2017 ASHRAE Annual Conference

June 24th - June 28th, 2017

ashrae.org/LongBeach

NY PDH G

*Symbols indicate sessions approved for New York State Professional Development Hours (PDHs) and American Institute of Architects Learning Units (LUs) as well as GBCI LEED AP CE Credits.

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Saturday, June 24

Saturday, June 24, 3:15 PM - 4:15 PM

Keynote

Plenary

Room: Regency Ballroom

***Derreck Kayongo**, CEO of the Center for Civil and Human Rights & Founder of the Global Soap Project*

Derreck Kayongo brings audiences to their feet with his compelling and courageous story of survival, discovery, and humanitarianism. From a young Ugandan refugee to a successful entrepreneur, human rights activist, and renowned global health expert, Kayongo galvanizes audiences to effectively solve any challenge. With undeniable charm, palpable passion, and endearing wit, Kayongo brings his story and guiding principles, coined as S.E.L.F. (Service, Education, Leadership and Faith) to life in emotionally packed presentations that stay with you long after his closing remarks. Kayongo is the founder of the Global Soap Project, which recycles partially used and discarded bars of soap from thousands of hotels and redistributes it to disadvantaged populations around the world. Since its founding in 2009, the Project has distributed soap to more than 90 countries where close to 2 million lives are claimed each year due to lack of proper hygiene. Kayongo's experience as a human rights activist, combined with his lifelong commitment to his work and notable rhetorical skills earned him his current role as the CEO at the National Center for Civil and Human Rights. Called a "living embodiment of the Center's mission," Kayongo is elevating the visibility of the Center and expanding its vision beyond its geography. Recognized with a range of honors and awards for his activism, including as one of CNN's Top 10 Heroes award in 2011, most recently Kayongo was selected by President Jimmy Carter to interview him as part of the National Archives' Amending America Initiative.

Sunday, June 25

Sunday, June 25, 8:00 AM - 9:00 AM

Forum 1

Commissioning Experience with California Title 24 VAV Lab Exhaust

Track: Commissioning: Optimizing New and Existing Buildings and their Operation

Room: 101A

Sponsor: 9.10 Laboratory Systems

Chair: Victor Neuman, P.E., Member, Laboratory Exhaust Certification LLC, San Diego, CA

California Title 24 Regulation has mandated for the first time that all new laboratories in the state have variable air volume (VAV) exhausts. This provides a wide variety of experiences from owners, engineers, contractors and commissioning agents. This forum confidentially discusses real world results in California for VAV lab exhausts and discusses the upcoming 2018-2019 revisions to California Title 24 for VAV lab exhausts.

8:00 AM - 9:00 AM

Workshop 1

Are We Afraid of What We'll Find? Using Real Buildings to Improve ASHRAE Standards and Publications

Track: HVAC&R Systems and Equipment NY PDH G

Room: 201A

Sponsor: 2.8 Building Environmental Impacts and Sustainability

Chair: Joy Altwies, Ph.D., P.E., Member, University of Wisconsin-Madison, Madison, WI

This workshop explains the results of a recent ASHRAE research project, 1627-RP, that studied the actual performance of buildings built using the ASHRAE 30% AEDG for schools and offices. Can we replicate the study to investigate the performance of buildings built using Standard 90.1? What will we find? Can the results be used to improve our future standards and publications?

1. Highlights of 1627-RP: Actual Energy Performance of Small Office and K-12 School Buildings Designed to Meet the 30% ASHRAE Advanced Energy Design Guides

***Dennis Jones, P.E., Member**, Group14 Engineering Inc., Denver, CO*

This workshop discusses the results of 1627-RP, completed in 2016. This research investigated the effectiveness of 30% Advanced Energy Design Guidelines (AEDGs) for K-12 schools and small office buildings, determined the factors common to well and poorly performing buildings and provided recommendations for how future AEDGs could be made more effective.

2. Potential New Research on the Actual Energy Performance of Buildings Designed to Comply with ASHRAE Standard 90.1-2010

***J. Kevin Cross, P.E., Member**, Honeywell, Fort Collins, CO*

Using the recent success of 1627-RP as a template, this workshop discusses the potential for additional research projects that identify statistically-significant samples of real buildings built using Std 90.1-2010. Can this type of research be replicated to provide real-world input to future ASHRAE Standards and publications? What guidance can the actual performance of these buildings provide?

Sunday, June 25, 8:00 AM - 9:00 AM

Workshop 2

Are You Ready For 21st Century Building Automation?

Track: Fundamentals and Applications 

Room: 101B

Sponsor: 1.4 Control Theory and Application, 7.5 Smart Building Systems

Chair: Marcelo Acosta, P.Eng., Member, Armstrong Fluid Technologies, Toronto, ON, Canada

In this session the panel engages the audience in exploring the obstacles and solutions to the disappointingly low levels of adoption of new technologies for building automation, despite their big potential. Why do most designers still opt for the inefficient old schemes unless pushed by legislation? Is energy too cheap? Are owners and operators ready? Does ASHRAE or YEA membership make a difference in your view? Whether you are a Baby Boomer, GenXer, or Millennial, are you ready to adopt new building control technologies?

1. Potentials and Disappointments: The Slow Adoption of Advanced Building Automation

***Marcelo Acosta, P.Eng., Member**, Armstrong Fluid Technologies, Toronto, ON, Canada*

Facts about the adoption rates for different technologies presented at almost every conference this century will be analyzed with the audience as well as their potential obstacles and solutions. Technologies: smart equipment, cloud optimization, automated diagnostics, total integration, performance predictive controls, occupant behavior prediction and self-learning controls.

2. Are Millennials Ready for Advanced Building Automation?

***Michelle Shadpour, Student Member**, SC Engineers, Inc., San Diego, CA*

The findings of a survey among Millennials exploring their slow adoption of new technologies is presented for discussion. Is the main obstacle lack of self-confidence, budgeted time or authority? Does YEA membership make a difference? Does the knowledge of successful stories remove concerns? Are Millennials too busy learning ductwork design to worry about controls? Is higher environmental conscience a strong enough driver in this group? Let's review together!

8:00 AM - 9:00 AM

Workshop 3

Bringing Standard 90.1 to the World: The Addition of Climate Zone 0

Track: Fundamentals and Applications 

Room: 103AB

Sponsor: , Chapter Technology Transfer Committee

Chair: Andy Cochrane, Member, Industrial Air Inc., Greensboro, NC

Discussion about the performance of buildings shows increasing connectedness of critical energy, power and water issues. Combined with analysis of environmental trends, these shared issues define an expanding international role for ASHRAE standards. Standard 169-2013, provides climate data for building performance assessment and includes data and maps for Climate Zone 0. This presentation explores Climate Zone 0 and changes to 90.1. Comparing and contrasting building performance requirements for Climate Zone 0 with previous editions, focusing on building envelope and air leakage impacting HVAC decisions and building energy performance. It concludes with discussion of areas ASHRAE standards should address building performance.

1. Bringing ASHRAE 90.1 to the World: The Addition of Climate Zone 0

***Chris Mathis, Member**, Mathis Consulting, Asheville , NC*

Until recently, the flagship standard on building energy performance – ASHRAE 90.1 – was silent on its application into these extremely hot climates. This presentation explores the new Climate Zone 0 and the recent changes to Standard 90.1 to expand its building performance guidance to these international locations. The presentation compares and contrasts critical building performance requirements for Climate Zone 0 with previous editions of the standard. It especially focuses on key building envelope and air leakage requirements that critically impact HVAC decisions and ultimate building energy performance. The session concludes with a discussion of additional areas where ASHRAE should expand its standards to address targeted building performance topics in CZ 0 and worldwide.

Sunday, June 25, 8:00 AM - 9:00 AM

Workshop 4

Common Commissioning Terminology for the Building Industry: An International Overview

Track: Commissioning: Optimizing New and Existing Buildings and their Operation G

Room: 203AB

Sponsor: AiCARR, CIBSE, SSPC 202

Chair: Livio de Santoli, P.Eng., Member, AiCARR, Milano, Italy

Commissioning is a process for ensuring that a system is designed and operated as intended; commissioning helps achieve larger goals of sustainable design and operation, Life Cycle Cost (LCC) effectiveness, efficient use of investments, minimizing overall maintenance and utility costs, component life reliability and performance expectations. AiCARR, ASHRAE and CIBSE have agreed to draw from definitions and terminology that appear in their publications or in their other resources for the purpose of harmonization by developing a first collective work on the topic. This workshop presents the state of terminology in each country and a proposal for a common overview.

1. ASHRAE Overview

***Walter Grondzik, P.E., Fellow Life Member**, ASHRAE, ATLANTA, GA*

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2. CIBSE Overview

***Hywel Davies**, CIBSE, London, United Kingdom*

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8:00 AM - 9:00 AM

Workshop 5

Engineers of Trial: You Decide Guilt or Innocence

Track: Fundamentals and Applications NY PDH G

Room: 102AB

Sponsor: 7.2 HVAC&R Construction & Design Build Technologies, 1.7 Business, Management & General Legal Education

Chair: Michael Cooper, P.E., Member, MCC, Metairie, LA

The session presents an actual case in which a practicing engineer was sued for negligence and malpractice. The workshop takes to form of each side of the case being presented, prosecution and defense and then the audience will breakout into smaller groups to discuss. Each group will have one individual speak for the group to convey what was discussed about the points of the different sides of the argument and then state if the group felt the engineer was guilty or innocent. At the end of the session, the actual decision is revealed.

1. The Case for the Plaintiff

***E. Mitchell Swann, P.E., Member**, MDCSystems, Paoli, PA*

The arguments for a guilty verdict are presented. The list of breaches of the contract and/or law are presented and the recommended remedy being sought is expressed. The damages to the plaintiff are presented that will include direct and consequential damages.

2. The Case for the Defense

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

The arguments for a not guilty verdict are presented. The counter arguments for each of the list of breaches are expressed as well as the argument that the damages sought are excessive.

Sunday, June 25, 8:00 AM - 9:00 AM

Workshop 6

Science and Technology for the Built Environment Writer's Workshop: Authoring Research Papers with Impact

Track: Research Summit G
Room: 202AB
Sponsor: Publication and Education Council
Chair: Reinhard Radermacher, Ph.D., Fellow ASHRAE, University of Maryland, College Park, MD
Hosted by the editorial staff and publishers of the ASHRAE archival journal, Science and Technology for the Built Environment, this workshop aims to teach authors of technical and research papers to write with maximum impact in a manner to maximize citations.

1. Writing for Maximum Impact
***Alexa Flood**, Taylor and Francis, Philadelphia, PA*

Finally getting your work on paper is only half the battle. Sure, having a published work is good to have on your resume, but having impactful work can make a career. Learn how to write research papers in a way that will garner citations, and get maximum mileage out of your work. This workshop touches upon the importance of selecting the best journal match for your work, how to maximize your article for hits from search engines and when to publish using open access. It also explains how to better understand writing about both methodology and research findings.

2. Writing Research Papers that Get Published.
***Alexa Flood**[1] and **Mary Baugher**[2], (1)Taylor and Francis, Philadelphia, PA, (2)University of Maryland, College Park, MD*

Avoid the pitfalls that plague many authors who submit papers to research journals. Learn how to write a compelling abstract, the importance of proper formatting and grammar, surviving the plagiarism cross-check and addressing reviewers' comments in a productive way.

8:00 AM - 9:00 AM

Workshop 7

Status of Standards and Codes in the USA, In View of the Application of Low GWP Refrigerants

Track: Refrigeration
Room: 201B
Sponsor: REFRIGERATION COMMITTEE
Chair: Steven Eckels, Ph.D., Member, Kansas State University Institute for Environmental Research, Manhattan, KS
Today there is work ongoing in different standard and code making committees related to the implementation of lower GWP refrigerants. This workshop aims to give a transparent view for both US and non US members about the status and work in progress of standards and codes including SNAP.

1. Status of ASHRAE 15, Related Codes and SNAP
***Phillip Johnson, P.E., Member**, Daikin Applied, Staunton, VA*

A status update on committee activities to update ASHRAE Standard 15 will set up the workshop discussion to follow. The relationships, interactions and relative timing between ASHRAE 15, building codes and US EPA SNAP is reviewed.

2. Status of UL Standards and Related Codes
***Brian Rodgers, Member**, Underwriters Laboratories, Northbrook, IL*

A status update on committee, working group and technical panel activities to update various UL standards. Interconnection and process between UL, CSA, ANCE, CANENA, and IEC is reviewed.

Sunday, June 25, 9:45 AM - 10:45 AM

Panel 1

The US Department of Energy's Recent Regulatory Activity on Water Heaters

Track: Residential Buildings: Standards Guidelines and Codes

Room: 202AB

Sponsor: 6.6 Service Water Heating Systems

Chair: James D. Lutz, P.E., Member, Hot Water Research, Oakland, CA

Water heating is the second largest energy load after space conditioning in residential buildings. The US Department of Energy has recently completed regulatory proceedings to update the test procedure and minimum energy efficiency standards for residential and residential-duty commercial water heaters to use the new Uniform Energy Factor metric. The Department is currently updating the minimum energy efficiency standards for commercial water heaters. This panel discusses the strengths and shortcomings of the regulations, the rulemaking process and ASHRAE's role in it. The panelists include the Department of Energy's engineer in charge of these regulations, AHRI's Chief Technical Advisor representing the water heater manufacturers and a representative from an efficiency advocacy organization who is also on ASHRAE RAC.

Panelist

Ashley Armstrong, US Department of Energy, Washington, DC, Frank Stanonik, Life Member, Air Conditioning, Heating and Refrigeration Institute, Washington, DC and Harvey Sachs, Member, ACEEE, Washington, DC

9:45 AM - 10:45 AM

Debate 1

Cumbersome and Correct vs. Half-Baked and High-Speed

Track: Fundamentals and Applications

Room: 203AB

Sponsor: 9.9 Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment, 4.10 Indoor Environmental Modeling

Chair: Nick Gangemi, Life Member[1], James W. VanGilder, P.E., Member[2], Mark Seymour, CEng, Member[3] and Nick Gangemi, Life Member[1], (1)Northern Air Systems, Rochester, NY(2)Schneider Electric, Andover, MA(3)Future Facilities Ltd, London, United Kingdom

Data center CFD is routinely and effectively used for upfront design of new facilities and ongoing management of existing facilities. Are you an extreme perfectionist kind of modeler or do you go for quick and dirty? Two experienced data center and CFD professionals will argue the case for using the bare bones of CFD for maximum benefit in minimum time in contrast to all the physics (but all in good time). But who will argue which side? A coin toss will determine. Come to this session and make your own informed decision.

Panelists

Nick Gangemi, Life Member[1], James W. VanGilder, P.E., Member[2], and Mark Seymour, CEng, Member[3], (1)Northern Air Systems, Rochester, NY(2)Schneider Electric, Andover, MA(3)Future Facilities Ltd, London, United Kingdom

Sunday, June 25, 9:45 AM - 10:45 AM

Conference Paper Session 1

Weather Modeling Applications

Track: Fundamentals and Applications 

Room: 103AB

Chair: Stephen W. Duda, P.E., Fellow ASHRAE, Ross & Baruzzini, Inc., St. Louis, MO

Weather analysis is critical in achieving successful design and operation of buildings and the built environment. This session looks at available weather data model types, as well as a newly proposed model type. A study is presented related to modeling the impact of heat waves or cold snaps on buildings and their occupants. Finally, weather and modeling considerations for the design of an air-conditioning system for an outdoor shopping area in a hot climate are considered.

1. Typical and Design Weather Year for Building Energy Simulation (LB-17-C001)

Yusuke Arima, BEAP*, Ooka Ryozo, Ph.D., OPMP, HBDP and BEAP and Hideki Kikumoto, Ph.D., BEAP, The University of Tokyo, Tokyo, Japan*

In building design or research processes, building energy simulations are conducted using weather data. There are two types of the weather data for building energy simulations; one is the typical weather year (TWY) to estimate annual cooling/heating load and the other is the design weather data (DWD) to estimate maximum cooling/heating load. In this paper, we propose a new type of year weather data which can be used as both the reference weather year and design weather data, here called as the typical and design weather year (TDWY). The TDWY presented in this paper include each quantile values of multi-year observation data, which means that the TDWY is also used for the versatile design weather data. In this paper, we investigate more detailed property of the TDWY such as the simultaneity of each weather components.

2. An Analytical Approach to the Impact of Heat Waves on Buildings and Their Occupants (LB-17-C002)

David Coley*[1], Alfonso Ramallo-González[1], Manuel Herrera[1] and Matthew E. Eames, Ph.D.[2], (1)University of Bath, Bath, United Kingdom, (2)University of Exeter, Exeter, United Kingdom*

Building dynamic simulation is a mature and advanced technique that has been used for decades to evaluate the thermal performance of building designs and existing buildings. Alternately, some researchers have developed reduced models that represent the thermodynamics of buildings using simple models based in real data. Lumped Parameter Models (LPMs), are lineal dynamic models that can be studied with the techniques developed in systems theory. This work identifies the LPMs that best represent 40 dwellings in the UK, and has applied system theory to study the response of those buildings in frequency to the driving forces of outside temperature, electricity and solar gains. The work has shown that the buildings present a response in frequency similar to low-pass filters with respect to outside temperature.

3. CFD and Wind Tunnel Study of the Performance of Outdoor Commercial Plaza Air-Conditioning System (LB-17-C003)

E. M. ElBialy, Ph.D. *and SA Ghani, Ph.D., Qatar University, Doha, Qatar*

Temperatures in the Gulf Arab region exceed 50 Celsius during the summer, making cooling one of the biggest issues facing the region. This paper investigates the effect of wind speed, direction and temperature on the air-conditioning system thermal performance in an outdoor shopping and setting area. Moreover, two methods of conditioned air supplying will be tested using displacement diffusers and jet diffusers. The effect of different roof designs will be simulated. Some wind mitigation methods were tested like trees and perforated panels. A three dimensional Computational Fluid Dynamics (CFD) model was built to simulate the air flow and temperature patterns between the buildings. Mass and energy conservation equations were added to the model. K-Turbulence model was in the calculations. In order to validate the numerical model, wind-tunnel tests were carried out and compared with the air-flow patterns from simulations. Comparison between air flow simulations and wind-tunnel results yielded good agreement.

