge of fault signatures, excessive false alarms and the need to generate actionable and valuable insights. Speakers discuss several analytics deployments, their benefits, challenges and lessons learned.

1. Deploying HVAC Analytics: Case Studies
Hayden Reeve, UTRC, East Hartford, CT

This presentation reviews the deployment of analytics to various HVAC systems and describes the resulting benefits. These case studies include the use of analytics to achieve optimal control and detect capacity loss for residential systems, application of remote monitoring analytics to large chillers in North America, automated commissioning of HVAC ventilation systems globally to ensure indoor air quality and energy efficiency and the verification and commissioning of custom production chiller plant controls on a virtual customer building prior to installation to reduce commissioning time. The presentation also discusses general challenges associated with HVAC analytics and lessons learned.

2. Whole Building FDD Using Data Driven Methods
Jin Wen, Member, Drexel University, Philadelphia, PA

In this presentation, promising data-driven building energy diagnostic techniques are introduced with a focus on whole building level fault detection and diagnosis. Needs and challenges associated with building energy diagnosis are discussed. Field testing results from a medium-sized commercial building, including results for both artificially implemented faults and naturally occurred faults, are described. Future research/development directions in this area are also proposed.

3. Real Life Deployment of Smart Building Platforms
Dennis Krieger, Switch Automation, Denver, CO

Most people think of smart building platforms by what they deliver: weather-normalized energy benchmarks, advanced fault detection and diagnostics (FDD), centralized command and control capabilities, and notifications on mobile devices. But what is the first step toward deploying a smart building platform? What features should you look for to properly evaluate these powerful software tools? How do you know if your building portfolio is compatible and ready for integration? This presentation references real-world stories of smart building deployments to provide a behind-the-scenes look at how these platforms work and how the tools are used in the real world.
Flooding: Safeguarding HVAC&R Systems: Hurricane Harvey: Strategies Implemented and Lessons Learned

Track: Safeguarding Your HVAC&R System

Room: 372CF

Sponsors: 2.5 - Global Climate Change, 2.7 - Seismic, Wind and Flood Resistant Design and 4.2 Climatic Information

Chair: Scott Sherwood, Eco Care Corporation, New York, NY

• Describe the emergency measures implemented during Hurricane Harvey to protect life safety and how protection of HVAC&R equipment was handled

• Discuss how Houston buildings dealt with Hurricane Harvey and their resiliencies measure they enacted before, during, and after

• Discuss in relationship to Superstorm Sandy, the similarities and differences between the historic weather events and how to learn for the future design of ASHRAE buildings

• Discuss the types of climatic data available, i.e., CO2, PM2.5 Temperature, Rainfall, Relative Humidity, etc.

Hurricane Harvey was a historic extreme weather event that caused over $120B in damage. Like Superstorm Sandy, extreme climate events, especially flooding, are causing major damage to buildings. The life safety and economic repercussions of not planning and designing HVAC&R equipment and systems to withstand major events is too high. Loss of equipment and systems can shut down a building, affect life safety, or cause major economic loss. Major Engineering firms will discuss how Harvey & Sandy effected buildings, what codes were changed as a result, and how design specifications are changing to deal with the changing environment.

3. Hurricane Harvey vs. Superstorm Sandy: Lessons Learned

Roel Garcia, City of Houston Code Enforcement Division, Houston, TX

How did Superstorm Sandy compare with Hurricane Harvey and how can the ASHRAE community learn to build better and safer building environments in extreme weather events in the future.

1. Disaster Engineering and Planning

Robert Simmons, Member, Petra Seismic Design, Houston, TX

Hurricane Harvey was a historic extreme weather event even for Texas. Case studies of how buildings dealt with Hurricane Harvey, how new codes are affecting MEP design and HVAC&R specifications in Texas.

2. Hurricane Harvey: Houston Will Never Be the Same Again

Tom Smith, Arup, Houston, TX

Case Studies in building preparedness, evacuation, shelter-in-place, recovery, rebuilding and resiliency. Discuss the costs of damage, operational failures, transportation shutdowns, etc., and the offsetting cost of Resilient design measures.


Scott Sherwood, Member, Eco Care Corporation, New York, NY

This presentation discusses fundamentals of climate change, Paris Agreement, ASHRAE Climate Change Position Document, current and historic flooding trends, HVAC&R degree days (heat/cool), CO2 levels, Temp, PM2.5, over the past 50 years, etc.
High CO2 and Other Contaminant Levels in Schools

Track: Fundamentals and Applications

Room: 370ABDE

Sponsor: 4.10 - Indoor Environmental Modeling

Chair: Donghyun Rim, Ph.D., Pennsylvania State University, University Park, PA

• Describe the effect of school HVAC systems on high indoor CO2 concentrations
• Explain the design of ventilation and airflow distribution in schools
• Distinguish the effective ventilation control to reduce CO2 levels in school classrooms
• Apply technologies to maintain low indoor CO2 levels at low energy cost

This session reports experimental and numerical studies of high CO2 levels in school indoor environments. The seminar discusses ASHRAE ventilation guidelines as well as effects of school HVAC systems and occupant density on high CO2 concentrations in classrooms in different countries.

1. Ventilation and Corresponding CO2 Levels in Classrooms

Atila Novoselac, Member, University of Texas at Austin, Austin, TX

This presentation reports findings about ventilation and CO2 levels in classrooms based on a larger study of 30 high school classrooms in Central Texas. Classrooms’ ventilation systems are characterized for portable buildings and permanent structures, and CO2 concentrations were measured in the supply airstream and the general room space. It was found that average CO2 concentrations during the occupied period exceeded the ASHRAE 62.1 recommendation for fresh air in more than 70% of classrooms. The results show that source of fresh air as well as the source of CO2 classrooms very much depends on the building structure, portable or permanent.

2. CO2 Sensors Used in Building HVAC Applications: How Reliable Are They?

Som Shrestha, Member, Oak Ridge National Laboratory, Oak Ridge, TN

CO2 sensors are widely used for demand controlled ventilation (DCV) system in buildings requiring mechanical ventilation and their performance can significantly impact indoor air quality and energy use in buildings. This presentation describes results from experiments that evaluated the accuracy, linearity, repeatability, hysteresis, humidity sensitivity, temperature sensitivity and pressure sensitivity of CO2 sensors as well as effect of long-term aging on sensor performance.

3. How to Ventilate Schools in Cold Climate with Possible Outdoor Air Pollution: A Proposal of Improvement

Xudong Yang, Fellow ASHRAE, Tsinghua University, Beijing, China

Most schools in China are currently ventilated by natural ventilation. Will this be sufficient to remove CO2 and other indoor generated pollutants? How to properly ventilate schools in cold climate in particular when outdoor air may be polluted by fine particles (e.g., haze)? This seminar presents results of indoor air quality based on field measurements in a few Chinese schools. Problems are identified based on field data analysis, followed by a comparison of possible solutions to solve the problems. A practical approach that could enhance the indoor air quality while maintaining low initial cost and energy consumption is proposed.
4. CFD Optimization of Carbon Dioxide Removal Efficiency in a Displacement Ventilation System

Ramin Rezaei, Associate Member, Southland Industries, Dulles, VA

Elevated levels of carbon dioxide may result in complaints of general discomfort, headaches and fatigue. The current study investigates the CO2 concentration in an interior office with a displacement ventilation system. The temperature, velocity and CO2 concentrations are measured in several locations. The data was used to validate the corresponding Computational Fluid Dynamics (CFD) results and fine-tune the implemented numerical models. The CFD model was then used as a tool to study the impact of the supply air location and supply air temperature on CO2 concentration in the space.

5. The Day that Fire Trucks, Ambulances and Engineering Analysis Adversely Impacted Elementary School Students

Duncan Phyfe, Associate Member, ARL, Alden, MA

This presentation examines the complex flows around buildings and local weather conditions that can cause building exhaust gases to be re-entrained into the fresh air inlet. This flow phenomenon can be predicted with CFD. This presentation also looks at an elementary school where such an event occurred, resulting in asthma attacks for two children and an epileptic seizure for another. The CFD model captures momentum, temperature, density and buoyancy of the flow out of the chimney and surrounding ambient building flows, resulting in the re-entrainment of the exhaust into the fresh air inlet.

Sunday, June 24, 11:00 a.m. - 12:30 p.m.
Seminar 14 (Intermediate)

How Can Net Zero Energy Goals, Low Sensible Loads and Ventilation Work in a Hot Humid Climate?

Track: Residential Modern Buildings in Hot and Humid Climates

Room: 371CF

Sponsors: 1.12 - Moisture Management in Buildings, MTG.BD - Building Dampness and Residential Building Committee

Chair: Neil Leslie, P.E., Gas Technology Institute, Des Plaines, IL

• Understand what sensible heat ratio means and why low load homes create a reversal in SHR’s compared to conventional construction
• Describe what kind of sensible heat ratios to expect from low load buildings that include high efficiency mechanical equipment
• Explain the value of hygric buffering in controlling humidity in high performance homes
• Apply holistic cooling, ventilation and dehumidification strategies to ultra-high performance homes

Climate specific building standards whose certification requirements and modeling tools reflect the psychrometric characteristics of humid climates present significant challenges for conventional cooling systems in homes. Holistic HVAC solutions which include properly designed and controlled dehumidification are essential for comfort and structural integrity. This seminar explores reasons for observed dehumidification challenges in ultra-efficient homes and combinations of cooling equipment, balanced ventilation systems and dehumidifiers to address these challenges with minimum incremental energy use. Certified design options are identified and illustrated through an example in an ultra-high performance home in Texas.

1. It's Not the Heat, It's the Humidity!

Robert Bean, P.L.(Eng.), Member, Indoor Climate Consultants Inc., Calgary, AB, Canada

You've heard it before, "It's not the heat it's the humidity". Ok but what is physiologically happening to your clients when they start screaming, "It's sticky, muggy nasty hot!" Understand thermal discomfort inside homes in hot and humid climates with ASHRAE Standard 55.

Nikki Krueger, Thermo-Stor LLC, Madison, WI

Sensible loads have declined while latent loads which are internally generated have remained the same in ultra-low load homes. This poses significant challenges for high efficiency equipment, especially during shoulder seasons. While these mechanical systems are an important part of net zero or ultra-low load homes, available products at this point aren’t able to match SHR’s especially when operating at partial load conditions. This presentation discusses the reversal in SHR which arises in low loads homes and compare field data from monitored high efficiency heat pumps.

3. Hot Humid Holistic HVAC Solutions

Kimberly LLewellyn, Mitsubishi Electric Cooling & Heating, Suwanee, GA

The impact of ventilation loads on the Sensible Heat Ratios on the buildings in hot humid climates is amplified due to ventilation loads. However, solutions do exist for ultra-high performance homes that approach zero energy performance. This presentation explores an example of certification compliant HVAC solutions for an ultra-low load house located in Austin, Texas. Factors impacting interior latent loads, especially during shoulder seasons, will be examined, along with design solutions that address the sensible/latent load profiles associated with ultra-high performance homes.

4. Houston, We Have a Problem!

Kristof Irwin, M.Eng., Member, Positive Energy, Austin, TX

Houston, we have a problem! Well actually several. How can you reduce the odds that your clients’ homes will not be too hot, cold, damp or dry? It’s all about identifying the problems, calculating the loads, designing the system and picking the equipment.

Sunday, June 24, 11:00 a.m. - 12:30 p.m.
Seminar 15 (Basic)

Unblock the Road to Your Career

Track: Professional Skills
Room: 372BE

Sponsor: YEA Committee
Chair: Stephanie Kunkel, JMT, Sparks, MD

• Understand the main key points that make an excellent elevator speech
• Learn how much of an impact the delivery of a concept or point of view has, and how a majority of the time it's just as important as the point of view itself
• Understand the value in becoming a registered Professional Engineer
• Understand the process to complete your registration as a Professional Engineer

Interested in improving your career and overcoming some roadblocks? Join several members of the Young Engineers in ASHRAE (YEA) Committee as they share their tips for sharing your passions, working with different viewpoints and the role of the Professional Engineering certification.

1. The Highway to the Perfect Elevator Speech

Rachel Romero, Member, NREL, Lakewood, CO

Interested in perfecting your elevator speech about your work or your involvement in ASHRAE? Learn about the key elements of your elevator speech, some pointers for perfecting it and ways to target your audience to achieve the most-effective communication about your work.
2. Open the Communication Street for Differing Viewpoints

**Lindsey King, Associate Member**, JCI, New Freedom, PA

This presentation reviews common methods of responding to strong differing viewpoints and the perception that goes with each. The presentation also explores positive ways of responding that accepts the points of view, responds to the statement or question, and then builds upon their comment with adding value of your own.

3. The Professional Engineer Avenue

**Stephen Wren, Member**, Mesa Associates, Inc, Chattanooga, TN

This presentation discusses the value of a professional engineering license including the ability to lead engineering projects, long-term job security and Principal Engineer roles. The attendees also learn the process for becoming registered in a “home state,” choosing a “home state,” and receiving licenses for future project/employment needs.

Sunday, June 24, 11:00 a.m. - 12:30 p.m.

Seminar 16 (Intermediate)

**Urban-Scale Energy Modeling, Part 8**

Track: Fundamentals and Applications

Room: 372AD

Sponsors: 1.5 - Computer Applications and 4.7 - Energy Calculations

*Chair: Joshua New, Ph.D., Oak Ridge National Laboratory, Oak Ridge, TN*

- Identify different models' strengths and weaknesses and suggest best practice procedures for administrators of other campuses interested in developing more sustainable campuses

- Understand the impacts of different thermal zoning methods and the use of floor multipliers on the Simulation Results of Urban Building Energy Models

- Provide an overview of energy system model advances and integration with urban building energy modeling

- Describe how a platform for data aggregation can be used to simulate various energy models

Development of urban-scale building energy models is becoming increasingly tractable for many applications including utility-scale energy supply/demand strategies, urban development planning, electrical grid stability, and urban resilience. This seminar has assembled researchers from MIT, Lawrence Berkeley National Laboratory and commercial entities to demonstrate and empirically validate city-scale capabilities in the field of urban-scale energy models as well as discuss the data, algorithms, workflow and practical challenges addressed in their applications involving creation, analysis and visualization of useful models of individual buildings at the scale of a city, urban or metropolitan area.

1. A Comparison of Two Modeling Approaches for Establishing and Implementing Energy Use Reduction Targets for a University Campus

**Shresnh Nagpal**, MIT, Boston, MA

To reduce global greenhouse gas emissions associated with building energy use, owners of large building portfolios frequently rely on energy models to better understand potential costs and benefits of retrofits. Model development workflows that are designed for individual buildings require a level of effort that is extremely time and cost prohibitive for large campuses. With the goal of overcoming these limitations, two separate urban energy models were developed for the campus of the Massachusetts Institute of Technology to evaluate future energy scenarios. This presentation reviews both models for their strengths and limitations and suggests best practice procedures for administrators of other campuses interested in undergoing a similar exercise.
2. Impacts of Building Geometry Simplification on Energy Simulation Results of Urban Building Energy Models
Tianzhen Hong, Member, Lawrence Berkeley National Lab, Berkeley, CA

This study evaluates the impacts of three zoning methods (one zone per floor, split perimeter and core zones, and prototype shape) and the use of floor multipliers on the simulated energy use of 940 buildings in San Francisco using CityBES. Results show that simulated source energy use of buildings with floor multiplier are marginally higher by up to 2.6% than those modeling each floor explicitly, which take three times longer to run. Using different zoning methods leads to very different auto-sized equipment capacities and energy use. The study demonstrates zoning method has significant impacts on simulated energy use in buildings.

Matt Cox, The Greelink Group, Atlanta, GA

Building energy modeling has progressed to advanced stages where accurate and detailed understandings of building operations can be gleaned from small amounts of information. They can be scaled to cover large areas, painting a picture of entire communities. New advances in high-resolution energy system modeling can now be paired with these tools to provide detailed information on the impacts on equity, economic development, public health, water resource utilization, and greenhouse gas emissions. Combining these tools provides a powerful way to tell the story of increased efficiency and on-site generation, from a single building up to entire regions.

Sunday, June 24, 11:00 a.m. - 12:30 p.m.

Workshop 4 (Intermediate)

Achieving Acceptability and Minimizing Adverse Health Effects through Ventilation: What You Thought You Knew

Track: Research Summit
Room: 371AB
Sponsors: EHC and SSPC 62.1 is primary sponsor

Chair: Jennifer Isenbeck, P.E., Sodexo, Tampa, FL

• Describe the pathways for airborne disease transmission
• Explain the current processes used in infection control
• Apply knowledge to understand in which situations additional ventilation is beneficial to clients and society
• Distinguish between generic "air changes" and effective ventilation practices

ASHRAE has a history of addressing adverse health effects from airborne constituents going back to ASHVE in 1885. Our understanding of the relationship between ventilation and health effects continues to evolve. Many of the old rules-of-thumb or even IAQ concepts are currently in question. This workshop presents current knowledge and practices related to ventilation. This interactive workshop presents information on airborne disease transmission, infection control practices in spaces where populations are vulnerable and overall relationships between ventilation, health and productivity. It also addresses the differences between room air changes and effective ventilation.

1. Airborne Disease Transmission
Mark Buttner, Nevada State Public Health Laboratory, UNLV Branch, Las Vegas, NV

Exposure to airborne microorganisms in the indoor environment may cause a variety of adverse health effects. Examples of airborne microbial agents of health concern are presented. Potential sources of airborne microorganisms indoors will be discussed, along with the role of ventilation in reducing airborne disease transmission.
2. Infection Control

Erica Stewart, Member, Kaiser Permanente National EH&S, Pasadena, CA

Infection control is a practice used in hospitals to limit the spread of disease. The basic principles are reviewed with a perspective on airborne contamination. Applying principles of infection control to situations outside of health care is also addressed.

3. Ventilation: Health and Productivity

William Fisk, Lawrence Berkeley National Laboratory, Berkeley, CA

ASHRAE was founded by a group of engineers who gathered to address ventilation practices. Since that time, multiple studies of ventilation and its relationship to acceptability and health have been published. Many studies on ventilation do not quantify health effects very well and many studies on health do not quantify ventilation. However, there are many studies that do both well and the answers converge. Studies of ventilation and productivity, especially amongst knowledge workers, are rare. However, new measurement techniques have revealed new findings that are confirmed by multiple studies. The results of current health and productivity studies are addressed in this session.

4. Ventilation Effectiveness

Hoy Bohanon, Member, Hoy Bohanon Engineering PLLC, Clemmons, NC

ASHRAE 62.1 uses a factor for ventilation effectiveness to adjust for the effectiveness of the air delivery system in providing ventilation air to the breathing zone. This value of Ez varies from 0.5 to 1.2. These factors apply to ventilation air supplied to dilute contaminants in spaces. There is an analogous mechanism wherein air is used to directly capture and exhaust contaminants. Exhaust effectiveness is not described in the same way in ASHRAE standards, but is usually associated with a minimum capture velocity. New systems and studies are described to illustrate that all air changes are not equal.

Sunday, June 24, 1:30 p.m. - 3:00 p.m.
Technical Paper Session 2 (Intermediate)

New Developments in HVAC Fundamentals

Track: Fundamentals and Applications
Room: 370CF

Chair: Marija Todorovic, Ph.D, University of Belgrade, Belgrade, Serbia

Understanding the basics of HVAC systems is critical to future advancements. This session identifies current research in understanding new technology and the underlying principles of those technologies. Topics range from refrigeration to analytics.

1. Non-Singular Terminal Sliding Mode Control of Compression Refrigeration System with a Disturbance Observer (IHO-18-004) *WITHDRAWN*

Junjian Liu, Ph.D, Innovent Biologics, Beijing, China

This paper studies the modeling and control method of compression refrigeration system. Firstly, a simplified model is proposed through mechanism modeling and experiment identification. The model shows high accuracy according to simulation and experiment results. Then, an extended disturbance observer of evaporator is proposed, and its error is proved to be bounded. The observer can calculate disturbance quickly and can reduce switching gain in sliding mode controller. Finally, according to simulation results, the proposed method shows better dynamic performance against disturbance and can alleviate chattering problem compared to traditional sliding mode control.
2. Development of a Distributed Building Fault Detection, Diagnostic and Evaluation System (HO-18-005)

Zixiao Shi, Carleton University, Ottawa, ON, Canada

This paper introduces a distributed system for building fault detection, diagnostic and evaluation (FDDE). The design of the distributed system aims to address computation and network limitations on a common commercial building automation system. This system aims to be adaptable to different fault detection and fault diagnostics algorithms developed by other researchers. The fault evaluation aspect of the system provides quantitative impact metrics of the potential faults to the building operators. Probabilistic representations of faults and symptoms are used and a continuous symptom severity value is developed to provide more granularity over the abnormal operation information. The proposed method is then tested with five fault cases simulated in EnergyPlus.

3. An Evaluation of Two Cooling Control Strategies with Variable Airflow Series Fan Powered Terminal Units (HO-18-006)

Dennis O’Neal, Member, Baylor University, Waco, TX

A mass and energy balance approach was implemented using Engineering Equation Solver to estimate the annual energy performance of a single-duct variable air volume system with variable airflow series fan powered terminal units. The fan models were based on the performance data provided by multiple manufacturers for fans with electronically commutated motors. Two control approaches (airflow and temperature) were evaluated for the cooling operations of the fan powered terminal units. In both approaches, secondary air is mixed with primary air to provide: (1) high enough air temperatures at full cooling to minimize condensation on discharge registers and (2) higher temperatures at low cooling loads to avoid “cold” call complaints.

4. Regression and Artificial Neural Network Models with Data Classifications for Building Energy Predictions (HO-18-007)

Nabil Nassif Ph.D, P.E, Member, University of Cincinnati, Cincinnati, OH

This paper discusses typical data-based building energy models and proposes new improvements by utilizing data classifications. Six different data-based models for estimating sub-hourly and hourly energy consumptions are presented and discussed. Those models are three typical single to multiple regression models, two proposed regression models and artificial neural network model with recommended classifications. Power data collected from existing buildings at 15 min intervals are used to build and test the models. Additional hourly energy data obtained from a well-known energy simulation program are also used for detailed analysis.

Sunday, June 24, 1:30 p.m. - 3:00 p.m.

Conference Paper Session 3 (Intermediate)

Balancing Indoor Climate Control with Aesthetics and Energy Efficient Construction of Residential Buildings

Track: Residential Modern Buildings in Hot and Humid Climates

Room: 371CF

Chair: Mini Malhotra, Ph.D, Oak Ridge National Lab, Oak Ridge, TN

Hot summers and cold winters, the balancing act. How can we keep indoor comfort energy efficient with so many different residential structures? A look at regression analysis, electrical consumption, fenestration and geo-thermal heating and cooling equipment.

Mingyang Qian, Da Yan, Ph.D., Tsinghua University, Beijing, China

In this paper, the cluster analysis is carried on the ground source temperature of different ground source heat pump systems from the field test. The results show that the ground source temperature in Hot Summer and Cold Winter zone change smoothly without the daily temperature fluctuation, which is different from the ground source temperature in America. The oversizing of capacity of ground heat exchanger is the reason for no daily temperature fluctuation, which is proven by a case study of the simulation for ground heat exchanger combined with the heating and cooling load measured by field test.

2. The Effect of Fenestration System on Building Daylighting and Solar Radiation: An Experimental Study in Humid Subtropical Climate (HO-18-C007)

Joseph Rendall1, Student Member, Stephanie Chin2, Student Member, Hui Shen1, Ph.D., Associate Member, Xiaoyu Liu1, (1) Texas A&M University-Kingsville, Kingsville, TX, (2) Massachusetts Institute of Technology, Cambridge, MA

This experimental case study uses two test houses (1.8 x 1.8 x 2.4 m) outdoors in a hot and humid climate to study the effect different window orientations, sizes and glazing properties (low-e) on Useful Daylight Illuminance (UDI) and daily Solar Heating Gain (SHG) to determine optimal designs. Shade controls on west and east orientations can reduce SHG and glare in the mornings and afternoons, respectively. South orientation can be protected by a shallow roof overhang. Regressions of transmission of light and thermal radiation were performed on summer data to generalize performance in hot and humid climates.

3. An Evaluation of the Effect of Age of House Construction on Electrical Energy Consumption in Montgomery County, Texas (HO-18-C008) *WITHDRAWN*

Melina Cedillo1, Ben Bigelow2, Ph.D., (1) Texas A&M University, College Station, TX, (2) University of Oklahoma, Norman, OK

This paper addresses and quantifies the actual impact on electricity consumption in the residential sector of homes constructed through the ages. Conclusions are drawn after analyzing the electricity consumption of homes built in different time periods in Montgomery County, Texas. This study seeks to answer the following questions: 1) What is the correlation between modern day construction and electricity consumption in homes? 2) With homes built in recent times, what is the quantification of the difference in kilowatt hours and dollars of electrical consumption for homes in Montgomery County, Texas? 3) Which time period had the largest decrease in electrical consumption?

4. Assessing the Risk of Overheating in High-Performance Social Housing Buildings With the Use of Regression Analysis (HO-18-C009)

Jean Rouleau, Student Member, Louis Gosselin, Member, Université Laval, Québec, QC, Canada

In this presentation, the risk of overheating in a social housing building in Canada is evaluated through a multivariate regression model created with measured data coming from a case study building. The model is able to identify influential weather (temperature, solar radiation), building (dwelling location, thermal mass) and occupant (opening of windows, use of electrical appliances) parameters and to quantify their impacts on overheating. A discussion on whether occupant behavior has a part to play on overheating is included, with suggestions on the possible actions to take by occupants to reduce overheating.
Sunday, June 24, 1:30 p.m. - 3:00 p.m.
Seminar 17 (Intermediate)

Documented HVAC System Efficiency Deterioration: A Case Study
Track: HVAC&R Systems and Equipment
Room: 370ABDE

Sponsor: 7.3 - Operation and Maintenance Management

Chair: Mina Agarabi, P.E., Agarabi Engineering PLLC, New York, NY

• Understand the basic test procedures and system performance scoring methods described in ASHRAE 221P
• Explain the distribution of typical system performance scores of installed equipment based on hundreds of field tests performed by HVAC contractors
• Understand the most common issues that contribute to low system performance scores
• Identify the potential for improving system performance scores through system renovations and upgrades

Three members of the ASHRAE 221P committee will present data from a case study documenting HVAC System Efficiency Deterioration of more than 150 field-installed unitary systems. Each system was tested and scored following the proposed standard showing a typical 30% to 50% reduction in system performance. From this data, evidence and impacts were determined that identify the typical deficiencies that deteriorate efficiency. Further data will be offering including measured improvement in the performance of the systems following customized system upgrades.

1. Documented HVAC System Efficiency Deterioration: A Case Study (1)
   Mel Johnson, Member, National Comfort Institute, Pekin, IL

Three members of the ASHRAE 221P committee will present data from a case study documenting HVAC System Efficiency Deterioration of more than 150 field-installed unitary systems. Each system was tested and scored following the proposed standard showing a typical 30% to 50% reduction in system performance. From this data, evidence and impacts were determined that identify the typical deficiencies that deteriorate efficiency. Further data will be offering including measured improvement in the performance of the systems following customized system upgrades.

2. Documented HVAC System Efficiency Deterioration: A Case Study (2)
   Ben Lipscomb, Member, National Comfort Institute, Whitefish, MT

Three members of the ASHRAE 221P committee will present data from a case study documenting HVAC System Efficiency Deterioration of more than 150 field-installed unitary systems. Each system was tested and scored following the proposed standard showing a typical 30% to 50% reduction in system performance. From this data, evidence and impacts were determined that identify the typical deficiencies that deteriorate efficiency. Further data will be offering including measured improvement in the performance of the systems following customized system upgrades.

3. Documented HVAC System Efficiency Deterioration: A Case Study (3)
   Rob Falke, Member, National Comfort Institute, Avon Lake, OH

Three members of the ASHRAE 221P committee will present data from a case study documenting HVAC System Efficiency Deterioration of more than 150 field-installed unitary systems. Each system was tested and scored following the proposed standard showing a typical 30% to 50% reduction in system performance. From this data, evidence and impacts were determined that identify the typical deficiencies that deteriorate efficiency. Further data will be offering including measured improvement in the performance of the systems following customized system upgrades.
Outcomes from IEA EBC Annex 66 Project on Occupant Behavior

Track: HVAC&R Analytics
Room: 372BE

Sponsors: MTG.OBB - Occupant Behavior in Buildings and 7.5 - Smart Building Systems

Chair: Bing Dong, Ph.D., University of Texas at San Antonio, San Antonio, TX

- Understand what are the key energy-related occupant behaviors in buildings, and why they are important
- Understand why over-simplifying occupant behavior in HVAC and whole building simulations leads to a huge gap between simulated and measured energy use
- Learn analytic tools, methods and case studies being developed by leading researchers that can describe and model occupant behavior in buildings, part of the IEA EBC Annex 66 on occupant behavior
- Identify why the key energy-related occupant behaviors in buildings are important

People spend more than 90 percent of time in buildings and as a result, occupancy behavior becomes a leading factor that affects building energy consumption, but it is quite often oversimplified. To better understand the occupant behavior in building, a group of 100 researchers from 20 countries worked together for last four years and have developed mathematical models, data analytics tools, simulation software and case studies. This seminar reports the final outcomes of Annex 66 that can leverage efforts and goals within the ASHRAE community.

1. Sensing Occupant Behavior and Associated Data Analytics in Buildings
   Bing Dong, Associate Member, University of Texas at San Antonio, San Antonio, TX

   Occupant sensing and data acquisition are an essential element for occupant behavior research. This presentation summarizes existing occupancy and occupant behavior sensing and data acquisition technologies in terms of field applications and develops nine performance metrics for evaluation. In addition, upon a comprehensive literature review, we will present that in total there are six listed categories of sensing technologies: image-based, threshold and mechanical, motion sensing, radio-based, human-in-the-loop, and consumption sensing. The presentation also presents example applications of those technologies in occupant behavior research include: occupant presence, people counting, human building interactions.

2. Assumptions and Models of Occupant Behavior in Building Performance Simulation: Do They Matter?
   Tianzhen Hong, Member, LBNL, Berkeley, CA

   Simplified assumptions of occupant activities have been used in building performance simulation. Is this practice adequate? What are potential pitfalls? This presentation introduces occupant behavior models at various levels of details, including occupants’ presence and movement in buildings and occupants’ interaction with building systems such as windows, shades, lights and air-conditioning systems. Results from simulation case studies are presented to demonstrate the importance of occupant behavior modeling on building energy use and on evaluation of building technologies. Several occupant behavior modeling tools from the Annex 66 project are also discussed.