Sunday, June 25, 9:45 AM - 10:45 AM

Conference Paper Session 2

How Healthcare Facilities and Infection Control are Affected by HVAC Systems

Track: Building Life Safety Systems 

Room: 101B

Chair: Sonya Pouncy, Member, Walker-Miller Energy Services, Detroit, MI

Healthcare facilities have unique requirements for HVAC systems that are not found in other industries. In addition to thermal comfort, normal IAQ and similar considerations, healthcare facilities have needs due to their occupants and operation. Patients with depressed immune systems and surgical rooms, to name a couple, need extra care taken in air quality. This session illustrates elements of healthcare facility HVAC design to accommodate those needs and advances in healthcare HVAC systems.

1. Analysis of HVAC Configurations for a Hospital Operating Room (LB-17-C004)

Kishor Khankari, Ph.D., Fellow ASHRAE*, AnSight LLC, Ann Arbor, MI*

Airflow patterns within the hospital operating rooms (OR) determine the levels of air speed, temperature, and flow path of contaminants to and from the sterile and non-sterile zones. This paper with the help Computational Fluid Dynamics (CFD) analysis analyzes the effect of various HVAC configurations on the resulting airflow pattern, temperature distribution, and importantly flow of path of contaminants between the sterile and non-sterile zones. With the help of airflow visualization this paper shows the effective flow path of the contaminants. The analysis provided in this paper is useful to practicing engineers in the healthcare industry in designing the HVAC systems for the operating rooms.

2. An Efficient Ventilation Configuration for Preventing Bioaerosol Exposures to Health Care Workers in Airborne Infection Isolation Rooms (LB-17-C005)

Deepthi Sharan Thatiparti, Student Member*[1], Urmila Ghia, Ph.D.[1] and Kenneth R. Mead, Ph.D., P.E., Member[2], (1)University of Cincinnati, Cincinnati, OH, (2)CDC- National Institute for Occupational Safety and Health (NIOSH), Cincinnati, OH*

An Efficient ventilation configuration of an Airborne Infection Isolation Room (AIIR) is essential for protecting Health care workers (HCW) from exposure to potentially-infectious patient aerosol. This paper presents the Computational Fluid Dynamics (CFD) study to predict airflow distribution patterns throughout the AIIR, air velocity vectors in the HCW's region, streamline of an air particle from patient's infectious source and the comfort working conditions for the HCW for a range of AIIR ventilation configuration design challenge.

3. Cross Infection Due to Pathogen Transport in Indoor Environments: Investigative Study Assessing Impact of Ventilation Type, Air Changes and Furniture Layout (LB-17-C006)

Shamia Hoque, Ph.D., Associate Member*, University of South Carolina, Columbia, SC*

Buildings impact human health. The design and operation of an indoor environment influences occupants' well-being. Aerosol transmission has been defined as "person to person transmission of pathogens through the air by means of inhalation of infectious particles". The source may be an infected person such as a flu sufferer sneezing. Aerosol generation can also happen via coughing, laughing or just exhaling. This paper focuses on investigating the spread of aerosols after sneezing in a ventilated office space and the length of time they reside in the breathing zone thus estimating the possibility of infection of another occupant.

Sunday, June 25, 9:45 AM - 10:45 AM

Seminar 1

Psychrometrics of Chilled Beam Systems

Track: Fundamentals and Applications 
Room: 201B
Sponsor: 5.3 Room Air Distribution
Chair: Donald E Larsson, Member, United States Green Building Council, Washington, DC
This seminar will explain the psychrometric calculations required for the application of a chilled beam system. Additionally, the requirements for a dedicated outside air unit will be determined for areas of high wet bulb ambient conditions. Engineers have been reluctant to design or specify these types of systems due to condensation concerns within the conditioned space. This seminar presents the correct calculations for design and selection of condensation free systems. Examples of successful installations in high wet bulb areas are presented.

1. Psychrometrics of Chilled Beam Systems
***Donald Larsson, Member**, United States Green Building Council, Washington, DC*

This presentation demonstrates the correct use of psychrometric calculations in the application of chilled beam systems for the conditioned space.

2. Application of Chilled Beam Systems
***Thomas Rice, Member**, SEMCO LLC, Columbia, MO*

Having an understanding of how a chilled beam works is the first step to having a successful application. Fully appreciating how that chilled beam is applied and interacts with the rest of the heating and air conditioning system is the second step. All chilled beam projects are similar in design regardless of building type and allows for a quick review by the consultant. In a simple overview, we will review 7 basic steps to chilled beam application so that the start of your project is simplified and accurate.

3. Successful Chilled Beam System Installations
***Paul Christy**, Clark County Public Schools, Winchester, KY*

This presentation focuses on successful installations of chilled beam systems. Correct psychrometric conditions, building pressurization and control sequences are highlighted.

9:45 AM - 10:45 AM

Seminar 2

Commissioning Complex Labs: Stories from the Field

Track: Commissioning: Optimizing New and Existing Buildings and their Operation 
Room: 102AB
Sponsor: 9.10 Laboratory Systems, 7.7 Testing and Balancing
Chair: Wade H. Conlan, P.E., Member, Hanson Professional Services, Orlando, FL
Commissioning on complex labs follows the same processes as other buildings but there are unique systems and challenges that are presented when dealing with laboratories. This seminar covers a case study of a major cancer research center and the balance between optimization and safety. In addition, an in depth look at lessons learned from the field when Commissioning Biosafety Level 3 laboratories.

1. Lab Building Case Study: Safety Vs. Energy Conservation
***Justin Garner, P.E., Member**, Engineered Air Balance Company, Inc., Houston, TX*

This seminar focuses on a specific project for a new laboratory building for a major cancer research institution. Specifically, the presentation discusses energy recovery, demand based ventilation, occupancy sequencing and building pressurization strategies that were implemented and the lessons learned during commissioning of the HVAC systems.

2. Continuous Improvement of Commissioning / Certification of Bsl-3 Laboratories
***Carol Donovan, Member**, Alares LLC, Quincy, MA*

There are a multitude of challenges associated with designing, constructing and operating BSL-3 laboratories. The combination of user expectations, regulatory compliance, risk considerations and contractor interpretation of specifications can result in a delay in opening these laboratories from 1-2 years or longer. This presentation discusses the practical implications of commissioning BSL3 laboratories. It will provide an overview of the different organizations providing regulatory compliance, discuss the various risk factors involved with programmatic decision making, review engineered systems and ventilation strategies and the impact these decisions have on operational strategies. This presentation highlights essential documentation for sustainable operation.

Sunday, June 25, 9:45 AM - 10:45 AM

Seminar 3

Smart Buildings, Smart Cities

Track: Controls 

Room: 201A

Sponsor: 1.4 Control Theory and Application

Chair: Joseph Kilcoyne, P.E., Member, SC Engineers, Inc., San Diego, CA

Progressive cities are taking building automation out of the building and applying it across their infrastructure of outdoor lighting, cameras and pumping stations. This seminar presents the latest advances in smart city technology, its proper application and the importance of interoperability. The role of traditional building automation systems in the smart city is discussed. See how San Diego became the first city in the US to deploy a smart wireless lighting network equipped with sensors and software to compile data for real-time analysis and its plans to take the smart city to a whole new level.

1. What Is Smart? The Architecture of a Smart City

***Ron Bernstein, Member**, RBCG, LLC, Encinitas, CA*

This session will cover the integration, interoperability and system architecture of a smart city. The presenter discusses new opportunities for connected cities using broadband communications and a vision for new solutions. Street lighting is central to a broader smart city vision that municipalities are starting to embrace in order to reduce energy and operational costs.

2. Turning Modern Cities into SMART Cities

***Parita Ammerlahn**, City of San Diego - Environmental Services Department, San Diego, CA*

This seminar will showcase what makes San Diego one of the most innovative, forward-thinking cities in smart infrastructure technology. The presenter explains how energy-efficient LED street lighting fixtures and wireless lighting controls will save the city more than $250,000 annually. The seminar describes a streetlight network that also controls holiday lights, contains chemical sensors to monitor and alert of air quality and toxic spills, provide Wi-Fi to low income neighborhoods, enhance cellular service with micro cells, act as electric vehicle (EV) charging stations and more.

Sunday, June 25, 11:00 AM - 12:30 PM

Conference Paper Session 3

Air Conditioning Large Spaces: Air Flow, Energy Efficiency and Tower Water Treatment

Track: HVAC&R Systems and Equipment 

Room: 201A

Chair: Joshua New, Ph.D., Member, ONRL, Oak Ridge, TN

Air conditioning of large spaces such as athletic stadiums and warehouses often involves different and more complex versions of the issues encountered in more common applications like offices and schools. This session reports results of CFD modeling to improve comfort with reduced capacity requirements in a large football stadium, results of a design study for a chiller retrofit and a project that provided required conditioning of a large pharmaceutical warehouse using less than half the energy of a conventional design. The final paper examines the implications of recent Legionnaires disease outbreaks for microbiological control in cooling towers.

1. Air Flow Regimes in an Air Conditioned Playground Zone of Open-Roof Football Stadium (LB-17-C007)

***Essam E. Khalil, Fellow ASHRAE**, Esmail ElBialy, Dr.Ing., Waleed AbdelMaksoud, Ph.D., P.E. and Mohamed E. Ashmawy, P.E., Cairo University Faculty of Engineering, Cairo, Egypt*

This paper examines developing air conditioning systems in the playground zone of a stadium by employing several kinds of technologies to cool the outdoor spaces. The most serious challenge of air conditioning in a playground zone in stadium is controlling the temperature and humidity in the outdoor area and also the enormous energy needed by the cooling system to maintain thermal comfort conditions within the football playground area. The main task for the analyzed model was to ensure the better method to distribute air to achieve the human comfort level for players and reducing the cooling capacity of playground zone by using a large sunshade to reduce the sun's rays and maintain the stadium's temperature.

3. Case Study of Chiller Selection for the Retrofit of a Large Building Cooling System (LB-17-C009)

***James Turcato, Student Member** and Kevin Anderson, Ph.D., P.E., Member, California State Polytechnic University at Pomona, Pomona, CA*

This paper describes the chiller selection design and procurement process for a building thermal management system. The design procedures described in this paper are based on those carried out during an energy efficiency engineering internship in a local Los Angeles company and thus serving as an example of real world training. This paper presents the results of a case study to replace chillers that are approaching the end of their useful life. This case study is an example of how engineering interns are exposed to the various ASHRAE Standards. The retrofit project was carried out according to specifications and drawing of the existing obsolete equipment and adhering to Standard 90.1 “Minimum Requirements for Chillers” and the ASHRAE “Chiller Life Expectancy” guidelines used to govern chiller selection and installation. Results for COP lift versus load and chiller load versus system load are presented in the paper.

Sunday, June 25, 11:00 AM - 12:30 PM

Conference Paper Session 4

HVAC Equipment Components

Track: HVAC&R Systems and Equipment 

Room: 101A

Chair: Daniel Pettway, Life Member, Hobbs & Associates, Norfolk, VA

Currently, the taxonomy of HVAC system and components has various basis, which can get quite complex creating ambiguity in communication, interpretation and documentation, therefore, one paper aims to develop a systematic classification. This session uses computational methods to investigate the problems of mismatch between the air and refrigerant flow distributions and propose different engineering solutions to remedy the problems. In another study, the vortex-enhanced air-side flow and heat transfer for offset strip-fin array is studied and an evenly balanced emphasis on detailed comparison of the computational results with experiments and the physics of the flow. It is of interest to determine the downstream flow field characteristics of air passing through louvers as they are primarily used in air conditioners, fans and air-coolers for directional circulation of air in a confinement.

1. Rapid Modelling of Air Flow through Louvers (LB-17-C011)

Vaibhav Arghode, Ph.D. *and Taaresh Taneja, Indian Institute of Technology - Kanpur, Kanpur, India*

Louvers (or vents) are primarily used in air conditioners, fans and air-coolers for directional circulation of air in a confinement. Hence, it is of interest to determine the downstream flow field characteristics of air passing through these louvers for cooling and ventilating the confinement. A detailed Computational Fluid Dynamics analysis can be done by resolving all the geometrical features of the louver and setting the appropriate boundary conditions. However, this involves high computational effort, especially, in case of physical movement of the louvers for time-varying directional delivery of the air. The central aim of this research is to develop a rapid airflow model which can replicate similar downstream flow characteristics while obviating the necessity to geometrically resolve the louver. This paper examines the results of this research.

2. Efficiency Enhancement of a V-Shaped Evaporator (LB-17-C012)

Zongqin Zhang, Ph.D., Member[1]*, Haijin Xu, P.E.*[1]*, Xinyu Zhang, P.E.*[2]*, Weixin Zhang, P.E.*[1] *and Donna M. L. Meyer, Ph.D.*[2]*, (1)Nanjing Canatal A/C Co., Ltd, Nanjing, China, (2)University of Rhode Island, Kingston, RI*

Air finned-tube evaporators and/or condensers, are the predominant type of heat exchangers used in building air conditioning applications. The compact V-shaped, or sometimes called A–shaped, finned-tube heat exchanger installation considerably enhance the capacity of heat transfer by allowing the maximum number of coils installed in a given space and increasing the total surface area of heat transfer. On the other hand, this design configuration creates noticeable problems of uneven distribution of air flow velocity over the heat exchanger surfaces, which decreases the energy efficiency of the air conditioning system. This paper uses computational methods to investigate the problems of mismatch between the air and refrigerant flow distributions and propose different engineering solutions at air flow side as well as refrigerant flow side to remedy the problems.

3. Flow and Heat Transfer in Vortex-Enhanced Offset Strip-Fin Array, Numerical Study (LB-17-C013)

Arindom Joardar, Ph.D., Associate Member[1] *and Anthony Jacobi*[2]*, (1)Carrier Corporation, Syracuse, NY, (2)University of Illinois at Urbana Champaign, Urbana, IL*

Streamwise longitudinal vortex generation is a promising method for enhancing air-side heat transfer performance of heat exchangers in a range of applications. In this paper, the vortex-enhanced air-side flow and heat transfer for offset strip-fin array is studied with an emphasis on understanding the relation between flow structure and heat transfer. The flow and heat transfer behavior of the baseline offset strip-fin geometry has been thoroughly investigated both experimentally and numerically in the literature. However, numerical modelling of vortex generator (VG) enhanced offset-strip fin array has not been reported. The predictive capability of the model in terms of the local flow and heat transfer characteristics is evaluated in such geometry for both baseline and enhanced cases.

4. A Systematic Classification for HVAC Systems and Components (LB-17-C014)

Han Li, Student Member[1]*, Yan Chen*[2]*, Jian Zhang, Ph.D., Member*[2]*, Rahul Athalye, Associate Member*[2]*, Vrushali Mendon, Member*[2] *and Yulong Xie, Ph.D.*[2]*, (1)Carnegie Mellon University, Pittsburgh, PA, (2)PNNL, Richland, WA*

Currently, the taxonomy of HVAC system and components has various basis, which can get quite complex because of the various components and system configurations. In addition, some of the system names might be commonly used in a confusing manner, such as “unitary system” vs. “packaged system.” Without a systematic classification, these components and system terminology can be confusing to understand or differentiate from each other, and it creates ambiguity in communication, interpretation, and documentation. It is valuable to organize and classify HVAC systems and components so that they can be easily understood and used in a consistent manner. This paper aims to develop a systematic classification of HVAC systems and components.

Sunday, June 25, 11:00 AM - 12:30 PM

Seminar 4

Designing, Operating and Living at a Net Zero Energy and Net Zero Water Building

Track: Net Zero Energy Buildings: The International Race to 2030 NY PDH G

Room: 103AB

Sponsor: 7.6 Building Energy Performance

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

Since the Chesapeake Bay Foundation (CBF) began operating the Brock Environmental Center in Virginia Beach, VA in 2014, Brock has produced 80% more energy than it has consumed and achieved Living Building Challenge (LBC) certification in April 2016, which requires net positive energy, net positive water and net zero waste. However, there have been bumps along the way. Stakeholders worked together to tune building systems and gathered countless lessons. This seminar aims to share those lessons learned from designing, operating and living at Brock from the three unique perspectives, including an owner, an engineer and occupants.

1. Owner's Perspective

***Mary Tod Winchester**, Chesapeake Bay Foundation, Annapolis, MD*

This presentation provides an owner's perspective on operating a net positive energy and water building. This includes an overview of the project, including goals, design, completion and operation of the building; the cultural shifts of staff who came from a traditional closed office environment and moved to a net zero open office environment; findings from formal polling about staff satisfaction that uncovered both the challenges and tangible benefits that have emerged since opening; and how building green has enhanced the organization's mission.

2. Engineer's Perspective

***Brian Coffield, P.E., Associate Member**, SmithGroupJJR, Washington, DC*

This presentation provides the challenges and lessons from designing and operating a net zero energy building from an engineer's perspective. This includes how daily energy reports and dashboards were used to diagnose problems; defining the energy implications of rainwater harvesting and how to further reduce that energy use; how operational data can inform assumptions for future designs; how to balance staff comfort with energy conservation; and the effectiveness of natural ventilation in mixed-humid climates.

3. Occupants' Perspectives

***Hyojin Kim, Ph.D., Member**, The Catholic University of America, Washington, DC*

This presentation highlights the results of an effort to evaluate energy and Indoor Environmental Quality (IEQ) performance of a net zero energy building from occupants' perspectives during its first year of operation. The assessment was performed based on the ASHRAE Performance Measurement Protocols (PMP) for Commercial Buildings. This includes an occupant IEQ satisfaction survey along with continuous measurements of selected energy and IEQ variables with occupancy. Lessons learned from the assessment are presented, including evidence that a net zero energy building can deliver high standards of comfort to their occupants.

11:00 AM - 12:30 PM

Seminar 5

(WITHDRAWN) Drones Have Arrived: Unmanned Aerial Systems (UAS) in the Built Environment

Track: Fundamentals and Applications

Sponsor: 1.5 Computer Applications

Drones have quickly become a widely diffuse technology for entertainment as well as innovative business. Come learn some of the applications of Unmanned Aerial Systems (UAS) in the built environment. Know the legal and safe way to leverage this technology to survey building envelopes and hard to reach locations, at lower cost and for improved safety.

Sunday, June 25, 11:00 AM - 12:30 PM

Seminar 6

Going Small in Exhaust Air Energy Recovery, for Multi-Family Buildings Size Doesn't Matter

Track: Residential Buildings: Standards Guidelines and Codes NY PDH G

Room: 203AB

Sponsor: 5.5 Air-to-Air Energy Recovery

Chair: Marc Tardif, Member, Innergytech Inc., Drumminville, QC, Canada

Despite the small size of exhaust air energy recovery in residential, it can have a huge benefit. This session reviews the design and application of exhaust air energy recovery in multi-family buildings. An overview of the requirements of ASHRAE Standard 90.2 and Standard 62.2 are discussed. Modeling methods and installation practices are also reviewed.

1. Introduction to the Residential Air-to-Air Energy Recovery Ventilator (ERV)

***Adam Fecteau, Member**, Aldes, Saint-Léonard-d'Aston, QC, Canada*

More and more high rise and multi-family projects now include residential ERVs but these residential units differ greatly from their commercial counterpart. This seminar lays out the basics of residential ERVs. It covers the main components of a residential ERV and their impacts/importance in a residential application. It addresses the different and typical features and capabilities available on the market from different manufacturers. It also demystifies the relationship between the different certification programs, test methods and limitations. It also briefly looks at different methods of installation.

2. Energy Recovery Ventilation (ERV) Applications for Mutifamily High Rise Dwelling Units in Northeastern Climate

***Nabar Manalee, P.E. (CA), CPHC**, Bright Power Inc, New York, NY*

This session explores the scopes of ASHRAE 62.2, the Passive House standard and the NYC mechanical code as they relate to in-unit ventilation. Although multifamily high rise buildings fall under the commercial code, individual apartments can be required to comply with ASHRAE 62.2. Fresh air is mandatory, recovering the energy contained in the stale indoor air helps reduce heating and cooling. How to decide what is needed for a project – ERV or HRV is discussed. Design of these systems, including various air sealing, filtration and insulation details is also discussed.

3. Single Residential and MURB Energy Modeling Programs and Air-to-Air Energy Recovery

***James Scudamore, P.Eng.**, Airia Residential Systems Inc, London, ON, Canada*

Code compliance in many jurisdictions allows for both prescriptive and compliance paths for a dwellings energy consumption. ASHRAE 90.2 is an example of a compliance path outlining the application of such simulation models. A reference house has been use to evaluate the accuracy of Air-to-Air Energy Recovery simulation and associated energy use reduction in these models. This presenation provides information on the effect in modeling of Air-to-Air Energy Recovery for residential dwellings and evaluate the role of Air-to-Air Energy Recovery in a net zero home.

4. ERVs for High Rise Residential Buildings

***James Dean**, dpoint Technologies, Inc., Vancouver, BC, Canada*

Multi-unit residential buildings (MURBs) represent a significant and growing proportion of housing in North America. Traditionally, ventilation air is provided by a central corridor air supply system and is distributed among the suites through entry door undercuts. This system, although being used for decades, has proven to be neither effective nor efficient from an energy or indoor air quality perspective. In this seminar results from a study on the impact of using individual in-suite Energy Recovery Ventilators (ERV) and Integrated Fan Coils (IFC) with energy recovery in high-rise residential buildings are investigated and compared to traditional centralized make-up air systems.

Sunday, June 25, 11:00 AM - 12:30 PM

Seminar 7

NZEB from Foundation to Financing: Nonresidential Buildings

Track: Net Zero Energy Buildings: The International Race to 2030 

Room: 201B

Sponsor: 6.7 Solar Energy Utilization, 6.8 Geothermal Heat Pump and Energy Recovery Applications, TC 2.8

Chair: Janice Means, P.E., Life Member, Lawrence Technological University, Southfield, MI

This seminar addresses commercial solar PV systems and discusses the steps to be followed during the design phase including system sizing. Also, it demonstrates the importance of demand savings that should be included in the economic analysis of PV systems. Other topics such as tax credits, third party financing and ownership and other methods are discussed to give project design professionals a full understanding of the options available to them to move toward Zero Net Energy Buildings. In addition, sustainability in historic buildings and the use of renewable energy systems is covered.

1. Introduction to Solar Electric Design and Installation

***Khalid Nagidi, BEAP, Member**, Energy Management Consulting Group, Wantagh, NY*

As the demand for solar electric systems grows, design professionals are looking to add solar PV as an option for their customers. This session covers grid-tied PV systems and provides attendees a solid understanding of the various solar PV components such as PV modules & inverters, system sizing, array configuration, shading analysis and estimation of energy production of a solar system based on site specifics including orientation and tilt angle. Also, different mounting and tracking systems is covered.

2. Photovoltaic (PV) Systems Impact on Electric Demand

***Svein Olav Morner, Ph.D., P.E., CPMP, Member**, Sustainable Engineering Group, Madison, WI*

Larger buildings electrical rates typically allocate the cost of electricity towards demand. The cost for demand can be similar or even exceed the cost of energy. Because of this, the economics for large buildings PV systems are less favorable when only the energy cost savings are considered. The rational to not attribute demand savings to the PV system have been that a cloud can reduce the output for 15 minutes and the peak for the month or year will be set. This presentation demonstrates that demand savings should be included in the economic analysis of PV systems.

3. Financing and Ownership Alternatives for Large Scale Solar PV Projects

***James Leidel, Member**, Oakland University, Rochester, MI*

The installed cost of solar photovoltaic installations has decreased significantly in the past decade. In some areas of the U.S.A. and many parts of the world, the long term 20 year cost of solar PV electricity is equal to or cheaper than the grid. However, the first cost hurdle must still be overcome by commercial projects. Tax credits, third party financing, third party ownership and other methods are discussed to give project design professionals a full understanding of the options available to move toward your Zero Net Energy Buildings.

4. Deep Energy Refurbishment of Historic and Heritage Buildings to Reach NZEB Status

***Marija Todorovic, Ph.D., P.E., Fellow ASHRAE**, University of Belgrade, VEA-INVI.Ltd Director, Belgrade, Serbia*

Sustainability begins with preservation - maximizing the use of existing materials and infrastructure, reducing waste and preserving the historic character of older towns and cities. Land availability surrounding the locations/sites of most of historic and heritage buildings, original bioclimatic adaptability and currently available environmental technologies, including HVAC and mature technologies of renewable energies supply systems, can supplement inherent sustainable NZEB's features without compromising the unique historic character. Presenting studies (Aviation Museum and Institute for Conservation) addresses methodologies, current knowledge and technologies use in refurbishment design process, as well as importance of relevant benchmarking, rating system and financing scheme development.

Sunday, June 25, 11:00 AM - 12:30 PM

Seminar 8

Occupant Behavior Based Modeling Predictive Control

Track: HVAC&R Systems and Equipment 

Room: 202AB

Sponsor: MTG.OBB Occupant Behavior in Buildings

Chair: Da Yan, Tsinghua University, Beijing, China

Occupant behavior is one of the major drivers of energy consumption in buildings, yet there is currently little integration of occupancy-estimation and feedback control systems. These savings can be achieved through occupant-based, operation or retrofit strategies. Accurate predictions of occupant behavior are needed to inform MPC algorithms to improve their efficacy. Conversely, the model used within an MPC controller can be used to test the energy (and peak power) implications of different occupant behavioral scenarios, and use this insight to inform the occupant about how to better interact with the building systems.

1. Occupant-Integrated Model Predictive Control of Building HVAC Systems: Benefits, Drawbacks and Challenges

David Blum, Ph.D., Associate Member*, LBNL, Berkeley, CA*

Within the last decades, needs for building control systems that reduce cost, energy, peak demand and that facilitate building-grid integration, district-energy system optimization and occupant interaction have come about. Model Predictive Control (MPC) is a control technique that utilizes system models and forecasts to predict performance and optimize control inputs in real-time. This presentation discusses in detail the ways occupant interaction with MPC-controlled building systems can occur, particularly as related to the control of HVAC systems, including benefits, drawbacks and challenges. This presentation discusses progress on current work that is exploring and implementing these interactions in demonstration buildings.

2. Behavior Driven Model Predictive Controls for Future Smart Buildings

Bing Dong, Associate Member*, University of Texas at San Antonio, San Antonio, TX*

This presentation reviews current occupancy behavior (OB) based MPC control projects for smart building at the University of Texas at San Antonio. Challenges and opportunities of OB-MPC for smart buildings are presented and discussed, particularly on models to use, occupancy data and optimization algorithms. Simulation results show that OB-MPC can achieve up to 24% energy cost reduction in residential buildings and 17% in commercial buildings.

3. Fault and Occupant Tolerant Model Predictive Control of Building HVAC System

Pengfei Li, Ph.D.*, United Technologies Research Center, East Hartford, CT*

This presentation covers the collaborative research work from cross-functional team effort behind the journal paper that was recently honored with ASHRAE Research Journal Best Paper of the Year Award. The development and application of a fault and occupant tolerant control technology, its online implementation, and results from several tests conducted for a large-sized HVAC system are discussed. The performance and limitations of the fault detection and diagnosis, model predictive control as well as the fault and occupant tolerant control algorithms are illustrated and discussed using measurement data recorded from multiple field tests.

4. The Combination and Application of Model Predictive Control and Occupant Behavior

Da Yan*, Tsinghua University, Beijing, China*

MPC is a new approach to controlling building systems to optimize equipment operation. Meanwhile, occupant behavior is a key contributor to the uncertainty of energy consumption. The combination of MPC and OB would foster great building energy saving potential. The integrated network to measure occupancy and behavior related with environmental parameters is introduced. With the measured data, the occupant behavior predicting models will be built and integrated with the building system model to improve the control logic. A demonstration of the predictive model application is presented to see the effect of occupant behavior based model predictive control.

Sunday, June 25, 11:00 AM - 12:30 PM

Seminar 9

Using Optimization to Squeeze More Performance Out of Existing Systems

Track: Fundamentals and Applications 

Room: 101B

Sponsor: 1.13 Optimization

Chair: Christopher R. Laughman, Ph.D., Member, Mitsubishi Electric Research Laboratories, Waltham, MA

While optimization is often viewed as part of the design process for new systems, it can also provide significant value for improving existing systems. This session discusses the use of optimization techniques to improve existing systems, ranging in size from heat exchangers to buildings, to achieve higher performance without restarting the system design process from scratch.

1. Optimization of Small Diameter Tube-Fin Heat Exchangers to Enable Performance Improvements, Charge Reduction and Cost Savings

***Daniel Bacellar**, University of Maryland, College Park, MD*

While small diameter (≤5 mm) tube-fin heat exchangers have the potential to improve performance, successful designs must meet many criteria. Three case studies are presented to illustrate how optimization techniques can be used to design drop-in 5mm tube-fin condenser replacements for a domestic refrigerator, a packaged terminal air conditioner, and a window air conditioner that meet engineering and economic objectives. An optimization method is applied to heat exchanger simulation tools to evaluate the performance of heat exchanger simulations to identify optimal configurations that meet many objectives. Results indicate that these designs can significantly enhance energy-efficiency, reduce refrigerant charge, and reduce material consumption and cost.

2. Improving Heat Exchanger Circuitry by Using Derivative-Free Optimization

***Christopher R. Laughman, Ph.D., Member**, Mitsubishi Electric Research Laboratories, Waltham, MA*

While the interconnections between the tubes of a heat exchanger can have a significant effect on its performance, this circuitry is difficult to design by hand because of the large number of possible designs and the nonlinear and discontinuous dependence of the performance on that circuitry. We formulate the circuitry design as a binary constrained optimization problem, and apply derivative-free optimization (DFO) algorithms. We apply a number of existing DFO algorithms to this problem, and demonstrate that they can find optimal or near-optimal circuitry designs for realistic coil sizes after a limited number of simulations.

3. Optimizing Mini-Split Air Conditioning Units Using Alternative Refrigerants

***Bo Shen, Ph.D., Member**, ORNL, Oak Ridge, TN*

Developments in the Montreal Protocol include the development of a global consensus to phase-down the use of HFC refrigerants, as well as the continuing transition among developing countries to phase-out the use of HCFC and introduce HFC as potential intermediary solution. This presentation covers efforts to develop optimized system designs for mini-split AC units used in developing and high ambient countries using alternative lower global warming potential refrigerants. There are available candidate refrigerants that can be introduced during the current phase-out transition in order to eliminate a costly 2-step transition from HCFC to HFC and HFC to lower GWP solutions.

4. Operation Optimization of Buildings As Virtual Batteries for the Grid with High Penetrations of Renewables

***Zheng O'Neill, Ph.D., P.E., Member**, University of Alabama, Tuscaloosa, AL*

One approach for realizing the potential for both building energy cost savings and the integration of renewable energy systems (RES) into the power grid involves the proactive integration of building operation into the power grid by optimizing the operation of energy sources with time-sensitive electricity price. The operation scheduling problem is formulated with the RES, electrochemical batteries as energy sources, and the building envelope as thermal energy storage, and is solved as a mixed integer programming problem. A case study using the AMPL platform shows that such energy storage technologies provide an effective way to connect energy supply resources and demands, and facilitate efficient building operations.

Sunday, June 25, 1:30 PM - 3:00 PM

Conference Paper Session 5

Thermal Comfort in Modern Transportation

Track: Fundamentals and Applications NY PDH G

Room: 101A

Chair: Edward A. Vineyard, Fellow ASHRAE, Texas A&M University, College Station, TX

This conference paper session addresses one of the key functions of the HVAC&R industry, occupant thermal comfort. The session discusses some basic room design considerations and looks more closely at the unique design considerations used in vehicle and aircraft cabins.

1. Ventilation Efficiency and Thermal Passenger Comfort of Novel Car Ventilation Concepts (LB-17-C015)

***Tobias Dehne, CPMP**, Johannes Bosbach, Daniel Schmeling, Pascal Lange and Andre Volkmann, German Aerospace Center (DLR) Institute of Aerodynamic and Flow Technology, Göttingen, Germany*

Passenger comfort and ventilation efficiency in cars have attracted the attention of scientists and car manufacturers during the last years due to their potential of improving thermal passenger comfort, increasing efficiency and attended energy reduction. Nowadays, state of the art for the ventilation of passenger compartments of cars is mixing ventilation (MV) which is based on a high mixing degree of inflowing air with cabin air. In cooling cases, this is realized by high-momentum jets of cold air, which enter the cabin at the dashboard. Among the potential benefits of new developed ventilation concepts, are an increased thermal passenger comfort by reducing draughts and simultaneously energy saving potential by increasing the heat removing efficiency (HRE). The latter is of great importance especially for electrically powered cars to improve their range.

2. Numerical Simulations of Air Flow Movement and Thermal Comfort in Commercial Aircraft Cabins (LB-17-C016)

***Essam E. Khalil, Fellow ASHRAE**[1], Esmail ElBialy, Dr.Ing.[1], Moustafa Salah, P.Eng.[1] and Ahmed Fahim, Ph.D., P.E.[2], (1)Cairo University Faculty of Engineering, Cairo, Egypt, (2)HBRC, Cairo, Egypt*

Improving comfortable environmental conditions for passengers has been the airlines' interests in the recent decades. This paper discusses air distribution systems and factors affecting the goal of a healthy and comfortable environment for the passengers and cabin crew. Research was done by using ANSYS FLUENT 17.0 with new features. The standard air distribution systems used in recent air cabin are combined between mixing ventilation and personalized ventilation and this study makes a simple applicable modification on the ventilation system that improves the ventilation efficiency, thus protecting the passengers from being infected by each other. Commercial airplane environmental control systems (ECS) currently mix air ventilation systems, which are necessary to make a safe, thermally comfortable and healthy cabin environment.

3. Effects of Diffuser Arrangements for Mixing and Displacement Ventilations on Indoor Environmental Qualities in Two Adjacent Spaces (LB-17-C017)

***Hyeunguk Ahn, Student Member**[1] and Donghyun Rim, Ph.D., Associate Member[2], (1)Pennsylvania State University, State College, PA, (2)Pennsylvania State University, University Park, PA*

A number of studies have shown that air distribution systems on the thermal comfort of occupants can vary depending on locations of diffusers and return outlets and types of ventilation systems. However, few studies have focused on air distribution strategies for serving multiple zones and their effects on local air quality and thermal comfort. Simulation results indicate that temperature distributions of two rooms were a strong function of ventilation type. However, indoor air quality of two rooms was significantly affected by both a ventilation type and an operation strategy. The results suggest that careful consideration is needed for designers and managers in selecting and operating air conditioning system to maximize the ventilation effectiveness and the thermal comfort in multiple zones.

4. Analysis of Heat Transfer Inside Vehicle Cabin by Means of Contribution Ratio of Indoor Climate (LB-17-C018)

***Yasuhiro Tanoue**[1], Hideaki Nagano, Ph.D.[1], Shinsuke Kato, Dr.Ing., Fellow ASHRAE[2] and Itsuhei Khori[1], (1)Tokyo City University, Tokyo, Japan, (2)University of Tokyo Institute of Industrial Science, Tokyo, Japan*

Air-conditioning systems are often designed based on the model experiment and the numerical simulation. However, such study methods spend much time and costs in order to obtain the result. Therefore, the prediction method of indoor thermal environment with less time and cost is required. As for the practical use period, the air-conditioning system controls the supply air temperature and the airflow rate based on the feed-back control system which has temperature sensors. In this paper, Contribution Ratio of Indoor Climate (CRI) is employed to predict the distribution of the air temperature for the sake of the more efficient control system. The vehicle cabin and its air-conditioning system are focused because in-vehicle environment is a relatively severe condition compared with indoor environment of building. The purpose of this paper is to investigate the prediction accuracy of the air temperature in vehicle with CRI in order to clarify its applicability.

Sunday, June 25, 1:30 PM - 3:00 PM

Seminar 10

Research Methods to Achieve Superior Comfort, Health and Well-Being in Buildings

Track: Fundamentals and Applications 

Room: 203AB

Sponsor: SGPC 10

Chair: Mark Jackson, Ph.D., McCree Consulting, Grand Praire, TX

Methodologies for design often consider competing or disparate criteria for the building separately, for example energy use, thermal comfort, IAQ and lighting. Yet we know these criteria interact, and to achieve superior comfort, health, and productivity these interactions must be overcome. This seminar will address current research methods to understand these interactions and create successful designs.

1. Health and Wellness in the Built Environment

***Nathan Stodola**, International WELL Building Institute, Brooklyn, NY*

The buildings in which we live, work, and play have a tremendous impact on our health, wellbeing, and productivity. This presents a unique opportunity to utilize the design, construction, and operation of buildings to promote and improve human health. Numerous green building programs exist that focus on environmental impact and sustainability within the building design and construction industries, but there remains limited guidance on factors that impact the health and wellbeing of occupants. This is a serious gap, as occupants are the reason buildings are constructed, so their needs must be considered.

2. Humidity Interaction Effect on the Building and Occupants

***Eric Brodsky, P.E., Member**, Research Products Corporation, Madison, WI*

Relative humidity has a significant impact on indoor buildings and occupants. Specifically relative humidity impacts occupant health and comfort, as well as building energy usage and preservation. The ASHRAE Handbooks reference humidity over 300 times. Recent changes to the building envelope, HVAC equipment, and occupant requirements will impact ASHRAE humidity recommendations. There are many different HVAC product solutions that can be applied based on ASHRAE's guidance. This seminar highlights some of the significant interactions concerning humidity levels, as well as outlining significant humidity recommendations and gaps.