3. Lessons Learned From Applications of Occupant Behavior Modeling
   Clinton J. Andrews, Member, Rutgers, The State University of New Jersey, New Brunswick, NJ

   Building occupant behavior modeling is beginning to enjoy wider application around the world. This presentation illustrates the range and types of applications, offers a framework for classifying types of applications, and considers which modeling approaches are most appropriate for which contexts. Summaries of thirty-two case studies gathered by IEA Annex 66 from North America, Europe, and Asia show which modeling strategy each adopts, given its context. Essential elements of the framework answer familiar questions: who, what, why, when, and where? In determining which model is most fit for each context, three dimensions emerge as being particularly important.
4. Development of Data Analytic Techniques to Integrate Occupant Behavior Into Building Design

Da Yan, Tsinghua University, Beijing, China

Occupant behavior features diversity in buildings, leading to discrepancy in building energy consumption. Typical behavior patterns are required in the analysis of the building performance. This presentation presents development of procedure to integrate occupant behavior into building design. While integrating a stochastic model into the building simulation program, appropriate repetition and time interval should be well analyzed. The presentation proposes a statistical framework to quantitatively describe and evaluate the randomness in building simulation with the integrated stochastic occupant behavior model, generally by applying hypothesis testing approaches.

Sunday, June 24, 1:30 p.m. - 3:00 p.m.

Seminar 19 (Intermediate)

Secondary Disinfection of Building Water Systems

Track: Fundamentals and Applications

Room: 372CF

Sponsor: 3.6 - Water Treatment

Chair: Dan B. Weimar, Chem-Aqua, Inc, Irving, TX

• Learn the criteria for determining when secondary disinfection should be considered
• Understand the different chemistries available for secondary disinfection and when to apply each
• Learn various methods of control and monitoring for secondary disinfection
• Describe conditions within building water systems (potable and utility) that allow Legionella and other bacteria to growth and spread

There is a lot to know about getting and keeping your building safe from water borne pathogens and not just Legionella. There are thousands of cases of Legionnaires’ disease occur annually and the CDC reports 20 or more outbreaks according to the CDC. This seminar addresses the most appropriate chemistry for maintaining good control for the building water systems. It also addresses how to evaluate the effectiveness of your water management program. If you are an independent building or fall under the new Centers for Medicare and Medicaid Services, this seminar helps you understand the requirements to reduce waterborne pathogens.

1. Secondary Disinfection of Building Water Systems: Preventing Disease due to Legionella and Other Waterborne Pathogens

Janet Stout, Associate Member, Special Pathogens Laboratory, Pittsburgh, PA

Thousands of cases of Legionnaires’ disease occur annually and the CDC reports 20 or more outbreaks of Legionnaires’ disease each year. Most outbreaks are in buildings with large water systems, such as healthcare facilities where Legionnaires’ disease can be responsible for up to 85% of the deaths. Centers for Medicare and Medicaid Services (CMS) now has requirements for facilities to develop water safety and management plans and procedures to reduce the risk of growth and spread of Legionella and other waterborne pathogens. This may require instituting control measures, including installing additional water treatment known as secondary disinfection.

3. Chemistry and Control of Secondary Disinfection Applications

Jon Cohen, ChemTreat, Naperville, IL

Using the most appropriate chemistry and maintaining the best control and monitoring is key to the success of any secondary disinfection application. When using secondary disinfection as a strategy for controlling waterborne pathogens or as part of a water management plan consistent with ASHRAE Standard 188-2015, appropriate chemistry and control is even more important. This seminar focuses on chemicals used for secondary disinfection, including control limits and application requirements for each option. Control and monitoring strategies and equipment are outlined. The presentation teaches an understanding of when and how to apply different methods of secondary disinfection.
The Future of CHP: Packaged Systems, Resilience and Microgrids
Track: District Energy and Cogeneration Plants
Room: 371DE

Sponsors: 1.10 - Cogeneration Systems, 6.2 - District Energy and 6.9 Thermal Storage and 8.3 Absorption and Heat Operated Machines

Chair: Timothy Wagner, Ph.D., United Technologies Research Center, East Hartford, CT

- Understand the engineering and economic risk reduction implications of Packaged CHP systems
- Be aware of the forthcoming DOE eCatalog for Packaged CHP systems
- Understand the nexus of CHP operability and economics regarding state and local resilience planning efforts
- Understand how CHP enables resilience at critical infrastructure and how it can be implemented as part of a cost effective microgrid

The future CHP systems are pre-engineered factory packaged systems incorporating the prime mover/generator, heat recovery, switchgear, emissions devices and controls. Packaged systems are proven to be cheaper and easier to install and operate and DOE is developing an eCatalog to support this approach. In addition energy resilience is emerging as a critical state and local policy initiative leading to deployment of microgrids. CHP is often called to anchor microgrids because of economics and dispatchability. This seminar updates attendees on the latest developments in packaging and provide an understanding of CHP’s resilience attributes and its implementation in microgrids.

1. CHP Systems: Reducing Risk and Improving Design, Packaged Systems Under 10 MW
Richard Sweetser, Life Member, Exergy Partners Corp., Herndon, VA

CHP currently represents approximately 8 percent of U.S. generating capacity compared to over 30 percent in countries such as Denmark, Finland and the Netherlands. Legacy approaches to the U.S. market meant that CHP systems were specifically designed for each project, often yielding unnecessary design differences in delivering the same amount of electric and thermal energy to different sites. This can lead to higher soft costs, higher packaging costs, higher installation costs, higher commissioning costs, higher delivery time and perhaps increased downtime. Pre-engineered, packaged CHP systems simplify installation and offer cost savings associated with a standardized design. This presentation explores state and national efforts to encourage packaged CHP system development and end-user risk reduction services, as well as results from existing programs.

2. CHP and Resilience Planning
Bruce Hedman, Entropy Research, LLC, Arlington, VA

Man-made and natural disasters, like Superstorm Sandy or hurricanes Katrina, Ike, Harvey, Irma and Maria focus attention on securing critical infrastructure (CI) for national or regional security, economic continuity and/or public health and safety. Virtually every community in the U.S. has facilities that fall within the definition of critical infrastructure, needing uninterrupted electricity and heating or cooling services. States and municipalities spend considerable time planning for and reinforcing their critical facilities and seeking resources to install the best economic solution. This presentation reports on state and federal efforts to enhance energy resilience planning by strategically adding in resilient CHP Microgrid solutions.
3. Resilient CHP Microgrid Design: Hospital Case Study

Gearoid Foley, Member

Designing CHP plants for resilient microgrid applications requires evaluation of the electric and thermal attributes of both the CHP components as well as the facility infrastructure. CHP provides continuous power and thermal energy in either grid connected or islanded modes. However, in order to properly fit the application, the system must incorporate considerations for ‘blue sky’ and grid island load requirements, black start, switchgear control, electric and thermal load management and equipment protection. The presentation examines these considerations through a case study of a CHP based resilient microgrid at a hospital that will allow the facility to operate at full capacity during long-term grid outages.

Sunday, June 24, 1:30 p.m. - 3:00 p.m.
Seminar 21 (Basic)

Your Ethics Tool Box: Building a Framework for Ethical Decision-Making With Case Studies

Track: Professional Skills
Room: 371AB

Sponsor: 1.7 - Business, Management & General Legal Education

Chair: Michael Bilderbeck, P.E., Pickering Firm, Memphis, TN

• Understand that decisions to ethical issues are often "situational"
• Understand that decisions to ethical questions may depend on the perspective of the decider
• Understand an engineer's "priorities of loyalty"
• Understand that lapses in proper ethical behavior can have long-reaching consequences

ASHRAE members are often confronted with ethical issues (whether they realize it or not). This session is part of a continuing program under which ASHRAE members engage in an interactive session where participants are presented with three NPSE ethics cases, discuss the cases in small groups and then reveal their decisions. The actual NSPE decisions are then be provided. Test your "Ethics IQ" against real cases and receive CE credit in the process.

1. Case Studies in Engineering Ethics, Part 1
James Arnold, Member
Haslett Heating and Cooling, Columbus, OH

This seminar covers an ethical framework to decision making. Using those decision making processes, the attendees evaluate three NSPE case studies in this interactive session.

2. Case Studies in Engineering Ethics, Part 2
Kristin Schaefer, Member
Schaefer Engineering, Katy, TX

This seminar covers an ethical framework to decision making. Using those decision making processes, the attendees evaluate three NSPE case studies in this interactive session.

3. Case Studies in Engineering Ethics, Part 3
Scott Fanning, Member
Fanning and Fanning, Lubbock, TX

This seminar covers an ethical framework to decision making. Using those decision making processes, the attendees evaluate three NSPE case studies in this interactive session.

4. Case Studies in Engineering Ethics, Part 4
Michael Bilderbeck, Fellow ASHRAE
Pickering Firm, Memphis, TN

This seminar covers an ethical framework to decision making. Using those decision making processes, the attendees evaluate three NSPE case studies in this interactive session.
Sunday, June 24, 1:30 p.m. - 3:00 p.m.

Workshop 5 (Basic)

Load Calculations Missing Link: Taking Load Calculations Through to Equipment Sizing
Track: Fundamentals and Applications
Room: 372AD

Sponsor: 4.1 - Load Calculation Data and Procedures
Chair: Glenn Friedman, P.E., Taylor Engineering, Alameda, CA

• Define a room load
• Identify loads to add to a room load for equipment sizing
• Recognize the correct outdoor weather conditions to use for load calculations for evaporative cooling equipment
• Select equipment using load calculations

TC4.1 Load Calculations limits its scope to room loads. Practitioners take these room loads and use them as the basis for equipment selection. There are many loads external to the room that affect the equipment selection such as weather conditions, ventilation loads, infiltration and sensible heat ratio. This workshop takes groups of attendees through load to equipment selection group exercises.

1. Load Calculations Missing Link: Taking Load Calculations Through to Equipment Sizing: The Vendor Perspective

James Pegues, Member, Carrier Corporation, Syracuse, NY

TC4.1 Load Calculations limits its scope to room loads. Practitioners take these room loads and use them as the basis for equipment selection. There are many loads external to the room that affect the equipment selection such as weather conditions, ventilation loads, infiltration and sensible heat ratio. This workshop takes working groups of attendees through load to equipment selection group exercises. James Pegues provides a vendor's perspective.

2. Load Calculations Missing Link: Taking Load Calculations Through to Equipment Sizing: The Design Engineer Perspective

Steve Bruning, Fellow ASHRAE, Newcomb & Boyd, Atlanta, GA

TC4.1 Load Calculations limits its scope to room loads. Practitioners take these room loads and use them as the basis for equipment selection. There are many loads external to the room that affect the equipment selection such as Weather conditions, ventilation loads, infiltration and sensible heat ratio. This workshop takes working groups of attendees through load to equipment selection group exercises. Steve Bruning provides a design engineer's perspective.

Sunday, June 24, 3:15 p.m. - 4:45 p.m.

Seminar 22 (Intermediate)

New ASHRAE Standard 209 on Simulation Aided Design for Buildings
Track: HVAC&R Systems and Equipment
Room: 372BE

Sponsors: 4.7 - Energy Calculations and SPC 209
Chair: Erik Kolderup, P.E., Kolderup Consulting, San Francisco, CA

• Describe the value of simulation analysis during early phases of design
• Perform a climate analysis to inform building design and system selection
• Use simple box modeling to evaluate conceptual design options
• Explain analysis results to architects and building owners

ASHRAE Standard 209, Simulation Aided Design, which is a new process standard that sets minimum requirements for the use of building energy simulation in the design of new buildings. A primary goal is to encourage the use of simulation during early design. Presentations include case studies that illustrate requirements of the Standard and provide some examples of innovative analysis and presentation methods.

1. Introduction to the New ASHRAE Standard 209 on Simulation Aided Design
Jason Glazer, Member, GARD Analytics, Inc., Arlington Heights, IL
This presentation introduces attendees to a new ASHRAE Standard 209, which covers simulation aided design for buildings. ASHRAE Standard 209 defines a set of requirements for the use of building energy simulation in the design of new commercial buildings. This first presentation by the committee chair describes the motivations for developing this new standard and introduces its requirements.

2. Climate Analysis Examples for ASHRAE Standard 209
Colin Schless, Thornton Tomasetti, San Francisco, CA
Evaluation of local climate for a new construction project can highlight energy saving opportunities. ASHRAE Standard 209 requires that all projects include a climate study. This presentation illustrates the requirement with interesting examples.

3. Analysis of Conceptual Building Designs in Compliance with ASHRAE Standard 209
Clark Denson, Member, Smith Seckman Reid, Nashville, TN
This case study describes how various architectural massing concepts of a hospital in upstate New York were analyzed using energy simulation tools in accordance with the requirements of ASHRAE Standard 209, Modeling Cycle #2 – Conceptual Design Modeling. This early design-phase analysis used a Sketch-up to BEM workflow that allowed for a high-level comparison of each design’s annual energy use, peak HVAC loads and first cost implications.

4. Optimization of Hospital Window Design in Compliance with ASHRAE Standard 209
Andy Brophy Associate Member, Smith Seckman Reid, Spring Hill, TN
This case study describes how various combinations of window area and window thermal performance were analyzed for a typical patient room of a hospital in upstate New York with the goals of optimizing energy performance, eliminating a perimeter heating system, and maintaining adequate thermal comfort. This analysis was conducted in accordance with the requirements of ASHRAE Standard 209, Modeling Cycle #6 – Integration and Optimization.

5. Innovative Graphical Presentations of Early Design Simulation Results
Alejandra Menchaca, Resource Refocus LLC, Menlo Park, CA
ASHRAE Standard 209 encourages the use of simulation early in the design phase. Graphical representation can improve communication of those results to building design teams. This presentation covers innovative examples of graphical presentations that represent results of Standard 209 modeling cycles. The presenter also introduces an online archive of examples developed to support the Standard.
Filtration for Improved Air Quality

Track: HVAC&R Systems and Equipment
Room: 371CF

Chair: John Dunlap, P.E., Dunlap & Partners, Richmond, VA

Increasing filtration for improved air quality while maintaining efficiency is a challenging task. This session explores filtration methods to improve air quality, while also looking at the effect of increased filtration on efficiency. The presentations consider pressure drops, air resistance and monitoring on air quality as well.

1. Comparison of Air Resistance Between Electrospun Nanofiber Filters and Conventional Filters (HO-18-C010)
Chun Chen, Ph.D., Associate Member, Tongling Xia, Student Member, The Chinese University of Hong Kong, Hong Kong

To reduce the fan energy consumption in the filtration units of HVAC systems, it is worthwhile to develop air filters with low air resistance. Nanofiber filters, typically fabricated using the electrospinning technique, have shown a great potential to achieve high particle removal efficiency with relatively low air resistance because of the gas slip effect. This presentation aims systematically compare the air resistance between electrospun nanofiber filters and conventional filters.

2. Particulate Matter Emission Rates from Common Scent Sources (HO-18-C011)
Ernesto Diaz Lozano Patino, Alireza Mahdavi, Student Member, Jeffrey Siegel, Ph.D., University of Toronto, Toronto, ON, Canada

This presentation measures particle emission (PM) rates from three common sources of scents indoors: burning incense (a combustion based method to produce scents), operating a wax warmer (a heat based method, akin to a flameless candle) and operating an ultrasonic oil diffuser (a mechanical device that uses ultrasonic vibrations to vaporize an emulsion of water and essential oil). Results found that incense resulted in the largest PM emissions, followed by the oil diffuser and the wax warmer. The paper also estimates the clean air delivery rate (CADR) of a portable air cleaner operating in the presence of these sources.

3. In-Situ Integrated Filter Efficiency Measurement (HO-18-C012)
Masih Alavy, Student Member, Alireza Mahdavi, Student Member, Jeffrey Siegel, Ph.D., Tianyuan Li, Student Member, Fellow ASHRAE, University of Toronto, Toronto, ON, Canada

A vital step towards understanding the overall performance of residential HVAC filters is measurement of their long-term in-situ efficiency. This paper introduces a novel method to measure the integrated in-situ efficiency of residential filters over their lifetime. The paper performs yearlong measurements in 6 single-family residential houses in Toronto, Canada. To validate this efficiency measurement method, the results were compared with a short-term in-situ mass-based PM10 efficiency measurement of the same filters in the same systems. Overall, the results suggest that this new long-term method is a good overall assessment of total efficiency that provides information distinct from other efficiency measurement approaches.

Defeng Qian, Student Member, Zheng O'Neill, Ph.D., P.E., Zhihong Pang, Student Member, University of Alabama, Tuscaloosa, AL

The presentation covers the performance test of some low-cost PM sensors in realistic indoor environmental settings. The setup of the test is introduced, including the low-cost sensor type, the range of measurement, sampling rate, environmental chamber setup, etc. In addition, the compatibility of low-cost PM sensor with building automation system is investigated.
Thermal Comfort in Buildings Around the World: Case Study Analysis and Control Approach

Track: HVAC&R Analytics

Room: 370CF

Chair: Marilyn Listvan, Ph.D, Listvan & Assoc., Edina, MN

This presentation looks at building energy modeling, performance, consumption and thermal comfort and the relation to system performance or lack thereof.

1. Application of Mobile-Internet-Based Occupancy Data in Building Energy Model Calibration: A Case Study (HO-18-C014)

Zhihong Pang1, Student Member. Peng Xu2, Ph.D., P.E., Member, Zheng O'Neill1, Ph.D., P.E., Member, (1) The University of Alabama, Tuscaloosa, AL., (2) Tongji University, Shanghai, China

High-quality occupancy data has a big impact on the performance of building energy model. However, traditional approaches to obtain such data tend to require implementations of large-scale sensors network or sophisticated and time-consuming computational algorithms. Compared with traditional ways, mobile-internet based occupancy data has advantages of precisely monitored, real-time updated, and easily accessible without any additional cost. This paper investigates whether and how mobile-internet positioning data can help improve the building model accuracy and simplify the calibration process.

2. Results From a Case Study: Fault-Detection in Air Handling Units in Commercial Buildings (HO-18-C015)

Suhrid Deshmukh, Student Member. Leon Glicksman, Fellow ASHRAE, Leslie Norford, MIT, Cambridge, MA

This paper explores the working of the air handling unit and the optimal amount of energy that the air-handling unit should consume in a normal operation. The paper introduces non-intrusive algorithms that can be used to detect a faulty operation in an air handling unit. Results from a real academic building in Boston are studied and analyzed. One of the most common faults that occurs in an air handler is simultaneous heating and cooling. Algorithms are developed to detect such faults in the summer and winter season.


Hamidrea Hasani Balyani1, Student Member, Ali Sohani2, Hoseyn Sayyaadi2, Ph.D., Member, Valeriy Maisotsenko3, Ph.D., Member, (1) University of Wisconsin Milwaukee, Milwaukee, WI, (2) KN Toosi University of Technology, Tehran, Iran, (3) Colorado Corp and Idalex Inc, Arvada, CO

This presentation discusses the different types of evaporative media used to analyse the performance of a direct evaporative cooling system. It also explains the experimental layout with effective parameters. Finally, the experimental results are presented.


Bharath Seshadri1, Adam Martin Rysanek2, Ph.D., Arno Schlueter1, Ph.D., (1) ETH Zurich, Zurich, Switzerland (2) University of British Columbia, Vancouver, Canada

This paper discusses the results of the 3 for 2 Beyond Efficiency research project in Singapore. The project established the region’s lowest energy consuming office space with a total base cooling load of 70 W/sqm and an overall annual energy efficiency index of 65 kWh/sqm/yr. Adding to the existing de-coupled air-conditioning system, a prototype modular low-lift chiller was integrated to provide high-temperature chilled water (17 to 18 OC) to the radiant cooling units.
Monday, June 25, 8:00 a.m. - 9:30 a.m.

Seminar 23 (Intermediate)

Faster, Cheaper, More Accessible: The Latest Research in Airflow and Thermal Modeling of Indoor Environments

Track: Research Summit

Room: 371DE


Chair: James VanGilder, P. E., Schneider Electric, Andover, MA

• Explain how proper orthogonal decomposition can be a valuable tool for predicting overall data center power consumption

• Identify the major advantages of In Situ Adaptive Tabulation (ISAT) over conventional reduced order models

• Explain what is meant by “Fast Fluid Dynamics”

• Explain the impact and role of time steps with the semi-Lagrangian method

While traditional CFD has proven its value, its relatively high cost and user-skill requirements coupled with its long solution times have driven the research community to develop lighter alternatives. This session highlights impressive recent advances in reduced order modeling across a wide range of approaches and applications. Application areas span data centers and general building environments while modeling techniques include Proper Orthogonal Decomposition (POD), In Situ Adaptive Tabulation (ISAT), and Fast Fluid Dynamics (FFD).

1. Use of Proper Orthogonal Decomposition to Study Data Center Thermally: Aware, Energy-Based Load Placement

Dustin Demetriou, IBM, Poughkeepsie, NY

POD represents a solution by its most “energetic” characteristics. In data centers, these include CRAH airflow and supply temperature, IT power and workload placement. This seminar describes a methodology to study thermally aware, energy-based (TEV) load placement to derive physics-based heuristics for the implementation of load placement in data centers. The goal is to find the combination of parameters that will minimize the total data center power consumption, without violating the server maximum temperature constraint. POD is used in a detailed hour-by-hour simulation tool to show how, using TEV, the cooling power can be reduced by 5.5% - 35.7%.

2. A Fast and Self-Learning Reduced Order Model for Indoor Airflow Simulation

Wangda Zuo, University of Colorado Boulder, Boulder, CO

Reduced order models trained by pre-computed computational fluid dynamics results are fast, but their predictions may be inaccurate when applied for conditions outside the training domain. To overcome this limitation, a fast and self-learning model based on an in situ adaptive tabulation (ISAT) algorithm, which is trained by a fast fluid dynamics (FFD) model as an example, is proposed. This presentation introduces our ISAT-FFD model and demonstrates its applications.

3. Adaptive Coarse-Grid Generation Methods Used in Simulating Indoor Airflow by Fast Fluid Dynamics

Qingyan Chen, Fellow ASHRAE, Purdue University, West Lafayette, IN

The control of indoor air quality and thermal comfort requires faster-than-real-time simulations of air distribution. This study develops two adaptive coarse grid generation methods by analyzing the grid-related truncation errors in the solution of the Navier-Stokes equations by Fast Fluid Dynamics (FFD). By using them to simulate three typical indoor air flows, the results show that the coarse grid generated by the methods can accelerate the FFD simulation significantly with similar computational accuracy.
4. Adaptive-Time Step and High-Order Fast Fluid Dynamics for Building Airflow Modeling
Liangzhu (Leon) Wang, Member, Concordia University, Montreal, QC, Canada

Recent years of developing fast and accurate building airflow modeling have achieved major progress, especially using semi-Lagrangian method of treating airflow advections. The semi-Lagrangian method makes it possible to utilize parallel computing, such as GPUs. Recently, new algorithms of semi-Lagrangian methods have been developed, including adaptive time steps, artificial compressibility and coupled with large eddy simulations etc. This presentation demonstrates these new perspectives, algorithms and applications with huge potentials to real applications of building airflow simulations, especially when compared to commercial software packages.

Monday, June 26, 8:00 a.m. - 9:30 a.m.
Seminar 24 (Intermediate)

How to Hit the Bulls-EUI: Setting Targets, Using Tools and Outcome-Based Compliance
Track: Fundamentals and Applications
Room: 370ABDE

Sponsor: 7.6 - Building Energy Performance

Chair: David Stewart Eldridge, P.E., Grumman/Batkus Associates, Evanston, IL

• Identify publicly available whole building energy performance datasets
• Identify and discuss some of the reasons why actual building energy performance can differ from simulation models
• Understand how whole building energy performance can influence building codes and beyond-code programs
• Identify challenges and opportunities related to an increased focus on whole building energy performance in building design and operation

Are energy standards and guidelines in the building sector staying on-track for the Architecture 2030 goal of achieving net zero energy buildings by 2030? This session covers the various data sources available for whole building energy performance and how they are interrelated. These data sources fall into two distinct categories: design-based models and metered operational performance data. A significant gap still exists between how buildings are designed to perform and how they actually perform in operation. The industry is aware that this performance gap exists but is it willing and equipped to deal with the implications?

Scott West, Member, HFA, Fort Worth, TX

Are energy standards and guidelines in the building sector staying on-track for the Architecture 2030 goal of achieving net zero energy buildings by 2030? This session covers the various data sources available for whole building energy performance and how they are interrelated. These data sources fall into two distinct categories: design-based models and metered operational performance data. A significant gap still exists between how buildings are designed to perform and how they actually perform in operation. The industry is aware that this performance gap exists but is it willing and equipped to deal with the implications?

2. On-Site and Off-Site Renewable Energy for Zero-Net-Energy Buildings
Charles Eley, Member, Eley Associates, San Francisco, CA

Movement toward zero-net-energy (ZNE) buildings is the adopted policy of ASHRAE, AIA and a number of other organizations. This presentation documents that commercial, institutional and mid- to high-rise residential buildings can be designed to achieve exceptional energy efficiency. The majority of such energy efficient buildings can achieve ZNE by installing on-site photovoltaic systems on the roof or building grounds. However, energy intensive buildings and mid- to high-rise buildings will need to also procure off-site renewable energy and these options are discussed and contrasted to on-site renewable energy.
3. Can Codes Deliver EUI Outcomes?

**Jim Edelson, Member**, New Building Institute, Vancouver, WA

Broad policy goals have set aggressive targets for building energy performance improvement. As energy codes increase in stringency, the percentage gap between regulated energy use and total energy use continues to increase. Some codes and jurisdictions are exploring building requirements focused on total building energy use (EUI) limits. While this opens up opportunities for more complete consideration of building energy use, significant regulatory and technical challenges remain. This presentation explores and describes the code and regulatory language approaches being developed to deploy outcome-based performance standards and the technical and implementation challenges inherent in this approach.

Monday, June 25, 8:00 a.m. - 9:30 a.m.

**Seminar 25 (Intermediate)**

**Modeling Durable Residential Buildings in Hot and Humid Climates and Their Impact to HVAC Systems**

**Track:** Residential Modern Buildings in Hot and Humid Climates

**Room:** 371AB

**Sponsor:** 4.4 - Building Materials and Building Envelope Performance

**Chair:** Paulo Cesar Tabares-Velasco, Ph.D., Colorado School of Mines, Golden, CO

- Describe the limitations of building energy simulations models for durable design
- Provide an overview of how a rule-based expert system can be used to offer expert guidance for building moisture safe walls
- Identify potential risks that systems can impose upon building envelope systems
- Understand different methods of considering moisture in building simulations and when to use each method

Building envelope plays an important role in the overall performance of buildings. Design of building envelope is critical and requires not only building energy simulations but also hygrothermal modeling. This seminar presents fundamentals and successful application of hygrothermal and building energy modeling for durable residential buildings in hot and humid climates:

1. **Modeling Moisture Buffering in Building Energy Simulations**

**Jason Woods, Member**, National Renewable Energy Laboratory, Golden, CO

Building materials adsorb and desorb moisture from the air, which has a significant impact on the indoor humidity. Building energy simulations need to model this buffering effect to accurately predict humidity and comfort. This presentation discusses a two-layer effective moisture penetration depth (EMPD) model. Field data from multiple single-family houses are used to estimate model inputs and validate the model. This two-layer EMPD model can be used to understand potential humidity problems for efficient houses, where sensible loads have been reduced but latent loads remain constant. The predicted effect of moisture buffering on these ‘low-load’ homes in hot-humid climates is discussed.

2. **Residential Whole Building Energy and Moisture Modeling for Integral Building Design for Hot and Humid Weather**

**Florian Antretter, Member**, Fraunhofer-Institut für Bauphysik, Munich, Germany

This presentation highlights the differences between regular building energy simulation and hygrothermal whole building simulation. Based on application examples the impact of moisture on building energy demand and durability of the envelope including the implications on the HVAC system are explained. The presentation explains successful modeling strategies to design healthy and durable residential buildings in hot and humid weather by utilizing hygrothermal whole building simulation.
3. What is Behind the Building Science Advisor?

Philip R Boudreaux, Associate Member, Oak Ridge National Laboratory, Oak Ridge, TN

The Building Science Advisor is a web tool that guides designers in building energy efficient walls that are also moisture durable. This presentation goes behind the user interface to see how the advisor incorporates a rule-based expert system, moisture durability judgement from experts and probabilistic hygrothermal simulation results to offer guidance in keeping walls moisture safe.

4. Modeling of HVAC Systems Interactions with the Building Envelope

Peter Adams, Morrison Hershfield Ltd, Toronto, ON, Canada

A building’s HVAC system and building envelope are intimately linked. Many envelope systems used for new construction and retrofit have poor thermal performance characteristics which can impose unexpected limitations on interior environmental set points and thermal comfort. Climate and indoor air moisture conditions can create high risks for building systems. Early collaboration between HVAC and envelope designers will enable the selection of systems and operational requirements that can mitigate problems, improve durability and ultimately result in a better performing new or retrofitted building.

Monday, June 24, 8:00 a.m. - 9:30 a.m.
Seminar 26 (Basic)

Reanalysis Data: How Good is It, How Do We Get It and How Useful is It?

Track: Fundamentals and Applications
Room: 372AD
Sponsor: 4.2 - Climatic Information
Chair: Juan Carlos Baltazar, Texas University, TX

• Introduce the concept of atmospheric climate reanalysis products for use in ASHRAE applications
• Explain reanalysis-derived climatic design condition parameters from a GIS-based web server
• Develop a basic understanding of climate reanalysis, and why it may or may not converge with ASHRAE's needs in weather data
• Develop a qualitative understanding and general quantitative awareness of how well does reanalysis data match observational data

This seminar describes to the ASHRAE community how good the reanalysis data is, how they can get reanalysis-derived climatic design parameters, and how useful is it in building energy simulations. The seminar presents background information on two reanalysis data sets, the NASA MERRA-2 and NOAA CFSR, along with some validation against surface stations. It also demonstrates how reanalysis-derived climatic design condition parameters can be downloaded via a GIS-based web server. Results from building energy simulations with reanalysis data as the input data is also discussed.