3. Implications of Modern Indoor Lighting on Circadian Health

***Frederick Marks, AIA**, Visiting Scholar, Salk Institute for Biological Studies, La Jolla, CA*

Light, whether it originates from natural or electrical sources, is a formable stimulus for regulating circadian, hormonal, and behavioral systems. Over illumination may cause headaches, fatigue, medically defined stress, anxiety and decreases in sexual function. Under illumination may lead to chronic diseases such as breast & prostate cancers, obesity and early-onset diabetes. When considering standards for building design, it is therefore important to balance the desirable and undesirable impacts of light or darkness. Achieving this balance begins with an understanding of how photoreceptors in the eye function and why different visual and non-visual wavelengths of light cause different responses.

4. The Well Living Laboratory: A Facility for Investigating the Impact of the Indoor Environment on Human Comfort, Health and Productivity

***Nicholas Clements, Ph.D.**, Well Living Lab, Rochester, MN*

Indoor environments greatly impact human comfort, health, and productivity. To investigate and quantify this impact, a highly controllable and reconfigurable laboratory, the Well Living Lab, was designed and built to simulate real-world office and residential spaces. This presentation provides an overview of the experimental capabilities of the Well Living Lab, which include an integrated and scalable building control system, environmental and biometric sensing, and experiment management system. An overview of on-going and planned human-subject research is also provided.

Sunday, June 25, 1:30 PM - 3:00 PM

Seminar 11

Absorption Heat Pump Applications: Industrial, Space Heating and Water Heating

Track: HVAC&R Systems and Equipment NY PDH G

Room: 102AB

Sponsor: 8.3 Absorption and Heat Operated Machines, 9.2 Industrial Air Conditioning

Chair: Patrick Geoghegan, Ph.D., Member, ORNL, Oak Ridge, TN

Absorption heat pumps are the lesser known variant of absorption chillers. Although technically very similar, their potential for energy recovery in industry and building heating is not widely known. This seminar addresses the engineer finding new solutions for clients. The seminar outlines the basic functionality of absorption machines, then highlights the potential in applications by using some typical and exotic examples. It covers the range from very large customized industrial systems to standardized packaged small systems for buildings, with a final presentation focusing on the potential for heating applications in the US.

1. Real World Examples of Industrial Absorption Heat Pumps: Exotic Applications, Working Fluids and Cycles (multi-effect)

***Jürgen Scharfe, P.E., Member**, JS Energie & Beratung GmbH, Erding, Germany*

This presentation introduces exotic applications of absorption heat pumps that have been actually implemented. These can serve to provide new creative solutions to modern challenges in industrial thermal management. After a quick introduction into absorption process, the examples are explained in their economic context, the technical solution is explained in brief and the results are explained in their economic and environmental context.

2. Case Studies from Around the World that Are Using Modern Absorption Heat Pumps to Save Energy and Water Resources on Planet Earth

***Douglas A. Davis, Associate Member**, Broad USA, Hackensack, NJ*

This presentation introduces numerous case studies from the US and beyond for successful applications of absorption heat pumps. A diverse set of examples is presented, and all are demonstrating real world savings of energy and water.

3. Mass Markets in the US for Sorption Heating Appliances

***Kyle Gluesenkamp, Ph.D., Associate Member**, ORNL, Oak Ridge, TN*

This presentation provides an overview of which mass markets have potential for large-scale adoption of packaged absorption machines. Whereas small scale cooling applications often struggle to compete on energy savings with electric-driven cooling, heating applications often have compelling energy and economic attributes. Small packaged units are beginning to be available to serve these applications.

Sunday, June 25, 1:30 PM - 3:00 PM

Seminar 12

An Interdisciplinary Framework and Survey for Investigating Cross-country Occupant Behavior in Buildings

Track: Research Summit G

Room: 201A

Sponsor: MTG.OBB Occupant Behavior in Buildings

Chair: Tianzhen Hong, Ph.D., Member, LBNL, Berkeley, CA

Occupant behavior in buildings is a key driver of energy performance and occupant comfort. However it is less understood due to its stochastics, diversity and lack of data. Obtaining occupant behavior data through sensing and monitoring takes time and resources and is limited to a small scale (small number of buildings or shorter time periods). This seminar introduces an interdisciplinary framework and questionnaire design to survey a large number of occupants in various countries on their occupancy and interactions with building systems. Survey results are analyzed to understand occupant behavior and used to improve energy modeling, building design and controls.

1. An Interdisciplinary Research Approach to Energy-Related Behavior in Buildings

***Simona D'Oca, Ph.D.**, LBNL, Berkeley, CA*

An interdisciplinary and international survey is developed for systematic identification of environmental, cognitive and behavioral factors (and their interrelations) influencing control options in office buildings. This study is conducted through the development of questions directed at attitude, subjective norms, perceived control and other related concepts as organized in the Social Cognitive Theory and the Theory of Planned Behavior. The survey is distributed to 14 Universities among six countries in four continents (America, Asia, Europe, Australia). The questionnaire survey assesses office configuration type, thermal comfort, social norms, attitudes toward energy saving, demographics, etc.

2. Performance Analysis of Occupant Behavior Questionnaire Survey Data in China's Residential Buildings
***Da Yan**, Tsinghua University, Beijing, China*

This study presents a new method to summarize typical behavior patterns in residential buildings in China regarding air-conditioning use. A large-scale questionnaire survey was designed and conducted to get behavior patterns, which were then used in energy simulation. Based on the energy consumption, the behavior patterns were classified into categories and a typical pattern was extracted from each category. Finally, the typical behavior patterns were validated by the distribution testing of building energy consumption. These typical behavior patterns could be used to estimate the energy consumption with different composition of occupants and evaluate the energy saving potential of different technologies.

3. Insights on Social Psychological and Contextual Factors Affecting Energy Behaviors and Conservation Intentions in Residential and Commercial Buildings
***Chien-fei Chen, Ph.D.**, University of Tennessee, Knoxville, TN*

The issues of energy consumption and occupant behaviors should not be an individualistic focus, assuming that people will control their behaviors and make rational choices. These complex issues extend to organizations and other social contexts as well. This presentation presents the empirical findings regarding the social-psychological and demographic variables affecting energy saving behaviors in both commercial and residential settings. In addition, the influence of social-psychological factors on the U.S. residents' public acceptance of smart meters and demand response programs is presented. Importantly, this presentation discusses several important social science theories in measuring energy saving behaviors and intentions.

4. Lightweight and Adaptive Building Simulation (LABS) Framework for Integrated Building Energy and Occupant Behavior Analysis
***Carol Menassa, Ph.D.**, University of Michigan, Ann Arbor, MI*

Traditional energy simulation tools only consider fixed energy-related schedules and do not incorporate real time effects of occupants' behavioral patterns in energy simulation. In this talk, an inter-disciplinary, Adaptive Building Simulation framework collecting actual building indoor environment data (through sensors) and human physiological and behavioral data (through wearable devices, polling apps, and surveys) and incorporate these data into a coupled and distributed software simulation system is presented. A case study performed using this framework measured occupants' thermal comfort related actions and its effects on energy use in buildings and the results indicated energy savings by influencing the occupant behavior.

Sunday, June 25, 1:30 PM - 3:00 PM

Seminar 13

Building EQ: ASHRAE and APPA Adapting to Energy Challenges Today

Track: Commissioning: Optimizing New and Existing Buildings and their Operation G
Room: 101B
Sponsor: Building EQ Committee
Chair: Hoy Bohanon, P.E., Member, Hoy Bohanon Engineering, PLLC, Clemmons, NC

ASHRAE is in the process of introducing an updated version of Building EQ. A web portal will be available soon for data entry and building energy evaluation. Concurrent with this offering, APPA is promoting the partnership with ASHRAE to its members. A college course is being offered through the student branches. Come and hear how an alliance between ASHRAE Chapters, ASHRAE Student Branches, University Facilities Managers (APPA) and University Instructors rolls into action this fall.

1. The New Building EQ
***Hugh Crowther, Member**, Swegon North America, Inc., Markham, ON, Canada*

Building EQ has many new features and offers support for ASHRAE members in their energy savings efforts. The most prominent change is that data will be entered through a web portal rather than filling out a spreadsheet. New marketing tools will be provided to members as the year progresses.

2. Adapt Building EQ
***Michael Brandemuehl**, University of Colorado, Boulder, CO*

Adapt Building EQ provides a college senior-level undergraduate or graduate course on building energy auditing and analysis using the ASHRAE Building EQ rating system as a learning framework. Students will experience project-based learning through hands-on engineering in real buildings under the guidance of industry professionals. The course is nominally three semester credit hours. It involves 10 weeks of classroom instruction followed by five weeks of hands-on field work in teams under the guidance of local industry mentors. Course content will be freely available through ASHRAE student branches. Students will be expected to purchase some resources through ASHRAE with student discounts.

3. ASHRAE's Partnership with APPA
***Daniel Redmond**, Carleton University, Ottawa, ON, Canada*

The ASHRAE Building EQ program benefits owners and managers of building portfolios. For each building, the program provides an energy rating along with actionable recommendations to improve building performance. These recommendations are made by a professional assessment of a building's energy use as determined by In Operation and/or As Designed ratings method. Building EQ is the only rating system that offers both methods with a consistent baseline to make comparisons along with detailed actionable recommendations. ASHRAE entered into an agreement with APPA in July 2016 with the commitment to cooperate across many areas including implementing Building EQ on university campuses.

4. APPA's Opportunity and Expectations of Building EQ
***Charles Scott**, Illinois State University, Normal, IL*

APPA is the preeminent organization for university facilities management in North America. APPA has 15,000 members at 1400 institutions. APPA is keenly interested in transforming the way we look at performance of buildings. APPA entered into an agreement with ASHRAE to cooperate in areas of mutual interest. Building EQ offers one opportunity to advance facilities management and help positively shape our current and future built environment.

Sunday, June 25, 1:30 PM - 3:00 PM

Seminar 14

Commissioning of Commercial Kitchen Ventilation Systems, Including Examples of Real World Successes and Failures

Track: Commissioning: Optimizing New and Existing Buildings and their Operation NY PDH G
Room: 201B
Sponsor: 5.10 Kitchen Ventilation, 7.9 Building Commissioning
Chair: Francis Kohout, P.E., Member, Cyclone Energy Group, Chicago, IL

This seminar features presentations describing some of the unique and challenging situations that must be considered as part of the commissioning process for Commercial Kitchen Ventilation (CKV) systems.

1. What Is Commercial Kitchen Ventilation Commissioning?
***Donald Fisher, P.Eng., Life Member**, Fisher Consultants, Danville, CA*

The commercial kitchen ventilation (CKV) system is just that, a system, complete with hoods, exhaust and makeup air fans, makeup air conditioning and delivery and in many cases, demand-based controls. Simply stated, when commissioning (Cx) is compromised, CKV performance falls short of client expectations! Unfortunately, commissioning a CKV system is a complex, multi-phase task not always understood by the design community. Many times, the failure of an exhaust hood to capture effluent from the cooking process could have been mitigated through effective commissioning. This is a high-level perspective on the commissioning process applied to a commercial kitchen.

2. Overall CKV Commissioning and the Critical Role of Testing and Balancing
***Jason Brown, Associate Member**, Melink Corp., Milford, OH*

What are the common issues typically found while performing a test and balance of a CKV system? Several examples are presented that display the common issues found when performing a test and balance as part of both new construction and rebalancing of existing sites due to inadequate design, improper installation and poor maintenance.

3. Commercial Kitchen Ventilation Operation and Performance: Reality Check from the Field
***Michael Morgan, Associate Member**, Captive Aire Systems, Inc., Allentown, PA*

Commercial kitchen ventilation systems (CKV) are a subset within the overall building HVAC, which requires a proper approach to system design, installation and commissioning for operation and performance. System design, quality products and integration are critical; however, the realities of field installations shows that, “where the rubber meets the road, your mileage may vary.” This seminar highlights many of the common issues discovered in the field when performing a system design verification to ensure proper and sustainable operation.

Sunday, June 25, 1:30 PM - 3:00 PM

Seminar 15

The IoT for Better Building Operation and Control

Track: Controls G

Room: 202AB

Sponsor: 7.5 Smart Building Systems, 1.4 Control Theory and Application

Chair: Michael Brambley, Ph.D., Fellow ASHRAE, PNNL, Richland, WA

The Internet of Things (IoT) is increasingly influencing our personal lives, businesses and infrastructures. It interconnects devices having embedded processing, sensors, data storage and physical capabilities, such as actuation. The interconnection of such devices enables the sharing of data and processing for mutual benefit. For buildings and their heating, ventilating and air-conditioning (HVAC) systems, the IoT can support improvements in monitoring of equipment and space conditions, energy management, supervisory control and participation in electric-utility demand response programs to mention a few. The presentations in this seminar provide examples of how the IoT can deliver improvements to building operation and control.

1. Smart Plug Enabled Intelligent Commercial Building Operations

***Gang Wang, P.E., Member**, University of Miami, Coral Gables, FL*

This presentation introduces an integrated technology that utilizes smart plugs as occupancy sensors, along with low-cost virtual outdoor-air flow rate and thermal energy meters for energy efficient operations and detection of energy faults of air handling units (AHU) or rooftop units. The smart plug uses power measurements coupled with occupancy sensors to accurately infer occupancy. The virtual meters determine outdoor-air flow rate and thermal energy use in AHUs indirectly through control valve, outdoor air damper and fan operation variables, which are readily obtained. The technology integrates plug load systems with HVAC systems in commercial buildings to enhance energy performance.

2. Iot Technologies Make Buildings More Energy Efficient and Way Smarter

***Xin (Sherry) Hu, Ph.D., P.E., Member**, BriteThings, San Francisco, CA*

IOT devices can measure energy use and other parameters accurately. Then the data will be pushed to cloud and analyzed using machine learning and artificial intelligence. The energy use is optimized with automatic and intelligent control strategies.

3. An Energy Balance Model for Detecting Anomalies in Residential Buildings

***Brent Huchuk**, ecobee, Toronto, ON, Canada*

The advent of the smart thermostat as part of the connected home has changed the opportunity for study of residential buildings. For the first time, systems in the average home have been monitored for prolonged periods of time with continued and indefinite monitoring still happening. As such, researchers are no longer confined to only small archetype buildings or lab settings. This seminar reveals a case study on the determining of anomalies in the energy balance of a home. In particular, discussing the challenges of using these noncommissioned data sets across a variety of situations and discovering insights across the population.

4. Connected Appliances for the Win-Win!

***Dane Christensen, Ph.D., Member**, NREL, Golden, CO*

This presentation discusses several recent R&D efforts at NREL which showcase opportunities for internet-connected residential HVAC and other "smart appliances" to cost-effectively provide mutual benefits to homeowners and utility systems. These include a Time-Of-Use study on HVAC interactions with the electric distribution system, a demonstration of residential equipment providing frequency regulation and a home energy management system which delivers reliable demand response without any reduction in homeowner comfort.

Sunday, June 25, 1:30 PM - 3:00 PM

Seminar 16

Use of Geothermal Heat Pumps to Achieve Net Zero

Track: Net Zero Energy Buildings: The International Race to 2030 
Room: 103AB

Sponsor: 6.8 Geothermal Heat Pump and Energy Recovery Applications

Chair: William Murphy, Ph.D., P.E., Fellow Member, University of Kentucky, Paducah, KY

The New Buildings Institute evaluated over 200 documented net zero and ultra low energy buildings and found that geothermal heat pumps were commonly used to minimize the energy utilization index and reduce the number of solar panels. Designers of net zero energy building systems will share their design techniques that implement geothermal technologies in schools and commercial buildings to achieve net zero energy use.

1. Big Data on a Net Zero Energy Building

***Benjamin Skelton, P.E., CPMP and BEMP, Member**, Cyclone Energy Group, Chicago, IL*

The Walgreens Net Zero Energy store in Evanston, Illinois opened in November of 2013 and now has over three years of operating data. The project incorporated an innovative heat pump technology with a vertical well geo-exchange system and a central heat pump system that provides chilled water, heating hot water and services the refrigeration cabinets. Detailed performance data has been collected on the building and the geo-exchange field. This study explores the benefit of the geo-exchange system and the lessons learned from operating a net zero energy building. The project won a 2016 ASHRAE Technology Award.

2. Evolution of Zero Energy Geothermal Schools from 2010 to 2016

***Ken Seibert, P.E., Member**, CMTA Inc., Louisville, KY*

The first documented net zero energy school in the United States was Richardsville Elementary in Warren County, Kentucky. One of the latest net zero energy schools is Discovery Elementary in Arlington, Virginia. This presentation addresses how geothermal heating and cooling was used to reduce the building energy requirements in these two schools and how net zero energy designs have evolved in this short period of time.

3. Use of Geothermal and Biofuels to Reach Net Zero in a Northern Public Transit Center

***Erin McConahey, P.E., HBDP, Fellow ASHRAE**, Arup, Los Angeles, CA*

The Olver Transit Center in Greenfield, Massachusetts is the first net zero public transportation center, using geothermal heat pumps, a 7300 sq ft ground mounted PV system and an on-site wood pellet boiler. The geothermal and pellet boiler are supplemented by air preheating with a solar wall and energy heat recovery. It includes office space on the second floor and is designed to also serve future rail service.

4. Geothermal Design for a 24/7/365 Net Zero Police Station

***Spivey Lipsey, P.E., Member**, CMTA Engineers, Lexington, KY*

The new Cincinnati, OH police station completed in late 2015 was intended to be a design-build LEED silver, but the winning bid showed that a net zero building could be built within the available budget. Forty geothermal bores with decentralized low-head pumps and 2-speed heat pump units greatly reduced the HVAC energy usage. Water-to-water heat pumps are used for domestic hot water and garage underslab heating to balance annual heat rejection and extraction. The building is always open for business and includes fitness/locker facilities, public spaces, offices and classrooms and a garage for police cruisers, each with unique IAQ requirements.

Sunday, June 25, 3:15 PM - 4:45 PM

Seminar 17

Those Who Cannot Remember the Past are Condemned to Repeat It: Modeling, Performance and Lessons Learned from Installation of Solar Energy Systems

Track: Net Zero Energy Buildings: The International Race to 2030 NY PDH G

Room: 103AB

Sponsor: 6.7 Solar Energy Utilization, 2.8 Building Environmental Impacts and Sustainability, 6.8

Chair: Michael Case, Ph.D., Associate Member, US Army Corps of Engineers, Champaign, IL

This session reviews modeled and actual performance and lessons learned from the installation of diverse renewable energy systems at Fort Huachuca and the Presidio of Monterey. It discusses the design, installation, operations and maintenance of these systems as well as work in progress on the installation of a Sterling solar thermal electric generator. The seminar presents the results of two models of geo-exchange heat pump system with solar thermal for a community located in Toronto. Simulation results show that by integrating a solar thermal system, heat pump performance in the heating mode improves by 26%.

1. Learning from History: Lesson Learned over 35 Years of Solar Energy at Fort Huachuca, AZ

***William Stein**, US Army Corps of Engineers, Champaign, IL*

This seminar discusses lessons learned at Fort Huachuca over the past 35 years with various renewable systems, including indoor pool solar water heating; solar domestic hot water; grid connected PV; transpired air solar collectors; daylighting; PV outdoor lighting; a dish/Sterling solar thermal electric generation; building integrated PV; utility owned 13.6 MW (AC) PV; and organic Rankine cycle electrical generation.

2. Solar Thermal Sizing, Modeling and Verification for an Army Barracks

***Jay Tulley**[1] and Brian Clark[2], (1)U.S. Army Garrison, Monterey, CA, (2)Engineer Research and Development Center, Construction Engineering Research Laboratory, Champaign, IL*

The US Army requires that projects install solar thermal arrays to provide 30% of domestic hot water load when there is an economic payback. There are challenges, however, improperly sizing a system to meet these design loads and verifying that the system meets the requirements is not required. This presentation looks at an Army barracks that specified an array that would meet 70% of the domestic load but encountered many problems during commissioning and the first 6 months of operation. Lessons learned and recommendations for future projects are presented.

3. Solar Community Heating and Cooling System with Central Heat Pump and Geo-Exchange System for Cold Climates

***Farzin Masoumi, Member**, Union Gas Limited, Toronto, ON, Canada*

For a hypothetical solar community located in Toronto, the viability of geo-exchange heat pump system with solar thermal was investigated. Two models were developed. The first model was based on the central heat pump system with borehole thermal storage, using a PV system as the heat pumps power. The second was a system with a solar thermal system added to the first model. Simulation results showed that for the communities with the annual heating and cooling ratio of more than 75%, by adding the solar thermal system, the heat pumps' performance, in the heating mode, will improve by 26%.

Monday, June 26

Monday, June 26, 8:00 AM - 9:30 AM

Panel 2

How Not to Design a Radiant Heating and Cooling System: Lessons Learned and Strategies for Success

Track: HVAC&R Systems and Equipment

Room: 202AB

Sponsor: 6.5 Radiant Heating and Cooling

Chair: Devin Abellon, P.E., Member, Uponor, Apple Valley, MN

Radiant heating and cooling systems have been proven as an effective strategy for reducing building energy usage while maintaining optimum thermal occupant comfort. This panel, featuring some of the leaders in the application of radiant systems, discusses some of the pitfalls, challenges and success stories associated with a number of landmark radiant installations throughout the world and provides valuable insights so that today's practitioners can design more effective and efficient systems.

Panelist

Robert Bean, Member, Indoor Climate Consultants Inc., Calgary, AB, Canada, Daniel Nall, P.E., Fellow Life Member, Syska Hennessy Group, New York, NY and Peter Simmonds, Ph.D., Fellow ASHRAE, Building and Systems Analytics LLC, Marina Del Rey, CA

8:00 AM - 9:30 AM

Conference Paper Session 6

Utilizing Predictive Occupant Behavior and Counting to Better Determine Hot Water and Heating Demand Loads and IAQ

Track: Research Summit 

Room: 101A

Chair: Vikrant Aute, Ph.D., Member, University of Maryland, College Park, MD

Accurate predictive occupancy data is crucial when using occupancy as one of the data points in energy modeling for buildings and for use by building operators to optimize day-to-day and hour-to-hour operations. This session provides information on why occupancy is important in predicting energy loads and different methods of determining occupancy which can then be used to develop more accurate modeling formats.

1. Sizing Methodology for Domestic How Water Systems Based on Accurate Occupant Behavior (LB-17-C019)

Jean Rouleau, Student Member[1]*, Louis Gosselin, Ph.D., P.E., Member*[1] *and Alfonso Ramallo-Gonzalez*[2]*, (1)Université Laval, Québec, QC, Canada, (2)University of Bath, Bath, United Kingdom*

As households are being required to be more energy efficient over the years, the energy consumption for producing domestic hot water (DHW) is receiving increasing attention. Hence, the design of hot water systems is becoming more important for a holistic approach to energy conservation. Current sizing for these systems is often based on estimations that obey empirical rules. An inaccurate evaluation of the hot water demand could lead to a poor hot water system design that is either undersized or oversized. This either means an insufficient amount of hot water available to occupants or an overpriced system that never gets to be used at its optimal operational point. Therefore, it is crucial to properly evaluate the hot water demand when designing hot water systems for dwellings. This paper discusses a stochastic tool constructed to generate hot water demand profiles for residential buildings using a 10-minute resolution.

2. Modelling Residential Building Stock Heating Load Demand, Integration of Occupancy Models (LB-17-C020)

Giuseppina Buttitta, Student Member*, William Turner, Donal Finn and Oliver Neu, University College of Dublin (UCD), Dublin, Ireland*

In the residential housing sector, a strong correlation exists between occupant behavior and space heating energy use. In particular, the occupancy scenario (e.g., daytime absence, morning presence, etc.) has a significant influence on residential heating load profiles, as well as on cumulative heating energy consumption. The share of households characterized by different occupancy scenarios is a crucial assumption in order to accurately model the residential building stock heating demand. The choice of the most suitable occupancy model is a trade-off between complexity, accuracy and computational effort, as well as model integration at large scale. This paper analyzes the combined influence of different occupancy assumptions and different occupancy models on the housing heating loads for a UK building stock sample.

3. Development and Comparison of Four Different Occupancy Counting and Estimation Solutions (LB-17-C021)
Junjing Yang, Ph.D., Associate Member[1]*, Alexandros Pantazaras*[1]*, Arun Kumar Chandran, Ph.D.*[1]*, Siew Eang Lee, Ph.D.*[1]*, Mat Santamouris, Ph.D.*[2]*, Kwok Wai Tham, Ph.D.*[1] *and Lawrence Wong*[1]*, (1)National University of Singapore, Singapore, Singapore, (2)UNSW, Sydney, Australia*

Occupancy information is important to building facility managers in terms of predictive control, safety, as well as the indoor environment quality. Previous works have addressed different occupancy counting and estimation solutions in different buildings or spaces. In this paper, we build up a test bed using the existing University lecture theatres to develop and compare four different occupancy counting methodologies. The paper addresses the occupancy counting challenge in educational building deployment scenario with large groups of people entering and leaving. Experiments have been conducted for three months with every 5 minutes data reporting interval. The results will be compared with the ground truth of real time pictures.

4. A Low-Cost Bi-Directional People Counter for Building Control (LB-17-C022)
Peng Yin, Ph.D., Associate Member *and Xiaoguang Xiao, Student Member, University of Louisiana at Lafayette, Lafayette, LA*

Accurate occupancy information is crucial to the demand response HVAC control. However, traditional passive infrared (PIR) occupancy sensors can only provide binary results of occupant presence without detecting the number of people in a room. In this paper, a low-cost bi-directional people counter was developed to determine the occupant number in a single entry room by detecting people entering or leaving the room. The developed people counter was designed to be installed in the doorway with a capability of recording the time and the number of people entering, leaving, and staying in the room separately. A field evaluation of the developed people counter was conducted in a single entry student lounge in a period of two weeks.

Monday, June 26, 8:00 AM - 9:30 AM

Seminar 18

Bridging the Information Gaps to Operation Management

Track: Commissioning: Optimizing New and Existing Buildings and their Operation G
Room: 102AB
Sponsor: 7.3 Operation and Maintenance Management, 7.9 Building Commissioning, 7.8 Owning and Operating Costs
Chair: Robyn Ellis, Associate Member, City of Hamilton - Public Works, Hamilton, ON, Canada

This seminar describes innovative approaches to bridging the information gaps that often occur throughout the project cycle, obscuring system intent, critical operating information (set-points, flow rates, etc.), performance history, training materials. Case studies include commissioning with a tablet-based information portal on the owner's cloud, semi-automated data-logging for FDD messaging and searchable information archiving. Impacts include improved energy efficiency and reduced operating costs. This seminar provides diverse perspectives from the owner, the consulting engineer and the researcher.

1. Bridging the Information Gap during Commissioning and Project Turnover to Operations
Chuck Dale-Derks, P.E., Member*, McClure Engineering, St. Louis, MO*

Participants will gain a better understanding of commissioning deliverables from the CxA and/or construction team to be passed to operations. An effective operation and maintenance program benefits when all relevant deliverables are received at project turnover, bridging a commonly experienced gap in information. It is also important to identify what documentation will benefit the relevant committees in their guidance to professionals in creating and receiving those deliverables. ASHRAE recently issued Guideline 1.4 on the Systems Manual. Is this a good starting point for documentation or just another formalization of process? This speaker examines the consultant's perspective.

2. Commissioning Documentation for Operations Management
John Gibbemeyer, P.E., Member*, George Mason University, Fairfax, VA*

Higher education projects are normally required to obtain a LEED certification. Embracing LEED requirements is challenging; but many are now convinced that it can significantly improve operations! LEED projects produce commissioning deliverables that are currently underutilized in bridging the gap to operations management. A higher level of awareness and improved implementation of the Final Commissioning Report and Systems Manual deliverables will greatly improve communication from schematic design through long term operation of the building. Developing an Owner's Project Requirement (OPR) early will ensure that what is proposed in the design and constructed can be maintained well at a low cost.

3. Building Re-Tuning with Automated Data-Logger Networks
Paul Reale*, Building Performance Lab, City University of New York, New York, NY*

It is often said that improvements in building operations can yield 10 – 20% energy savings. Effective Building Re-tuning (BRT) techniques developed by Pacific Northwest National Laboratory that identify energy efficiency opportunities rely on data from a Building Automation Systems. Unfortunately, many buildings have no such trending abilities. Using loggers, sensors and a methodology, BRT-like measures developed by CUNY Building Performance Laboratory identifies operational improvements across building systems. This seminar describes CUNY BPL's experience creating and applying solutions to many building systems; it also speaks to the potential for automation to reduce operator effort in acquiring recommendations for operational improvements.

4. Commissioning in the Cloud
***Kris Kinney, Member**, Highwoods Properties, Raleigh, NC*

A case study is examined where the information gap between construction and operations was successfully bridged at the commissioning phase of a project utilizing a tablet-based information portal on the owner's cloud. In this example, operational information which is critical to thermal comfort and energy performance was effectively communicated and leveraged a video archive. The necessity of this communication occurs not only at the commissioning phase and project turnover to operations but also serves as a useful information resource for the life of the facility and its systems.

Monday, June 26, 8:00 AM - 9:30 AM

Seminar 19

Changes to Heat Gain Tables in the Handbook Commercial Load Calculations Chapter 18

Track: Fundamentals and Applications 

Room: 201A

Sponsor: 4.1 Load Calculation Data and Procedures, 5.10 Kitchen Ventilation
Chair: Jeff Stein, P.E., Member, Taylor Engineering, LLC, Alameda, CA

This session presents the results of ASHRAE research projects that updated the office equipment and kitchen appliance heat gain tables in the Fundamentals Handbook Chapter 18, Nonresidential Cooling and Heating Load Calculations. The office equipment heat gain project was research project RP-1742, Update to Measurements of Office Equipment Heat Gain Data. The kitchen appliance heat gain project was RP-1631, Countertop Commercial Appliance Emissions.

1. RP-1742 Update to Measurements of Office Equipment Heat Gain Data: Experimental Approach and Results Overview
***Christian Bach, Ph.D., Associate Member**, Oklahoma State University, Stillwater, OK*

This seminar introduces the experimental approach and selected test sites used to update the heat gains and diversity factors for different office equipment in the ASHRAE Fundamentals handbook tables. The seminar gives an overview on the data logger's selection criteria for measurement and calibration purposes as well as the testing duration for different equipment. An overview of the experimental results for both, heat gains and diversity factors is also given. Transient data is shown and some typical and atypical findings are pointed out.

2. RP-1742 Update to Measurements of Office Equipment Heat Gain Data: Data Analysis and Parametric Studies
***Omer Sarfraz, Student Member**, Oklahoma State University, Stillwater, OK*

This seminar gives an overview of methods used for the determination of recommended heat gains and diversity factors for different office equipment in the ASHRAE Fundamentals Handbook tables. In particular, the effects of a number of tested pieces of equipment as well as the interval duration for data reduction are investigated. Analysis on the effect of the different number of tested pieces of equipment and averaging interval on the diversity factor is also discussed. Recommendations for minimum equipment count for determining diversity factors as well as recommendations for future work are given.

3. RP-1631 Update to Kitchen Appliance Heat Gain Data
***Rich Swierczyna, Associate Member**, Fisher-Nickel, San Ramon, CA*

Commercial kitchens and dishrooms house equipment that generate the most intensive concentrations of sensible and latent loads. This seminar presents the heat gain findings from RP1631 Countertop Commercial Appliance Emissions along with the updates to the appliance heat gain tables in the handbook.

Monday, June 26, 8:00 AM - 9:30 AM

Seminar 20

Preventing Headlines: Securing Building Automation Systems

Track: Controls 

Room: 103AB

Sponsor: 1.4 Control Theory and Application, 1.5 Computer Applications, 7.5 Smart Building Systems

Chair: Michael Pouchak, P.E., Member, Honeywell International, Golden Valley, MN

Building Automation Systems have grown in complexity and now routinely integrate with HVAC DDC, energy monitoring, automated demand response, lighting control and interfaces to fire and smoke managements. A large percentage of the Building automation systems have been enabled for the ability to control and monitor from the Internet. The failures of computer security in corporations and high profile attacks on computer networks and resources have created significant news stories and has led to increased scrutiny on the source and protection of these valuable resources. This seminar discusses problems and solutions to Building Automation cybersecurity.

1. Specifying Cyber Security Requirements for Building Automation Systems: An Introduction to Industry Challenges, Opportunities and Best Practices

***Ron Bernstein, Member**, RBCG, LLC, Encinitas, CA*

This seminar discusses current issues of control networking security standards for Building Automation solutions and the need for cybersecurity best practices. As more devices are connected to the building network requiring access to the BAS and then to the Internet, the greater the opportunity for exploitation of both internal and external network access. IoT technologies provide direct access from a cloud service to a device, in many cases, bypassing the constraints set up by IT. This session discusses risks and opportunities associated with cybersecurity and efforts to develop smart building specifications to minimize the potential risks while balancing the desire for new solutions.

2. The 20 Minute Risk Assessment

***Bruce Billedeaux, P.E., Member**, Maverick Technologies, Portage, MI*

In every cyber security standard there is a common step, the “Risk assessment”. But what is a risk assessment and how do I do one? This presentation explains how to perform a risk assessment. This information helps the building owner, design engineer and automation professional determine the value of cyber security.

3. Using a Systems Approach to Secure Networks

***Mike Pouchak, P.E., Member**, Honeywell, Golden Valley, CA*

This seminar discusses important system engineering and fundamental topics related to HVAC system security. Key issues of cybersecurity risk analysis, threat model and system security design principles are discussed.

4. Cybersecurity Compliance Testing

***Dan DesRuisseaux**, Schneider Electric, Lake Forest, CA*

This seminar discusses issues related to building automation security testing and information existing industrial cybersecurity standard IEC 62443 and related certification.

Monday, June 26, 8:00 AM - 9:30 AM

Seminar 21

Passive and Net Zero: An Envelope Perspective

Track: Net Zero Energy Buildings: The International Race to 2030 

Room: 201B

Sponsor: 4.4 Building Materials and Building Envelope Performance

Chair: Achilles Karagiozis, Ph.D., Member, Owens Corning, Granville, OH

Passive and net-zero-energy buildings have many similarities, as both methodologies have the objective to reduce the amount of heating and cooling energy used by having energy efficient and air-tight envelopes. However, there are also important differences beyond being one is created in Europe and another in North-America. This seminar describes the role the envelope has in both methods to minimize energy use and the importance envelope has on HVAC systems.

1. Climate Specific Passive Building Challenges

***Katrin Klingenberg**, Passive House Institute US | PHIUS, Urbana, IL*

Passive house standard are among the highest in relationship with building envelope. Since building envelope is a key component in net zero buildings, many of the design procedure can also be applied to net zero buildings. This presentation covers the fundamentals and climate considerations with designing passive construction.

2. Building Energy and Envelope Performance of a Near Net Zero Energy Building
***Stanley Gatland II, Member**, Saint Gobain Corp., Philadelphia, PA*

Pennsylvania State University's GridSTAR Experience Center, located at the Philadelphia Navy Yard, features a near net zero energy building. A unique combination of building materials, construction methods, energy management strategies and renewable energy sources were employed to approach net zero. Research was conducted to evaluate building energy and envelope performance. The results of the measured building energy performance were compared to whole-building energy simulations and one-dimensional hygrothermal modeling. This presentation covers important envelope considerations and lessons learned to achieve near net zero energy residential buildings.

3. Hygrothermal Considerations for Building Envelopes in Passive Buildings
***Florian Antretter, Member**, Fraunhofer-Institut für Bauphysik, Munich, Germany*

Net zero and passive buildings are intrinsically air tight. This can present challenges if the envelope and HVAC systems are not correctly designed. This presentation covers hygrothermal fundamentals as well as design and modeling considerations for building envelopes in passive and high efficiency buildings.

Monday, June 26, 8:00 AM - 9:30 AM

Seminar 22

What is the Prospect for Low-Cost Chemical and Biological Threat Detection and Response in Commercial Buildings?

Track: Building Life Safety Systems NY PDH G
Room: 101B

Sponsor: 2.3 Gaseous Air Contaminants and Gas Contaminant Removal Equipment, 2.4 Particulate Air Contaminants and Particulate Contaminant Removal Equipment

Chair: Russell Taylor, Ph.D., Member, United Technologies Research Center, East Hartford, CT

This session provides DHS and DOD perspectives on the need for biological and chemical agent threat detection in commercial buildings. Possible threat scenarios are discussed along with the potential for low cost sensors integrated with existing life safety systems to detect the presence of those threats. Building responses through the HVAC systems and the effectiveness of those responses for mitigating the threat in a specific building case study is discussed. Finally, there is a discussion of efforts to model threat detection and response scenarios in broad classes of commercial buildings.