1. Introduction to Climate Reanalysis for Use in ASHRAE Applications

Michael Roth, Klimaat, Guelph, ON, Canada

Reanalysis data combines a numerical weather prediction model with historical station, ship, buoy and satellite observations to produce a complete and consistent hourly picture of the entire atmosphere over multiple decades. This presentation provides some background on several reanalysis data sets (NOAA's CFSv2 and NASA's MERRA-2) and summarizes some early results from ASHRAE 1745-RP, "Evaluation of Climate Reanalysis Products for use in ASHRAE Applications".
2. ASHRAE Climatic Design Parameters Derived from Reanalysis Data and Delivered Via a GIS-Enabled Web Portal

David John Westberg, Member, SSAI / NASA Langley Research Center, Hampton, VA

This presentation provides a few validation examples, demonstration of the website accessibility of, and case study using the NASA’s ½ x ½ degree resolution MERRA-2 (Modern Era Retrospective-analysis for Research and Applications) Reanalysis Data. The NASA Prediction of Worldwide Energy Resources (POWER) team at the NASA LaRC Research Center has deployed its first version of the revitalized POWER geophysical parameter website that employs Esri Geographic Information System (GIS) tools. The new capabilities of this new NASA POWERNext website provide access to MERRA-2 derived ASHRAE climatic parameters such as HDD, CDD, CZ, and Climatic Design Conditions.


Drury Crawley, Fellow ASHRAE, Bentley Systems, Inc., Washington, D.C.

While satellite data covering the planet means that it will be much easier to find weather data for any location, it is important to understand the impacts of these data on building energy performance. This presentation presents a comparison of building energy performance calculated using typical year data based on weather stations against the data obtained through NASA MERRA-2 reanalysis data.

4. Comparison of Reanalysis to Observational Weather Data in Different Climates and an Analysis of Their Impact on Building Load Calculations and Energy Simulations

Yu Joe Huang, White Box Technologies, Moraga, CA

Climate reanalysis data has the appeal of providing weather data for any location and time-period in the world. However, many issues remain as to the resolution and accuracy of reanalysis data, especially for ASHRAE’s purposes that are focused almost entirely at surface conditions in urban locations. The bottom line is what are the benefits of reanalysis data as compared to the observational data that has served the ASHRAE community to date. This presentation compares reanalysis to observational data for several locations around the world with contrasting climates and availability of observational data.

Monday, June 25, 8:00 a.m. - 9:30 a.m.

Seminar 27 (Intermediate)

Supermarket Refrigeration System Diagnostics: Opportunities and State of the Art

Track: Research Summit

Room: 372BE

Sponsors: 7.5 - Smart Building Systems and 10.7 - Commercial Food and Beverage Refrigeration Equipment

Chair: David Yuill, Ph.D., P.E., University of Nebraska - Lincoln, Omaha, NE

• Describe the operational demands of supermarkets potentially addressed by fault detection and diagnostics
• Define the key components most common supermarket controls architectures and instrumentation available to support FDD
• Understand existing Fault Detection and Diagnostics (FDD) methods applicable to supermarket systems
• Explain the typical operational characteristics of a supermarket and how the onsite controls can be combined with a cloud based analysis system to deliver energy and maintenance savings

Supermarket refrigeration systems are large and complex, energy intensive and they are typically custom designed and field constructed. For these reasons, they can experience a significant number of operating faults that can significantly increase operating costs, making them an excellent candidate for fault detection and diagnostic (FDD) systems. This seminar describes the challenges of constructing and operating refrigeration systems, common faults and opportunities for using FDD. The results of the recently-completed RP-1615, which examined FDD for supermarkets will be presented along with insights from equipment manufacturers.
1. Delivering Supermarket Energy and Maintenance Savings Utilizing Fault Detection and Diagnostic, Controls and Cloud-Based Analytics

**John Wallace, Member, Emerson Commercial & Residential Solutions, Kennesaw, GA**

Supermarket operators face competing priorities (regulatory compliance, keeping food safe, new forms of competition) and relatively thin (typically mid-single digits) operating margins. Managers are being asked to do more with less, including dealing with a lack of skilled technicians (which is a general problem in the industry). Advanced fault detection systems, when combined with analytics and action oriented dashboards can help these managers pinpoint operational issues and optimize their operations, lowering their maintenance and energy costs. This presentation examines real world metrics which will illustrate the operational challenges operators face and how they can be addressed utilizing FDD with other technologies.

2. Opportunities for Fault Detection and Diagnostic in Supermarket Refrigeration

**Jon Douglas, Member, Lennox Industries, Carrollton, TX**

Supermarket operators would greatly benefit from the application of FDD to their refrigeration systems, yet FDD systems are rare. This seminar illustrates that supermarket systems are fertile ground for FDD development as they currently have the infrastructure necessary to support FDD. An introduction to supermarket system design, controls architecture and operation are presented to demonstrate the FDD support infrastructure.

3. Fault Detection and Diagnostic (FDD) Methods for Supermarkets (RP-1615)

**Alireza Behfar, Student Member, University of Nebraska – Lincoln-Omaha, NE**

Supermarket systems can undergo various operating faults that may cause energy waste, equipment damage and risk of food waste. Several Fault Detection and Diagnostic (FDD) methods have been developed and tested, as described in the literature and patents and showed great potential to provide an early warning of a fault. This describes some methods, tests of the methods using real-world data, and insights into the potential and the requirements for FDD application in these systems.

**Monday, June 25, 8:00 a.m. - 9:30 a.m.**

**Seminar 28 (Intermediate)**

**Using District Energy to Survive a Storm: Case Studies in Disaster Preparedness**

Track: Safeguarding Your HVAC&R System

Room: 372CF

**Sponsors:** 6.2 - District Energy, 1.10 - Cogeneration Systems and TC8.3 and TC6.9

**Chair: Tim M. Anderson, P.E., Applied Engineering Services, Inc, Indianapolis, IN**

- Recognize key hazards to identify for each type of natural disaster; such as hurricane, tornado or other wind event
- Identify actions taken to keep an operation running through a disaster such as flood walls and closing flood doors in time
- Identify capital investments that have been made by others to improve their chances of surviving a rain or wind event
- Understand how Microgrid and district heating/cooling systems can help mitigate dependency on area infrastructure to maintain operations during a natural disaster

As catastrophic events, such as earthquakes, forest fires, mud slides, hurricanes, tornados, high density rainfall and flooding tend to re-occur in specific geographic areas, the damage that is caused must be evaluated with the idea of mitigation of damage and loss, while making the facility more resilient and hardened to those effects can be addressed. This seminar examines the costs and benefits of “getting into catastrophic disaster planning and mitigation” using experiences from institutions in the south Texas area and incorporates the lessons learned by three area facilities that have dealt with recent natural disasters.
1. Dealing with Hurricane Harvey Using the Resiliency of the District Energy System

Bruce Flaniken, Fellow Life Member, Methodist Hospital, Houston, TX

Catastrophic events, such as earthquakes, forest fires, mud slides, hurricanes, tornados, and high density rainfall and flooding tend to re-occur in specific geographic areas on a regular basis. The damage that is caused must be evaluated with the idea of mitigation of damage and loss, while making the facility more resilient and hardened to those effects. This presentation examines the costs and benefits of “getting into catastrophic disaster planning and mitigation” using a case study approach and incorporates the lessons learned from a decade of surviving recurring catastrophic events with Best Practices Engineering to harden a site and make it more resilient to damage.

2. Wading Through Harvey at Houston Airports

Eren Selcen, Member, Houston Airport System, Houston, TX

During Hurricane Harvey, the Houston Airport System (HAS) went into “emergency mode” to ensure the safety and security of passengers and employees as well as maintain the airport’s infrastructure. The airport’s emergency operations center (EOC) was activated and staffed with essential Tier 1 employees. All flights were cancelled in and out of the airport and the roadways surrounding the airports were not passable due to water accumulation and ponding. HAS’ Central Utility Plant at William P. Hobby Airport and hybrid Central Utility Plant at George Bush Intercontinental which has both electric and steam turbine chillers was able to handle Harvey without any issues.

3. University of Texas at Austin: Disaster Preparedness using a Microgrid with CHP and District Energy

Juan Ontiveros, University of Texas, Austin, TX

The University of Texas at Austin has been operating a microgrid since 1929 that has had to evolve into the largest university utility in the United States. This presentation demonstrates how this energy system is operated/ has operated to protect the campus and experience just five campus wide power outages in 54 years using efficiency, technology and off the shelf systems to finance $250 million in improvements by being revenue neutral and carbon neutral to space growth since 1997. In addition, fuel and emissions have achieved 1976 levels though nine million GSF have been added to the campus.

Monday, June 25, 9:45 a.m. - 10:45 a.m.

Conference Paper Session 6 (Intermediate)

Effective Ways to Address Thermal Comfort and Cooling Load

Track: Fundamentals and Applications

Room: 371DE

Chair: Ratnesh Tiwari, Ph.D, University of Maryland, Hyattsville, MD

Engineers are always looking to find new ways to increase thermal comfort and decrease energy load. In recent years, new management systems, sensors and individual controls have been employed to that end. This session explores additional measures that can be taken to increase thermal comfort and reduce cooling load.


Niraj Kunwar, Student Member, Kristen Cetin, Ph.D., P.E., Ulrike Passe, Associate Member, Iowa State University, Ames, IA

The presentation covers the full-scale implementation and testing of fully-automated dynamic shading control strategies as a part of ASHRAE RP-1710, specifically focused on interior venetian blinds. The setup used for the shading devices and logic for the control strategies is discussed. The impact of the shading and lighting control strategy on overall energy demand based on sub-metered energy consumption measurement is also discussed. Finally, annual energy saving potential of the shading device and lighting control strategies using calibrated simulation is presented.

Rebecca Yang, W. M. Pabasara Upalakshi Wijeratne, RMIT University, Melbourne, VIC, Australia

Australia has excellent solar resources in terms of both land mass and solar exposure, with the highest solar radiation per square meter of any continent. There are number of professional PV design and management systems on the market which aim to address some, if not all, consideration of design and development of a PV project. This paper conducts an extensive market study and comparison of the available PV design and management systems to identify the gaps in the current PV system design in relation to its effect on building cooling load.

3. Use of Optical Distributed Sensors for Spatial Temperature Measurements in HVAC&R Research (HO-18-C020)

Brian M Fronk, Gregory DuChane, Member, Tabeel A Jacob, Student Member, Oregon State University, Corvallis, OR

This paper summarizes the principles of operation of a distributed temperature measurement systems using fiber optics and variable frequency laser and a coherent optical frequency domain reflectometer. The paper presents experimental results characterizing temperature distributions in a single phase, tube-in-tube heat exchanger. These measurements are confirmed with conventional RTD measurements co-located within the test section. Demonstration of the viability of this technique for HVAC&R related work opens up the possibility of understanding temperature distributions in air flow, temperature glides of zeotropic mixtures, coil tube surface measurement and other applications of interest to ASHRAE.

Monday, June 25, 9:45 a.m. - 10:45 a.m.

Conference Paper Session 7 (Intermediate)

HVAC Ventilation Control for Maximum Efficiency and Comfort

Track: HVAC&R Analytics

Room: 371CF

Chair: Samir Traboulsi, Ph.D, P.E., Thermotrade/Ranec, Beirut, Lebanon

This session looks at occupancy demand strategy and flow rates to determine best practices for balancing comfort and efficiency.

1. Testing Occupancy-Driven Controls to Reduce Energy Consumption of a VAV System (HO-18-C021)

Joel Dickie, Student Member, Liping Wang, University of Wyoming, Laramie, WY

This presentation showcases occupancy information gathered from multiple sensors to control a VAV system and the energy consumption reduction possible when using this information to control a VAV system. An occupancy agent describing occupant behaviors was created based on the occupancy data gathered, and an agent for the VAV system was also created. Using multi-agent controls, the VAV system is controlled optimally and the energy consumption is evaluated. The results from this study specify how justifiable implementing an accurate occupancy determination network to control a VAV system is and how justifiable creating a multi-agent control scheme is.

2. Data Driven Ventilation Reset Control for Educational Institutions (HO-18-C022) *WITHDRAWN*

Lourdes Marozas-Aliaga, Roger Chen, Ph.D., Thomas Trabold, Rochester Institute of Technology, Rochester, New York

ASHRAE Standard 62.1 allows to reset the outdoor air intake flow and the ventilation zone airflow as operating conditions change. There are technologies available to count occupancy, however, before investing in new systems, what if we use data that is already available? Machine learning is the new trend, so in this presentation, with a dataset from 10 campuses in New York State, which spans 892 classrooms, attendees learn the basics of clustering and other statistical methods than can be used to reset the ventilation settings using occupancy patterns. Details of the method, work in R and implementation are presented.
Ulla Haverinen-Shaughnessy, DSc, Tomas Novotny, Samy Clinchard, 720 Degrees Ltd., New York, NY

Knowing the outdoor air ventilation rate of an occupied space is one of the fundamental issues when assessing IAQ and its effects on the occupants' comfort, health and productivity. This study was undertaken to develop a robust approach to estimate ventilation rates based on long-term, continuous, real time CO2 data in an office building. The resulting estimates could be utilized to examine ventilation rates of the monitored rooms on a continuous basis.

Monday, June 26, 9:45 a.m. - 10:45 a.m.
Conference Paper Session 8 (Intermediate)

The "Design Team": How to Improve Design Team Cooperation, Performance, and Effectiveness
Track: Professional Skills
Room: 370CF

Chair: Bass Abushakra, United States Military Academy, West Point, NY

As industry designs become more complex it is necessary for the design team to improve performance through cooperation of multiple disciplines and experience. Experience and education are important. Cooperation brings the team together for high performance and success.

1. The Different Effects of a Morphological Approach on Design Team Cooperation With Students and Professionals (HO-18-C024)
Wim Zeiler, Eindhoven University of Technology, Eindhoven, Netherlands

Integrated design needs methodology especially in the beginning of the process. An approach using morphological overviews was developed and tested with professionals.

2. Forming Design Teams for Improved Performances (HO-18-C025)
Wim Zeiler, Eindhoven University of Technology, Eindhoven, Netherlands

Design teams are essential in the conceptual design phase. Groups can develop themselves in a certain order into a team: forming, storming, norming, performing and adjourning. A method to support this team building process aimed to improve the effectiveness of the conceptual design is presented and evaluated by workshops with students as well as professionals.

Monday, June 25, 9:45 a.m. - 10:45 a.m.
Conference Paper Session 9 (Intermediate)

Thermal Comfort at the Forefront of HVAC Design
Track: HVAC&R Control Freaks
Room: 372AD

Chair: Chris Laughman, Mitsubishi Electric Research Lab, Waltham, MA

From personal controls to new simulation methods, thermal comfort systems have taken the forefront of many design choices. This session looks at recent advancements in thermal comfort systems.
1. PCM Cooling Vests of Different Melting Temperatures in a Two-Bout Strategy to Enhance Comfort and Sensation: An Experimental Study (HO-18-C026)
Mariam Itani¹, Nesreen Ghaddar¹, Ph.D., Kamel Abou Ghali¹, Beatrice Khater¹, M.D., Djamel Ouahrani², Ph.D., (1) American University of Beirut, Beirut, Lebanon, (2) Qatar University, Doha, Qatar
Phase change material (PCM) cooling vests have been shown to reduce heat strain of humans performing many types of activities for a certain duration at different ambient conditions. However, as the environment gets hotter and for prolonged activity durations, the cooling vest performance deteriorates. This necessitates finding new ways to enhance the cooling performance of the cooling vest such as the use of PCM packets with a relatively low melting temperature. Another way could be introducing a two-bout strategy, where two cooling vests of different melting temperatures will be used consecutively to assess human subject perception of it.

Ryozo Ooka¹, Member, Doyun Lee¹, Shintaro Ikeda¹, Wonjun Choi¹, Ph.D., Associate Member, Younghoon Kwak², Ph.D., (1) University of Tokyo, Tokyo, Japan, (2) Kyonggi University, Suwon, South Korea
This presentation gives an example of Model Predictive Control (MPC) implementation to a building HVAC system equipped with an air-source heat pump and thermal energy storage. It is expected that this example will contribute to making standard guidelines for MPC implementation to building energy systems.

Ana Julia Campos Kfouri, Student Member, Cristóvão Vicente Scapulatempo Fernandes, Ph.D., Federal University of Parana, Curitiba, Brazil
This paper performs a thermal analysis at a Brazilian public university in order to address the subjective and physical variables that influence thermal comfort in educational buildings. Regarding the physical variables, air temperature and humidity were measured along with meteorological variables collected from a nearby weather station. Moreover, a computer simulation using the EnergyPlus software to reproduce the same physical variables was conducted. Finally, the software outputs were analyzed and compared with the on-site measurement results to get a conclusion related to the local thermal conditions and its influence in educational buildings.

Monday, June 25, 9:45 a.m. - 10:45 a.m.
Seminar 29 (Intermediate)

Control Freaks and Internet of Things Geeks: The Future of Building Automation
Track: HVAC&R Control Freaks
Room: 371AB
Sponsors: 1.4 - Control Theory and Application and 7.5 - Smart Building Systems
Chair: Joseph Kilcoyne, P.E., SC Engineers, Inc., San Diego, CA
• Explain what IoT can offer to buildings today
• Explain the opportunities and drawbacks of IoT equipment control vs. a local control system
• Explain what a Cognitive solution is, and how it will affect our buildings
• Determine what type of buildings can benefit the most from IoT
Take a crash course on the “Internet of Things” (IoT) and the impact it is making on building automation and beyond. Machine learning, artificial intelligence (AI), cloud analytics and big data are more than just buzzwords. These concepts are changing how we interact with our environment, including the built environment! This presentation highlights emerging technologies in HVAC Control through embedded IoT applications as well as the opportunities that IoT cognitive solutions present to building operators and users. The session explores fundamental topics including ownership of data and the extent of IoT’s role in building automation.

1. IoT is Here: An Internet of Things Readiness Guide
   Tunji Asiwaju, Member, Armstrong Fluid Technology, Toronto, ON, Canada
   What does the Internet of Things (IoT) offer to buildings today? What can it do and what can’t it do? What type of buildings can benefit the most from IoT? What does it take to use it effectively? Is it compatible with BAS or replaces it? Who owns the data produced? This session explores these questions and provides lessons learned from an engineer tasked with developing an IoT service for a major HVAC equipment manufacturer.

2. Big Data and the Cognitive Era: What Does It Mean for Our Buildings?
   Kevin Bailey, IBM, Dublin, Ireland
   Cognitive solutions use the full breadth of IOT data and provide the capability to predict and understand energy flows and building occupancy. Operators can finally start to consider and deliver the comfort preferences of the users and relate to the user within context of the weather, time of day, amongst other aspects – and the real beauty is, the older the cognitive solution gets, the smarter it becomes! This presentation highlights the opportunities that IOT and Cognitive solutions present to building operators and more importantly, building users.

   Monday, June 25, 9:45 a.m. - 10:45 a.m.
   Seminar 30 (Intermediate)

Have We Succeeded in Decoding Low Delta T?

Track: Fundamentals and Applications

Room: 372BE

Sponsors: 6.1 - Hydronic and Steam Equipment and Systems and 6.2 - District Energy

Chair: Rex Scare, P.E., Armstrong International Inc, Three Rivers, MI

• Explain the technologies available and where to apply them
• Define effective remedial methods to improve chilled water delta T
• Understand the common causes of low delta T
• Define how the commissioning manager adds value during the design and commissioning process to improve system efficiency

Several case studies are presented regarding chilled water Delta T improvements from the perspective of a control valve manufacturer, consultant and commissioning agent. The manufacturer discusses typical issues encountered and the different technologies available to improve Delta T. The consultant presents a case study to highlight the techniques used to almost double the system delta T at Los Angeles airport. The commissioning manager presents a project that had a verified energy savings of 1.8 million Kwh and a 6 month payback.

1. Pressure Independent Technology and its Effect on Systems and Energy
   Tricia Bruenn, Member, Belimo Americas, Danbury, CT
   Pressure Independent Valve design and their effect on system design is explained. Answers are provided to the following questions: What is the difference in technologies? What is the effect on system layout? Is there a noticeable effect on the delta T of a system? Finally, do pressure independent valves support or detract from your energy saving goals? A case study of a retro-fit site in Asia is presented where PI valves were used. The process of selection and the effect on the system is also discussed.
A District Cooling Case Study: Chilled Water Delta T Improvement at LAX

Steve Tredinnick, Member, Burns & McDonnell, Downers Grove, IL

The Los Angeles International Airport was expanding and adding a new international terminal. The existing terminals were served by a district energy plant dating back to 1961. The new plant doubles the capacity of the existing plant in order to serve additional growth and increase the operating efficiency. But in order to obtain the nameplate efficiency of the heating cooling system, the operating temperature differential of the terminals had to be increased. This seminar addresses what the original problem was, what was modified and added to the system to double the original operating delta Ts.

3. Retro-Commissioning of Chilled Water System at Northwestern Memorial Hospital

Mark Chmura, Burns & McDonnell, Downers Grove, IL

The steps taken during the retro-commissioning process are discussed in detail. The steps include: Surveying the building equipment to identify energy/cost saving opportunities, provide contractors with a comprehensive scope of work, functionally testing the implemented measures and verifying energy savings after implementation. The controls contractor was provided a new sequence of operation for the entire chiller plant and functional testing of the new sequences was performed after implementation. Water and airside measures included: differential pressure reset, condenser water temperature reset, chiller staging modifications, static pressure reset, economizer optimization, and unoccupied zone volume setback at the VAV box level.

Monday, June 25, 9:45 a.m. - 10:45 a.m.

Seminar 31 (Intermediate)

Leveraging Compressor Methods of Test for Research and Development

Track: Research Summit
Room: 370ABDE

Sponsor: 8.1 - Positive Displacement Compressors
Chair: Craig Robert Bradshaw, Ph.D., Oklahoma State University, Stillwater, OK

• Distinguish between in-system and calorimeter performance measurements

• Describe the operation of a calorimeter with an internal heat exchanger (economizer) and downstream extraction of the injected refrigerant

• Describe the flexibility of the hot-gas bypass load stand design and how it facilitates rapid compressor testing and development

• Understand what factors are critical when evaluating the reliability/endurance and performance of a compressor

This seminar presents the leveraging of standardized/common methods of test as a basis for the development of novel test facilities and advanced methods of test for compressor development. This includes a modification of a compressor calorimeter performance test environment to include economization, which enabled the development of new compressor performance map methods. The hot-gas bypass performance load stand design is improved upon to develop a one-of-a-kind test environment that can test a large variety of light commercial compressors. Finally, a presentation on a spectrum of reliability testing highlights the empirical evidence obtained and leveraged in compressor development activities.

1. Measurements of a Refrigerant Vapor Injected Scroll Compressor Using a Calorimeter

Davide Ziviani, Purdue University, West Lafayette, IN

Economized, refrigerant vapor-injection (VI), vapor compression cycles have been considered promising solutions with scroll compressors for reducing the compressor discharge temperature for systems with large compression ratios. A single-port injection R407C scroll compressor has been tested on a calorimeter including vapor-injection as well as liquid-vapor injection. The instrument measurement accuracies, testing procedures and test results were compliant to the ANSI/ASHRAE Standard 23.1. A methodology for mapping the compressor performance was also developed and compared to the existing AHRI polynomial equations.
2. Development of a Light-Commercial Hot-Gas Bypass Load Stand for Accelerated Compressor Development
Drew Schmidt, Student Member, Oklahoma State University, Stillwater, OK
This presentation describes the design and fabrication of a custom-made hot-gas bypass load stand for the testing of light-commercial compressors. The presentation also describes the unique features of the load stand such as control over vapor/liquid injection, OCR control, and oil-injection and how the features may be leveraged to assist with research and development.

3. Lubricant and Other Studies for Optimized Compressor Reliability and Performance
Joe Karnaz, Member, Shrieve Chemical, Houston, TX
Compressors provide the mechanism for transporting the thermodynamic effects of the refrigerant in an air conditioning and refrigeration system. Changes in compressor design, application of use and especially changes to refrigerants and lubricants require a validation of the compressor reliability and performance. This presentation focuses on both pre and post compressor proof testing for products that are typically mass produced for various residential and commercial refrigeration and air conditioning applications. Methods of test for various compressor mechanisms are described along with understanding other lubricant-refrigerant evaluations that can be done prior to compressor focused testing.

Monday, June 25, 9:45 a.m. - 10:45 a.m.
Seminar 32 (Intermediate)

State of the Art in Moist Air Properties Calculations
Track: Fundamentals and Applications
Room: 372CF
Sponsor: 1.1 - Thermodynamics and Psychrometrics
Chair: Omar Abdelaziz Ahmed Abdelaziz, Ph.D., CLEAT Consulting, Dubai, United Arab Emirates

• Understand the different available methods for calculating thermodynamic properties of moist air
• Identify the differences between the ideal gas model and the real-gas model for evaluation of moist air thermodynamic properties
• Learn the state of the art models for the calculation of the transport properties of the pure components of the mixture moist air, dry air and water
• Explain the differences between the new diagrams for viscosity and thermal conductivity for moist air compared with those from the current ASHRAE Handbook of Fundamentals

Accurate moist air properties calculation is crucial for the HVAC&R industry. This seminar presents newly developed ASHRAE SPC-213P suggested calculations for thermodynamic properties of moist air to further improve the accuracy and the new efforts for accurate transport properties calculations based on the ASHRAE RP-1767. The first presentation provides a summary of the SPC-213P and means to efficiently calculate the thermodynamic properties of moist air. The second presentation provides a summary of the ASHRAE RP-1767 and new accurate moist air transport properties are developed.

1. Overview of SPC213P Equations for Calculating Thermodynamic Properties of Moist Air
Vikrant Aute, Member, University of Maryland, College Park, MD
At present, there is no ASHRAE standard to calculate the thermodynamic properties of moist air. This presentation discusses the new equations proposed in the Standard SPC213P for calculating thermodynamic properties of moist air. The proposed equations are more accurate than the ideal gas model-based equations and yet easy to implement for common applications. The results are compared against those presented in the latest version of the ASHRAE Handbook as well as against the most accurate equations developed as a part of RP1485 research project. The range of applicability of these equations are discussed. This seminar also provides an opportunity for members to provide feedback to SPC213P.
2. Updated Transport Properties of Moist Air
Sebastian Herrmann, Zittau/Goerlitz University, Zittau, Germany

This presentation provides the state of the art calculation method for transport properties of moist air carried out through the ASHRAE Research Project RP-1767. Starting with the recent transport properties research for the two components of moist air, dry air, and water, these results are included in the mixture model for transport properties of the mixture moist air. The results are compared against experimental data used to adjust the mixture model. New tables of transport properties, as well as two new diagrams for viscosity and thermal conductivity for the ASHRAE Handbook of Fundamentals, are presented as a part of the ASHRAE RP-1767 effort.

Monday, June 25, 11:00 a.m. - 12:00 p.m.

Conference Paper Session 10 (Intermediate)

Consumption, Diversity, and Efficiency of Energy Use in Public Communities and the Demand on District Energy Systems

Track: District Energy and Cogeneration Plants

Room: 370CF

Chair: Hyojin Kim, Ph.D, The Catholic University of America, Washington, D.C.

The environmental benefits of district energy provides opportunity for load diversity and requires smart management to insure sustainability and scaling to meet demand. This seminar provides examples from public community, campus and residential district heating and cooling systems.

1. Sustainability and Resilience: Examples of Community and Campus Energy Assessments (HO-18-C029)
Chonghui Liu, P.E., Member, Popli Design Group, Syracuse, NY

In the current utility and facility management landscape, sustainability and resilience goals, rising energy costs and lean O&M budgets present fundamental challenges in the way communities and campuses manage their energy and facility resources. This paper focuses on the assessment of energy efficiency improvements and peak demand mitigation opportunities in a community scale microgrid as well as energy assessments and energy master planning performed on representative campuses (university campuses and an institutional campus) served by district energy plants. Several case studies are presented for large-scale energy assessments that support both community-level and campus-level energy efficiency initiatives.

2. Analysis of Load Diversity in China Residential Districts and Its Influence on District HVAC System Design (HO-18-C030)
Jingjing An, Da Yan, Ph.D., Tsinghua University, Beijing, China

District cooling systems are widely used in urban residential communities in China. Most of such systems are oversized, which leads to low operational efficiency and waste of energy. Accurate understanding of the thermal load demands of building users in a district can support the rightsizing of cooling equipment. This presentation analyzes the thermal load diversity among different households based on real data, and also discusses the smoothing effect on peak load, total thermal consumption and load distribution with the amount of households increasing, and provides a group of fitting formulas which can assist future district HVAC system sizing.

3. Influence of the Rate of Renovation of the Public Communities on the Efficiency of the District Heating Systems (HO-18-C031)
Aleksandrs Zajacs, Anatolijs Borodinecs, Member, Raimonds Bogdanovics, Riga Technical University, Riga, Latvia

Section 431 of EISA 2007 increased the federal energy reduction goal from 2 percent per year to 3 percent per year. In order to predict influence of the future energy efficiency measures on the efficiency of the existing DH systems, district heating planning tool was used for evaluation of the particular DH system. Consistent simulations of the proposed future development scenarios for a particular DH system with different building renovation rates of 3 %, 5 %, and 7 % have shown natural reduction in thermal energy consumption in a 15-year perspective by 13.5 %, 22.5 % and 30 %.
Life Safety System Design

Track: Fundamentals and Applications

Room: 371CF

TC 5.6 – Control of Fire and Smoke

Chair: Paul Turnbull, Siemens Industry, Inc., Buffalo Grove, IL

Design of life safety systems is an important function of engineers to ensure the safety of building occupants during potentially disastrous events. This session explores modeling and design techniques for fire and smoke, life safety systems.

1. CFD Modeling of Flammable Refrigerant Leaks Inside Machine Rooms: Emergency Ventilation Rate for Different Size Chillers (HO-18-C032)

Shiling Zhang, Ph.D., Paul Papas, Larry Burns, Member, Parmesh Verma, Richard Lord, Fellow ASHRAE, United Technologies Research Center, Carrier Corporation, East Hartford, CT

Computational fluid dynamics (CFD) simulations were undertaken to quantify ventilation dilution requirements needed for mitigating flammability risks during leaks of flammable refrigerants from smaller sized chillers inside machine rooms in extension of prior work for sustained leaks from very large chillers. This paper focuses on small chillers and the results were used to establish a relationship for the emergency ventilation rate needed for mitigating risks for major refrigerant leaks inside machine rooms for the full range of refrigerant charge or chiller sizes.


John Klote, Fellow Life Member, John Klote Fire and Smoke Consulting, Leesburg, VA

Door opening forces are very important in smoke control because people cannot escape the threats of fire and smoke when door-opening forces are excessive. In 1981, the equation for calculating the opening force of a hinged door with a door knob in a smoke control system was developed. This equation has been used extensively. Door hardware has changed considerably due to concerns about accessibility. Today, most doors in buildings have lever handles and panic hardware. This paper updates the old equation for today’s hardware. The impact of today’s hardware on design and acceptance testing of smoke control systems are discussed.

3. Design Considerations for Modulating Stair Pressurization Systems (HO-18-C034)

Steven M. Strege, Member, Brandon Charles Ingram, P.E., Jensen Hughes Inc., Baltimore, MD

In high-rise buildings, modulating stair pressurization systems are frequently used in Smokeproof Enclosure designs. This is especially true for stair pressurization involving design doors open. One important design consideration is the time it takes to sense changes in air pressure and then respond with changes in air supply. This paper investigates the potential impact that the opening and closing of stair doors could have on the operation of a modulating stair pressurization system, and suggests potential design features to minimize these effects. Airflow modeling software was utilized to model an example system and characterize its ability to maintain the required pressure range.
Blade vs. Venturi Laboratory Controls: Proper Application and Testing to Safeguard Your Lab

Track: Safeguarding Your HVAC&R System

Room: 370ABDE

Sponsors: 7.7 - Testing and Balancing and 9.10 - Laboratory Systems

Chair: Thomas Schlachter, P.E., Engineered Air Balance Co Inc, Richardson, TX

- Identify standard test procedures when specifying airflow control performance
- Apply performance requirements and component specifications using the client's contamination control objectives
- Design an offset lab control system that tracks airflow of the general lab exhaust with the fume hood exhaust and maintains an offset from the lab supply
- Describe the various field tests required to establish a lab control system is operating properly

Air flow control systems for laboratories apply different types of air valves: venturi style valves and single-blade dampers. This seminar describes the technical characteristics of each. Basic function and operation are discussed, including several fine design details and special features. A test program to qualify and evaluate air flow control systems based on the valves is described. Performance test results are discussed. Measured operating characteristics of the valves and associated control systems are presented to help laboratory HVAC designers select and specify appropriate equipment. Field tests are described that determine if an installed system performs as it should.

1. Fundamental and Sustainable Strategies Using Venturi–Type Air Valves (VAV Terminals) in Lab Applications
   **David Rausch**, Phoenix Controls, Acton, MA
   This presentation reviews the fundamental performance characteristics of a venturi valve, how it works and why it is used in many lab applications today. It explains how venturi support basic design strategies and sustainable strategies used in open lab applications to high density Fume hood controls applications to even Biocontainment applications.

2. Fundamental and Sustainable Strategies Using Blade-Type Air Valves (VAV Terminals) in Lab Applications
   **Paul Fuson**, Siemens Building Technologies, Buffalo Grove, IL
   This presentation reviews the fundamental installation requirements, operating parameters and performance characteristics of a blade type VAV box, how it works and how operation can be verified in the field. It shows how this technology supports basic and complex lab design strategies used in single room and large open lab applications using airflow tracking to maintain a fixed offset.

3. Blade vs. Venturi Laboratory Controls: Proper Application and Testing to Safeguard Your Lab
   **Justin Garner, Member**, Engineered Air Balance Company, Inc., Houston, TX
   The performance characteristics of modern laboratory airflow controls systems are largely proprietary to the individual vendors based upon key design elements of each system. In an attempt to level the playing field and gather data for specifying engineers and owners, a standard test procedure was developed to verify airflow performance and speed of response for a standard laboratory with fume hood face velocity control. Various vendors submitted their products for testing in a controlled, third party environment. The result of this testing is presented with comparisons between performance characteristics of venturi vs. blade valve control.
Monday, June 25, 11:00 a.m. - 12:00 p.m.

Seminar 34 (Advanced)

**Industrial HVAC 101**

Track: Fundamentals and Applications

Room: 372CF

**Sponsor: 1.7 - Business, Management & General Legal Education**

*Chair: Eileen Jenseen, Bonneville Power Administration, Vancouver, WA*

- Provide relevant information for design of heating, ventilation and air conditioning (HVAC) systems that should be followed for all phases of a project to ensure a quality, cost effective, safe and sustainable design

- Provide an up to date design approach to Industrial HVAC engineering and design

- Specify HVAC equipment and components manufactured from materials, or having protective coatings, that minimize life cycle costs over the operating lifetime of the installation

- Implement a basis of design that provides adequate pressurization, outdoor air ventilation, air filtration, heating, cooling, humidification or dehumidification in line with the nominated internal and external conditions

Certain industrial spaces may contain flammable, combustible, and/or toxic concentrations of vapors or dusts under either “Normal or Abnormal” conditions. In spaces such as these, there are life-safety issues that need to be addressed. Special precautions must be taken in accordance with requirements of recognized authorities and authorities having jurisdiction (AHJs). In all situations, engineers, designers, and installers who encounter conflicting codes and standards must defer to the code or standard that best addresses and safeguards life safety.

1. **Industrial HVAC Design and Construction 101**

   **Erich Binder, Member**, Erich Binder Consulting Limited, Calgary, AB, Canada

   This presentation provides the design basics for Industrial HVAC Engineering and Design. Certain industrial spaces may contain flammable, combustible and/or toxic concentrations of vapors or dusts under either “Normal or Abnormal” conditions. In spaces such as these, there are life-safety issues that need to be addressed. Special precautions must be taken in accordance with requirements of recognized authorities and authorities having jurisdiction (AHJs). In all situations, engineers, designers and installers who encounter conflicting codes and standards must defer to the code or standard that best addresses and safeguards life safety.

2. **Industrial Commissioning 101**

   **Michael C. Connor, P.E., Member**, WSP USA, Atlanta, GA

   Industrial processes span a wide set of applications from food and beverage to pharmaceuticals to semiconductor. Most industrial process areas are hazardous by nature and require a different approach to commissioning and start-up than a commercial facility. HVAC systems are often called upon to create safe environments or zones to maintain worker safety from flammable, explosive or poisonous atmospheres. This presentation will focus on the methodology to commission a control system that is tasked with being a safety instrumented system performing a safety control function.
Inverse Design and Modeling for Indoor Environment

Track: Research Summit
Room: 372BE
Sponsor: 4.10 - Indoor Environmental Modeling
Chair: Liangzhu (Leon) Wang, Ph.D., P.E., Concordia University, Montreal, QC, Canada

- Explain concept of inverse modeling and how it is used for built environment design
- Apply principles of CFD-based genetic algorithm and adjoint method for optimizing inverse solutions with real-world examples
- Describe principles of inverse design with reduced-order proper orthogonal decomposition of thermo-flow fields with real examples
- Identify pros and cons of each method and understand the road-map for the method integration

Conventional indoor environmental designs follow a "forward-manner" requiring systematic evaluations of a large number of scenarios and parameters, e.g. supply/return locations, speeds, angles, thermal comfort and airflow distribution, which is often highly time-consuming and inefficient. To significantly shorten design cycles and costs, especially using computational fluid dynamics (CFD) techniques, this seminar introduces three novel inverse design and modeling methods, starting directly from design objectives and inversely seek for the optimal design values by CFD-based genetic algorithm method, CFD-based adjoint method and CFD-based proper orthogonal decomposition method. The methods will be well demonstrated for indoor environment designs of building offices and airliner cabins.

1. Inverse Indoor Environment Designs by CFD-Based Genetic Algorithm Method
Qingyan Chen, Fellow ASHRAE, Purdue University, West Lafayette, IN
Optimizing indoor flow distributions with specific design goals requires systematic evaluation and prediction of the influences of critical flow control conditions such as flow inlet temperature and velocity. In order to identify optimal flow control conditions, the conventional approach simulates a large number of flow scenarios with different boundary conditions for comparison. This presentation introduces a method that combines the genetic algorithm (GA) with computational fluid dynamics (CFD) technique, which can efficiently predict and optimize the flow boundary conditions with various objective functions.

2. Inverse Indoor Environment Designs by CFD-Based Adjoint Method
Qingyan Chen, Fellow ASHRAE, Purdue University, West Lafayette, IN
This presentation demonstrates the use of a CFD-based adjoint method to inversely design an indoor environment by identifying optimal designs that satisfy the objectives, including inlet location and size, supply temperature and velocity. This study implemented the method in OpenFOAM and validated it for achieving the measured air velocity and temperature in an indoor environment. It shows that the computing costs did not depend on the number of design variables. For practical demonstrations, real designs of the desirable thermal environments in an office and a single-aisle airliner cabin are introduced to find the optimal design values for air supply inlet location, inlet size, temperature and velocity.

3. Inverse Indoor Environment Designs by CFD-Based Proper Orthogonal Decomposition Method
Tengfei (Tim) Zhang, Dalian University Of Technology, Dalian, China
To speed up an inverse design, an efficient solution to the CFD equations for indoor environmental performance is needed. Proper orthogonal decomposition (POD) of the thermo-flows is a way to meet this need. POD extracted the coherent structures of the thermo-flows into POD modes, providing a lower-order description of the thermo-flow fields by linear combinations of a small number of POD modes. This presentation introduces the basic principles of the POD-based approach for proper design of indoor environments. The method first sampled representative thermo-flows with full CFD simulations, and then the POD modes and their coefficients were extracted.
Let's Optimize the Usability of Building Automation Systems
Track: HVAC&R Control Freaks
Room: 371AB

Sponsor: 7.6 - Building Energy Performance
Chair: Wade H. Conlan, P.E., Hanson Professional Services, Maitland, FL

- Learn how to include energy management into BAS graphics
- Learn how to optimize the BAS GUI to improve O&M response capabilities
- Learn how to plan BAS installations in a large campus application
- Learn how to configure the BAS for advanced Fault Detection and Diagnostic Analytic analysis

There are numerous opportunities to improve upon the standard approach to BAS graphics and configuration of the data. Optimizing the GUI through the lens of O&M staff, energy managers and even commissioning agents could greatly impact O&M costs and energy costs. This session focuses on simple tweaks to the graphics that completely change the way we look at and use the BAS. This session will also focus on planning the BAS installations in individual buildings that are part of a large campus, to attempt to standardize and avoid a controls catastrophe.

1. Let's Optimize Your BAS GUI for Operation and Maintenance Management Savings
Nate Boyd, Member, Hanson Professional Services Inc., Maitland, FL

Let's be honest, most BAS graphics are set up to match the design control schematics, with little else. Sure, that conveys some important details, but leaves a lot to be desired. Nearly all control front ends are now web-based, but we're not treating these graphics like web pages. Why is that? These graphics could do so much more, like document management of as-builds, equipment nameplate information and energy management calculations. Shall we also digress and talk about optimizing these graphics for Cx functional testing?

2. Standardization and Managing Building Automation for Large Campuses
Alex Parlato, Member, University of Central Florida, Orlando, FL

A single building controls system implemented in "any which way" is not the end of the world. Technicians can familiarize themselves with that way of doing things. Now if you have many buildings and the controls systems are implemented in "any which way," you have a catastrophe. Campus controls managers need to take standardization seriously and the larger the campus the more impact it makes, especially with advancing technology. Standardization of naming, addressing, alarming, trending, visualization and analytics are going to make or break the success of the operations team of a large campus. This presentation explains what to do in those situations.

Selection and Application Considerations of Fans Used in Variable Air Volume Systems
Track: HVAC&R Systems and Equipment
Room: 371DE

Sponsors: 5.1 - Fans and 5.9 - Enclosed Vehicular Facilities
Chair: Walter Mecozzi, P.E., ClimateCraft, Inc, Edmond, OK
• Use a fan curve and draw a properly configured VAV system curve to determine the minimum speed and flow a VAV system

• Evaluate FEG and FEI metrics and how they enhance or limit the part load efficiency capabilities of a fan system

• Use VAV system characteristics to estimate system efficiency and power at full- and part-load

• Understand the impacts of fan system air leakage on energy performance

Variable air volume (VAV) systems are commonly used in commercial buildings to provide zone temperature control and ventilation to multiple spaces in the building. This seminar discusses the types of fans used and the best methods to specify and select the fans for a VAV system. It also discusses the effects of duct static pressure control and system air leakage on energy consumption and the importance of TAB/commissioning to achieve maximum system efficiency as the load on the building varies.

1. Selection Considerations for Fans Used in Variable Air Volume Systems

Mark W Fly, P.E., Fellow ASHRAE, AAON, Inc., Tulsa, OK

Successful design of variable air volume (VAV) system that utilizes multiple VAV control boxes requires a detailed understating on how these boxes ductwork and other components effect the fan system curve. When selecting fans for these systems, the peak point operation selection point on the fan curve directly effects how slow the fan speed can be turned down before the fan operating point becomes unstable. Selecting the fan so that the full load condition coincides with the peak efficiency on the fan curve can limit the available air flow turn down before the fan becomes unstable and may limit part load efficiency gains.


Craig Wray, P.Eng, Member, Retired, Winnipeg, MB, Canada

Commonly used “system curves” ignore effects of duct static pressure control and linear-like pressure drop characteristics of filters and coils. Ignoring these effects can lead to large errors in fan energy use estimates. Assuming constant component efficiencies (i.e., for the fan, belt, motor and drive) and ignoring air leakage can lead to substantial additional errors. This seminar describes operating characteristics of system components, and how to use them to estimate system energy performance at part load. It then presents opportunities to detect system deficiencies using TAB and commissioning, with a focus on using ASHRAE Standard 215 to assess system leakage.

Monday, June 25, 11:00 a.m. – 12:00 p.m.

Workshop 6 (Intermediate)

Speaking the Same Language: Best Practices in Standards Authoring

Track: Safeguarding Your HVAC&R System

Room: 372AD

Sponsor: 1.6 – Terminology and Publication and Education Council

Chair: Art Hallstrom, P.E., AD Hall and Associates, Lexington, KY

• Identify how various authoring bodies are already creating and updating terms and their definitions

• Understand the pros and cons for each method in use now

• Understand best practices in authorship

• Make better decisions when creating or updating a term, including the use of the TC 1.6 repository of terms

TC 1.6 invites all authoring committees and interested parties to join a discussion about best practices in authoring terms. The purpose is to gain common understanding of the methods being used now and use that understanding to see if a set of best practices can be developed and agreed upon. Following a primer presentation on the topic, time will be allotted to discuss various methods of choosing a term and its definition (author, collaborate, reference, copy etc). The last discussion will be regarding how best to prioritize the methods.
1. ASHRAE Standards Authorship: Moving Toward a Convention
Kyle Kisebach, P.E., Kisebach Consulting, Olympia, WA

ASHRAE's TC 1.6- Terminology is making the entire repository of terms and definitions available for ASHRAE authors. This will facilitate harmonization of terms where possible. This workshop provides a forum for Standards and Guidelines committee members to discuss this topic. Questions include: What are the best practices for creating or updating terms and their definitions, within a Standard of Guideline? What should be the order of preference for finding or creating a term and its definition? When if ever should ASHRAE refer to outside bodies' terms? Is there reason to collaborate between authoring committees?

Monday, June 25, 2:15 p.m. – 3:45 p.m.
Debate 1 (Intermediate)

Fellow’s Debate: Are Cities Sustainable?
Track: Fundamentals and Applications
Room: 372BE

Sponsors: College of Fellows and EHC

Chair: Larry Spielvogel, P.E., Consulting Engineer, Bala Cynwyd, PA

Recently, the world’s population made a subtle but significant shift: 54% of the world’s population now live in cities. In North America, 82% live in urban areas. By 2050, 62% of the world’s population will live in cities with over 40 cities at populations over 10 million by 2030. But investment in infrastructure, services and other necessities and accoutrements has lagged behind this movement. Will this density of people overtax the energy, infrastructure and resource carrying capacity of these human-made socio-ecosystems or are we headed for a colossal collapse? Come to hear this debate on the question are cities sustainable?

1. Frank Mills, CEng, Life Member, Frank Mills Consulting, Leyland, United Kingdom
2. Jin Jin Huang, Member, Safari Energy, New York, NY
3. Ashish Rakheja, P.E., Member, AEON, Noida, India
4. Larissa Williams, Associate Member, City of Houston
5. E. Mitchell Swann, P.E., Member, MDCSystems LLC, Philadelphia, PA
6. William Bahnfleth, Ph.D, P.E., Presedential Fellow ASHRAE, Pennsylvania State University, University Park, PA

Monday, June 25, 6:30 p.m. – 9:00 p.m.
Seminar TC (Intermediate)

Early HVAC System Modeling and Efficiency Comparison Tool using the New Building Energy Efficiency Ratio (BEER)
Track: HVAC&R Analytics
Room: 370CF

Sponsor: 1.5 – Computer Applications

Chair: Richard M. Bostian, HIA-C, Edmond, OK
OPEN SESSION: No badge required; no PDHs awarded; presented during the TC's meeting. This presentation discusses a method to compare the Energy and Life Cycle Cost of HVAC systems at the early design stage of a project. The 15 minute discussion is to seek advice and direction on peer review of the comprehensive modeling logic. Currently 30 predefined complete HVAC systems which use AHRI data as the base are corrected for basic "as applied" models. The methodology follows ASHRAE Standard 209P minimum requirements and is included in the free downloaded program.

Tuesday, June 26

Tuesday, June 26, 8:00 a.m. - 9:30 a.m.

Technical Paper Session 3 (Intermediate)

Optimization and Simulation of HVAC Systems

Track: HVAC&R Analytics

Room: 371CF

Chair: Bass Abushakra, United States Military Academy, West Point, NY

Simulation is a significant tool for engineers in the design of HVAC systems. Designing the best approach for efficiency is critical for today's design. Likewise, optimizing those systems once installed is equally important. This session provides information on both sides of the equation.

1. Indoor Air Quality Modeling and Assessment Indoor Air Quality Modeling and Assessment (HO-18-008)
   Ronald Dougherty, Ph.D, University of Kansas, Lawrence, KS
   This paper presents a comparison of VRP and IAQP for specific cases, using a combination VRP-IAQP model. Modeling results show how reduced intake of outdoor air compares to VRP’s requirements: where IAQP may be a better choice than VRP, and where VRP may be the better choice. Typically, VRP is better for situations wherein filtration/cleaning is minimal and the building/occupants produce reasonably significant contaminant levels. IAQP is better when outdoor air intake is reduced to no less than 50% of VRP’s intake and when filtration/cleaning efficiency is in the 50%+ range. For some specific cases filtration/cleaning efficiency can be as low 20%, and still improve on VRP’s contaminant concentrations.

2. Airflow and Energy Simulations to Assess Energy Savings from Vestibules and Air Curtains (HO-18-009)
   Liangzhu (Leon) Wang, Member, Concordia University, Montreal, QC, Canada
   ASHRAE Standard 90.1 requires vestibules to be installed in climate zones 3-8 based on building energy simulations with a series of assumptions, which can be avoided by using a new method of airflow and energy simulations. Meanwhile, besides vestibules, it is believed that air curtain can also reduce infiltration and the associated energy loss through building entrances. Therefore, this study uses the proposed method to estimate energy savings from vestibule and air curtain doors for two United States Department of Energy reference buildings in 16 U.S. climate zone locations in terms of national weighted average energy savings and a sensitivity study of different contributing parameters.

3. Simulation Tool for Ground Source Heat Pump System with Multiple Ground Heat Exchangers (HO-18-010)
   Takao Katsura, Hokkaido University, Sapporo, Japan
   This paper explains how the authors have developed a simulation tool for the ground source heat pump (GSHP) system with multiple ground heat exchangers (GHEXs) by combining the Infinite Cyrindrical Source (ICS) solution with the Infinite Line Source (ILS) solution. In the developed tool, superposition of the temperature field in space is applied in calculating the underground temperature due to heat extraction or injection form multiple GHEXs. Then, the ICS solution is applied for temperature change due to heat extraction or injection of the considered GHEX and the ILS solution is applied for temperature change due to the heat extraction or injection of other neighboring GHEXs.

Ali Hasan, Amanties, Doha, Qatar

This presentation explains why air separation devices used to separate air from water in hydronic systems are important devices. Dissolved air in hydronic systems must be reduced to an acceptable levels for an acceptable performance and possibly protect other hydronic components from a reduced life cycle or even damage. Typical challenges and not limited to; are optimizing efficiency and keeping pressure drop to a minimum. An industrial air elimination device was simulated using CFD simulation, and then as a first step have the CFD results validated against the device data sheets.

Tuesday, June 26, 8:00 a.m. - 9:30 a.m.

Conference Paper Session 12 (Intermediate)

Optimization and Performance of Heat Pumps

Track: HVAC&R Analytics

Room: 370CF

Chair: David A. Yashar, Ph.D, NIST, Gaithersburg, MD

Heat pump systems vary in design, function and operation. This session looks at an assortment of heat pump applications. Design, optimization, performance and cost analysis of this diverse set of applications is discussed.

1. Investigation and Evaluation of Multi-Source Heat Pump Units for Maximizing System Efficiency (HO-18-C035)

Yao Yu, Ph.D., Associate Member, Grylord Olson, Rui Miao, Student Member, North Dakota State University, Fargo, ND

The purpose of using Multi-Source Heat Pumps (MSHPs) is to maintain high heating and/or cooling output with high system efficiency. The current development of MSHPs has already demonstrated superior performance compared to conventional HVAC systems with a single energy source. Nevertheless, there is room for improvement in terms of system design and layout, control strategies, economic feasibility, etc. This paper identifies and discusses shortcomings of current MSHP systems, and an improved MSHP system will be proposed, which uses a dry cooler, underground loops, and/or solar collectors, to optimize the MSHP design.


Yaoyu Li¹, Feng Cao², Ph.D., Wenyi Wang¹, (1) University of Texas at Dallas, Richardson, TX, (2) Xi’an Jiaotong University, Xi’an, China

For a vapor-injection air-source heat pump (ASHP) with the internal heat exchanger (IHXC), a model-free real-time optimization strategy is proposed for minimizing the power consumption using the Extremum Seeking Control (ESC) strategy. The ESC takes the total power consumption as the only feedback, while the manipulated inputs are the intermediate pressure of injected vapor and the outdoor unit fan speed. With a Modelica based dynamic simulation model, simulations of the proposed ESC strategy show the capability of finding and tracking the optimum intermediate pressure and outdoor fan speed that minimizes the total power consumption, under fixed and variable load/ambient conditions.


Kajen Ethirveerasingham, Student Member, Alan S. Fung, Member, Ryerson University, Toronto, ON, Canada

In Canada, cold winters result in significant energy usage for space and water heating in residential homes, resulting in higher energy consumption and expenses to homeowners. Numerous sustainable technologies are available, but most are powered by electricity and with rising electricity prices in Canada, natural gas is still seen as the most cost-effective option. To keep operation costs low, while also reducing the emissions, transitional technologies are a potential option to avoid using costly electricity as the primary source. Gas-fired absorption heat pump (GAHP) for residential use is a fairly new concept for heating and cooling purposes.

Thomas Butcher¹, Ph.D., Member, Christopher Keinath², Ph.D., Member, Michael Garrabrant³, (¹) National Oilheat Research Alliance, Alexandria, VA, (²) Stone Mountain Technologies, Inc., Johnson City, TN

The development of a low cost absorption heat pump (AHP) technology has positioned this technology to offer a next level high efficiency fuel fired product beyond condensing for residential heating. Annual performance of several liquid fuel fired AHP configurations are compared against standard liquid fuel fired boilers, furnaces, as well as electric heat pumps. The hybrid AHP system is shown to offer the highest annual energy, operating cost, CO2 savings and 15 year total cost. The heating only AHP offers the second best savings. The payback periods for this AHP technology will allow it to be competitive with current technologies.

Tuesday, June 26, 8:00 a.m. - 9:30 a.m.
Seminar 38 (Intermediate)

Energy Efficient Building Technologies
Track: Research Summit
Room: 372AD

Sponsor: Publication and Education Council
Chair: Reinhard Radermacher, Ph.D., University of Maryland, College Park, MD

• Identify an effective method for defrost which can lead to energy savings and the reduction in numbers and duration of defrost cycles in a given period of heat pump operation
• Discuss how UVGI can be used for cooling coils and the associated benefits
• Describe the basics of ultraviolet germicidal irradiation systems (UVGI)
• Understand the design of building technology for nZEB requirements and monitor results of real performance data of nZEB building

This seminar presents material from three recently published papers from ASHRAE's archival journal, “Science and Technology for the Built Environment”, on the subject of energy efficient building systems. Three presentations: (1) a novel method of reverse airflow that can substantially reduce the energy consumed during defrost cycles; (2) a promising study about the potential of applying UVGI to enhance heat transfer and mitigate low DeltaT syndrome; and (3) an article on how researchers were able to surpass nZEB criteria in a building equipped with high-performance building envelope, ground-source heat pump, and ventilation heat recovery.

1. An Experimental Study on Energy Saving Analysis in the Defrost Cycle of Residential Heat Pumps with the Use of Reverse Air Flow During Defrost

Michael M. Ohadi, Fellow ASHRAE, University of Maryland, College Park, MD

This presentation proposes a novel method that can substantially reduce the energy consumed during defrost cycles. It involves the controlled use of reverse airflow on the outdoor coil surface during the defrost cycle, which cleans the coil surface more thoroughly by improving the draining of the melted frost. This process results in decreased number of defrost cycles needed for a given duration of heat pump operation. Energy savings of 56% and 31% were demonstrated experimentally for the above-freezing and below-freezing environments, respectively, as compared to a baseline that represents the ASHRAE recommended operating conditions.
2. Effects of an Ultraviolet Coil Irradiation System on the Air-Side Heat Transfer Coefficient and Low ΔT Syndrome in a Hot and Humid Climate

Chandra Sekhar, Fellow ASHRAE, National University of Singapore, Singapore, Singapore

Biological fouling on cooling coil surfaces acts as thermal insulation, impeding heat transfer from air to coil surfaces, decreasing air-side heat transfer coefficient and degrading coil cooling capacity. It is also a common cause of low DT syndrome in chilled water distribution systems. The effects of a commercially available ultraviolet germicidal irradiation (UVGI) system installed in a variable air volume system on the air-side heat transfer were evaluated via a field test in a hot and humid climate. The results of this study revealed promising potential of applying UVGI to enhance heat transfer and mitigate low DT syndrome.

3. Heat Pump Application in NZEB

Carsten Wemhoener, HSR Hochschule für Technik Rapperswil, Rapperswil, Switzerland

In Uster near Zuerich, a Swiss nearly Zero Energy Building (nZEB) with mixed residential and office use has been monitored in detail for two years. The building is equipped with high-performance building envelope, ground-source heat pump, mechanical ventilation heat recovery, a larger PV and PV/T system, electric vehicle as well as floor heating system, which is also used for direct cooling by the borehole heat exchangers of the ground-source. The results confirm that the nZEB criteria were fulfilled and even a surplus was reached. The office use also proved to be favourable for PV self-consumption and demand response.

Tuesday, June 25, 8:00 a.m. - 9:30 a.m.

Seminar 39 (Intermediate)

How to Field-Measure and Score the Performance of an Installed HVAC System

Track: HVAC&R Systems and Equipment
Room: 370ABDE

Sponsor: 7.3 - Operation and Maintenance Management

Chair: John Constantinide, Alpha MRC Architects Engineers, Merritt Island, FL

• Quantify deterioration of an HVAC system performance caused by poor installation practices
• Comprehend the infield testing required to score the performance of an installed HVAC system
• Calculate the basic performance score of an installed HVAC system
• Compare an installed HVAC system performance score to the rated equipment efficiency

ASHRAE Standard 221P offers a test method to score the performance of an installed HVAC system. This seminar discusses each individual test and calculation used to score a forced air HVAC system. For decades, the efficiency of an installed system has been assumed to be the equipment laboratory rated efficiency. This test method documents the decline in efficiency a system suffers from design to installation. Supporting tests also pinpoint the cause of the efficiency losses so the installed system defects can be repaired.

1. How to Field-Measure and Score the Performance of an Installed HVAC System (1)

Don Langston, Member, Aire Rite Air Conditioning, Huntington Beach, CA

ASHRAE Standard 221P offers a test method to score the performance of an installed HVAC system. This seminar discusses each individual test and calculation used to score a forced air HVAC system. For decades, the efficiency of an installed system has been assumed to be the equipment laboratory rated efficiency. This test method documents the decline in efficiency a system suffers from design to installation. Supporting tests also pinpoint the cause of the efficiency losses so the installed system defects can be repaired.
2. How to Field-Measure and Score the Performance of an Installed HVAC System (2)
Rob Falke, Member, National Comfort Institute, Avon Lake, OH

ASHRAE Standard 221P offers a test method to score the performance of an installed HVAC system. This seminar discusses each individual test and calculation used to score a forced air HVAC system. For decades, the efficiency of an installed system has been assumed to be the equipment laboratory rated efficiency. This test method documents the decline in efficiency a system suffers from design to installation. Supporting tests also pinpoint the cause of the efficiency losses so the installed system defects can be repaired.

Tuesday, June 26, 8:00 a.m. - 9:30 a.m.
Seminar 40 (Intermediate)

Noise and Vibration Impacts of Safeguarding Buildings and HVAC Systems
Track: Safeguarding Your HVAC&R System
Room: 371AB
Sponsors: 2.6 - Sound and Vibration and 2.7 - Seismic, Wind and Flood Resistant Design
Chair: Erik Miller-Klein, P.E., A3 Acoustics, LLP, Seattle, WA

• Discuss the need for emergency power from a building owner’s perspective
• Discuss the resiliency of emergency power during adverse weather and events
• Understand and visually identify common seismic and restraint details that are negatively impacting your acoustical performance
• Explore the common and unique noise control requirements for emergency generators

Emergency support systems, such as generators, are commonplace in modern buildings and for good reason with potential power outages and the critical nature of building systems. In addition to emergency power many locations require seismic restraints. Though both of these required installations can create day-to-day noise and vibration issues. This session explores the requirements for these safeguarding systems, and the design and installation needs to ensure these systems meet the building's acoustical performance goals.