1. Biological and Chemical Threat Detection in Commercial Buildings: A DHS Perspective
***Matthew Davenport**, Department of Homeland Security, Washington, DC*

High profile targets for biological and chemical attack are relatively easy to identify and thus provide appropriate protection. However, a low but real risk is present for many other commercial buildings, particularly those that have large numbers of occupants (so called soft targets). The low probability of such an event, combined with the high cost of sensors capable of confirming the presence of hazardous agents are problematic for widespread adoption. Consequently, DHS is studying technology that could both detect hazardous agents in buildings and improve the performance of existing life safety systems, at minimal additional cost to the building owner.

2. The Need for Low Cost Biological Agent Detection in Buildings: A DOD Perspective
***Patricia Buckley**, US Army ECBC (Edgewood Chemical Biological Center), Parkville, MD*

This presentation provides an overview of the need and prospects for low cost biological and chemical agent detection from the perspective of the DOD.

3. A Decision Support Framework for Automated Building Systems Response to Mitigate Occupant and Facility Impacts from Chemical and Biological Agents
***Angela Waterworth**, Pacific Northwest National Labs, Richland, WA*

A methodology to determine automated heating, ventilation and air conditioning (HVAC) system and building response mitigations for bio-aerosol or chemical threats in commercial buildings is under development at Pacific Northwest National Laboratory (PNNL). Models of indoor contaminant dispersion are used to identify and respond to threats based on distributed sensor data. Model scenario verification will be performed; however, validation will be limited to agent surrogates.

4. A Study of Hazardous Agent Propagation in an Office Building to Evaluate HVAC Threat Mitigation Strategies
***Russell Taylor, Ph.D., BEMP, Member**, United Technologies Research Center, East Hartford, CT*

Computer flow network models and experiment are used to create a release of a chemical/biological surrogate agent and understand its propagation in a commercial office building. Manipulation of the building HVAC system is used to mitigate the spread of the surrogate and limits its possible effects on building occupants.

Monday, June 26, 8:00 AM - 9:30 AM

Seminar 23

Contamination Control and Lubricant Considerations during Retrofits to Low GWP Refrigerants

Track: Refrigeration

Room: 203AB

Sponsor: 3.3 Refrigerant Contaminant Control, 3.2 Refrigerant System Chemistry, 3.4, MTG Low GWP

Chair: Ed Hessell, Ph.D., Associate Member, Chemtura Corp., Fords, NJ

This seminar discusses some of the near term and long term low global warming potential refrigerant options for retrofits in select applications. Also presented is information on lubricant considerations during retrofits as well as practical recommendations for avoiding contamination during the retrofit process.

1. Lubricant Considerations during Retrofits to Low GWP Refrigerants

***Joe Karnaz, DSc, Member**, Shrieve Chemical, Houston, TX*

Transitioning of refrigerants involves a great deal of consideration, particularly for new product implementation. OEM's tests units to make sure system performance is at least maintained. Sometimes new refrigerant developed for OEM operation doesn't always mean it will work effectively for retrofit situations. One particular detail that needs investigation, is will the retrofit refrigerant work effectively with lubricant that was formerly used in the unit. Previous refrigerant transitions showed some additional manipulation of the lubricant was needed. Today there is another transition to using lower GWP refrigerants which will once again require evaluation of the lubricant in retrofit situations.

2. Impact of Contamination on the Stability of Low GWP Refrigerants

***Sarah Kim, Ph.D., Associate Member**, Arkema, Inc., King of Prussia, PA*

Servicing with low GWP refrigerants is becoming common in the HVAC&R industry due to the phase out of conventional refrigerants. It is important to follow best practices such as refraining from mixing refrigerants and using the recommended lubricants while considering that HFOs will exhibit a different nature than HFC or HCFC refrigerants. This session covers the impact of common contaminants that may influence the system performance and reliability of some very low GWP refrigerants containing unsaturated molecules such as R-1234yf and R-1233zd(E). In addition, stabilizers which can prevent the deterioration of performance due to contaminants is discussed.

3. Key Learnings from Conversions of Commercial Refrigeration Systems to Low GWP Alternatives

***Andrew Pansulla** and Charles Allgood, Ph.D., Chemours, Wilmington, DE*

The search for replacements for HCFC and HFC based refrigerants such as R-22 and R-404A, being phased out globally due to stratospheric ozone depletion and global warming potential issues, has led to the development of low GWP HFO blend alternatives, such as R-449A. This presentation includes the retrofit procedure for HFO refrigerants in low and medium temperature commercial refrigeration systems that were originally designed for HCFC and HFC refrigerants. Also, data obtained during actual system conversions, including compatibility with seals/lubricants as well as operational and energy performance is reported.

Monday, June 26, 9:45 AM - 10:45 AM

Debate 2

Commissioning Agents For Smart Buildings: Whose Side Am I On?

Track: Commissioning: Optimizing New and Existing Buildings and their Operation

Room: 203AB

Sponsor: 1.4 Control Theory and Application, 7.5 Smart Building Systems, HVAC Security TG2

Chair: Frank Shadpour, P.E., Fellow ASHRAE, SC Engineers, Inc., San Diego, CA

The commissioning agent's role is to ensure that the Owner's Project Requirements (OPR) are met; however, the commissioning agent (CxA) is frequently hired by the Contractor. The Owner's goal is a high-performance building; the Contractor's goal is maintaining budget. Does this relationship pit the commissioning agent against the owner? This debate covers the benefits of commissioning from an Owner's perspective and a Contractor's perspective. Does the Owner get a high-performance building when the commissioning agent is hired by the Contractor or does an Owner-hired CxA guarantee better results? An Owner and Contractor debate lessons learned from commissioning smart building controls.

Participants

Frank Shadpour, P.E., Fellow ASHRAE[1], Daniel Farrow[2] and George Rogers[3], (1)SC Engineers, Inc., San Diego, CA(2)Palomar Health, San Diego, CA(3)RQ Construction, Carlsbad, CA

9:45 AM - 10:45 AM

Technical Paper Session 1

How Will Technology Lead Us to a More Efficient Built Environment?

Track: Fundamentals and Applications 

Room: 102AB

Chair: Rachel Romero, P.E., Member, NREL, Golden, CO

This session presents three findings of how advances in technology have advanced building efficiency. Two presentations enumerate how variables in modeling a building's performance can indicate where the largest energy savings can be accomplished. The third presentation highlights how advances in robotic energy audits can increase the efficiency of existing buildings.

1. Autonomous Robotic Building Energy Audits: Demonstrated Technology and Open Challenges (LB-17-001)

Christopher Bay, Student Member*, Trevor Terrill and Bryan Rasmussen, Ph.D., P.E., Member, Texas A&M University, College Station, TX*

Building operations are a significant consumer of energy and contributor to carbon emissions in the U.S. and around the globe. Energy audits offer significant potential in reducing building energy use by providing tailored recommendations involving equipment upgrades, operational adjustments and building recommissioning. However, energy audits are a time intensive process that requires significant experience and training. This causes high costs related to performing an audit and prevents many businesses from having an audit completed. Automating the audit process will not only reduce the cost of audits, but clients will be provided with more repeatable and accurate recommendations based on improved data collection and analysis. Previous work and the current state of the art of robotic auditing tools are discussed in this paper, followed by open challenges and future possibilities of autonomous vehicles for conducting audits.

2. First-Year Calibration of a Design Energy Model at a Medical Office Building (LB-17-002)

Thomas Langran, P.E.*[1] and Michael Weller[2], (1)Kaiser Permanente, Anaheim, CA, (2)Glumac, Irvine, CA*

A building owner can use a realistic energy model to understand the future building's energy performance. But what happens when the design energy model predicted energy use and the utility bills have a significant variance? Can adjusting the energy model to match the utility bill, or calibrating it, successfully identify the cause of the variance? Will this show strategies to bring the actual energy use back in line with the predicted energy use? This paper reviews the calibration effort of a Medical Office Building where the actual energy use was significantly above the predicted energy use.

3. Development of Maximum Technically Achievable Energy Targets for Commercial Buildings (RP-1651) (LB-17-003)

Jason Glazer, P.E., Member*, GARD Analytics, Inc., Arlington Heights, IL*

How energy efficient can commercial and multifamily buildings become in the near future if first cost is not considered? The paper describes how building energy simulation modeling was used to try to answer this question. The first step was to assemble a list of energy efficiency measures that can be included in the design of non-residential buildings. The list included both commonly used and cutting edge energy efficiency measures with the goal of being comprehensive, at least for measures that can be modeled. Input was sought from many people to ensure that the list of measures did not exclude any important ones.

9:45 AM - 10:45 AM

Conference Paper Session 7

Improving Refrigeration in the Retail Food Establishments

Track: Refrigeration

Room: 101B

Chair: Xiwang Li, Student Member, Drexel University, Philadelphia, PA

Refrigeration is often the largest single energy use in supermarkets. This session examines three widely different topics related to the refrigeration systems used in retail food establishments. The first examines the potential for use of a water-cooled condenser that rejects heat to soil via an intermediate water circuit. It then moves on to examine issues related to the use of HCF 245fa and HCF 124a blowing agents in insulation that is widely used in refrigerated structures. The final paper examines design procedures used to reduce the risk of fire when using flammable refrigerants.

1. Defining Room Area for Connected Spaces for Flammable Refrigerants (LB-17-C023)

William Hansen, P.E., Member *and Stephen Kujak, Member, Trane, Ingersoll Rand, La Crosse, WI*

Flammability risk, in the event of a leak, can be lowered by reducing the potential for forming a refrigerant/air mixture that can reach the lower flammability limit (LFL) in the event of a leak into a confined space. The determination of effective room area and space volume has become critical to safety. This paper will describe an approach for determination effective room area, including methods to utilize adjacent connected spaces. Computational fluid dynamic (CFD) analysis was performed to support the justification for the methodology. An approach, utilizing the principles of natural convection and forced convection will be described for determining the effective room area and volume for individual rooms and connected rooms for unventilated spaces.

2. Long-Term Thermal Performance of Polyurethane Insulation within Cold Storage Panel Systems Used in U.S. Retail Grocery Environments (LB-17-C024)

***James M Costanza, Member**, KPS Global LLC, Fort Worth, TX*

This paper presents details of a study which investigates the long-term thermal resistance (LTTR) performance of polyurethane insulation within discrete cold storage panels used in the US retail grocery environment. The research seeks to better define the potential benefit of extending the productive life of the insulation through longer cold storage service or through recycling into another insulative material. A total of ten U.S. retail chain grocery store sites were semi-randomly selected for the extraction of polyurethane panel specimens from decommissioned cold storage structures. Thermal performance of the cold storage panel specimens was determined by using the ASTM C518-10 Standard Test Method.

3. Analysis of Water-Cooled Refrigeration Systems for the Food Retail Industry (LB-17-C025)

***Maria-Aliki Efstratiadi, M.D.**, Salvador Acha, Ph.D., Associate Member, Nilah Shah, Ph.D. and Christos N. Markides, Ph.D., Imperial College London, London, United Kingdom*

The need for refrigeration in the retail industry and specifically in supermarkets, currently accounts for around 30% to 60% of the total energy consumed in stores. A key characteristic of this consumption, is the high amount of low-grade (i.e., low-temperature) heat rejected by the condensation units to the ambient air. This paper focuses on the transcritical CO_2 (R744) refrigeration cycles and aims to assess whether the use of a water-cooled condenser rejecting heat to the soil via an intermediate closed water-circuit, can reduce the energy consumption, while also considering the economic implications of this modification.

Monday, June 26, 9:45 AM - 10:45 AM

Conference Paper Session 8

Considerations in Stairway Pressurization and Underground Structure's Life Safety

Track: Building Life Safety Systems 

Room: 101A

Chair: Peter McDonnell, McClure Engineering, Inc., Twin Falls, ID

This session presents the latest ASHRAE research project on fire stairway tower test validation of CFD modeling, the installed fire & life safety systems installed in a modern large underground metro system and life safety considerations in Tunnel Smoke Control Systems. The real world issues associated with providing integrated Life Safety Systems that incorporate both current and potentially new Code considerations is discussed. These papers provide valuable insights into current and new standard considerations for many types of buildings.

1. Pressurized Stairwells with Open Doors and the IBC (LB-17-C026)

***John Klote, P.E., Fellow Life Member**[1], Paul Turnbull, Member[2] and Douglas H. Evans[3], (1)John Klote Fire and Smoke Consulting, Leesburg, VA, (2)Siemens Building Technologies, Inc., Buffalo Grove, IL, (3)Clark County Building Division, Las Vegas, NV*

In the past, the International Building Code (IBC) has required pressurized stairwells to maintain pressurization with all exit doors closed. Most jurisdictions in the U.S. are adopting the 2015 IBC that considers the status of exterior doors as opened or closed. A 2016 ASHRAE research project (RP-1447) has shown that a tenable environment can be maintained in stairwells with many open doors provided that the stair doors on the fire floor are closed. Smoke that leaks into the stairwell is quickly diluted resulting in a tenable environment in the stairwell. There are stairwell systems that are intended to maintain pressurization with a number of open doors, but many such systems are complex and have dangerous failure modes. This paper discusses these issues including suggested stairwell pressurization systems.

2. Fire and Life Safety Systems at Delhi Metro Underground Stations (LB-17-C027)

***Rajesh Kumar Jain**, Anoop Kumar Gupta, Member and Abdhesh Kumar Singh, Member, Delhi Metro Rail Corp. Limited, New Delhi, India*

Delhi Metro is the world's thirteenth largest metro system in terms of length and is India's first modern public transportation system built on state of the art technologies. The life safety systems are of paramount importance while carrying millions of passengers daily, the systems are required to be designed in such a manner that in case of any emergency situation the passengers shall be safely evacuated from transit network in minimum time. This paper discusses in detail the different life safety systems provided in the underground metro station building e.g. Smoke Management System, Fire Fighting System, Fire Alarm System, Emergency Power Supply System and Emergency Lighting System.

3. Life Safety Considerations in Tunnel Smoke Control (LB-17-C028)

***Yoon Ko, Ph.D., Member** and Ahmed Kashef, P.E., Member, National Research Council Canada, Ottawa, ON, Canada*

Mechanical Emergency Ventilation Systems (EVS) have been widely used in tunnels to mitigate fire hazards. However, a number of catastrophic tunnel fires have occurred and have raised questions about the effectiveness of the current tunnel fire safety systems. This paper discusses life safety issues that need to be considered in designing different types of the EVS commonly used in tunnels including transverse and longitudinal ventilation systems. It also discusses how airflow induced by the longitudinal and transverse ventilation systems could impact on the fire development and smoke dispersion in the tunnel. Tenability along the length of the tunnel produced by each type of the ventilation systems is also examined.

Monday, June 26, 9:45 AM - 10:45 AM

Seminar 24

As Cool as it Sounds: Strategies to Mitigate the Acoustic Challenges of Radiantly-Cooled Environments

Track: Research Summit NY PDH G

Room: 103AB

Sponsor: 6.5 Radiant Heating and Cooling

Chair: Devin Abellon, P.E., Member, Uponor, Apple Valley, MN

As building owners answer the call to establish more stringent energy-use standards for their new construction projects, design teams are looking beyond traditional HVAC solutions to systems such as radiant cooling. A radiant cooling design embodies the integration of architectural design and HVAC systems design with overall energy efficiency and comfort in mind. However, because these systems rely on hard exposed surfaces for heat exchange, designers are often faced with acoustical challenges. This session explores current research on the necessary balance between performance and environmental sound quality and explores different strategies used to create optimally comfortable spaces.

1. Effect of Acoustical Coverage and Air Movement on the Cooling Capacity of a Radiant Chilled Ceiling

***Fred S. Bauman, P.E., Member**, Center for the Built Environment (CBE), University of California, Berkeley, CA*

Radiant slab systems have the potential to achieve significant energy savings. However, when applied in the ceiling, the exposed concrete may create acoustical challenges due to the high reflectivity of the hard surface. The purpose of this study is to conduct laboratory experiments for an office with varying coverage of free-hanging acoustic clouds and fans. Different fans configuration were tested against a reference case with no air movement. The tests conducted showed that the cooling capacity decreases as acoustical coverage increases. Adding fans brought an increase of the cooling capacity of 22-26% depending on fan configuration and acoustical coverage.

2. Effects of Horizontal and Vertical Sound Absorbers on the Cooling Capacity of Thermally Activated Building Systems (TABS)

***Marcos Dominguez, Student Member**, Technical University of Denmark, Lyngby, Denmark*

As part of this study, the effects of horizontal and vertical free hanging sound absorbers on the cooling performance of TABS and on the occupants thermal comfort were measured in a full-scale TABS laboratory environment. The investigations have also been supported with Computational Fluid Dynamics (CFD) simulations to study the nature of the heat exchange between the TABS and the room when the sound absorbers are present.

9:45 AM - 10:45 AM

Seminar 25

ASHRAE's Residential Energy Performance Standards for New and Existing Buildings

Track: Residential Buildings: Standards Guidelines and Codes NY PDH G

Room: 202AB

Sponsor: 7.6 Building Energy Performance, SSPC 100, SSPC 90.2, Residential Building Committee

Chair: Michael Deru, Ph.D., Member, NREL, Golden, CO

Standard 100-2015 with recent revisions (for existing buildings) and revisions to ASHRAE Standard 90.2-2007 (for new buildings) each include performance compliance requirements for residential buildings that are intended to provide designers, retrofit contractors, and building owners a great amount of flexibility when choosing design alternatives for compliance. However, the two standards use significantly different metrics and methodologies to determine building energy performance. This seminar provides information on the development and application of the performance requirements in these two standards. It also illustrates impacts of the different methodologies as well as examples of performance options and calculations for compliance.

1. Standard 90.2: The Path to Performance

***Theresa A. Weston, Ph.D., Member**, DuPont Building Innovations, Richmond, VA*

The revision of ASHRAE Standard 90.2-2007 represents a new approach in residential building energy performance. This new Standard 90.2 seeks to deliver residential building energy performance that is at least 50% more efficient than the energy efficiency defined by the 2006 IECC. Key to accomplishing this objective is delivery of an accurate, flexible performance-based tool to enable user creativity in meeting the performance objectives. This presentation describes the pathway to transform the standard.

2. Standard 100 Residential Applications and Options
***Neil P. Leslie, P.E., Member**, Gas Technology Institute, Des Plaines, IL*

When first hearing about Standard 100, most people think it is a commercial building energy efficiency standard. However, Standard 100 also establishes building energy performance requirements for five different residential building types using climate-dependent target tables derived from the 2009 Residential Energy Consumption Survey database. This presentation summarizes the derivation of these table entries, identify and characterize differences in methodology between Standard 90.2 revisions and Standard 100, and illustrate application of the target tables to real-world homes. Plans for further refinements to the Standard 100 performance calculations are also discussed.