1. Vibration Control of HVACR Systems that Require Seismic, Wind or Thermal Restraint
Roman Wowk, Associate Member, Papadimos Group, San Francisco, CA

Vibration control often conflicts with the need for seismic and wind restraint or control points for thermally expanding pipes. Often in the form of springs or soft mounts, vibration control aims to break rigid contact between vibrating equipment and the building structure, thus introducing the potential for movement. Restraint devices, on the other hand, must limit or control any such movement. This presentation reviews vibration control fundamentals and outlines key strategies to follow when vibrating equipment and services must be restrained. Case-studies are also used to help bridge the gap between textbook theory and real project examples.

2. Generator Noise Control
Dan LaForgia, Member, Vibro-Acoustics, New York, NY

As we move into 2018, backup power for all types of buildings has become more and more critical. The main building types that utilize generators are hospitals, universities, schools, data centers and high rise residential. The acoustic concern for generators is both indoor and outdoor noise levels. This could be adjacent spaces within the building or exceeding dBA levels at the property line. Noise control for generator applications can be quite challenging as there are usually space constraints and limits to allowable pressure drop.
3. Seismic Source International
James Carlson, Member, Seismic Source International, Omaha, NE
Modern building codes and standards acknowledge the vulnerability of electrical power supplied by the utility companies and therefore require that critical facilities have at some emergency power capability when normal electrical power is lost. FEMA 1019 examines the vulnerability of electrical power systems to natural hazards, describes what equipment in critical facilities should be supplied by emergency power sources, how long the emergency power may be needed, the specific equipment needs of different types of critical facilities, and how emergency power can be supplied.

Tuesday, June 26, 8:00 a.m. - 9:30 a.m.
Seminar 4 (Advanced)
The Future of Thermal Cooling to Support Resilient CHP Systems
Track: District Energy and Cogeneration Plants
Room: 372CF
Sponsors: 8.3 - Absorption and Heat Operated Machines, 1.10 - Cogeneration Systems and 6.2 District Energy & 6.9 Thermal storage
Chair: William Arthur Ryan, Ph.D., P.E., Univ. of Illinois at Chicago, Chicago, IL
• Identify and understand the technology discussed
• Understand the practical applications of the technology
• Identify the positive aspects in applications of this technology
• Identify the negative issues in applications of this technology
This seminar covers any absorption application, whether chillers, air conditioners, heat pumps, or heat transformers using any solution pair for use or used in conjunction with CHP systems can covering system analysis or policy issues, research issues or case studies

1. Pinellas County Jail: Decoupled "CCHP" in the Sunshine State with Modern Absorption
Douglas A. Davis, Associate Member, Broad USA, Hackensack, NJ
This case study of a 4000 ton hybrid cooling plant with "CHP" combine d heat power covers the following concepts: How this 2 Megawatt combined heat cogeneration plant recovers waste heat from a reciprocating engine with a single multi-energy absorption chiller with 3 energy inputs; tailpipe exhaust (high grade heat) two stage absorption heat recovery; jacket water (low grade heat) single stage absorption heat recovery and natural gas for supplemental firing with or without the cogeneration system operating.

2. Busting the Myths of Absorption Cooling Technology
Rajesh Dixit, Associate Member, Johnson Controls, Inc., York, PA
This seminar describes and busts the myths surrounding the lithium bromide-water absorption cooling technology; such as, crystallization, low COP, high cost and rigid operational range. The seminar also discusses the advances of absorption cooling technology making it a very reliable and sustainable solution, particularly for waste heat recovery and Cogeneration or CHP (Combined Heat and Power) applications.

Ongun Berk Kazanci, Associate Member, Technical University of Denmark, Kgs. Lyngby, Denmark
Heat generated in cogeneration or trigeneration systems may be utilized in several ways. In practice, absorption and or adsorption machines (sometimes in tandem) are used to generate cold if there is a feasible demand. This presentation investigates from a rational exergy management point of view whether it is the best method to generate cold rather than utilizing the heat in other alternative applications, if there are both heat and cold demand. In order to shed light on this issue, a single stage absorption cycle system is modeled, which uses 90C hot water that is delivered from a cogeneration unit.
Tuesday, June 26, 8:00 a.m. - 9:30 a.m.

Seminar 42 (Intermediate)

**Thermal Energy Storage at the Small Scale: Technologies and Applications for Residential and Small Commercial Buildings**

**Track:** Residential Modern Buildings in Hot and Humid Climates

**Room:** 371DE

**Sponsors:** 6.9 - Thermal Storage and TC4.4, Residential Building Committee (RBC)

**Chair:** Chris Mincey, P.E., Crom LLC, Gainesville, FL

- Discuss current thermal energy storage technologies and strategies for residential buildings
- Discuss trade-offs of battery energy storage vs. thermal energy storage for cooling in off-grid setting
- Provide potential cost savings for energy storage in residential buildings
- Describe operating scenarios for thermal storage in residential and microgrid applications beyond peak load shifting

Many studies have highlighted the role that energy storage could have in the electric grid of the future and utilities are still attempting to discern the various ways to best incorporate storage technologies. Past research, as well as many real-world deployments have shown that there is potential for thermal energy storage (TES) to help balance the grid through demand response and load shifting applications. While most studies and deployments have focused on large, commercial or industrial-scale thermal storage systems, this session discusses and evaluates the potential for thermal storage at the smaller scale: residential and small commercial.

1. **Estimating Cost Savings for Residential TES**

   **Paulo Cesar Tabares-Velasco, Member**, Colorado School of Mines, Golden, CO

   Energy storage is a key technology that can increase energy cost savings, and add flexibility to the grid. However, cost savings are an important factor to consider from the building owner’s perspective. This presentation shows a rapid approach that allows for visualization of potential cost savings by introducing energy storage as a peak load control for residential buildings in California. A combination of multiple software is used to analyze the potential cost savings when cold storage is implemented and TOU rates are applied. The study presents potential cost savings of $420 annually and storage capacities of 24 kWh.

2. **Isolated Microgrids: An Analysis of Off-Grid Energy Storage**

   **Charles Upshaw, Member**, University of Texas at Austin, Austin, TX

   Traditionally, small and remote microgrids such as ‘off-grid’ houses have relied on a few methods of energy generation and storage to manage household loads. Energy consumption for heating and cooling is often the largest load in a house or small-scale microgrid, and the demands are typically not coincident with renewable generation. To meet these thermal comfort loads on-demand, generators and/or significant battery storage are required. This paper discusses potential applications for thermal storage in isolated microgrid scenarios, and evaluates thermal storage vs. battery storage in an off-grid single family residential home as an example.

3. **PCM Based Thermal Energy Storage for Residential Applications**

   **Stephen Bourne, Member**, University of Texas at Austin, Austin, TX

   Dr. Stephen Bourne will describe a high-density, PCM-based thermal storage system design that has demonstrated a storage density 2 to 7 times that of conventional chilled water thermal storage systems. The increased density of this system makes it suitable for residential retrofit or new construction applications. Dr. Bourne will also describe a hybrid convection-conduction finite volume model for this design that allows for real-time predictions of the thermal store state with sufficient accuracy for use in HVAC system controls, allowing for optimal use of the thermal storage system.
4. Case Study: PCM Performance in Residential Applications
Sajith Wijesuriya, Member, Colorado School of Mines, Golden, CO

Peak electric energy demand inflicts a great stress on the electric grid during the summer in the United States. As most years surpassing the immediate past year for the warmest year ever recorded, the cooling requirement will continue to increase in the coming decades. Energy storage can potentially reduce electric demand. Among different technologies, phase change materials (PCMs) embedded in the building envelope has the potential to shift cooling energy demand. This presentation presents numerical results from a study that optimizes PCMs in a new home located in Phoenix, Arizona, USA.

Tuesday, June 26, 8:00 a.m. - 9:30 a.m.
Seminar 43 (Intermediate)

What is BACnet Tagging About?
Track: HVAC&R Control Freaks
Room: 372BE

Sponsors: 7.5 - Smart Building Systems, 1.4 - Control Theory and Application and SSPC 135, TC 1.5
Chair: Carol Lomonaco, Johnson Controls, Milwaukee, WI

• Understand what a tag is and how they may be able to benefit from their use
• Understand why relationships are needed to fully define equipment and applications
• Define proprietary tags within their own namespace
• Understand how tags and relationships can be used with BACnet

Building data, whether it be in controls communications or in databases or anywhere else, typically comes along with instance identifications and some sort of hints of what that data may mean and represent. Often the semantic of the data is conveyed in some descriptive data or names. Given that there are no common rules on such formatting, the binding of applications to such data is typically a manual process. This seminar explains tagging, why the tagging model is essential to having interoperable smart devices that can communicate and the vision of using tags moving forward using BACnet and 223P Standards.

1. Semantic Information on Building Data
Bernhard Isler, Siemens Switzerland, Zug, Switzerland
The semantic of the data is normally only recognizable by a human and binding the applications onto it is a manual configuration process, which can become very expensive in particular for applications that consume a lot of data. With the more modern concepts of semantic tagging of building data, machines can understand the semantic information and a much higher degree of automation of the binding procedures become possible. But with new tagging concepts, in order to achieve interoperability between applications and data, standardized semantic information concepts and semantic tag dictionaries are essential to the building automation systems and more importantly to the end users, specifying engineers and product developers.

2. Why the Tagging Model is Essential to Having Interoperable Smart Devices That Can Communicate on an M2M Basis
Grant Wichenko, Member, Appin Associate, Winipeg, MB, Canada
This presentation covers why the tagging model is essential to having interoperable smart devices that can communicate on a machine-to-machine (M2M) basis from a specifying engineer's and/or user's point of view.

3. The Vision for Using Tags Moving Forward
Clifford Copass, Johnson Controls, Milwaukee, WI
In order to realize the full potential that is possible using tags, several improvements to the current state of affairs need to be made. Commonly used tags need to be standardized with common meanings that can apply across many vendors. Vendors need to supply appropriate tags with their products. The dictionary of commonly used tags must be expanded and made generic to apply to many building subsystems such as security, lighting, evacuation, fire protection, smoke control, energy management as well as a broad range of HVAC technologies. Rules and guidelines for tag selection must be published.
Energy Flexibility and Demand Control Systems are Important for Building Energy Consumption

Track: District Energy and Cogeneration Plants

Room: 371CF

Chair: Stephen Duda, P.E., Ross & Baruzzini, Inc., Saint Louis, MO

Building control of renewable energy, distribution of onsite energy generation, and managing load requirements as a sustainable strategy. Finding the system with flexibility that works for energy storage and maximum control.

1. Active Participation of Buildings as a Source of Energy Flexibility (HO-18-C039)

Wim Zeiler¹, Kevin de Bont², Student Member, Michiel Voerman¹, (1) TU Eindhoven, Eindhoven, Netherlands, (2) Kropman Building Services, Netherlands

The total electricity grid transition and associated processes can be described as a change in power grid from "passive" to "active", in which connected power system units play an active role in the management of the power grid. Controllable building load systems like Air Handling Units (AHU), chillers and humidifiers are important in demand side flexibility as they can be switched on/off or increase/decrease in capacity during moments of power grid congestion and other balancing services. Experimental studies are conducted related to Demand-Side Management (DSM) strategies. The study focuses on the effects of the chiller load shifting strategies as service to the grid.

2. Buildings' Energy Flexibility from the User to the Smart Grid to Cope with Fluctuations of Renewable Energy (HO-18-C040)

Wim Zeiler, Kennedy Aduda, Kevin de Bont, Student Member, Eindhoven University of Technology, Eindhoven, Netherlands

Energy flexibility of buildings becomes more and more important when applying renewable energy to reach the necessary grid stability. This presentation describes an application on an existing office building.

3. Energy Flexibility of Battery Electricity Storage System: Design, Commissioning, and Application (HO-18-C041)

Wim Zeiler¹, Kevin de Bont², Student Member, Michiel Voerman², (1) Eindhoven University of Technology, Eindhoven, Netherlands, (2) Kropman Building Services, Netherlands

In this study an office building integrated BESS is designed, developed, built and commissioned in order to test Smart Grid facilitating Demand Side Management (DSM) strategies. The second part of the study describes the BESS as an application for control strategies towards the Smart Grid. A BESS software agent is designed that respond to the day-ahead electricity pricing and building energy demand and schedules the battery discharge profile.
• Understand common control issues and knowing where to look for them
• Understand the value of trend analysis
• Define the purpose and value of Trim and Respond foundation capabilities
• Compare operation differences between High Performance sequences of operation (SOO) to traditional SOO

This session focuses on a series of case studies to show practical ways of ensuring that high performance building are functioning correctly, and highlight where to find methods of improved performance. With high performance sequences of operation, such as ASHRAE GP36, being implemented into buildings, we’ll look at how these case study buildings responded to the sequences, what feedback the system provided and lessons learned during the correction process.

1. ASHRAE GP36 Case Study for High Performance Sequences
Bill Gnerre, Interval Data Systems, Waltham, MA
This seminar presents the implementation of ASHRAE’s 36P High Performance Sequences of Operation in a 3-year-old 512K SF science/lab/office building. With an EUI 100 higher than the energy model we set about to reduce energy usage, improve comfort and reduce on-going maintenance efforts. All operational improvements were achieved via SOO changes. We’ll review the implementation of Trim and Respond, Supply Air Temperature Reset and Static Pressure Reset including results achieved. ASHRAE Standard 62.1 was correctly implemented too. Along the way we had to fix a myriad of other control issues before fully implementing the high-performance sequences.

2. Reinhard Seidl Session: Implementation and Pitfalls of Advanced Controls
Reinhard Seidl, Member, Taylor Engineering, Alameda, CA
This presentation shows practical ways of ensuring that high performance sequences are functioning correctly and highlight where to find methods of improving performance. They illustrate pitfalls in control system implementations on a variety of projects using real world data, caused by common errors in communication between engineers, field technicians, interpretations of code and sequences of operations. They show how both daily operators and commissioning providers can improve system operations by understanding sequences, demanding some key controls interface features, and using free tools.

Tuesday, June 26, 9:45 a.m. - 10:45 a.m.
Seminar 45 (Intermediate)

Case Studies to Evaluate Performance Measurement Protocols
Track: HVAC&R Analytics
Room: 372CF
Sponsor: 7.6 - Building Energy Performance
Chair: Bruce Hunn, Ph.D., Hunn Building Energy, Raleigh, NC
• Define current fundamental requirements in the PMP for the six categories
• Describe the procedures for testing the PMP in various buildings
• Explain what the challenges are in conducting experiments following the PMP
• Describe the validity, reliability, and practicality of the protocols

ASHRAE research project 1702: Case Studies to Test Performance Measurement Protocols— provides a basis for the update of the 2010 ASHRAE Performance Measurement Protocols for Commercial Buildings document. The PMP defines a method of measuring and analyzing building performance in six categories: energy, water, thermal comfort, indoor air quality, lighting and acoustics, at three levels (basic, intermediate and advanced). Case studies were conducted for five buildings in three climate zones. Results are presented for measurements covering the six performance categories at all three levels. Results and recommendations are presented for the evaluation of the validity, reliability, and practicality of the protocols.
1. Lessons Learned From the Building Case Study on Performance Measurement Protocols (PMP) in Laramie, WY
   Liping Wang, Member, University of Wyoming, Laramie, WY
   An introduction to the current version of the performance measurement protocols is presented followed by key lessons learned from the building case study focusing on water use measurement at the intermediate and advanced levels in Laramie, WY. Validity, reliability and practicality of the PMP and recommendations are also discussed on water category based on our experiences with on-site calibration of the ultrasonic flow meter, estimating landscape water use for a building served by a centralized landscape water system and monitoring data center humidifier water use.

2. Lessons Learned From the Building Case Study in Tuscaloosa, AL
   Zheng O'Neill, Member, University of Alabama, Tuscaloosa, AL
   Two key lessons learned from the building case study in Tuscaloosa, AL are presented in this seminar. First, experience with advanced inverse-modeling of building energy usage and second, experience of conducting indoor environment quality survey.

3. Lessons Learned From the Building Case Study in Des Moines, IA
   Xiaohui Zhou, Ph.D, P.E., Member, Seventh Wave, Madison, WI
   Three key lessons learned from the building case study in Des Moines, IA are presented in this session. First, experience with water use measurement at intermediate and advanced levels. Second, comparison of luminance measurements using HDR photography vs. luminance meter and third, experience of hiring an acoustic expert in conducting IEQ acoustics measurements at intermediate and advanced levels.

Tuesday, June 26, 9:45 a.m. - 10:45 a.m.

Seminar 46 (Intermediate)

Comparing the Energy, Emissions and Economic Impacts of Buildings in Energy Performance Calculations

Track: Fundamentals and Applications
Room: 371AB

Sponsors: 2.8 - Building Environmental Impacts and Sustainability and Residential Building Committee

Chair: Larry Brand, Gas Technology Institute, Davis, CA

- Describe how the energy, emissions and economics impact calculation framework can be used in energy performance comparisons
- Explain how the EEE framework complements the ASHRAE Standard 90.1 and 189.1 performance calculation methods
- Understand how to apply the relative valuation of metrics in determining energy performance compared to a baseline
- Apply the EEE Impact methodology to a residential building energy performance comparison

Measuring and comparing technology and building energy performance equitably with minimum unintended consequences has been challenging for decades. One reason is the use of a single metric such as energy cost to determine and compare performance of different options. With increased focus on environmental impacts, the energy cost metric may be incomplete or misleading. This seminar describes a new way to evaluate performance based on relative valuation of metrics related to energy use, greenhouse gas emissions and cost (EEE) impacts. Application and benefits of the EEE impacts approach in ASHRAE standards and other initiatives are discussed.
1. EEE Impacts Framework for Determining Energy Performance
Neil Leslie, Member, Gas Technology Institute, Des Plaines, IL

Determining energy performance for comparisons and decision making fairly is a daunting and complex technical and policy challenge. A single performance metric that may be fair for one primary intent may be unfair or misleading when trying to achieve another key policy objective. This presentation provides the rationale and technical framework for a new performance evaluation methodology that incorporates two or more metrics and enables relative valuation across the metrics. The presentation describes the methodology used to compare options based on their energy, emissions and economics (EEE) impacts compared to a baseline technology, system or building.

2. Application of EEE Impacts Methodology Options to Meet Multiple Policy Objectives
David Goldstein, Natural Resources Defense Council, San Francisco, CA

Building energy standards, including ASHRAE Standard 90.1, 90.2, and 189.1, have a performance path that compares a proposed design to a baseline design, typically at a whole building level. Each of these standards uses different metrics and methodologies to compare baseline and proposed building performance and the rank ordering of different choices can vary as a consequence of the differences. This presentation illustrates the challenges when using these methodologies and metrics to achieve multiple objectives. Examples of improved whole building comparisons using the EEE framework, including relative valuations across metrics and specific factors and values, are provided.

Tuesday, June 26, 9:45 a.m. - 10:45 a.m.
Seminar 47 (Intermediate)

Controls and Fault Detection

Track: Research Summit
Room: 372AD
Sponsor: Publication and Education Council
Chair: Reinhard Radermacher, Ph.D., University of Maryland, College Park, MD

• Learn how the transient operation system provides a district cooling and heating by employing distributed heat pumps exhibiting high energy saving effect for the entire system
• Learn how complicated combined system can be controlled for operation, and the important roles of each system plays within entire operation
• Describe classification of automated fault detection and diagnostic studies based upon the method and building system
• Select an appropriate automated fault detection and diagnostic method for the relevant system and building

This seminar presents material from two recently published papers from ASHRAE's archival journal, “Science and Technology for the Built Environment”, on the subjects of controls in a transient operation, and fault detection in buildings. The first presentation examines a transient operation characteristics and control method for a combined system consisting of both single-stage compression-type and single-effect absorption-type refrigerators. The second presentation provides a summary of review papers and examples of AFDD methods, highlights of building systems methods, distribution of studies based on each method and system, and using the study as a guideline in selecting AFDD methods.

1. Transient Operation Characteristics and Control Method in Combined Air-Conditioning System
Jongsoo Jeong, Waseda University, Tokyo, Japan

This system consists of both single-stage compression-type and single-effect absorption-type refrigerators and is driven by the shaft power and waste heat from a gas engine. Given the complicated nature of the system, determining the unsteady-state performance and control characteristics of the entire system is difficult. Hence, it must be equipped with an adequate control system to maintain an acceptable system performance. Our results reveal that this system is controlled, as predicted, under unsteady-state conditions by using a novel control method. In the result, the entire system is governed by the absorption-type refrigerator, although the cooling capacity of the absorption-type refrigerator is only 13% of the entire cooling capacity.

Srinivas Katipamula, Fellow ASHRAE, Pacific Northwest National Laboratory, Richland, WA

In 2004, a two-part review paper was published in the ASHRAE’s Science and Technology for Built Environment. In 2017, another review paper that summarized automated fault detection and diagnostic (AFDD) studies since 2004 was published. This presentation summarizes both review papers and provides examples of AFDD methods, highlights of methods suitable for building systems, the distribution of studies based on each AFDD method and HVAC system and how industry can use the study as a guideline for selecting an appropriate AFDD methods. Emerging trends in AFDD and gaps in the current research and development effort are also highlighted.

Tuesday, June 26, 9:45 a.m. - 10:45 a.m.

Seminar 48 (Advanced)

New ASHRAE Hot Climate Design Guide

Track: Residential Modern Buildings in Hot and Humid Climates

Room: 372BE

Sponsors: MTG.HCDG - Hot Climate Design Guide and 2.8 - Building Environmental Impacts and Sustainability

Chair: Frank Mills, CEng, Frank Mills Consulting, Leyland, United Kingdom

- Develop strategies for cooling in hot climates
- Identify the scope for passive design and where mechanical systems will be needed
- Describe the energy usage patterns of buildings in hot climates and possible strategies for net zero
- Develop proposals for external cooling of areas around buildings in hot climates

This seminar provides information on the scope and content of the new guide and invites ASHRAE members and others to comment and contribute new ideas. This guide is proposing new low carbon design solutions and also ways to integrate traditional ‘passive solar’ concepts into modern buildings. The seminar covers building design and also external cooling of areas around buildings and semi external spaces such as Atriums, where members of the public may want to gather, meet, sit, eat, drink, relax and in some cases work. Hybrid and passive designs are explored to consider applications

1. The New ASHRAE Hot Climate Design Guide

Frank Mills, CEng, Life Member, Frank Mills Consulting, Leyland, United Kingdom

This new design guide is aimed at practicing engineers involved in the design, construction and operation of buildings in hot climates. This includes any locations which have short term hot climates as well as those which have continuously hot climates and will be able to assist those who are working to develop successful buildings in areas which are seeing climate changes toward hotter summers, but with cold winters. Recent evidence shows that there are buildings in these locations which are predicted to fail due to global changes which will lead to overheating and failure of chiller plants because of increasing temperatures and a trend toward hot climate conditions in summer months.

2. Low Energy Cooling Techniques in Hot Climates Including External

Melvin G Glass, Member, EMC Engineers, El Paso, TX

Development in Hot Climates are providing external spaces which can be used by not only building occupants but also visitors and the general public as amenity spaces to meet, greet, relax, eat and drink. These spaces can also be used for public meetings, performances, sports and arts and crafts events. These spaces must be designed to profile protection from direct solar gain and even local cooling using shading, thermal mass evaporative water cooling and other such techniques. This presentation describes the range of options available and provides examples of successful external ‘public realm’ features.
Uncertainty Analysis for Methods of Measurement and Test
Track: Fundamentals and Applications
Room: 371DE
Sponsors: 1.2 - Instruments and Measurements, 6.6 - Service Water Heating Systems and SSPC 41, SPC 118.2
Chair: Richard L Hall, P.E., Hall Consultants LLC, Worthington, OH

- Describe uncertainty in measurements and methods of test
- Explain uncertainty analysis
- Convey the use and value of uncertainty analysis in a method of test
- Determine the required accuracy of measurements taken during a rating test

This session focuses on uncertainty estimates applied to instrument measurements and method-of-test results. Uncertainty is the measure of the potential error in a measurement or test result that reflects the lack of confidence in the measurement or test result to a specific confidence level. Each of the 41-series measurement standards require the user to estimate the uncertainty for each measurement. The first speaker will summarize two uncertainty examples for measurements, and the second speaker will describe the importance and potential benefits for estimating uncertainty for system performance test results.

1. Using Uncertainty Analysis to Identify the Impact of Different Parameters
Adam Michalson, Montana State University, Bozeman, MT
Two uncertainty examples that have been developed for inclusion into current 41-series revisions will be summarized to illustrate the method for estimating uncertainty in accordance with ASME PTC 19.1, Test Uncertainty and to show how altering the error contributions from different error sources can lead to beneficial changes. In one case, replacing a cooling water mass flow meter with a more accurate one reduced the uncertainty in the refrigerant mass flow rate measurements from ±14.5% to ±0.8%.

Christopher Stone, Member, Air-Conditioning, Heating and Refrigeration Institute (AHRI), Arlington, VA
Creating uncertainty estimates for testing unitary air-conditioning and heat pump systems will strengthen test results by providing a measure of the potential error in the results at a specific confidence level. The uncertainty examples that are included in the current revisions of ASHRAE Standard 41.2, Standard 41.1 and Standard 41.6, will provide the starting points for these estimates. One benefit of doing these estimates is that relative contributions of each of the sources of error will be computed and will clearly identify the potential benefits from, for example, substituting a more accurate humidity measurement method to significantly reduce the overall uncertainty.
Forum 2 (Intermediate)

Lead, Follow or Get Out of the Way: ASHRAE Standards in the Residential Market Space
Track: Residential Modern Buildings in Hot and Humid Climates
Room: 370CF

Sponsor: Residential Building Committee, SSPC 90.2
Chair: Chris Mathis, Mathis Consulting, Asheville, NC

ASHRAE holds a unique and powerful position through its standards in defining and shaping residential building performance. This forum examines ASHRAE’s opportunities in the residential space, low-rise, high-rise, single-family and multi-family, new construction and existing construction with the objective of discovering new ways to leverage ASHRAE’s content and expertise.

Tuesday, June 26, 11:00 a.m. - 12:30 p.m.

Technical Paper Session 4 (Intermediate)

Advancements in HVAC Control
Track: HVAC&R Control Freaks
Room: 370CF

Chair: Marija Todorovic, Ph.D, University of Belgrade, Belgrade, Serbia

Controlling air flow and use of new tools are important aspects of HVAC design. This session details research into control systems and applications for ventilation and modeling approaches to enhance control diagnostics.

1. Experimental Comparison of Pressure Loss in Typical Flexible and Sheet Metal Residential Duct Systems (HO-18-012)
   D. Kulkarni, Tennessee Tech University, Cookeville, TN

Tests were performed to measure air flow characteristics of multi-branch duct systems comprised of wire-wound flexible ducts and rigid sheet metal ducts. When flexible duct systems were not sized and installed per applicable standards required to design residential duct systems, the total system pressure loss penalty was as much as 44%, when expressed in terms of the measured system loss coefficients. However, the difference in pressure loss for typical residential duct systems constructed from properly sized and installed wire-wound flexible ducts and similar systems constructed from rigid steel ducts was negligible at design conditions.

   Christopher Thompson, Ph.D, P.E., U.S. Army Corps of Engineers, Fort Belvoir, VA

This paper presents a slice of an enormous facility equipment database, containing failure and maintenance information for more than 100,000 power, mechanical, and electronic components. The U.S. Army Corps of Engineers collected the data, motivated by a vested interest in the resilience of critical infrastructure. Heating, ventilation and air-conditioning equipment are well-represented in the database – some 13,000 unit-years of information describe the reliability and maintenance activity of over 1,600 air handling units and condensers. The analysis of this equipment sheds light on failures that are inherent to the design of equipment and those that can be influenced by preventative maintenance.
Mikhail Nudelman, Aero Building Solutions, Franklin Park, IL
This presentation explains the methodology and benefits of utilizing existing components of an air handling unit, such as heat exchangers, heaters and other apparatuses, as effective orifice air flow meters. The quasi-orifice meters can be utilized in lieu of airflow monitoring stations and standard orifice meters to help monitor and control many types of HVAC systems.

4. A Quantitative Model-Based Fault Detection and Diagnostics (FDD) System for Zone-Level Inefficiencies (HO-18-015)
Justin Berquist, Student Member, Carleton University, Merrickville, ON, Canada
Heating, ventilation and air-conditioning (HVAC) systems account for a significant portion of energy consumption in buildings. The majority of fault detection research has neglected zone-level faults. In this study, the methodology of a quantitative model-based fault detection and diagnostics (FDD) system for the zone-level is presented. The creation of a basic thermal model for a private office was completed using Matlab. Analyses were conducted and five zone-level inefficiencies were identified. The severity of these inefficiencies was analyzed and an excessive amount of air handling unit (AHU) fan energy consumption was detected.

Tuesday, June 26, 11:00 a.m. - 12:30 p.m.
Conference Paper Session 14 (Intermediate)

Diverse Applications of Ventilation Design
Track: HVAC&R Systems and Equipment
Room: 371CF
Chair: John Dunlap, P.E., Dunlap & Partners, Richmond, VA
Different applications on buildings require different approaches to ventilation design. Engineers who design ventilation systems must understand the challenges in designing for these applications. This session illustrates ventilation design techniques for diverse systems.

1. Comparison on Ventilation Requirements for Electric Cooking Appliances Between Wall-Mounted Hood and Single Island Hoods (HO-18-C042)
Toshiya Iwamatsu, Associate Member, Wataru Urabe, Central Research Institute of Electric Power Industry, Komae, Japan
The purpose of this research is to investigate the ventilation requirements for electric cooking appliances installed over wall-mounted hoods and single island hoods. The ventilation requirements of single island hoods for IH table, electric fryers, electric griddles and electric noodle cookers are from 1 to 2 times larger than that of wall-mounted hoods. However, these ventilation requirements of single island hoods are from 0.5 to 0.9 times smaller than those of Japanese conventional ventilation standard. It suggests that there is potential to reduce ventilation rates for electric cooking appliances installed over whichever wall-mounted and single island hoods.

2. Analysis of Spread Index: A Measure of Laboratory Ventilation Effectiveness (HO-18-C043)
Kishor Khankari, Fellow ASHRAE, AnSight LLC, Ann Arbor, MI
Laboratories frequently employ high ventilation rates which makes laboratory ventilation systems energy intensive. Ideally the supply air should effectively sweep the laboratory space and dilute the contaminant concentration at acceptable levels. This presentation, with the help of Computational Fluid Dynamics (CFD) analysis, evaluates the impact of airflow patterns on the ventilation effectiveness which is expressed in terms of Spread Index (SI) and Purge Time (PT). Effect of lab HVAC configuration on Spread Index and Purge Time is also evaluated. This analysis provides valuable insights into practicing and design engineers related to the design and operation of laboratory ventilation systems.
3. Effect of Intermittent Personalized Ventilator Coupled with Mixing Ventilation on the Dispersion of Contaminants in the Macroclimate of a Typical Office Space (HO-18-C044)

Douaa Al Assaad¹, Carine Habchi², Kamel Abou Ghali¹, Member, Nesreen Ghaddar¹, Member, (1) American University of Beirut, Lebanon, (2) Lebanese University, Beirut, Lebanon

Personalized ventilation (PV) provides thermal comfort and good breathable air quality (BAQ) to occupants in offices. However, PV might help in spreading contaminants in the space in case the PV user was infected which may affect the health of uninfected occupants. Recently, intermittent PV is used to enhance comfort, however it might enhance turbulence and deteriorate BAQ even more. This study uses an experimentally validated 3D transient CFD model to investigate the effect of an oscillating flow PV coupled with a mixing ventilation system on the dispersion of contaminants in an office space in case the PV user was infected.

4. Food Service Building Asset Rating Methodology and Analysis (HO-18-C045)

Supriya Goel, Alex Vlachokostas, Ph.D., Juan Gonzalez Matamoros, Na Wang, Ph.D., Pacific Northwest National Laboratory, Portland, OR

This paper presents an asset rating methodology developed for comparison and analysis of food service buildings. It identifies the energy energy use drivers in commercial kitchens and a methodology for evaluating the energy efficiency of the same. A normalization approach is discussed which addresses the variation in operations and loads between commercial kitchens so that food service buildings can be compared and rated on the same scale.

Tuesday, June 26, 11:00 a.m. - 12:30 p.m.

Seminar 50 (Basic)

Assessing the Impacts of Extreme and Future Weather Scenarios on the Building, City and Grid Scale

Track: Safeguarding Your HVAC&R System

Room: 371AB

Sponsor: 7.5 - Smart Building Systems

Chair: Paulo Cesar Tabares-Velacso, Colorado School of Mines

• Identify the types and characteristics of extreme weather events that are likely to impact buildings and building energy consumption and performance
• Describe the different types of methods used to develop building- and city-scale future climate scenarios
• Explain the impacts of extreme weather events on building energy use and performance
• Provide a comparison of different studies' assessment of impacts of extreme events on residential buildings

Buildings and their systems, including residential and commercial buildings, are designed based on historical weather data, however predictions of future climate scenarios in the U.S. demonstrate that weather and extreme events moving forward may be significantly different than current weather. This may have significant impacts on buildings. This seminar covers recent research efforts to predict what short term and long-term future climate scenarios will be, and what impacts future climate weather data has on building and energy performance at the building, city and grid scale.

1. Prediction and Uncertainty Quantification of Future Heat Waves on the City Scale

Elham Jahani, Student Member, Iowa State University, Ames, IA

The modern electric grid faces significant challenges and uncertainties, particularly as a result of extreme weather which is expected to increase in frequency in future years. In particular, heat waves and extreme drought can significantly impact electricity production and consumption. This presentation covers the results of the development of extreme heat and drought future climate scenarios for cities using Global Climate Models combined with WRF modeling using urban canopy parameterization. These are a part of a broader study developing an integrative framework to assess impacts of extreme events on the grid, to aid cities in preparing for such events.
2. Climate Change Impacts on Building Performance
Scott Schuetter, Member, Seventhwave, Madison, WI

The climate is changing as evidenced by the recent updates to the climate zones and design conditions in ANSI/ASHRAE Standard 169-2013, Climate Data for Building Design Standards. How will the changing climate impact building design and operation? At present, there are no standardized methods for estimating future climate impacts to building systems. This presentation discusses developing a building energy modeling framework to examine the impacts of future climate variability on building energy consumption, peak demand and energy costs. We additionally look at adaptation strategies to mitigate these impacts.

3. Robust Asset-and-User-Aware Power Grid Dispatch during Extreme Temperatures
Salman Mohagheghi, Colorado School of Mines, Golden, CO

This presentation seeks a solution for proactive dispatch of the energy resources in a distribution system exposed to extreme ambient temperatures, e.g. during a heat wave event. Extreme temperatures can negatively affect the rated capacity of many grid components. A temperature-based energy dispatch solution for the power grid is proposed. The presentation models the effects of excess temperatures on available generation/transmission capacity of components, as well as on their loss of life due to overloading or operating under harsh conditions. Indoor temperatures at residential homes are incorporated into the demand response dispatch by developing thermal models for the houses.

Tuesday, June 26, 11:00 a.m. - 12:30 p.m.
Seminar 51 (Intermediate)

Demonstration of Conventional and Advanced Hot Water Systems in Commercial Kitchens
Track: HVAC&R Systems and Equipment
Room: 372BE
Sponsor: 6.6 - Service Water Heating Systems
Chair: Denis Livchak, Frontier Energy, San Ramon, CA

• Identify features of conventional and advanced hot water systems
• Improve existing hot water systems based on the various optimization practices tested in the lab and demonstrated in the field
• Design innovative hot water systems based on modern practices and existing high-efficiency products
• Understand the importance of hot water delivery performance in commercial foodservice applications

This session benchmarks overall system efficiency at the point-of-use and delivery performance of existing and advanced hot water systems in commercial kitchens. The goal of the field testing is to demonstrate innovative high performance systems. The lessons learned will inform the development of a hot water system laboratory. The lab is set up to mimic the operation of systems were various heaters, distribution system designs and control strategies can be tested for a 24-hour period in a controlled environment. A design tool and cost calculator based on the findings is developed to support designers.

1. Results from a Hot Water System Replacement Project in an Elementary School
Denis Livchak, Associate Member, Frontier Energy, San Ramon, CA

This presentation summarizes the results from monitoring an existing conventional and replacement high efficiency hot water system in a k-6 school that included point-of-use monitoring in the dishroom. The hot water delivery performance and overall system efficiency in the dishroom is also discussed.
2. Results from an In-Depth Hot Water System Replacement Project in a Full Service Restaurant

**Michael Slater**, Frontier Energy, San Ramon, CA

This presentation discusses a study that monitored hot water use from generation to all point of use in a full-service restaurant. Details are provided on the original and replacement system’s energy and water use, delivery performance and overall system efficiency. Details regarding the design and installation of the optimized system are covered in the presentation.

3. Results from 2nd-Generation Commercial Hot Water System Testing Laboratory at PG&E

**Michael Slater**, Frontier Energy, San Ramon, CA

This presentation explains final results from testing completed at the 2nd-generation Commercial Hot Water System Laboratory at PG&E. This lab measured incremental savings from various optimization practices by mimicking the operation of hot water systems in full service restaurants. The lab tested four types of water heaters, two distribution systems and various system controls for a total of approximately 60 test scenarios that each span for a 24-hour period.

4. Demonstration of Commercial Hot Water System Design Tool and Cost Calculator

**Denis Livchak, Associate Member**, Frontier Energy, San Ramon, CA

This presentation details the development of a design tool and cost calculator based on the lab and field findings which is intended for use as a conceptual tool for the hot water system design and engineering community. The purpose of the tool is to allow the user to select various water heaters, distribution system layouts, recirculation options and end use equipment options to get a better understanding of the collective impact of the hot water system design from a water and energy use, installed cost, operating cost, system efficiency and hot water delivery performance standpoint.

**Tuesday, June 26, 11:00 a.m. - 12:30 p.m.**

**Seminar 52 (Advanced)**

**HVAC for Tall and Super Tall Buildings in Hot Humid Climates**

**Track**: Residential Modern Buildings in Hot and Humid Climates

**Room**: 372CF

**Sponsor**: 9.12 - Tall Buildings

**Chair**: Duncan A Phillips, Rowan Williams Davies & Irwin, Guelph, ON, Canada

- Describe the difference in temperature, humidity and wind conditions at grade and at height
- Understand the viability of natural ventilation in tall and supertall buildings and the special considerations of these
- Utilize the case studies to inform their designs for tall buildings in hot humid climates
- Describe additional passive design measures in their building projects in hot humid climates

The climate conditions in hot humid climates at the top of a building are generally cooler and dryer than those at grade. While standard equations exist to describe conditions as one goes up - these are average conditions but not enough to design with. The HVAC systems for a cooler/dryer climate should be different than those for a hotter/moister one. However, rarely do designs include this influence in a single building. This seminar details the impact of the different conditions. Presentations cover active and passive systems, using real meteorological data presented for a building in a hot humid climate.

1. Meteorological Data in a Humid Climate at Grade and 1970ft / 600m

**Duncan A Phillips**, Rowan Williams Davies & Irwin, Guelph, Canada

This presentation provides the background information for the rest of the session. Information regarding ASHRAE's standard atmosphere will be compared to advanced atmospheric modeling. The modeling is described and the results for temperatures, winds, humidity and other variables will be presented that show the opportunities to optimize the design for the HVAC system in a tall and supertall building.
2. Natural Ventilation in Supertall Buildings in Hot Humid Climates
Peter Simmonds, Fellow ASHRAE, Building and Systems Analytics LLC, Marina Del Rey, CA

It would be reasonable to expect natural ventilation to be easier to accomplish in at the top of a tall or supertall building. The weather at the top of the building is more predictable and typically cooler and dryer. However there are consequences to naturally ventilating at height. This seminar looks at challenges naturally ventilating tall and supertall buildings through cases studies and analyses.

3. Designing Supertall Buildings with Geography and Height in Mind
Mehdi Jalayerian, P.E., Member, Environmental Systems Design, Inc., Chicago, IL

Passive measures are one means to reduce the energy demand of any building. The measures available to tall and supertall buildings at height differ from those at grade. The passive measure available in humid climates different from those in dryer ones. This presentation discusses the passive measures available to designers of tall and super tall buildings especially in hot humid climates. The benefit of these measures, and the changes to active systems are discussed in context with the data provided in the first seminar.

4. Active Systems at Grade and Height in Tall and Supertall Buildings
Luke Leung, Member, Skidmore, Owings, & Merrill LPP, Chicago, IL

The temperature and humidity at the top of tall and supertall buildings is lower than that at grade. This changes the mechanical systems, air flow rates and other design parameters. This seminar uses case studies to show how system design can change in a manner that reduces cost and energy demand associated with heating and cooling the upper levels of a tall building when compared to those at grade.

Tuesday, June 26, 11:00 a.m. - 12:30 p.m.
Seminar 53 (Intermediate)

HVACR Novel Measurement Techniques: The Next Generation
Track: Research Summit
Room: 372AD

Sponsors: 1.3 - Heat Transfer and Fluid Flow and 1.2 - Instruments and Measurements
Chair: Melanie Derby, Ph.D., Kansas State University, Manhattan, KS

• Explain high level operating principles of fiberoptic temperature measurement techniques
• Understand currently used and new techniques to determine average and local air-side heat transfer coefficients
• Understand of the different measurement methods that can be used for refrigerant and oil charge measurements
• Explain the relationship between the measured capacity and the void fraction

This seminar presents ongoing research relevant to the ASHRAE community, including two projects currently sponsored by ASHRAE (Fronk and Bach). Thermal systems require accurate temperature and heat transfer coefficient measurements; new research-based approaches include a distributed temperature fiber optic sensing technique based on Rayleigh backscatter phenomena and a novel visualization method designed to obtain local air-side heat transfer coefficient distributions of an entire heat exchanger. Refrigeration systems require additional measurements and sensing, including research to determine refrigerant-oil void fractions through non-invasive means and an evacuative charge measurement approach for determining local refrigerant charge in refrigeration systems.
1. CP 71 Title: Exploring Potential of Distributed Fiber Temperature Sensing in HVACR Applications
Brian M Fronk, Oregon State University, Corvallis, OR
This seminar introduces the basic principles of operation of a distributed temperature fiber optic sensing system based on Rayleigh backscatter phenomena. Then using examples from research, the seminar explores practical challenges for obtaining accurate measurements of fluid and surface temperature of interest to the ASHRAE community. Finally, the seminar offers some thoughts on potential future applications.

2. Quantification of Local Air-Side Heat Transfer Through a Novel Optical Method
Stefan Elbel, Member, University of Illinois, Urbana, IL
Low air-side heat transfer coefficients (HTC) are often the bottleneck of heat exchanger performance. However, the measurement of local air-side heat transfer coefficients for the entire heat transfer surface is not a trivial task. Current experimental methods often only work on scaled-up samples which typically cannot deliver continuous HTC distributions across the surface of interest. Moreover, some methods require very precise and costly equipment such as lasers. Therefore, a novel visualization method is designed to obtain local air-side HTC distributions of an entire heat exchanger with a relatively simple experimental facility.

3. A Novel Measurement Technique for Refrigerant and Oil Charge Measurements in Heat Exchanger Coils (ASHRAE RP-1785)
Christian Bach, Associate Member, Oklahoma State University, Stillwater, OK
Residential split system heat pumps require knowledge of the refrigerant and oil charge in their coils for a wide range of operating conditions to appropriately size refrigerant accumulators and to pre-charge a sufficient amount of oil. RP-1785 will provide a set of reference data that can be used as validation data for charge models. This seminar gives a brief overview over different methods used for charge measurements and then go into additional detail for the novel method employed in RP-1785.

Davide Ziviani, Purdue University, West Lafayette, IN
In two-phase flow, the void fraction is one of the key parameters to characterize the flow behavior as well as to predict pressure drop and heat transfer. A number of experimental methods have already been proposed to measure the void fraction of two-phase flow. Most of these methods are either intrusive (e.g., wire mesh tomography), not widely applicable (e.g., optical methods) or very complex and expensive (e.g., gamma or neutron attenuation). To this end, a capacitive void fraction sensor has been developed in order to measure the capacitance of the flow based on the difference in dielectric constant between the phases.

Tuesday, June 26, 11:00 a.m. - 12:30 p.m.
Seminar 54 (Intermediate)

Projecting the Adoption of Building Efficiency Technologies: An Introduction to Interdisciplinary Modeling Approaches
Track: HVAC&R Analytics
Room: 371DE
Sponsor: MTG.OBB - Occupant Behavior in Buildings
Chair: Jared Langevin, Ph.D., Lawrence Berkeley National Laboratory, Berkeley, CA
• Understand building technology adoption behavior dynamics and their impact on the stock-wide energy savings potential of energy efficient building technologies
• Identify existing methodologies for modeling building efficient technology adoption decisions
• Describe the data currently available for developing models of energy technology adoption and novel sources of data for future model development
• Explain adoption modeling approaches in other fields (e.g., vehicles) that may be leveraged to model technology adoption in the buildings sector
The total energy savings impact of energy efficient (EE) building technologies depends upon the rates at which the technologies are adopted into target markets over time. However, policy makers, utilities, and technology vendors lack reliable methods for projecting market penetration across the wide range of technologies that their EE portfolios typically cover. This seminar introduces several approaches for modeling the adoption of energy efficient technologies, ranging from simple regression-based models to system dynamics and agent-based modeling. While the focus of the seminar is on energy efficient technologies in the buildings sector, informative work from the transportation sector is also presented.

1. Modeling Decision Makers in Technology Adoption Agent Based Models
   Ralph Muehleisen, Member, Argonne National Laboratory, Argonne, IL

   Technology adoption models are key components to successful energy efficiency policy, incentive programs and new technology rollouts. These models range from high level systems dynamics and diffusion models to detailed, bottom up, agent based models. When agent based models are used, the decision processes of individual decision makers are modeled. Owners vary in many ways including the type of building they own, the ownership structure of the building, available capital and financing for equipment purchases, weighting of economic, energy, economic risk tolerance and importance of non-energy/non-economic properties of the technology. This presentation covers the development of a building owner decision model used in an agent based technology adoption model.

2. Modeling at the Speed of Light: The Challenges of Forecasting the U.S. LED Market
   Mary Yamada, Navigant Consulting, Washington, D.C.

   The Department of Energy (DOE) Solid-State Lighting (SSL) Program estimates that in 2016, there were 6.9 billion lighting systems installed in the U.S., and that they consumed approximately 5.5 quads of energy annually. Making lighting one of the top consuming end-using in buildings and households. In efforts to track the proliferation of SSL technology, the DOE SSL Program has developed the U.S. lighting market model. This presentation covers the modelling approach employed by the U.S. DOE SSL Program’s U.S. lighting market model, including the identified key market parameters, data sources and biannual process by which the model is updated.

3. Impact Model for US-China Clean Energy Research Center for Building Energy Efficiency
   Nihan Karali, Lawrence Berkeley National Laboratory, Berkeley, CA

   There are few publicly available models of national building energy consumption with which to test the impact of building energy efficiency technology. To predict correctly the effectiveness of policy concepts requires realistic models of technology adoption and regulation. A suitable mathematical framework is presented, and as an example estimates the impact of the portfolio of Building Energy Efficiency technologies advanced by the US-China Clean Energy Research Center. Compared to the Reinventing Fire China baseline scenario, introduction of the CERC-BEE 1.0 portfolio of advanced building energy efficiency technology at equivalent prices to incumbent technologies, and subsequent free-market adoption, reduces energy consumption by 8% by 2030 and 11% by 2050.

4. Bottom-up Electric Vehicles Growth Model
   Yoonsoo Lee, National Grid, New York, NY

   The market penetration of EVs has gained attraction in the utility sector because of its growing impact on the grid. As a result, correctly predicting the EV growth in the utilities’ service territory has become one of their critical priorities as this growth is expected to offset the savings achieved by Energy Efficiency Program and PV deployment. It also has the potential to change the daily load curves for the electric system, requiring a fresh approach to system planning. Currently there are numerous reports and databases on EVs that cover market insights, registration status and forecasts.
The Future of Thermal Energy Storage Supporting Resilient District Energy, CHP Systems and Microgrids

Tuesday, June 26, 11:00 a.m. - 12:30 p.m.

Seminar 55 (Intermediate)

The Future of Thermal Energy Storage Supporting Resilient District Energy, CHP Systems and Microgrids

Track: District Energy and Cogeneration Plants

Room: 370ABDE

Sponsors: 6.9 - Thermal Storage, 8.8 - Refrigerant System Controls and Accessories and 1.10 - Cogeneration

Chair: Geoffrey Bares, Enwave Chicago, Chicago, IL

• Describe how cool thermal energy storage can complement renewal energy generation
• Distinguish the most practical applications of electrical energy storage and thermal energy storage
• Explain how Thermal Energy Storage can add resilience to a district energy system
• Describe the primary economic drivers of cool thermal energy storage installation and operation

This is one in a three-part series exploring the inherent synergies between District Energy systems, Combined Heat & Power generation, and Thermal Energy Storage (TES), focusing more closely on the current and future role of TES. This seminar explores how TES can increase the use of renewable power and microgrids, investigates the roles of thermal and electrical storage in our future infrastructure and demonstrates the resiliency provided by TES through specific case studies.


Mark MacCracken, Member, CALMAC Corp, Fair Lawn, NJ

Recent headlines related to Energy Storage have focused on electrical energy storage using battery technology. Thermal “batteries” can be more effective and significantly less costly than traditional electric batteries in storing bulk energy. Electric batteries and thermal energy storage both have a role to play in stabilizing our electricity grid. Come hear why thermal energy storage, as well as batteries, should be an integral part of the future energy infrastructure.


Steve Swinson, Thermal Energy Corporation (TECO), Houston, TX

With extreme weather events on the rise, infrastructure resilience has become a topic of increasing importance. District energy cooling systems are known for their reliability, even in times of adversity and thermal energy storage systems help provide that added resilience. This presentation discusses two such district energy systems in Houston and their experiences weathering the storm using thermal energy storage.


Geoffrey Bares, Associate Member, Enwave Chicago, Chicago, IL

With extreme weather events on the rise, infrastructure resilience has become a topic of increasing importance. District energy cooling systems are known for their reliability, even in times of adversity, and thermal energy storage systems help provide that added resilience. This presentation discusses two such district energy systems in Houston and their experiences in weathering the storm using thermal energy storage.

4. Sustainable Microgrids with Renewable Generation: Decoupling the Load with Cool TES

Douglas Reindl, Fellow ASHRAE, University of Wisconsin-Madison, Madison, WI

Increasing the utilization of renewable energy sources, particularly in a microgrid framework with limited generating source diversity, will require a way to capture off-peak energy production and deploy it during times of peak consumption. This presentation discusses how thermal storage can provide a reliable and cost effective solution.
Tuesday, June 26, 1:30 p.m. - 3:00 p.m.

Seminar 56 (Intermediate)

Advances in Compressor Bearing Technology
Track: HVAC&R Systems and Equipment
Room: 372BE

Sponsors: 8.2 - Centrifugal Machines, 8.1 - Positive Displacement Compressors and YEA

Chair: Ahmad Abu-Heiba, Oak Ridge National Laboratory, Oak Ridge, TN

- Identify common terms, definitions and categories of traditional and emerging bearing technologies used in HVAC&R compressors
- Identify considerations necessary for "high-speed" rolling element bearing
- Understand the bearing requirements imposed by the use of the new low GWP refrigerants
- Define how magnetic bearings work and what their design requirements are

Bearings are critical components to compressors. HVAC applications impose unique requirements on the bearings used for the compressors. This seminar gives an overview of the different types of compressor bearings for HVAC&R applications. Then it gives a more in-depth look into three different types of bearings.

1. Overview of Bearing Types and Applications
    Raymond Good, Danfoss Turbocor Compressors, Inc., Tallahassee, FL

    Bearings are an integral and essential component for HVAC&R compressors. Bearing choice will, in fact, dictate compressor design, maintenance and reliability. This presentation gives an overview of traditional and emerging bearing technologies providing context for the speakers which follow. Definitions, terms, history and applications of both traditional and emerging bearing types are covered. Bearings and their supporting lubrication, cooling and power systems are described.

2. Ceramic Hybrid Bearings for Low GWP Compressors
    Ulf Jonsson, United Technologies Research Center, East Hartford, CT

    Ceramic Hybrid bearings provide options for oil-free or reduced-oil bearing lubrication for compressors operating with low GWP refrigerants such as R1233zd, R1234ze and R1234yf. Despite the new benefits of hybrid ceramic bearings, the unique interactions between the low GWP refrigerants and the ceramic balls/steel races must be studied and considered in determining the expected life of the bearings, which is typically above a 100,000 hrs. Test protocols and the test rigs used to qualify the bearings are discussed in this presentation. In addition molecular dynamic modeling used to understand the chemical interactions between the bearing race/ball and the refrigerants will be described.

    Jeff Morgan, Daikin Applied, Bridgeton, MO

    This presentation describes the underlying physics of magnetic bearings, considering mechanics, rotordynamics and controls. It also provides the general characteristics in order to explain why they are suitable in some applications and poor in others. Finally, it describes some details of centrifugal compressor applications.

4. Advances in High Speed Rolling Element Bearings
    Joseph Heger, Member, Trane International, La Crosse, WI

    Rolling element bearings have historically enjoyed wide use in HVAC compressor designs. They are compact, efficient and reliable when applied correctly. The industry has trended to higher speed, direct drive compressor designs which poses additional challenges for rolling element bearings. This seminar covers the fundamentals of rolling element bearing application in refrigeration compressors with a specific focus on the additional considerations necessary for high speed application.
Tuesday, June 26, 3:15 p.m. - 4:45 p.m.

Seminar 57 (Basic)

Centrifugal Machines in Unusual/Niche Applications
Track: HVAC&R Systems and Equipment

Room: 372BE

Sponsor: 8.2 - Centrifugal Machines

Chair: Lindsey King, JCI, New Freedom, PA

• Identify differences in evaluating chiller selections for both flow based and load based systems
• Evaluate unloading curves using both AHRI Tower Relief and Constant Tower Water
• Understand the benefits and challenges of using centrifugal compressors in small scale heat pumps
• Understand multiple Niche Applications of centrifugal machines including data data centers, industrial processes, water side free cooling and single vs. multiple chiller plants

This seminar discusses some unique applications of centrifugal machines. It begins by discussing some fundamental questions that should go into selecting a centrifugal machine and how often times, there is more to a selection than the lowest efficiency. The seminar also gives an example of both an unusual and niche application for centrifugal machines and some benefits and challenges to both of these applications.

1. Evaluation of Centrifugal Chillers for Fundamental, Unusual and Niche Applications
Trenton Hunt, Member, Mechanical Products Intermountain, Midvale, UT

Many feel that the proper evaluation of a chiller’s efficiency is to base judgement on full load and part load IPLV/NPLV efficiencies. While both full/part load efficiencies are important, the relevance of the evaluated efficiency is wholly based upon the application. This presentation discusses: differences in evaluating chiller selections for both flow based and load based systems; evaluation of unloading curves using both AHRI Tower Relief and Constant Tower Water; assessment of centrifugal chiller efficiency differences when using an AFD/VFD vs. a Solid State/Wye-Delta Starter; the influence of oil-free vs. oil-based chiller design relating to chiller efficiency and specific applications such as data centers, industrial processes, water side free cooling, and single vs. multiple chiller plants.

2. Benefits and Challenges of Using Centrifugal Compressors in Small Scale Heat Pumps
Ahmad Abu-Heiba, Associate Member, Oak Ridge National Laboratory, Oak Ridge, TN

The introduction of scroll compressor in the 1990s caused a step increase in the coefficient of performance of heat pumps. Since then, increase in coefficient of performance has been incremental at best. A key enabler for improving compression efficiency is multiple stage compression with intercooling. However, this approach is challenged by oil migration. Oil also degrades the heat transfer in the evaporator. Using centrifugal compressors in heat pumps enables oil-free design but introduce significant design challenges. This presentation discusses the benefits and challenges of using centrifugal compressors in residential and commercial scale heat pumps and introduces latest developments.

3. Operating Centrifugal Machines Outside the Standard Operating Map
Maccrae Monteith, Associate Member, Johnson Controls, Inc., New Freedom, PA

Centrifugal compressor water chillers deliver high efficiency and low noise, low vibration performance when application and site conditions match the specific compressor setup: impeller geometry and speed control. However, actual site application can deliver conditions outside the expected design operating map for the compressor, which could lead to lesser efficiency or unstable operation. Newer technologies including variable diffusers and speed control expand the stable operating map for centrifugal compressors. This presentation reviews applications and operating impact to traditional centrifugal compressor and new centrifugal compressor technologies during non-ideal conditions.
Not Just Blowing in the Wind

Track: Fundamentals and Applications

Room: 370CF

Chair: Chris Laughman, Mitsubishi Electric Research Lab, Waltham, MA

Air flow and indoor air quality are key considerations for HVAC design engineers. Applying standards, maintaining air quality with increased efficiency and ventilation all play critical roles. This session addresses these concerns and provides useful information to the design engineer.


Meghan McNulty, Associate Member, Barry Abramson, P.E., Member, Pamela Moua-Vargas, Associate Member, Servidyne, LLC, Atlanta, GA

ASHRAE Standard 62.1, developed as a design standard, is cited as a basis for evaluating minimum outside air flow rates in existing buildings by rating systems including LEED EB O&M, ENERGY STAR and ASHRAE Building EQ. A proposed new Informative Appendix to the standard (Addendum b) attempts to provide a simplified method for calculating required minimum outside air flow in existing buildings. This paper presents the results of a comparative analysis between this simplified approach and the full calculations, using data from over 50 office buildings throughout the U.S. varying in climate zone, building age and HVAC system type.

2. Transient Air Flow Regimes in a Large Scale High Density Data Centers (HO-18-C047)

Essam E. E Khalil, Ph.D., P.E., Fellow ASHRAE, Yousri AbdelRahman, P.E., Cairo University, Cairo, Egypt

Computer systems have been a source of high power dissipation either from microprocessors, memory and support chips and mass storage. A high thermal density data center using these computer systems has resulted in a very high power density at room level. These computer systems are represented by and included in a rack. Normally a standard rack is two meters high and can accommodate an equivalent of 34 thin desktop computer systems. In this paper, a computational fluid dynamics (CFD) model of a prototype data center is presented to make the case for such modeling. The study is carried out using CFD simulation techniques as embedded in the commercially available CFD code (ANSYS V.16). The CFD modeling techniques solved the continuity, momentum and energy conservation equations in addition to standard k µ model equations for turbulence closure.


Wim Zeiler, Milad Golshan, Eindhoven University of Technology, Eindhoven, Netherlands

Nearly Zero Energy schools have been built with the focus on their energy balance, but what about their thermal comfort and Indoor Air Quality. In ten recent schools this was investigated. It proved that most of the schools did not reach the aimed design goals.
4. The Effects of Ventilation on Indoor Air Quality in Schools (HO-18-C049)
Lexuan Zhong, Ph.D., Member, University of Alberta, Edmonton, AB, Canada

Exposure to volatile organic compounds (VOCs) has been an indoor environmental quality (IEQ) concern in schools and other buildings for many years. In order to reduce children's exposure to pollutants in classrooms, it is necessary to understand the effect of ventilation on school air quality and then develop an appropriate ventilation strategy. This paper examines VOCs and IEQ parameters in 144 classrooms in 37 conventional and high-performance elementary schools in the U.S. with the objectives of providing a comprehensive analysis and updating the literature. Tested schools were built or renovated in the past 15 years, and included comparable numbers of conventional, Energy Star, and LEED-certified buildings.

Wednesday, June 27, 8:00 a.m. - 9:30 a.m.
Seminar 58 (Intermediate)

ASHRAE’s First Standard for Commercial Energy Audits or “How I Spent My Summer Vacations”
Track: Fundamentals and Applications
Room: 371DE
Sponsor: 7.6 - Building Energy Performance
Chair: Jim Kelsey, KW Engineering, Oakland, CA

• Provide a basic understanding of the requirements of Standard 211 for Energy Audits
• Understand the different purposes of Level 1, 2 and 3 audits
• Understand the new reporting requirements for energy audits
• Understand how Std 211 can be used with BuildingSync xml and DOE’s Asset Scoring tool

The business of performing energy audits has long lacked regulation or standardization of approaches. What makes an energy audit acceptable, good, or great has been the subject of much discussion and debate. Best practices in the field have been passed like an oral tradition, where practitioners pass knowledge and approaches from person to person. In 2018 ASHRAE will release its first standard for energy audits in commercial and multifamily buildings.