Monday, June 26, 9:45 AM - 10:45 AM

Seminar 26

Evolution of Underfloor Design and its Application for Millennial Office Spaces

Track: HVAC&R Systems and Equipment NY PDH G
Room: 201A
Sponsor: 5.3 Room Air Distribution
Chair: Matt Bhumbla, Member, Price Industries, Suwanee, GA

This seminar discusses the evolution of underfloor system design over the last 20 years. Early design practices and challenges are discussed and how some of those challenges led to the invent of the latest systems and their application. Project related CFD results are also shared to review how the new way of designing is pushing the envelope with energy savings. The presentation also covers items that engineers need to be aware of while applying these systems. The importance of a collaborative approach is discussed to achieve the best possible integration with building structure and services.

1. Top Five Application Considerations for Successful UFAD Systems
***Jim Megerson, P.E., Member**, Design Mechanical Inc., Kansas City, KS*

Presentation content includes items that engineers need to be aware of so that obstacles to a successfully operating system can be avoided. UFAD systems are highly integrated with other services and more closely couple with the building structure than compared to traditional overhead mixing systems. This inherent characteristic of UFAD systems demands an integrated and collaborative approach when working on these types of projects. This seminar addresses issues that need attention and sometimes get overlooked when designers treat UFAD projects similar to overhead mixing system during design.

2. Underfloor System Design Evolution
***Dan Nall, AIA, Fellow ASHRAE**, Syska Hennessy, New York, NY*

The major challenge for design of underfloor air distribution systems is the reconciliation of comfort requirements between the interior and perimeter zones served by the system. For a variety of reasons, the past UFAD design strategy has proved less effective. Newer strategies have been proposed and applied to overcome this issue. Each of these strategies has implications for the building architecture, first cost and performance for specific weather conditions. Some strategies may even be used together. This presentation reviews each of these strategies, discusses their benefits and limitations and presents energy modeling results for the strategies for a large office project.

9:45 AM - 10:45 AM

Forum 2

Great Minds Don't Always Think Alike: What Is Needed for a "Good" Project Specification?

Track: Fundamentals and Applications
Room: 201B
Sponsor: 9.8 Large Building Air-Conditioning Systems
Chair: Heather Schopplein, P.E., Member, Haldeman Inc., San Diego, CA

Engineers, manufacturers, contractors and architects have different and valuable ideas on what constitutes a good specification. This forum addresses the needs from each discipline and helps communicate what makes the document valuable for the whole project team.

Monday, June 26, 11:00 AM - 12:00 PM

Technical Paper Session 2

Cooling Systems Design, Operation and Commissioning

Track: HVAC&R Systems and Equipment 

Room: 102AB

Chair: Sonya Pouncy, Member, Walker-Miller Energy Services, Detroit, MI

This session follows advances in cooling systems design from heat pump controls, chilled water plant design optimization and chilled water system commissioning.

1. Performance Monitoring of a Chilled Water Distribution System HVAC-Cx (LB-17-004)

***Natascha Milesi Ferretti, P.E., Member**, Mike Galler, Member and Steven Bushby, National Institute of Standards and Technology, Gaithersburg, MD*

Automated tools facilitate an ongoing commissioning process to improve occupant comfort, ensure the persistence of correct system operation and reduce energy consumption. These tools decrease the time and the skill level required to carry out necessary quality assurance measures, and as a result they enable more thorough testing of building heating, ventilating and air-conditioning (HVAC) systems. This paper describes the algorithm developed by the U.S. National Institute of Standards and Technology (NIST) to analyze chiller loops and presents the results of a passive monitoring investigation using field data obtained from BACnet controllers and field validation of the findings. The tool was successful in detecting faults in system operation in its first field implementation for performance monitoring.

2. Optimizing the Design of Chilled Water Plants for Commercial Building Energy Systems (LB-17-005)

***Nabil Nassif**, Nihal AlRaee and Fouad AlRifaie, North Carolina A&T University, Greensboro, NC*

Design of chilled water plants has a very large impact on building energy uses and energy operating costs. This paper proposes a design tool for optimal design of chilled water plants. The tool that integrates system models with a genetic algorithm optimization solver minimizes the life cycle cost by finding the design variables such as chilled water and condenser piping diameters, chilled and condenser water temperature differences and chilled water supply temperature. The proposed modeling methods depend on detailed cooling load analysis and head and energy calculations. The pump head calculations including piping, all fittings, valves, and devices are achieved by using the Darcy-Weisbach equation with given flow parameters. The energy calculations are done by using generic chiller, fan, and pump models. The hourly cooling loads need to be obtained from any energy simulation software. The method is tested on an existing three-story, eighty-eight thousand square foot building.

3. Low-Cost Control System Built Upon Consumer-Based Electronics for Supervisory Control of a Gas-Operated Heat Pump (LB-17-006)

***Ahmad Abu-Heiba**[1], Randall Wetherington[1], Isaac Mahderekal, Ph.D., Member[2] and Edward A. Vineyard, Fellow ASHRAE[3], (1)ORNL, Oak Ridge, TN, (2)Energy Studies and Services Group, Henderson, NV, (3)Texas A&M University, College Station, TX*

A preliminary evaluation of the performance of a consumer-based control system was conducted by the Oak Ridge National Laboratory (ORNL) and Southwest Gas as part of a cooperative research and development agreement (CRADA) authorized by the Department of Energy (DOE) (Mahderekal et al. (2013). The goal of the research was to evaluate the low-cost approach as a solution for implementing a supervisory control system for a residential gas-operated heat pump. This technical paper explains the research process. A robust data set was produced that allowed detailed assessment of the reliability and the operational performance of the newly developed control system. Experiences gained from the test provided important points of improvement for subsequent evolution of the heat pump technology.

Monday, June 26, 11:00 AM - 12:00 PM

Conference Paper Session 9

Residential High Efficiency

Track: Residential Buildings: Standards Guidelines and Codes 

Room: 203AB

Chair: Mini Malhotra, ORNL, Oak Ridge, TN

Thermal and economic performances are compared for a single-family house in the Phoenix, Arizona, USA for three types of residential-scale solar-powered heat pump systems: silica gel-water adsorption, single-effect LiBr-water absorption (both thermally driven) and solar photovoltaic (PV) powered vapor compression systems. The hybrid-GSHP project currently being developed in a research house located in Tyler, Texas will investigate the economic and technical feasibility of a system using a water-to-air heat exchanger as an ancillary heat exchanger. In addition, this session discusses the design and pilot testing of an integrated thermal energy and rainwater storage system (or ITHERST) for a small residential house.

1. Residential Hybrid-Ground Source Heat Pump – Phase I (LB-17-C029)

Nelson Fumo, Ph.D., Associate Member[1] *and Vicente Bortone, P.E.*[2]*, (1)University of Texas at Tyler, Tyler, TX, (2)Johnson Controls, Inc., Lenexa, KS*

A hybrid-GSHP project currently being developed will investigate the economic and technical feasibility of a system using a water-to-air heat exchanger as an ancillary heat exchanger. The project has been planned to be developed in three phases, in order to have one year data for each phase. This paper describes the research facility, the concept of the hybrid-GSHP to be developed in three phases, and the energy performance of the system in Phase I from the data collected.

2. Thermoeconomic Comparison of Residential Solar-Powered Heat Pump Systems (LB-17-C030)

Yeshpal Gupta, Ph.D. *and Patrick Phelan, Lincus, Inc., Tempe, AZ*

Residential zero net energy/low energy buildings require integrated renewable energy air conditioning systems especially in harsh climates such as Phoenix, AZ. In this paper, the thermal as well as economic performances for three types of residential-scale solar-powered heat pump systems is compared. The systems selected for this study were silica gel-water adsorption, single-effect LiBr-water absorption (both thermally driven), and solar photovoltaic (PV) powered vapor compression systems. An hourly building simulation model was developed for a single-family house in the Phoenix, Arizona, USA metropolitan area and performance of each of these systems was determined to satisfy the hourly cooling demand. The effect of solar collector area and storage capacity was also investigated.

3. Design and Pilot Testing of a Residential Chilled Water Thermal Storage System as Part of a Net Zero Energy and Water House (LB-17-C031)

Charles R Upshaw, Ph.D., Associate Member[1]*, Joshua Rhodes, Ph.D., Student Member*[1] *and Michael Webber, Ph.D., Member*[2]*, (1)University of Texas at Austin, Austin, TX, (2)University of Texas, Austin, TX*

Residential air conditioning represents nearly half of peak electrical demand on the Texas electricity grid during the summer, so finding ways to reduce peak demand have significant value for homeowners and grid operators. Thermal storage systems provide a means of shifting air conditioning load off-peak while maintaining cooling operation and thermal comfort levels, but are typically not deployed at the residential level due to cost constraints. This paper discusses the design and pilot testing of an integrated thermal energy and rainwater storage system (or ITHERST) for a small residential house. The paper summarizes the system design, describes the testing process and preliminary results, and concludes the report with a discussion on lessons learned and future work.

Monday, June 26, 11:00 AM - 12:00 PM

Seminar 27

Best Practices for Employing VRF Systems

Track: HVAC&R Systems and Equipment 
Room: 201A
Sponsor: 8.7 Variable Refrigerant Flow (VRF), 7.9 Building Commissioning
Chair: Lee Riback, Member, McKinstry, Dallas, TX
With the increased popularity of Variable Refrigerant Flow systems, it is easy to often overlook the complex nature and nuances of this unique equipment, which may lead to difficulties after acceptance of the systems and equipment. This presentation reviews the best practices of engineers whose involvement spans the full project scope from design through continuous system operation. Lessons learned from various stages of different projects will be discussed to prepare professionals for future work with these systems.

1. Best Practices and Quality Control Considerations for VRF Projects
***Bill Artis, Member**, Daikin, New York, NY*

While the design and installation of Variable Refrigerant Flow systems is not inherently difficult, there are nuances and details specific to these systems that if overlooked can lead to costly repairs, poor comfort control and improper system operation. This seminar discusses methods of mitigating potential issues before they occur and reviews best practices and considerations for equipment design and selection, contract documents, functional testing and installation quality control.

2. Lessons Learned through Commissioning
***Thomas Conn**, Horizon Engineering Associates, New York, NY*

This seminar reviews lessons learned from projects utilizing VRF systems from the perspective of the commissioning agent. The importance of properly commissioning these sophisticated systems, means of identifying and addressing common oversights found in various project stages and developing realistic plans for incorporating commissioning into a projects scope are discussed. Additionally, examples and lessons learned from projects the speaker has personally been involved with are reviewed to further improve the confidence among industry professionals responsible with commissioning these systems.

Monday, June 26, 11:00 AM - 12:00 PM

Seminar 28

Commercial Kitchen Ventilation: Insights into Energy and Water Efficiency!

Track: HVAC&R Systems and Equipment 
Room: 101B
Sponsor: 5.10 Kitchen Ventilation
Chair: Donald Fisher, P.Eng., Life Member, Fisher Consultants, Danville, CA
The energy intensity and utility costs associated with operating a commercial kitchen ventilation (CKV) system are well recognized within the HVAC design community. However, there is no piece of equipment that generates more controversy within the foodservice industry than the exhaust hood, in all its styles and makeup-air combinations. There are opportunities to dramatically reduce the amount of energy (and water) consumed by the kitchen ventilation and HVAC systems through optimization and application of emerging technologies.

1. The Potential for Exhaust Air Heat Recovery in Commercial Kitchen Ventilation
***Rich Swierczyna, Associate Member**, Fisher-Nickel, San Ramon, CA*

Thermodynamically, the application of heat recovery to kitchen exhaust air is very attractive to design engineers and foodservice facility managers. Exhaust air temperatures are significantly higher than space conditions (due to heat load from the cooking equipment) and the makeup air heating loads are recognized as a major energy end use within foodservice facilities. Because of the recent advances in commercial kitchen ventilation, the potential for heat recovery is more viable than ever before. This seminar presents the potential for energy recovery and the technologies that have recently taken advantage of the opportunities for heat recovery in commercial kitchens.

2. Field Test Results of an Air-to-Water Heat Exchanger in a Commercial Kitchen
***Michael Watz Jr., P.E., Member**, Accurex a Greenheck Company, Schofield, WI*

This seminar discusses the results of the application of commercial kitchen hood grease filters with integral air to water heat exchangers. Topics in this seminar include a system overview, recommended applications, energy advantages and grease extraction and hood system cleaning advantages.

3. Clean in Place Hoods, the Labor and Water Resource Trade Off
***Russell Robinson, Member**, Gaylord Industries, Tualatin, OR*

Utilizing various technologies, today's Clean In Place hoods reduce water consumption while providing labor savings and increased employee safety but at what cost? With rising minimum wages, increasing labor and utility costs, does a compelling business model exist to offset the initial capital and long term investment? This presentation focuses on validating the variable costs.

4. Modeling Demand Controlled Kitchen Ventilation Systems
***Vernon Smith, P.E., Life Member**, Smith Energy Engineers, LLC, Niwot, CO*

DCKV systems are becoming more popular as food service designers strive to achieve higher energy savings. However, DCKV systems can be a challenge for energy modelers due to unknowns with expected system operation and lack of features in modeling software. For example, varying the rate of exhaust and makeup air in relation to cooking process heat, smoke, or vapor load is not explicitly modeled in available software. This presentation highlights modeling methodology for three popular energy modeling software packages and provide tips for work-arounds.

Monday, June 26, 11:00 AM - 12:00 PM
Seminar 29

Urban-Scale Building Energy Modeling, Part 5

Track: Commissioning: Optimizing New and Existing Buildings and their Operation 

Room: 101A
Sponsor: 1.5 Computer Applications, 4.7 Energy Calculations
Chair: Bass Abushakra, Ph.D., Member, United States Military Academy, West Point, NY

Development of urban-scale building energy models is becoming increasingly tractable for many applications including city-wide energy supply/demand strategies, urban development planning, electrical grid stability, and urban resilience. This seminar has assembled several researchers with capabilities in the field of urban-scale energy models to discuss an overview of the field as well as the data, algorithms, workflow, and practical challenges addressed in their applications involving creation of useful models of individual buildings at the scale of a city, urban, or metropolitan area.

1. Automatic Building Energy Model Creation (AutoBEM)
***Joshua New, Ph.D., Member**, ONRL, Oak Ridge, TN*

National labs, universities, and industry are all developing significant capabilities for urban-scale building energy modeling…once a virtual city is constructed. To construct the models, most rely on local data sources that work at the scale of a city or county (such as a tax assessor's database) or flyover of the area of interest, but do not use data sources or algorithms that would scale to areas the size of a metropolis, state, or entire country. This presentation will show recent advances in scalable capabilities for automatically creating fully-articulated OpenStudio and EnergyPlus models of individual buildings for any area of interest.

2. Simplified Estimation of Energy Use Intensity Based on Building Façade Features
***Joon-Ho Choi, Ph.D., Associate Member**, University of Southern California, Los Angeles, CA*

A building's façade is a major element that accounts for 70% of building energy performance. Compared with the internal mechanical system and operation schedule, façade features information is relatively easy to obtain from the visual aspects of a building. Instead of using traditional and complicated simulation methods, a mathematical model can be established to estimate EUI baselines based on sufficient existing building practices data. This prediction modeling approach will provide a more realistic EUI estimation tool for calculating an energy use baseline and will enable real-time energy usage monitoring and management of each targeted building.

3. Retrofitting District-Scale Buildings to Cut Energy Use By 50%: A Case Study
***Yixing Chen, Ph.D., Associate Member** and Tianzhen Hong, Ph.D., Member, LBNL, Berkeley, CA*

Buildings in cities consume 30 to 70% of the cities' total primary energy. Retrofitting the existing building stock to improve energy efficiency and reduce energy use is necessary to reduce green-house-gas emissions and mitigate climate change. We present a case study on district-scale energy retrofit analysis using CityBES, a web-based toolkit developed by LBNL. Two retrofit scenarios are studied: evaluating energy savings and cost of typical energy conservation measures (ECMs) for a portfolio of hundreds of buildings in downtown San Francisco; and optimizing a package of ECMs that can achieve 50% energy savings for all buildings in the district.

Monday, June 26, 11:00 AM - 12:00 PM

Forum 3

Accreditation of HVAC&R Engineering Programs: Who Cares?

Track: Fundamentals and Applications
Room: 202AB
Sponsor: Student Activities Committee
Chair: Michael Brandemuehl, University of Colorado, Boulder, CO
Graduates from engineering and engineering technology programs, both two-year and four-year, comprise the next generation of ASHRAE members and HVAC&R practitioners. The purpose of this forum is to guide ASHRAE's input on accrediting these programs. What do we expect graduates to know? What do we expect them to be able to do? What are the differences in expectations between engineering and engineering technology graduates? What are the differences in expectations between two-year and four-year graduates? What is the role of program accreditation to ensure the desired outcomes?

11:00 AM - 12:00 PM

Forum 4

What the FPT Is Commissioning for Design Build Projects?

Track: Commissioning: Optimizing New and Existing Buildings and their Operation
Room: 103AB
Sponsor: 7.9 Building Commissioning, 7.2 HVAC&R Construction & Design Build Technologies
Chair: Will Mak, P.E., Member, Cyclone Energy Group, Chicago, IL
Methods for commissioning building projects with traditional design-bid-build delivery methods are well established. However, projects using the design build delivery method have become more popular and require a different approach for implementing the commissioning process on these types of projects. This forum opens the discussion between engineers, architects, contractors and owners on how design build projects should be commissioned. The goals after the forum are to develop a guideline on commissioning for design build projects and to conduct a seminar / workshop on the guideline at a future ASHRAE conference.

11:00 AM - 12:00 PM

Workshop 8

Opaque OPRs Produce Obscure Objectives

Track: Commissioning: Optimizing New and Existing Buildings and their Operation G
Room: 201B
Sponsor: 7.3 Operation and Maintenance Management, 1.7 Business, Management & General Legal Education
Chair: E. Mitchell Swann, P.E., Member, MDCSystems, Paoli, PA
To have a successful project it is essential to bridge the communication gap among owner, designer and commissioning provider. This workshop focuses on the elements of an effective Owner's Project Requirements (OPR). Attendees, working in small groups, will craft a section of an OPR in response to a demanding yet visionary owner. The groups will then come together, compare their OPRs, and engage in an interactive discussion designed to meld the best ideas into a single high-quality document.