1. Meet ASHRAE’s Newest Standard: How Energy Audit Levels 1, 2 and 3 Have Changed
Jim Kelsey, Member, KW Engineering, Oakland, CA

There are several major changes to ASHRAE’s prior guidance on energy audits that are significant improvements over prior approaches. Do you still know the difference between a Level 1 and a Level 2 Audit? Come and see. This presentation provides an overview of the new requirements, as well as clarification of the purpose of the audit levels 1, 2 and 3. The presentation also discusses the standard-setting process and what happens when you try to bring engineers, policy-makers and contractors to consensus in an ANSI governed setting (spoiler alert – it’s not a dull as you think).

2. New York City Experience: How the Largest Mandatory Energy Audit Program Informed Standard 211
Michael Bobker, CUNY Institute for Urban Systems, New York City, NY

New York is among the world’s leading cities in policies setting aggressive greenhouse-gas reduction goals. It was the first major U.S. city to require energy audits in its existing building stock. With the energy audit ordinance, the City immediately recognized the need for standard language to ensure quality and scope of those audits. This presentation relates experience with a large mandatory audits program, discusses the findings of the most recent audits and the contributions towards an understanding of energy use at scale, and how regulator experience has informed decisions and approaches within Standard 211.
3. Raising the Bar Through Improved ASHRAE Energy Audit Forms

Ben O'Donnell, Associate Member, CodeGreen Solutions, New York, NY

As part of ASHRAE Standard 211, ASHRAE is publishing energy audit reporting forms that will show clients and regulators that minimum requirements of the standard are met. The forms were designed to catch or highlight common issues with energy audits such as reasonableness of savings calculations, transparency of benchmarking calculations and alignment of end use consumption with historical utility bills. Key excerpts of the new Standard will be referenced and explained. This presentation demonstrates their use, with an emphasis of how recipients of energy audits can validate their quality.

4. Linking Energy Audits and Building Simulation Using BuildingSync

Supriya Goel, Member, Pacific Northwest National Laboratory, Portland, OR

The presentation introduces two DOE tools, Building Energy Asset Score tool and BuildingSync. Building Energy Asset Score is a web based tool that rates the as-designed efficiency of a building through a whole building energy simulation using EnergyPlus. BuildingSync is an XML schema that allows for data exchange between multiple tools. The presentation discusses how the data entered into 211’s required forms may be imported into Asset Score tool through the BuildingSync. This capability will allow users collecting L2 audit data to generate an Asset Score report and an energy model for their building with minimal additional inputs.

Wednesday, June 27, 8:00 a.m. - 9:30 a.m.

Seminar 59 (Intermediate)

Beneficial Carbon Reduction Strategies: Cogeneration, Electrification and Consumer Options

Track: District Energy and Cogeneration Plants

Room: 372BE

Sponsor: 2.8 - Building Environmental Impacts and Sustainability

Chair: Kevin Brown, P.E., The Linc Group, Atlanta, GA

• Explain the impacts that existing building energy policies have on the tradeoffs between incumbent fuel sources, new distributed energy resources and energy efficiency

• Understand how building energy policies can evolve to accommodate and encourage the market adoption of zero energy and zero carbon buildings

• Distinguish the role of electrification of previously fossil-fueled end uses from other approaches to carbon emission reduction

• Identify the role of CHP and other affordable options as alternatives to electrification in a balanced carbon emission reduction strategy

High performance building technologies such as combined heat and power, heat pumps, and photovoltaic panels can be an integral part of beneficial greenhouse gas emission reduction strategies. Rapid advancements in each of these areas, along with dynamic changes in the electric grid, are creating opportunities and challenges when trying to determine a balanced approach to achieving the ultimate goal of zero carbon emissions. Diverse viewpoints on technology improvements, policies that may inadvertently or intentionally favor one type of fuel over another and emission reduction options that provide consumer and societal benefits are shared.
1. Getting to Zero Carbon: Distributed Energy Source Strategies and Options

Jim Edelson, Member, New Building Institute, Vancouver, WA

Energy options for high performance buildings are rapidly expanding in type, cost, and environmental impacts, making zero energy and zero carbon buildings a real customer option. Many existing energy policies were written when there were fewer energy source options. For greenhouse gas emission reduction strategies, a fair accounting of energy and environmental impacts of different options is needed. This presentation identifies zero carbon pathways and illustrates the roles and challenges facing incumbent fuels and new options, such as community solar. CHP, district energy and other distributed resources are reviewed as viable options in a zero carbon strategy.

2. Electrification, Cogeneration and Emissions Efficiency

David Farnsworth, Regulatory Assistance Project, Montpelier, VT

Rapid technology change means cleaner, lower-cost and more resilient options for meeting customers’ energy needs are increasingly available. This presentation describes the potential for electrification of energy end uses—such as space heating, water heating and transportation to achieve ambitious greenhouse gas emission reduction goals using high efficiency electric options such as heat pumps and electric vehicles. It will also highlight the potential role of cogeneration and local renewable power options to meet the evolving demand for electricity while reducing GHG emissions.

3. Retaining Worthy Consumer Options for Carbon Reduction

Neil Leslie, Member, Gas Technology Institute, Des Plaines, IL

Greenhouse gas emission reduction policies must carefully balance the benefits of reliable, affordable and efficient consumer energy options with the desire to minimize environmental impacts. A balanced energy strategy acknowledges the value of using appropriate, efficient and cost-effective energy sources to meet specific consumer needs and societal objectives equitably. This presentation summarizes an analysis of the energy use, environmental impact and cost-trade-offs of potential future residential energy use scenarios. The role of natural gas and electricity in homes, including heating, water heating, cooking, drying and combined heat and power, will be explored, including potential implications for consumers and society.

Wednesday, June 27, 8:00 a.m. - 9:30 a.m.

Seminar 60 (Intermediate)

Building Simulation Tools and Models Needed for Assessing the Impacts of Extreme and Future Weather Scenarios on the Building, City and Grid Scale

Track: Safeguarding Your HVAC&R System

Room: 372AD

Sponsor: 7.5 - Smart Building Systems

Chair: Xiaohui Zhou, Ph.D, P.E, Member, Seventh Wave, Madison, WI

• List the types of reduced order models that can be used for large scale energy analysis

• Describe how internet of thing (IoT) technologies can help reduced building electric peak demand

• Understand how to simulate more realistic HVAC energy use at a 1-minute timestep

• Provide a comparison of different studies' tools to assess impacts of extreme events on residential buildings

The successful development and operation of a smart electric grid hinges on the dynamic operation of both the supply and the demand of electricity use. For electric utilities companies to manage the smart grid, they have developed computer-based remote controls and automation tools and procedures. However, there is a growing need for a more intimate knowledge of the dynamic electricity demands of, in particular, residential buildings. This seminar covers some of the models required to simulate electric energy use at the building level can be used at multiple scales for analysis of future weather or heat waves.
1. Reduce Building Order Models for Grid Optimization and Analysis  
**Paulo Cesar Tabares-Velasco, Associate Member**, Colorado School of Mines, Golden, CO  
This presentation reviews and compares reduced order models that can be used for modeling residential neighborhoods and special attention is given to grey-box and black-box ROMs. The presentation also shows results from an ongoing project that has developed and compared a grey-box and black-box model using data from field data as well as artificial data from six different homes using EnergyPlus.

2. Data Driven Energy Consumption Prediction  
**Mina Sartipi**, University of Tennessee-Chattanooga, Chattanooga, TN  
The rapid introduction of new IoT solutions allows building operators to make their properties smarter, more observable and more controllable. For instance, we can deploy massive temperature sensors to monitor fine-grained air temperature distribution in real time. The goal is to reduce the total energy consumption in the building, while considering both human comfort and environment sustainability. As a critical and necessary input to plan and optimize energy usage in smart buildings, an energy consumption prediction tool will be proposed exploring computational modeling. Based on energy consumption prediction, we can forecast energy budget needed for temperature adjustment in a certain building area.

3. On-Off Cycling Controller in EnergyPlus for Residential HVAC systems  
**Niraj Kunwar, Student Member**, Iowa State University, Ames, IA  
The ability to simulate HVAC cycling creates outputs from building energy simulation programs that will provide key insights into how the performance of a building with on/off cycling HVAC systems can influence the smart grid and the role building(s) can play. This presentation covers the development of an EMS (energy management system) to simulate on/off cycling performance of DX systems in EnergyPlus. A Case study will be presented where field test data was collected, including energy data, indoor temperature data, and weather data, and the model was validated using this data.

Wednesday, June 27, 8:00 a.m. - 9:30 a.m.  
Seminar 61 (Intermediate)

**Convective Vs. Radiant Load Calculations: Are They Different?**  
Track: Research Summit  
Room: 372CF  
**Sponsor: 4.1 - Load Calculation Data and Procedures**  
*Chair: Som Shrestha, Ph.D., Oak Ridge National Laboratory, Oak Ridge, TN*  
- Understand the differences between traditional all-air-based loads and radiant cooling space loads  
- Learn about the ASHRAE research process and understand what RTAR, Work Statement and ASHRAE bid process are  
- Understand the assumptions behead Heat Balance Method (HBM) and Radiant Time Series (RTS) load calculation methods  
- Learn the experiments conducted to validate modeling and calculation procedures  

Radiant cooling uses cooler surfaces to remove heat from a space. Traditional load calculations are based on assumptions of a well-mixed space with surface temperature symmetry and a time lag between radiant heat gains and when the all-air-based system removes the heat. How accurate are traditional load calculations for a radiantly cooled space? To answer this question, ASHRAE is funding research project RP 1729 - Experimental Verification of Cooling Load Calculations for Spaces with Non-Uniform Temperature Radiant Surfaces. This session provides the history of this research projects development through ASHRAE's research process and presents the research methodology and results.
1. Why ASHRAE Needed the Research on Cooling Load Calculations for the Radiant Cooling System?
Christopher K. Wilkins, Member, CBR USA, Cambridge, MA
The calculation of the cooling load for space is an essential first step in the design process for air conditioning systems. The load has long been defined as the amount of heat extracted by the air. Radiant systems fundamentally change the way that heat is extracted from space and led to questions regarding the appropriateness of traditional cooling load calculation methods when applied to these systems. This presentation looks at how these questions led to the identification of a need for an ASHRAE research project to explore the differences in the dynamics of the cooling load in a space.

2. Navigating ASHRAE Research: Research Project RP 1729 Journey from Concept Through Research
Glenn Friedman, Fellow ASHRAE, Taylor Engineering, Alameda, CA
Research is an important part of our industry's growth and improvement. Glenn Friedman unravels the mystery of ASHRAE’s research process and how RP 1729 started from a concept and navigated its way from the research subcommittee through TC 4.1 Load Calculations Technical Committee to a Research Topic Acceptance Request (RTAR) for formal approval by ASHRAE’s Research Administration Committee (RAC), then on to a Work Statement for ASHRAE to use for bidding the research project. After the bids, the journey continued through a Project Evaluation Subcommittee (PES) and a contract and a Project Monitoring Subcommittee (PES).

3. Can We use Heat Balance Method and Radiant Time Series Method for Load Calculation with Radiant Cooling Systems?
Atila Novoselac, Member, University of Texas at Austin, Austin, TX
Load calculation methods, such as the Heat Balance Method (HBM) and Radiant Time Series (RTS) Method, are developed for all-air systems. They assume that all heat energy is extracted via air through convection from internal surfaces. However, this is not correct for systems that include radiant cooling components; the dynamics of heat transfer in a room with radiant panels is very different. This presentation shows the fundamental differences in convective, conductive and radiative heat transfer in rooms with all-air and radiant cooling systems. It points out the deficiencies of HBM and RTS when applied to designs utilizing radiant systems.

4. Comparison of Radiant Cooling and All-Air systems, Methodology for Experimental and Numerical Load Analysis
Stephen Bourne, Member, University of Texas at Austin, Austin, TX
The presentation describes the methodology for a side-by-side performance comparison of radiant cooling and all-air systems applied in a typical office space. It will show how two identical test rooms, with interchangeable HVAC and façade systems, are used for the development of experimental benchmark data when considering cooling load calculations. A set of comparison experiments are developed for different types of heat gains, operation conditions, and control strategies. The experimental results are also used to develop computational models that are further utilized to compare these two systems. The presentation also outlines the accuracy of experimental and computational methods.

5. Difference in Cooling Loads for Radiant and All-Air Systems for Different Types of Heat Gains and Control (Operative vs. Air) Temperature
Ardeshir Moftakhari, Student Member, University of Texas (UT) at Austin, Austin, TX
This presentation highlights major differences in the cooling load dynamics and load intensity of radiant and all-air systems based on experimental and modeled data. The study shows how the type of heat sources in the space (transmitted solar, internal radiative, internal convective, or combination) impacts the cooling load. The experimentally measured loads are compared to those obtained by Heat Balance and Radiant Time Series methods and the differences are explained. Also, the presentation shows the importance of controlled variable (air vs. operative temperature) when considering nominal cooling loads as well as the energy consumption and air/surface temperature distribution.
Design and Implementation of Solar-Assisted Geothermal Systems: From A to Z

Track: Fundamentals and Applications

Room: 370ABDE


Chair: Janice Means, P.E., Lawrence Technological University, Southfield, MI

- Integrate a solar-assisted geothermal system with a building and its mechanical systems
- Understand why and how hourly energy modeling can be used during the building design process to reduce costs and improve the performance of a solar-assisted geothermal system
- Understand how to properly design a chilled beam system that is efficient, reliable and cost effective while seamlessly working with the other parts of the solar-assisted geothermal system
- Explain the impact of recognizing geothermal field issues late in the construction process so that such issues can be preempted

Solar and geothermal systems play an enabling role in the race to net-zero buildings and communities. Their integration and interaction with the mechanical systems of the building must be clearly understood to ensure optimal performance and operation. This seminar describes the steps of integrated design and implementation of solar-assisted geothermal systems: Modeling, Design, Installation and Commissioning.

1. Optimizing the Ground Heat Exchanger for a Renewable System

Edward Lohrenz, GEOptimize Inc, Winnipeg, MB, Canada

Ground-loop heat exchanger (GLHE) replaces both the gas line and cooling tower needed by a conventional HVAC system. The size and cost is sensitive to peak heating and cooling loads of the system it is connected to and the balance of annual heating and cooling loads. In effect, it is an energy storage device: absorbing energy removed from the building while cooling and serving as a heat source for when heating.

2. The Integrated Renewable System, Thermal Storage and Hybrid

Edward Lohrenz, GEOptimize Inc, Winnipeg, MB, Canada

The energy model is built and the design team has incorporated changes balancing energy loads. Designing the ground-loop heat exchanger (GLHE) system begins with evaluating site assets. GLHE designers need to incorporate system assets as needed, such as solar thermal and borehole thermal storage. Low energy pumping and specialized control sequences are added to optimize renewable/conventional asset operation. This presentation guides mechanical engineers through the design challenges and effective solutions of a GLHE integrated with solar thermal and borehole thermal storage.

3. Active Chilled Beam with GSHP and Solar Together: Highest Efficiency Becomes Possible

Khalid Nagidi, Member, Energy Management Consulting Group, Wantagh, NY

Designers are always looking for technologies that can assist them reduce the energy required to operate a cooling & heating system. Therefore, combining active chilled beam with ground source heat pump and solar hot water systems can achieve the highest efficiency possible. This presentation provides designers with solid knowledge on Active Chilled Beam technologies in commercial buildings. It explains the steps to be followed during the design phase from sizing the water and air sides to control strategies.
4. Commissioning of Geothermal Fields

Andy DeRocher, Member, Sustainable Engineering Group LLC, Middleton, WI

This presentation demonstrates how commissioning can improve the quality of the design, installation and operation of geothermal fields and illustrates this with case study examples. The presentation also enables designers to predict and balance energy loads to and from the ground early in the design process, using hourly energy modeling simulations as a design tool. This way, the size of the GLHE can be reduced and the long term performance of the system becomes more stable and predictable.

Wednesday, June 27, 8:00 a.m. - 9:30 a.m.
Seminar 63 (Intermediate)

Moisture-Induced Residential Building Failures: Lessons Learned in Recent Humid Climate Residential Construction

Track: Residential Modern Buildings in Hot and Humid Climates
Room: 371CF

Sponsors: 1.12 - Moisture Management in Buildings, 4.4 - Building Materials and Building Envelope Performance

Chair: Lan Chi Nguyen Weekes, InAIR Environmental Ltd, Ottawa, ON, Canada

• Understand the change in material properties of stucco assemblies
• Recognize common water damage problems associated with recent home construction
• Identify causes of mold growth associated with condensation and elevated relative humidity
• Learn how mold growth potential differs between modular residential and conventional construction methods

Modern residential design and construction is on the rise, driven by economic growth and sustainability. While this is a positive trend, problems often begin when the focus on innovative building technology fails to fully take into consideration the impact of the vernacular environment. Modern residential design is challenging in hot, humid climates, and difficult to minimize moisture and mold problems. The causes of these types of problems can be traced to the use of unfamiliar products, misapplications of products, and failures at intersections of scope of work using case studies to introduce some of the more common moisture issues that arise.

1. The Coming Stuccopolis and Other Wet Home Trepidations
Paul Haas, Building & Forensic Sciences, LLC, West Palm Beach, FL

This session examines the changes in materials and construction practice leading to stucco failures. It will review stucco components and their contribution to retaining excess moisture. Case studies diagnosing stucco failures will be discussed. Finally, recommendations for installing, maintaining stucco to avoid mold growth and rot will be provided. Drawings, illustrations and photographs will illustrate failures in stucco components including Portland cement plaster, control/expansion joints and substrate leading to leaks and water damages. Construction and finishing methods will also be discussed as related to moisture and water infiltration and expected life of the assembly.

2. Resolution of Mold Issues in New Home Construction
Ed Light, Building Dynamics, LLC, Ashton, MD

This presentation identifies root causes of mold growth in recent home construction, evaluates the efficacy of response actions and recommends quality control measures to avoid mold issues. Mold growth associated with water damage originates from either incomplete drainage control, infiltration prior to close-in, flashing failures or plumbing releases. Mold growth associated with humidity control is dependent on duration of damp conditions, material susceptibility, condensing surfaces and HVAC operation. Recent requirements for tighter envelopes and mechanical outside make humidity control more challenging. Mold growth may occur during the construction process or not become apparent until after occupancy.
3. Deja Vu All Over Again: Risks for Moisture and Mold Problems in Modern Modular Domicile Construction

Donald Snell, P.E., Liberty Building Forensics Group, Zellwood, FL

There has been a recent resurgence in domicile modular construction nationwide. Despite the obvious interest in this particular type of building, many within the design and construction industry are not aware of the moisture and mold problems that modular construction has historically encountered, especially in hot and humid climates. This presentation examines these risks.

Wednesday, June 27, 8:00 a.m. - 9:30 a.m.
Seminar 64 (Intermediate)

Radiant Heating and Cooling Systems: Past, Present and Future

Track: HVAC&R Systems and Equipment

Room: 371AB

Sponsors: 6.5 - Radiant Heating and Cooling and SSPC 55

Chair: Devin Anthony Abellon, P.E., Uponor, Phoenix, AZ

- Describe early radiant systems, with an understanding of how architecture and construction methods helped shape heating strategies
- Explain the typical design parameters used today in commercial radiant heating and cooling systems, including capacities, operating water temperatures and slab construction
- Differentiate between the benefits of high-thermal-mass embedded-tube systems versus low-mass panel solutions
- Describe how some of the research being done today can impact the design and efficiency of future radiant systems

The evolution of radiant heating and cooling systems through the centuries and around the world has focused on the engineer's continuous journey to integrate building mass, surfaces and thermal energy to create comfortable and healthy indoor environments. This seminar explores the history of radiant systems from it's early beginnings in Asia and Europe, provide an overview of how radiant systems are designed and utilized today and look towards what the future holds thanks to two research projects that are underway.

1. The History of Radiant Heating and Cooling Systems

Robert Bean, P.L.(Eng.), Member, Indoor Climate Consultants Inc., Calgary, AB, Canada

Present history books show radiant floor systems have been around at least since 3000 B.C. Decades before the Greeks and Romans, inhabitants of present day Korea and Alaska used forms of radiant systems that later found themselves in hospital tents of the American Civil War. This session explores the past of radiant floor heating systems to present day.

2. Radiant Best Practices: Leveraging Yesterday's Lessons Learned to Design Effective Systems Today

Peter Simmonds, Fellow ASHRAE, Building and Systems Analytics LLC, Marina Del Rey, CA

Contrasting how radiant systems were designed over the past few centuries, this session focuses on how radiant systems are typically designed today. This session explores how lessons learned over recent years have helped improve the effectiveness, efficiency and constructability of embedded tube radiant heating and cooling systems.

3. Using Today's Radiant Research to Improve Tomorrow's Indoor Thermal Environment

Ongun Berk Kazanci, Associate Member, Technical University of Denmark, Kgs. Lyngby, Denmark

This presentation provides an overview of an experimental comparison of two cooling systems. The studied systems were a radiant cooling system (radiant ceiling panels and mixing ventilation) and a combined radiant and convective cooling system (combination of a different kind of ceiling panels and diffuse ceiling ventilation). By better understanding how these systems work, future radiant systems can be more effectively incorporated into building designs.
4. Radiant Research on Indoor Thermal Comfort: Are We Missing the Diversity Factor?
Dolaana Khovalyg, Technical University of Denmark, Lyngby, Denmark

There are four major factors differentiating individuals: demographics, geographical location and the context of buildings, the indoor environment, and cognition. The requirements for thermal comfort for adult males and females differ due to different physiology, metabolic rate, activity level and clothing patterns. Geographic location is important for any factors considered – human physiology, climate, thermal management practices may differ in various parts of the world. This presentation addresses the question of whether we are missing the diversity factor when we define indoor comfort conditions.

Wednesday, June 27, 9:45 a.m. - 10:45 a.m.
Conference Paper Session 16 (Intermediate)

Comparison of New Refrigerants

Track: Research Summit
Room: 371CF
Chair: Jaya Makhopadhyay, Montana State University, Bozeman, MT

Improvements in refrigerants and refrigerant applications seem to occur at a lightening fast pace. This session looks at advancements in refrigerants and refrigerant application.

1. Examination of a Novel R410A (HO-18-C050) *WITHDRAWN*
Kenneth Schultz, Member, Stephen Kujak, Member, Ingersoll Rand, La Crosse, WI

This paper reports the performance of a new and innovative R410A alternative in two air conditioning platforms. System performance results with this new refrigerant will be presented for a 100 RT air-cooled packaged water chiller along with R410A as baseline, as well as R32 and R452B. The chiller comprised scroll compressors, a brazed plate evaporator, and microchannel condenser. Additionally, system performance results with the new refrigerant will be presented for a 4 RT residential split system along with R410A as baseline. The new refrigerant was designed to be compatible with existing R-410A equipment, requiring minimal equipment modifications at both standard air conditioning and high ambient temperature operating conditions.

2. Comparison of Pressure Drop and Cooling Duty of Green Secondary Refrigerant (Ice Slurry) with Chilled Water in a Plate Heat Exchanger (HO-18-C051)
Rajinder Singh, Member, Pusa Institute of Technology, New Delhi, India

This paper reports the experimental comparison of cooling duty and pressure drop of ice slurry with chilled water. Experiments were performed on plate heat exchanger (PHE) using chilled water and ice slurry as secondary fluids. Propylene Glycol (PG) and Mono Ethylene Glycol (MEG) are used as depressants (10%, 20%, 30% and 40% concentration) in ice slurry formation. The results show that by using ice slurry in place of chilled water in plate heat exchanger, cooling duty found to be higher and pressure drop is slightly higher in case of ice slurry.

3. Design-Guidelines for Liquid Tub in Immersion System Using Natural Convection Below PUE = 1.04 (HO-18-C052)
Morito Matsuoka1, Member, Hideo Kubo2, Ph.D., Kazuhiro Matsuda1, (1) Osaka University, Osaka, Japan, (2) Fujitsu LTD, Kawasaki, Japan

For liquid immersion technology utilizing natural convection of refrigerant as a cooling method for HPC (High Performance Computing) systems with PUE = 1.04, this paper examines the effect of the geometry of the liquid tub on the natural convection in detail. An open flow path having an adequate cross-sectional area that is the least obstructive to the natural convection surrounding the slot is essential for cooling a highly efficient board. The slot insertion and removal and task fluctuation had little influence on other slots or CPU cooling efficiency.
Variable Speed, Variable Options
Track: Fundamentals and Applications
Room: 372AD
Chair: Xiufeng Pang, Ph.D, Berkeley Lab, Walnut Creek, CA

Variable speed drives, once too costly and underutilized, are common in most HVAC applications today. As with any technology, advances and application experience continue to provide better design and efficiency. This session shows the advancements in using VFD in HVAC applications.

1. Experimental Comparison of Energy Consumption between Constant and Variable Speed Air-Conditioner under the Korean and Saudi Arabian Climate Conditions (HO-18-C053)
JaeHun Lim1, MyungSup Yoon1, Ph.D., Turki Al-Qahtani2, Yujin Nam1, (1) Pusan National University & Korea Testing Laboratory, Jinju, South Korea (2) Saudi Standards, Quality and Metrology Organization, Riyadh, Saudi Arabia

It is well known that inverter-driven variable speed compressor (or inverter) air-conditioners are more efficient than constant speed air-conditioners. But someone believes that inverter air-conditioners are not energy efficient in hot areas like Saudi Arabia. This paper quantitatively measures the energy savings of inverter versus constant speed air-conditioners in several cities in Korea and Saudi Arabia. SASO(Saudi Standard Organization) and KTL(Korea Testing Laboratory) carry out joint research on energy saving effect of inverter air-conditioners. Results show that energy reduction effects of using inverter air-conditioner are largely depend on the temperature and cooling load changes for a day or a season.

2. Variable Speed HVAC Systems and the Moving Target for Designing Noise Treatments (HO-18-C054)
Roman Wowk, Associate Member, Papadimos Group, San Francisco, CA

Manufacturers' predictions of equipment noise output are typically based on maximum design operating conditions. However, equipment often operates at variable speeds and the discrepancy between the "worst-case design" and more typical noise levels can be significant. In certain cases, choosing one over the other can substantially change the noise control approach on a project. This paper presents previous examples where this has occurred, suggesting that having manufacturers' equipment noise predictions under the full range of operating conditions rather than a single point on the curve are not only beneficial but necessary for making informed project decisions for noise treatments.

3. Energy and Economic Analysis of Variable-Speed Operation for Packaged Rooftop Units (HO-18-C055)
Jie Cai, Ph.D., James E. Braun, Ph.D., P.E., Fellow ASHRAE, University of Oklahoma, Norman, OK

This paper presents economic and energy performance assessment results for variable-speed technology used in rooftop units.

Air Flow Control from Text Book to Test Standard
Track: HVAC&R Control Freaks
Room: 372CF
Sponsors: 1.4 - Control Theory and Application, 9.10 - Laboratory Systems and SPC 195
Chair: James Coogan, P.E., Siemens Industry, Inc., Buffalo Grove, IL
• Specify a level air flow control performance that supports operational objectives for the buildings they design
• Use ASHRAE Standard 195 to specify and evaluate performance in a construction project
• Apply instrument accuracy concepts when evaluating air flow control systems, recognizing the effects of components on overall accuracy
• Apply concepts of control loop dynamics when evaluating air flow control systems, recognizing effects of components on speed and stability

Airflow control is one of the most frequently applied HVAC functions. This seminar teaches specifying, assessing and achieving flow control performance. Speakers connect text book definitions of loop performance with consequences for people in the building. This results in a range of performance specifications for different circumstances. The session also covers designing control loops for performance. Speed, accuracy and tunability of the loop are explored as affected by the measurable, specifiable characteristics of controllers, actuators, sensors and dampers. ASHRAE Standard 195 is presented as the vehicle to specify and verify performance in applications.

1. Control and Instrument Principles Applied to Air Flow at Terminals
   Xiaohui Zhou, Ph.D, P.E., Member, Seventh Wave, Madison, WI
   This presentation explores the engineering fundamentals of variable-air-volume terminal unit air flow controls: VAV box air flow pickup types and the impact of various inlet duct conditions; VAV controller air flow sensor types, measuring principles and limitations; VAV controller I/O resolution and its impact on control accuracy; and PID control loop dynamics. The performance of VAV air flow control loops is also defined.

2. Achieving Air Flow Control Performance
   James Coogan, Associate Member, Siemens Industry, Inc., Buffalo Grove, IL
   Performance of an air flow control loop includes accuracy, speed and stability. All 3 are related to characteristics of the components (damper, actuator, sensor) and software features. Details of these relationships are explored through a combination of test data, dynamic simulations and analysis. The results come together to indicate suitability of different combinations of components for a given air flow control application.

3. Energy Efficiency, Air Flow Control and ASHRAE Test Standard 195
   Jeff Stein, Member, Taylor Engineering, LLC, Alameda, CA
   This presentation covers how clever zone control sequences like “Dual Maximum” and “Time Averaged Ventilation” save energy and improve comfort compared to other commonly used sequences. It also addresses how zone minimum flow rates are commonly determined and how they should be determined as well as a summary of ASHRAE Standard 195, why it is needed, and how it will drive change in the industry and save energy worldwide.

Wednesday, June 27, 9:45 – 10:45
Seminar 66 (Intermediate)

Foodservice Design for Hot and Humid Climates
Track: Fundamentals and Applications
Room: 372BE

Sponsor: 5.10 - Kitchen Ventilation

Chair: Fuoad Parvin, P.E., Halton Company, Scottsville, KY
• Learn design strategies to combat commercial kitchen humidity and mold in hot and humid climate zones
• Properly select rooftop system for their restaurant in hot and humid climates
• Properly integrating Demand-control Ventilation (DCV) in commercial kitchens with the facility at large
• Utilize only high efficiency hood and replacement air delivery strategies for efficient operation
This seminar provides efficient whole building integrated HVAC designs for restaurants in hot and humid climate. In this climate, replacement air is a major source of moisture that represents a significant fraction of the HVAC load to neutralize. Best practices are presented that optimize operation of the HVAC system through proper selection of RTUs with dedicated outdoor air units, high efficiency hoods, variable speed cooling, integration of demand-control ventilation (DCV) in kitchens and replacement air quality and delivery strategies. In all, these measures achieve comfortable space conditions throughout the foodservice facility, increase productivity, prevent mold growth and are key to reducing operational costs.

1. Energy Efficient and Comfortable Restaurant Design: Hood, Makeup and Fan
   Russ Robison, Member, Gaylord Industries, Tualatin, OR
   With hood replacement air a major source of moisture in our commercial kitchens located in hot and humid climates, efficient placement, quality of replacement air and hood performance are key to reducing operational costs, maximizing worker comfort and preventing the propagation of mold. Let’s change the paradigm of “If you can’t take the heat, get out of the kitchen”.

2. Demand-Control Ventilation (DCV) Integration with Foodservice Facilities
   Jason Brown, Melink Corporation, Cincinnati, OH
   This session reviews the various aspects of properly integrating DCV in commercial kitchens with the facility at large. Topics covered include sequence of operation, user interface and training, VFD & BAS communication, supply air integration and maintenance.

3. Integrated Whole Building Design With Replacement Air: Limitations of Standard Rooftop Units
   Gregory DuChane, Member, Trane, Columbus, OH
   The landscape of the traditional rooftop unit have changed over the years. There are many options available for engineers and owners to select the proper rooftop system for their restaurant. From traditional constant volume units to variable supply air flow and variable speed cooling. The rooftop unit works either stand alone or in conjunction with other dedicated outdoor air units to provide replacement air for the exhaust hoods and selecting the “right” unit is essential from a comfort and energy perspective. This presentation reviews various approaches to replacement air with operational parameters of the various rooftop configurations from a pros & cons perspective.

   Wednesday, June 27, 9:45 a.m. - 10:45 a.m.
   Seminar 67 (Basic)

Fundamentals of Thermal Bridging and Mathematical Models

Track: Fundamentals and Applications

Room: 370ABDE

Sponsor: 4.4 - Building Materials and Building Envelope Performance

Chair: Diana Fisler, Ph.D., Johns Manville, Littleton, CO

- Describe a thermal bridge
- Estimate the magnitude of the effect thermal bridges can have on whole wall performance
- Describe qualitatively various mathematical approaches to calculating assembly performance
- Explain the pros and cons of various methods

Whole assemblies may not perform as desired thermally due to thermal bridges which can leak heat at a higher rate than the components. This session provides a general overview of types of thermal bridges, their impacts and methods of mitigation through improved detailing based on on-going work within the ASHRAE 90.1 thermal bridging task group. It also describes calculation methods for determining whole-assembly R-values and compare methodologies.
1. Fundamentals of Thermal Bridging

Juan Crandell, Ares Consulting, Paris, France

Thermal bridges are commonly understood and included when determining U-factors for building envelope assemblies. Less known are thermal bridges created at various interfaces between building envelop assemblies such as junctures between floor edges and walls, roof edges and walls, and fenestration and walls. While largely ignored in codes and practice, poor detailing of insulation continuity, structure, and cladding support at these locations can account for as much as 20 to 70 percent of the heat flow through a building envelope. This presentation addresses a variety of thermal bridges, their impacts and methods of mitigation through improved detailing.

2. New Methods for Calculating Whole Wall Assemblies

Alexander McGowan, WSP Canada, Richmond, BC, Canada

Standards such as ASHRAE 90.1 require total-assembly R-values, for prescriptive, trade-off or performance compliance. This presentation explains how and why various calculation methods work and describes ASHRAE research comparing hot-box tests, computer simulation and various hand calculation methods. Methods discussed include physical testing, 2D and 3D computer simulation, parallel-path and isothermal-planes methods, zone method, modified zone method, ISO/DIS 6946, BRANZ method and methods required by ASHRAE 90.1. These approaches are assessed for accuracy, ease of use and repeatability of results.

3. Mathematical Models for Addressing Thermal Bridging

Dave Yarbrough, Ph.D, P.E., R&D Services, Inc., Cookeville, Tennessee

In buildings, thermal bridges are responsible for significant number of thermal performance and durability problems. With the implementation of high energy performance code regulations for today’s buildings, yielding a common usage of advanced thermal insulations and complex building structures, a single change in a material configuration may often compromise local thermal performance and cause durability problems within the exterior envelopes. This presentation addresses different scenarios where optimum performance of thermal insulation is compromised by highly conductive structural members and fasteners. Some engineering solutions, which help in minimizing thermal bridges, reducing uncontrolled heat losses or gains, and, in many cases, limit the risk of moisture condensation, are discussed as well.

Wednesday, June 27, 9:45 a.m. - 10:45 a.m.
Seminar 68 (Basic)

Racing to Zero Through Innovative Residential Design

Track: Residential Modern Buildings in Hot and Humid Climates
Room: 371AB

Sponsor: Student Activities, Residential Buildings Committee

Chair: Megan Sierl, P.E., Montana State University, Bozeman, MT

• Understand the successes of the student design competition in advancing the residential and commercial building industry

• Understand innovative technologies used for low-income housing in a Houston urban single-family home

• Understand the requirements for a Zero Energy Ready home

The Race to Zero Student Design Competition inspires collegiate students to become the next generation of building science professionals through a zero energy ready buildings design challenge. To increase the level of knowledge in the industry, teams from varying disciplines develop comprehensive, high-quality designs with industry partners that are market-ready across national and international climates. This session covers the benefits of competing in the design arena and the application of the Zero Energy Ready Home program in Houston by a successful Race to Zero team in a modern residential building.
1. Modern Residential Design through the Race to Zero

Rachel Romero, Member, NREL, Golden, CO

Through an interdisciplinary and collaborative approach to design, Race to Zero teams are leading the industry with their superior building designs, which are aesthetically pleasing, cost effective and highly efficient. Their work is shared with industry partners, jurors, and DOE, so others can learn. This presentation covers the Race to Zero program and the requirements for participation. It reviews the success of the 2018 Race to Zero competitions and describes the amazing winning designs and the future professionals in building science.

2. Independence in Residential Design

Shelley Pottorf, Prairie View A&M University, Prairie View, TX

This presentation shares the design of the Prairie View A&M Race to Zero urban single-family home in Houston, Texas that meets Zero Energy Home requirements. The Independence Heights neighborhood was the first incorporated black municipality in Texas (1910). The Independence Heights neighborhood sustained significant damage from multiple storms: Allison, Ike and most recently Harvey in August of 2017. This year, the Prairie View A&M team approached the project from a modular perspective as the Fabrication Lab was completed in January 2018. The goal was to design, energy model, and build various options to provide affordable, modular, high-performance housing to a low-income community.

Wednesday, June 27, 9:45 a.m. - 10:45 a.m.
Forum 3 (Intermediate)

Operation and Maintenance Management Training: How Useful Is It Really?

Track: Professional Skills
Room: 370CF
Sponsors: 7.3 - Operation and Maintenance Management and 7.9 - Building Commissioning

Chair: Mina Agarabi, P.E., Agarabi Engineering, PLLC, NY, NY

Proper O&M is critical to the successful operation of any building, especially high performance buildings, yet many technicians are ineffectively trained. Managers should create a master training plan, decide who will be trained, select the training topics and approve the training content. Additionally, the ASHRAE O&M training book suggests that “Training quality and documentation should be reviewed during training to verify that [it] meets the… specifications.” But is this a general practice? Is classroom training more effective than on-the-job training? How do you verify post-training improvement in staff performance?

Wednesday, June 27, 9:45 a.m. – 10:45 p.m.
Workshop 7 (Intermediate)

"First Do No Harm": Managing a Contractor's Risks When Work & Standard of Care Involve Environmental Health

Track: Safeguarding Your HVAC&R System
Room: 371DE
Sponsor: EHC

Chair: Donald Weekes, InAIR Environmental, Ltd., Ottawa, ON, Canada

• Have a greater understanding of what a contractors standard of care includes
• Have a greater understanding of expert witness standards, including knowing whether nonscientific evidence is admissible in the state in which construction work is performed
• Understand sources and pathways and how these can manifest into illnesses including infection
• Recognize the influence that innovation can sometimes have on environmental health

Today's buildings are complex and dynamic, often creating hidden micro-environments. Unfortunately, by the time these micro-environments become visible or apparent, oftentimes building failure(s) have already occurred. Despite great strides in sustainability and high performance, unfavorable environmental health conditions can manifest in any type of building. Engineers, contractors, EH practitioners, owners, and those in operation and maintenance need to know how to be on the lookout for warning signs before it's too late.

1. Insights on Construction Standard of Care on Cases Involving Environmental Health

Donald Snell, P.E., Liberty Building Forensics Group, Zellwood, FL

In this portion of the multidisciplinary workshop, Mr. Snell introduces what happens when an environmental health issue arises in a building and the contractor's standard of care is questioned as well as what a contractor's fundamental Standard of Care includes, whether the construction is a modern multi-family dwelling, office building, or hospital bed tower wing. How expert witness standards may differ state to state, including knowing whether nonscientific evidence is admissible in the state in which you are performing construction work (in the event that construction defect or liability claims are filed).

1. Minimizing Environmental Health Concerns on Your Next Construction Project

W. Elliot Horner, Ph.D., Member, UL Environment, Marietta, GA

In this portion of the multidisciplinary workshop Dr. Horner introduces what happens when an environmental health issue manifests in a building and the influencers are not so apparent. What are examples of sources, pathways and illness (including infection) that can manifest from an environmental health issue? The workshop also addresses how innovation can sometimes influence environmental health. (These risks can exist in both high-performance green buildings and non-high-performance, non-green buildings.

Wednesday, June 27, 11:00 a.m. - 12:30 p.m.

Conference Paper Session 18 (Intermediate)

Design and Implementation of Energy Efficient HVAC Systems

Track: Research Summit

Room: 371AB

Chair: Marilyn Listvan, Ph.D, Listvan & Assoc., Edina, MN

Energy efficient design continues to be a hot topic in the HVAC industry. This session contains 4 presentations for designing and implementing energy efficient design and tools to facilitate energy efficiency in HVAC systems.

1. Comparison of Four Methods to Generate Typical Summer Days Using in HVAC Design (HO-18-C056)

Siyue GUO, Da Yan, Ying CUI, Tsinghua University, Beijing, China

Typical summer day is one of the most important input. However, the results of existing method have a big difference with the real situation. As hourly data is easy to be acquired, it is possible to use real data to generate the typical days. This paper discusses four new generating methods for typical summer day using real data. Then the cooling design days of five cities in China are generated and analyzed.

2. Design and Commissioning of Photovoltaic-Generation System (HO-18-C057)

Wim Zeiler, Kevin de Bont, Student Member, Eindhoven University of Technology, Eindhoven, Netherlands

This presentation explains how the commissioning on PV systems is far more important than thought. It might save up to 12% generated energy.

Wim Zeiler, Kevin de Bont, Student Member, Eindhoven University of Technology, Eindhoven, Netherlands

Design requirements for renewable energy systems as building facility are discussed based on a realized project within an average office building. This approach is applicable for most of the office buildings and is a good structured method.


Zoltan Nagy, Jose Vazquez-Canteli, June Young Park, The University of Texas at Austin, Austin, TX

This paper presents an occupancy detection method based on the Bluetooth (BT) signal of mobile devices to infer the occupancy schedule in a university building. In addition, we monitor the environmental conditions (temperature and relative humidity) in these spaces as provided by the BAS. This allows us to estimate potential energy savings from temperature set-backs based on the psychrometrics. Our approach provides a fast to deploy (< 15min), low-cost ( $20) and scalable solution to retrofit a building with occupancy detection and potential savings estimation.

Wednesday, June 27, 11:00 a.m. - 12:30 p.m.

Conference Paper Session 19 (Intermediate)

Energy and Water: Ways to Improve Efficiency

Track: Fundamentals and Applications

Room: 372AD

Chair: Peng Yin, University of Louisiana at Lafayette, Lafayette, LA

Resource conservation is a key component in modern design. This session describes different methods to consider for addressing conservation of energy and water and calculating these savings.

1. Beneficial Use of Air Handling Unit Condensate for Laboratory Building HVAC Energy and Water Recovery in Hot and Humid Climates (HO-18-C060)

William Eades, P.E., Member, US EPA, Research Triangle Park, NC

Although there has been much research into reduced potable water consumption derived from air handling unit (AHU) condensate for sites situated in hot and humid climates, relatively few studies have explored its energy recovery potential. In hot and humid climates, AHU condensate can be leveraged as a source for pre-cooling and cooling tower make-up water. This presentation describes the methodology used to analyze and predict AHU condensate’s energy and water recovery potential by presenting a case study for a 100% outside air laboratory building sited in Houston, Texas. Results indicate 4% energy and 31% water savings utilizing this approach.


Joseph Carpenter, Keith Woodbury, Ph.D., P.E., Member, Zheng O'Neill, Member, University of Alabama, Tuscaloosa, AL

This study proposes two simple methods to estimate energy savings opportunities using airside economizers and using variable frequency drives onto cooling towers. To analyze the energy reduction from airside economizers a simple spreadsheet compares return air conditions to outdoor air conditions and shows an airside economizer results in up to a 40% energy reduction. To determine the energy savings from a VFD on cooling tower fans a spreadsheet using TMY data and a liquid-to-gas ratio was developed and shows that installing a VFD on cooling towers results in energy reduction of the cooling tower fans by over 40%.
3. An Interaction Between Occupant Related Energy Consumption Among Different Spaces (HO-18-C062)

Prashant Anand, Student Member, Chandra Sekhar, Ph.D., Fellow ASHRAE, David Cheong, Ph.D., Member, Junjing Yang
National University of Singapore, Singapore, Singapore

In the past few years, research has gained momentum to study and model the stochastic energy use pattern of the occupant. Most of the past research discusses occupants within a specific space type (e.g., Office workplace) or activity type (e.g., opening/closing of a window or switching on/off lights). Further to existing research, this study discusses energy use interaction between different spaces occupied by the same group of occupants.


Donald Reising, Amee Patel, Mina Sartipi, Ph.D., Mohammed Fadul, T. Daniel Loveless, Ph.D., University of Tennessee at Chattanooga, Chattanooga, TN

Estimation of heating energy consumed within a room using measured instantaneous temperature is presented herein. Instantaneous temperature was recorded using eight sensors placed throughout a typical laboratory. Finite difference methods are used to approximate the solution to heat flow partial differential equations. The heat flow into and out of a collection of differential volumes is approximated using basic Fourier Law and energy balance equations. A time varying temperature profile is created to enable transient state analysis to calculate the total energy increase in every differential volume. The total energy is estimated by summing the energy values across all time increments.

Wednesday, June 27, 11:00 a.m. - 12:30 p.m.

Conference Paper Session 20 (Intermediate)

Heating and Cooling Applications with Improved Operation

Track: HVAC&R Systems and Equipment

Room: 371CF

Chair: Mini Malhotra, Ph.D, Oak Ridge National Lab, Oak Ridge, TN

Whether choosing the most energy efficient system or highest performing systems, the modern engineer has many options to consider. Understanding new technologies and their applications is important. This session contains comparisons and application information on several "outside the box" alternatives.

1. Nationwide Energy Saving Analysis of Radiant Floor System in the United States (HO-18-C064)

Yanfei Li, Fuxin Niu, Defeng Qian, Zheng O’Neill, University of Alabama, Tuscaloosa, AL

There is a lack of study of the nationwide energy saving potentials of radiant the floor system for all climate zones and all the main commercial building types across the U.S. This paper investigates the energy saving potentials of the radiant floor system with DOAS for 9 commercial building types in 16 climate zones across the U.S. using DOE reference commercial buildings as the baselines. The baselines are ASHRAE 90.1-2010 and IECC-2012 compliant. The selected nine building types are: small office, medium office, hospital, outpatient healthcare, restaurant of fast food, restaurant of dining in, retail standalone, retail of strip mall, primary school, and secondary school.

2. Comparison of Cooling Load Between Radiant Slab and Air Systems in Large Space Buildings With Solar Radiation (HO-18-C065)

Haida Tang, Tao Zhang, Xiaohua Liu, Department of Building Science, Tsinghua University, Beijing, China

Through a harmonic method, this presentation derives the analytical solution of the dynamic cooling load for a radiant slab system and air system in a large space building with high-intensity solar radiation. The results indicate that peak value of the cooling load of a radiant system in a 24h operation is slightly larger than the air system because the conventional slab floor has a larger decay rate and time lag for the direct solar radiation than the radiant slab. However, the cooling load difference between the two systems is less than 10 W/m2 (3.17 Btu/ft2h).
3. Effectiveness of Parallel versus Counter Flow in Liquid Desiccant Permeable Membrane Cooled Ceiling in Preventing Condensation (HO-18-C066)

Nesreen Ghaddar1, Member, Assaad Assaad Zoughaib2, Fracastoro Giovanni Vincenzo3, Joseph Virgone4, Kamel Ghali1, Marco Simonetti3, Mohamad Hout1, Nagham Ismail2, Racha Syblany1, (1) American University of Beirut, Beirut, Lebanon, (2) Hariri University, Beirut, Lebanon (3) Politecnico Di Torino, Turin, Italy, (4) Claude Bernard University, Villeurbanne, France, (5) ARMINES Mines ParisTech, Paris, France

In this study, parallel and counter flow configurations of desiccant solution flow in permeable ceiling for space cooling are compared under transient conditions. A mathematical model is developed of the air boundary layer at the ceiling membrane for a space conditioned by a cooled liquid desiccant membrane ceiling and displacement ventilation. The model predicts the temperature and humidity adjacent to the ceiling when subject to sudden increase of humidity in the space which allows the assessment of the condensation risk. The effect of increasing the solution temperature or flowrate or changing the supply air conditions are investigated for both configurations.


Xingchao Zhou, UNSW & CSIRO, Newcastle, Australia

This paper describes an air-conditioning system constituted by an internally-cooled desiccant wheel and dew point evaporative cooled. The new wheel used in this system could eliminate the effects of adsorption heat and carry-over heat resulting an improvement of dehumidification performance. In addition, it could also lower the temperature of regeneration air. So the system could be used in hot and humid climate driven by solar energy.

Wednesday, June 27, 11:00 a.m. - 12:30 p.m.
Seminar 69 (Basic)

Fundamentals of Centrifugal Chillers

Track: HVAC&R Systems and Equipment

Room: 371AB

Sponsor: 8.2 - Centrifugal Machines

Chair: Meagan Gibbs, Henderson Engineers, Lenexa, KS

• Convey the basic operation of a Centrifugal Chiller

• Explain the differences between a Centrifugal Chiller and a positive displacement chiller

• Describe the typical options that are available when specifying centrifugal chillers, what the option provides and what the advantage of the option is

• Define centrifugal chiller efficiencies and explain the requirements of ASHRAE 90.1 relative to centrifugal chillers

Have you ever wondered exactly how that centrifugal chiller works? This seminar covers the basics of centrifugal chiller operation and function, including component and overall system efficiency and help you understand the most common applications for a centrifugal chiller. Then we’ll discuss the possible applications for centrifugal chillers, how to size a chiller to get the best efficiency and cost for your application. The session covers what happens to the operation and efficiency of the compressor, evaporator and condenser and varying loads and lift conditions. After determining your operating conditions, we'll dive into which compressor, motor and starter to choose.

1. Centrifugal Chiller Basics

Frederick Betz, Life Member, PEDCO E & A Services, LLC, Cincinnat, OH

This seminar discusses centrifugal chiller basics and the difference between a centrifugal and positive displacement chiller. After you know the basics, the presentation covers the possible applications for centrifugal chillers, how to size a chiller so that you get the best efficiency and cost for your application and which physical component options (aren’t all water boxes the same?) are available to choose from.
2. Operation and Efficiencies of Compressor, Evaporator and Condenser

Lindsey King, Associate Member, New Freedom, PA

This presentation discusses what happens to the operation and efficiency of the compressor, evaporator and condenser and varying loads and lift conditions. Each of your components will be affected by these different conditions and it’s helpful when specifying a chiller to know these effects to make sure that you’re pairing your chiller well the rest of the system.

3. Compressors, Motors and Starters

Brandon Moss, Carrier Corporation, Charlotte, NC

Now that you know which conditions you want to operate at, which compressor, motor and starter is going to help you get there? This presentation discusses the many standard options that are available today. It concludes with the centrifugal chiller portion of ASHRAE standard 90.1 and how this relates to you when choosing a chiller today.

Wednesday, June 27, 11:00 a.m. - 12:30 p.m.

Seminar 70 (Intermediate)

Optimization for HVAC Systems

Track: Research Summit
Room: 372CF

Sponsor: Publication and Education Council

Chair: Reinhard Radermacher, Ph.D., University of Maryland, College Park, MD

• Understand how cascaded control provides a simple alternative for improved HVAC control and why cascaded control improved the performance of a heat pump system

• Develop familiarity in modelling methods for occupants’ thermostat use behavior and the application of adaptive occupant-learning controls

• Recognize that compactness and thermal-hydraulic performance are inversely proportional to surface hydraulic diameter

• Understand the use of multi-scale analysis, automated CFD simulations, multi-objective optimization and additive manufacturing

This session presents material from three recently published papers from ASHRAE's archival journal, “Science and Technology for the Built Environment”, on the subject of optimization for HVAC systems. The first paper defines two nonlinear gap metrics used to quantify closed loop linearization and proper tuning of non-linear HVAC systems. The second includes an analysis of thermostat keypress actions with concurrent occupancy, temperature and relative humidity data in private office spaces. The third paper presents a proof-of-concept design with small finless tubes and novel shape and shape optimization leveraging automated CFD simulations and Approximation Assisted Optimization techniques.

1. Optimal Tuning Cascaded of Control Architectures for Nonlinear HVAC Systems

Christopher Price, Student Member, Texas A&M University, College Station, Texas

Cascaded control has been shown to significantly reduce hunting behavior and improve performance for a range of HVAC equipment. The cascaded architecture uses nested Proportional-Integral-Derivative loops to minimize effects of load dependent nonlinearities. This presentation builds on previous work by defining two Nonlinear Gap Metrics that can be used to quantify closed loop linearization and enable proper tuning. This is followed by development of a Linear Quadratic framework that enables simultaneous tuning of inner and outer loop gains. The metrics and tuning procedures are demonstrated through two case studies of an example system and a two-ton heat pump system.
2. Development and Implementation of a Thermostat Learning Algorithm

Burak Gunay, Carleton University, Ottawa, ON, Canada

This presentation analyzes the thermostat keypress actions with concurrent occupancy, temperature and relative humidity data in private office spaces. The occupants interacted with their thermostats infrequently (on average once every 56 h of occupancy); and when they did so, occupants changed the temperature setpoint on average by 1°C (1.8°F). About one-third of the thermostat overrides were either to decrease the setpoints during the heating season or to increase the setpoints during the cooling season. The temperatures leading to the thermostat overrides changed by ~3°C (5.4°F) seasonally.

3. Design Optimization and Validation of High Performance Heat Exchangers Using Approximation Assisted Optimization and Additive Manufacturing

Daniel Bacellar, University of Maryland, College Park, MD

The airside thermal resistance of air-to-fluid heat exchangers (HX) dominates the overall thermal resistance. On conventional HX’s, fins are required to address such challenges; but their benefits are not limitless and are bounded mainly by the tube size and shape. This presentation explores three main objectives. First, it discusses the importance of fins on typical air-to-fluid HX’s and how they become unattractive at smaller characteristic lengths. Second, it presents a proof-of-concept design with small finless tubes and a novel shape. Third, it presents a comprehensive multi-scale analysis and shape optimization leveraging automated CFD simulations and Approximation Assisted Optimization (AAO) techniques.

Wednesday, June 27, 11:00 a.m. - 12:30 p.m.
Seminar 71 (Advanced)

Recent Advances in Solid-State Cooling Technologies

Track: HVAC&R Systems and Equipment
Room: 372BE
Sponsors: Refrigeration Committee, 1.1 - Thermodynamics and Psychrometrics and 8.1 Positive Displacement Compressors; 10.7 Commercial Refrigeration
Chair: Georgi Kazachki, Ph.D., Dayton Phoenix Group, Inc., Dayton, OH

- Provide an overview of caloric cooling technologies
- Learn the magneto-caloric materials performance
- Summarize the recent advances in ferroelectric materials exhibiting large electro-caloric effect
- Explain the principles and potential of the elastocaloric cooling

Air conditioning systems are consuming 1.26 Quadrillion watt-hours of electric energy per year. While the vapor compression technology is a major player for the air conditioning systems, there is great interest in more environmentally-friendly cooling technologies that use working fluids with low global warming potential and are more efficient. Cooling technologies using solid-state materials are called solid-state cooling technologies. Thanks to recent development in new solid-state materials, solid-state cooling technologies have advanced their potentials. This session introduces the working principles and recent advancements in solid-state cooling technologies, as well as performance comparison with current vapor-compression technologies.


Vitalij K. Pecharsky, Iowa State University, Ames, IA

At the U.S. Department of Energy’s Ames Laboratory, a materials research consortium started in 2016 to enhance a new research collaboration of national laboratories, universities and corporate partners. The goal of the research is improving the energy-efficiency of refrigeration technology by 20 to 30 percent within a decade through the use of caloric materials for cooling. This presentation provides an overview of the consortium and describes current progress.
2. Electrocaloric Cooling: Current States and Future Perspective
Qiming Zhang, Penn State University, University Park, PA
Electrocaloric effect (ECE) is the ability of a dielectric to change its temperature and entropy as an electric field is applied and released. It provides an effective means to realize solid-state cooling devices that are environmentally benign and potentially highly energy efficient. In this talk I will present briefly the recent advances in ferroelectric materials exhibiting giant electrocaloric effect. EC cooling devices reported recently based on these new materials as well as challenges and strategies in transition these materials breakthroughs to practical devices and future perspectives are discussed.

3. Overview of Elastocaloric Cooling
Yunho Hwang, Member, University of Maryland, College Park, MD
Elastocaloric cooling utilizes a stress induced solid phase latent heat between martensitic and austenite phase in shape memory alloys (SMA). This presentation provides the summary of recent researches on elastocaloric cooling in different SMA developments and various device designs. Researchers demonstrated different SMA shapes such as wire, ribbon, foil, plate, and tube. While tension-based elastocaloric cooling’s are investigated by most of researchers, compression-based work is followed. Major challenges and prospects of elastocaloric cooling are described.

Wednesday, June 27, 11:00 a.m. - 12:30 p.m.
Seminar 72 (Intermediate)

What will ASHRAE Standard 62.1-2019 Look Like with the Proposed Changes to the IAQA, NVP and VRP?
Track: Fundamentals and Applications
Room: 370ABDE
Sponsors: TRG4 - Indoor Air Quality Procedure Development and SSPC 62.1 is primary sponsor of this session
Chair: Daniel Pettway, Hobbs and Associates, Chesapeake, VA

• Know that there are major changes proposed in Standard 62.1
• Understand the new Natural Ventilation Rate Procedure
• Understand the new Indoor Air Quality Procedure
• Understand the changes in the Ventilation Rate Procedure

SSPC 62.1 is making major modifications to the standard that need to be communicated to the membership. These include a new Natural Ventilation Rate Procedure, a new Indoor Air Quality Procedure and changes to the Ventilation Rate Procedure that will have major impact on the way the the standard will be applied.

1. Overall Direction for Modifications to Standard 62.1
Hoy Bohanon, Member, Hoy Bohanon Engineering PLLC, Clemmons, NC
SSPC 62.1’s mission is to maintain a design standard providing ventilation procedures for acceptable indoor air safety and quality for the built environment. After a year of discussions, the committee made an important decision. That decision is to make the quality of indoor air more comparable between the different pathways. This presentation addresses the modifications to ASHRAE standard 62.1.
2. The New NVP

Stephen Ray, Associate Member, North Park University, Chicago, IL

The natural ventilation procedure has changed over the years in 62.1. It was relocated from section 5 to section 6 and became a ventilation procedure. It was recently modified to require mechanical ventilation with certain exceptions. This addendum provides specific requirements for the exception by providing a clear compliance path. It also recognizes that there are inherent health issues with outdoor air in many locations in the world and updates the prescriptive requirements based on recent studies and airflow evaluations.

3. The New IAQP

Marwa Zaatari, University of Texas at Austin, Austin, TX

This presentation discusses the design requirements of the New IAQP. Those requirements include; identification of contaminants of concern, determining indoor and outdoor sources, identifying a concentration limit and exposure period, specifying percentage of building occupants to be satisfied with perceived IAQ and performing a mass balance analysis for selected compounds.

4. Changes to the VRP

Brian Hafendorfer, Member, Trane, Lexington, KY

Ventilation Rate Procedure is the prescriptive design procedure presented in Section 6.2, in which outdoor air intake rates are determined based on space type/application, occupancy level, and floor area, shall be permitted to be used for any zone or system. Informative Note: The Ventilation Rate Procedure minimum rates are based on contaminant sources and source strengths that are typical for the listed occupancy categories. The requirements for atypical sources are spelled out in new addenda. There is a simplified VRP that incorporates a default Ev. This helps designers who do not wish to perform the more complex calculations in Appendix A. The use of this simplified procedure is described.

Wednesday, June 27, 11:00 a.m. - 12:30 p.m.
Forum 4 (Intermediate)

Gauging Current Interest in Forming a Multi Task Group to Combine All Available Air Cleaning Technologies with the Goal of Establishing a Test Method and/or Standard to Validate the Contribution of Each Technology When Combined

Track: Fundamentals and Applications
Room: 370CF

Sponsors: 2.9 - Ultraviolet Air and Surface Treatment, 2.3 - Gaseous Air Contaminants and Gas Contaminant Removal Equipment and 2.4 - Particulate Air Contaminates and Particulate Containment Removal Equipment

Chair: Sam Gazman, American Ultraviolet Company, Hackettstown, NJ

This session gauges the interest of the attendees in forming an MTG on the use of multiple air cleaning technologies to control the growth and spread of pathogens in an indoor environment. The session consists of industry experts discussing the use of shortwave ultraviolet energy, photo-catalytic oxidation, bi-polar ionization, and particle filtration. Attendees will discuss the advantages and limitations of each technology and how a combination of technologies may provide the best results for the space. The goal of the forum would be to establish a working group and potentially a TC within ASHRAE.