1. Owner's Perspective of an OPR
***Wayne Webster, Member**, Princess Towers, Inc., Kingston, ON, Canada*
This workshop includes the building owner's perspective on the definition of OPR, why the OPR is important and summarizes their responsibilities in developing the OPR. Key points to be discussed are: The communication gap between Owner, Designer and Cx provider; Who takes (or should take) the lead? The audience will break into small groups and provide an opaque OPR. The Owner and Cx provider will have a pre-written script and play the role of an Owner of a commercial office building. The groups will interview the Owner and rewrite the section of the OPR to reflect the actual needs of the Owner. The Cx provider will then present an example of an effective OPR, stimulate open discussion and questions and compare the example OPR against a selected group's document.

2. Cx Provider's Perspective of an OPR
***Mina Agarabi, P.E., CPMP, Member**, Agarabi Engineering PLLC, New York, NY*
An experienced commissioning (Cx) provider shares their perspective on the definition of OPR, why the OPR is important and summarizes the essential components. Key points to be discussed are: A clear definition of the Owner's expectations reduces the risk of unclear intent, unfulfilled expectations and unnecessary disputes; An OPR that reflects the actual needs of the Owner, the users or occupants, and facility staff is needed for Cx to be successful.

Monday, June 26, 2:15 PM - 3:45 PM

Seminar 30

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

Track: Fundamentals and Applications 

Room: 103AB

Sponsor: 1.7 Business, Management & General Legal Education

Chair: James Arnold, P.E., Member, Haslett Heating and Cooling, COLUMBUS, OH

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

1. Your Ethics Tool Box: Building a Framework for Ethical Decision-Making

***Kathleen Lacey, J.D.**, Ukleja Center for Ethical Leadership at California State University, Long Beach, Long Beach, CA*

Making an informed, responsible ethical decision is not as easy as it may seem. This workshop provides tools to enhance your ability to frame engineering and business dilemmas in accordance with ethical principles in order to make the critical and informed decisions in the workplace. You'll learn how to apply an ethical framework to future decision-making – using a model that you can put into practice right away. You'll have a better understanding of ethical challenges, how to analyze them while considering implications for any stakeholders, and how to choose the right course of action based on ethical principles.

2. Case Studies in Engineering Ethics Part 1

***Kristin Schaefer, P.E., Member**, Schaefer Engineering, Katy, TX*

This is an interactive session where participants hear about an ethical violation, then break up into small groups and discuss the ethics case adjudicated by the NSPE. Test your ethics IQ against an actual case decided by a board of your peers and obtain ethics continuing education credits in the process. Three cases are presented along with the final outcome.

3. Case Studies in Engineering Ethics Part 2

***Mike Bilderbeck, P.E., Fellow ASHRAE**, Pickering, Inc., Memphis, TN*

This is an interactive session where participants hear about an ethical violation, then break up into small groups and discuss the ethics case adjudicated by the NSPE. Test your ethics IQ against an actual case decided by a board of your peers and obtain ethics continuing education credits in the process. Three cases are presented along with the final outcome.

Tuesday, June 27

Tuesday, June 27, 8:00 AM - 9:30 AM

Conference Paper Session 10

Using Occupancy and Actual Short-Term/Long-Term Energy Data to Develop More Accurate Modeling Tools

Track: Fundamentals and Applications NY PDH G

Room: 101A

Chair: Alamelu Brooks, Member, ICF International, Columbia, MD

Improved accuracy in modeling can be dependent on getting the data points right. Some of the key elements in modeling any particular building can be affected by issues such as: determining what equipment will actually be part of the plug load; sudden changes in building operation due to transient-state vs. steady-state trending; and accurate predictions of occupancy. This session introduces research dealing with each of these areas and how they can be utilized to obtain more accurate modeling.

1. Case Study on the Validity of Energy Simulation and Energy Measuring in the Office ZEB in California, U.S. (LB-17-C032)

Hidemitsu Koyanagi, Ph.D.[1] *and Alan Meier, Ph.D.*[2]*, (1)TAISEI Corporation, Yokohama, Japan, (2)Lawrence Berkeley National Lab, Berkeley, CA*

In California there are 70 non-residential and apartment house ZNE projects in 2015, whereas there are 21 ZNE projects in Japan in 2015. Hence, it's supposed to be a good example for ZNE dissemination in Japan to clarify the problems toward ZNE dissemination in California. This paper addresses the energy performance of a ZNE office building in Northern California from the perspectives of simulation, measurement, verification, and code compliance. Simulations of the building's energy use were undertaken during the design stage to demonstrate code compliance and measurements of actual energy use were taken for six months after occupancy.

2. Improving the Accuracy of Building Energy Simulation Using Real-Time Occupancy Schedule and Metered Electricity Consumption Data (LB-17-C033)

Chandra Sekhar, Ph.D., Fellow ASHRAE*, Junjing Yang, Ph.D., Associate Member, Prashant Anand, Student Member and David Cheong, Ph.D., Member, National University of Singapore, Singapore, Singapore*

Occupancy plays a significant role in the amount of energy used in buildings and their presence is stochastic in nature. There is extensive evidence to suggest that buildings usually do not perform as well as predicted by energy simulation. Use of unrealistic occupancy data as an input of building energy modelling (BEM) is a major reason behind it. As a result, large discrepancies are being observed between predicted and actual energy performance, typically averaging around 30% and reaching as high as 100% in some cases. This paper covers research that aims to develop an occupancy prediction model using Artificial Neural Network (ANN) for improving the accuracy of building energy simulation.

3. Half-Hourly Regional Electricity Price Modelling for Commercial End Users in the UK (LB-17-C034)

Salvador Acha, Ph.D.*, Aitor Soler, Gonzalo Bustos, P.Eng. and Nilah Shah, Ph.D., Imperial College London, London, United Kingdom*

The increase in the electricity bills and the new opportunities to participate in the electricity market has encouraged companies with activities not related to the energy industry to engage and actively participate in the electricity market to reduce costs and become more competitive. With the overarching goal of making cost-effective investments and decarbonizing their operation, the first step to improve these companies' bottom line is to comprehend their electricity costs. This paper focuses on detailing a methodology to model electricity commercial bills and generate real-time price curves; thus allowing customers to calculate their half-hourly true cost of electricity and to assess the challenges of reaching net zero energy buildings for different UK regions and connection voltage levels, across every month up to the financial year 2019-20.

4. A Systematic Feature Selection Procedure for Data-driven Building Energy Forecasting Model Development (LB-17-C035)

Liang Zhang, Student Member *and Jin Wen, Ph.D., Member, Drexel University, Philadelphia, PA*

Data-driven (black-box) models are widely used in real-time short-term building energy forecasting models due to their advantages over white-box and gray-box models in terms of computational efficiency, engineering practicability, and low engineering cost. However, in most cases, data-driven models temporarily lose their accuracy when dealing with sudden change of building operation like heating or cooling start-up, shut-down, and set-point changes. In other words, most black-box models are not able to precisely describe or predict situations with both steady-state data and transient-state data. In this paper, an experiment is designed to quantify the influence of transient-state data on linearity of data space and accuracy of black-box models.

Tuesday, June 27, 8:00 AM - 9:30 AM

Seminar 31

Feedback: The Essential Ingredient for High Performance Green Homes

Track: Residential Buildings: Standards Guidelines and Codes 

Room: 201A

Sponsor: 2.8 Building Environmental Impacts and Sustainability, 4.4 Building Materials and Building Envelope Performance, Residential building committee

Chair: Audrey Dupuis, Member, Pageau Morel, Montreal, QC, Canada

In high performance homes, comfort drives design, design drives energy use and careful design choices drive actual energy performance and occupant satisfaction. However, thermal comfort standards don't include energy efficiency compliance requirements, leading to mismatches between comfort and energy efficient designs. This seminar explains why and how to use the vocabulary of thermal comfort as the first solution in solving residential energy problems. It also describes how feedback tools can be useful in calibrating modeling inputs to verify and ensure that actual performance outcome are achieved by design. The cost of poor design choices is also discussed.

1. Feedback Tools for Designing and Implementing Comfortable Efficient Homes

***Dan Perunko**, Balance Point Home Performance, Nevada City, CA*

Designing comfortable and efficient homes requires that designers and installers set performance targets and revise their designs to meet those performance targets. If modeling is used to predict enclosure performance or potential comfort, other tools must be used to verify that the modeled assumptions are achieved. Those same tools can be useful in calibrating inputs for future designs to assure performance outcome is achieved. Ongoing performance feedback is now realistic for residential applications. This presentation focuses on lessons learned from those feedback tools and how to use them to enhance performance outcomes in future designs.

2. Which Should Come First in Housing, Energy Efficiency or Thermal Comfort?

***Robert Bean, Member**, Indoor Climate Consultants Inc., Calgary, AB, Canada*

This usually comes as a shock to energy geeks, but compliance requirements found in efficiency programs are not found in thermal comfort standards. Furthermore, energy related terms like U-values, conduction, air changes, kilowatts, therms and thermal bridging are abstract constructs for the general public. But the vernacular language of cold, hot, dry, humid, muggy and drafty needs no communication effort. This presentation explains why and how to use the vocabulary of thermal comfort as the first solution in solving residential energy problems.

3. The Energy and Environmental Benefits of Design Choices that Provide Excellent Comfort

***Jim Larsen**, Cardinal Glass Industries, Eden Prairie, MN*

Design choices for home envelopes and appliances have a large impact on comfort, energy consumption and environmental impact. A positive impact requires a well-considered design objective as well as its successful implementation. This presentation provides examples of affordable design choices that combine superior comfort with significant life cycle cost benefits, reduced primary energy consumption and reduced greenhouse gas emissions. It focuses primarily on the role of the envelope in providing affordable and environmentally beneficial comfort for the occupants, but also illustrates the synergy with smaller equipment selection and better comfort control when the envelope is optimized for efficiency.

Tuesday, June 27, 8:00 AM - 9:30 AM

Seminar 32

Ejector Systems in Transport Refrigeration

Track: Refrigeration

Room: 201B

Sponsor: 10.6 Transport Refrigeration

Chair: Robert Chopko, Member, Carrier Transicold, Syracuse, NY

Two-phase ejectors are an attractive replacement for conventional expansion devices due to the opportunity to recover expansion work that can be used to improve cycle efficiencies, particularly with natural refrigerants such as CO2. Optimal use requires careful design of the components and system with regard to the full operating envelope, with attention to both the performance characteristics as well as manufacturability. Systems using natural refrigerants require additional technologies or considerations. This session covers important aspects of design and manufacturing for refrigeration ejector systems, including a study on the use of CO2 for transport refrigeration applications.

1. Modeling, Design and Efficiency of Two-Phase Ejectors to Increase Cop of Transport Refrigeration Systems

***Stefan Elbel, Ph.D.**, University of Illinois at Urbana-Champaign, Urbana, IL*

Two-phase ejectors are an attractive replacement for conventional expansion devices due to the opportunity to recover expansion work that can be used to improve cycle efficiencies. This presentation covers important aspects of ejector modeling and will provide basic design guidelines. The different ejector components are explained and typical efficiency and performance metrics are introduced. The presentation also elaborates on different control options that enable the use of ejectors for efficient part load operation and operation at off-design.

2. Manufacturing Considerations for Ejector Systems
***David Lee, Member**, Mueller Refrigeration, Hartsville, TN*

Two-phase ejectors are an attractive replacement for conventional expansion devices due to the opportunity to recover expansion work that can be used to improve cycle efficiencies. Optimal use requires careful design with regard to the full operating envelope, including attention to manufacturability considerations. This seminar covers important aspects of manufacturing for ejector systems and their resulting impact on system design.

3. Application of Natural Refrigerant CO2 in Container Transport Refrigeration Systems and Potential Benefits and Impacts with CO2 Ejector Cycle
***Ciara Poolman**, United Technologies Corporation Climate Controls and Security, Jupiter, FL*

CO2 Natural Refrigerant has been introduced in container transport refrigeration systems. Working in a wide range of ambient temperatures, meeting various set temperature requirements and temperature management are key to success. The background of the changes to natural refrigerant CO2 and technologies used in CO2 container refrigeration systems to meet product requirements is presented, and performance comparisons with alternate refrigerant systems is discussed. Additionally, follow on technological advances such as those in the areas of CO2 ejectors are reviewed, including their potential benefits and impacts to the current system design.

Tuesday, June 27, 8:00 AM - 9:30 AM

Seminar 33

Flooding, Superstorm Sandy: Lessons Learned and Strategies Implemented

Track: Building Life Safety Systems NY PDH G
Room: 202AB
Sponsor: 2.5 Global Climate Change, 2.8 Building Environmental Impacts and Sustainability, 4.2 Climatic Information
Chair: Scott Sherwood, Member, Eco Care Corporation, Bronx, NY

An in-depth discussion regarding the issues and decisions that NYC building engineers, architects, and facility operators faced during and in the aftermath of Superstorm Sandy. Understanding the response by a major NYC healthcare facility and the initiatives taken to increase sustainability, resilience, and an environmental friendly facility. Understanding what kind of climatic data and trending is available from ASHRAE to the ASHRAE community and the type of information sought by engineers, architects, and facility operators). Discuss the terms, people, and issues involved in understanding climatic events and the effects on life safety & HVAC&R systems.

1. Superstorm Sandy: Lessons Learned
***Chris Colasanti, P.E., Member**, Jaros Baum & Bolles, New York, NY*

Superstorm Sandy provided an extreme climate event to learn many lessons on how buildings were designed and how they operated during and in the aftermath of Hurricane Sandy. This includes the infrastructure that is so vital to the operation of Buildings and their HVAC&R systems.

2. Superstorm Sandy: New Codes & Design Considerations
***Jessica Sheridan**, Mancini Duffy, New York, NY*

Discuss of NYC sustainability and resiliency strategies during and in the aftermath of Hurricane Sandy. New codes and design requirements to strengthen the HVAC&R and life safety systems of buildings during extreme climate events.

3. Life Safety Issues That Occurred at NYU Medical during and in the Aftermath of Superstorm Sandy
***Richard Cohen**, NYU Langone Medical Center, New York, NY*

Discuss the issues and situations that occurred at NYU Medical during Superstorm Sandy in regard to life safety and HVAC&R. Infrastructure design changes to reduce/eliminate the effects of future flooding/climatic events. Discuss how NYU achieved significant energy savings and energy reduction, while reducing its carbon footprint.

4. Climatic Information: History & Current Data & Trending
***Scott Sherwood, Member**, Eco Care Corporation, Bronx, NY*

This presentation discusses the history of climate change and the founding scientists whom developed instrumentation to measure climate change predictors and parameters, i.e., ozone depletion, global warming, CO2 levels, etc.

Tuesday, June 27, 8:00 AM - 9:30 AM

Seminar 34

Not-in-Kind HVAC Technologies (Part 1)

Track: Fundamentals and Applications NY PDH G

Room: 101B

Sponsor: Publication and Education Council

Chair: Pradeep Bansal, Ph.D., Fellow ASHRAE, ASHRAE STBE Editorial Board, Atlanta, GA

There is a strong need to develop not-in-kind technologies to replace conventional vapor compression refrigeration technology that can improve the energy efficiency and environmental friendliness of residential and commercial building equipment. Such technologies will be critical to provide energy savings or other environmental benefits for space conditioning, water heating and refrigeration. This seminar presents material from three recently published papers from ASHRAE's archival journal, Science and Technology for the Built Environment, on the subject.

1. Compressor Driven Metal Hydride Heat Pumps Using Adsorptive Slurry and Isothermal Compression

***Nelson James, Student Member**, James Braun, Ph.D., Fellow ASHRAE, Eckhard Groll, Dr.Ing., Fellow ASHRAE and Travis Horton, Ph.D., Member, Purdue University, West Lafayette, IN*

Environmentally-friendly heat pumps operate using reversible adsorption and desorption of hydrogen from metallic compounds, which were incorporated in a cycle having a work input (compressor) or thermal energy input (generator). Some challenges faced by compressor-driven metal hydride heat pumps are poor heat transfer in the metal hydride beds and high compressor discharge temperatures. To overcome these challenges, a metal-hydride slurry in conjunction with various isothermal compression techniques were used. Liquid-flooded, electrochemical and liquid piston compressors were modeled and integrated into a system model in order to assess their impact on the performance of the slurry-based metal hydride heat pump system.

2. Design of a Hydraulically Driven Compressive Elastocaloric Cooling System

***Yunho Hwang, Ph.D., Member**[1], Suxin Qian, Ph.D., Member[2], Yunlong Geng, Ph.D., Member[1], Yi Wang, Ph.D., Member[1], Jan Muehlbauer, Member[1], Jiazhen Ling, Ph.D., Member[1], Reinhard Radermacher, Ph.D., Fellow ASHRAE[1] and Ichiro Takeuchi, Ph.D.[1], (1)University of Maryland, College Park, MD, (2)Xi'an Jiaotong University, Xi'an, China*

This paper presents the design of elastocaloric cooling system driven by hydraulic actuators. Ni-Ti tubes under axial compressive loading mode are used to provide cooling and heating. Those Ni-Ti tubes are enclosed in four identical beds, which are driven by two one-way hydraulic cylinders. Operated under the single-stage reverse Brayton cycle, the system achieves heat transfer and heat recovery by using a heat transfer fluid network controlled by solenoid valves. System coefficient of performance of 11.0 and temperature lift of 24.6 K are estimated based on a dynamic model developed in our previous study.

3. Design and Performance of a Novel Magnetocaloric Heat Pump

***Michael Benedict, Ph.D., Member**[1], S.a. Sherif, Ph.D., Member[2], Michael Schroeder, Member[1] and David Beers, Member[1], (1)General Electric, Louisville, KY, (2)University of Florida, Gainesville, FL*

This presentation covers an investigation into the design and preliminary results of a room temperature magnetic refrigeration prototype and describes the physical prototype along with its operational and measurement envelopes. General design goals included: A wide range of cycle parameter control, independent fluid and magnetic circuits, extensive measurement capability and compact design. The maximum no-load span recorded was 21 K and the maximum power recorded was 26 W at a span of 1 K. Three cyclical parameters were varied to help determine the optimal cycle for such a machine.

Tuesday, June 27, 8:00 AM - 9:30 AM

Seminar 35

Advancing Standard 90.1 to Net Zero Energy Buildings

Track: Net Zero Energy Buildings: The International Race to 2030 NY PDH G

Room: 103AB

Sponsor: 7.6 Building Energy Performance, SSPC 90.1

Chair: Bing Liu, P.E., Member, PNNL, Portland, OR

ANSI/ASHRAE/IES Standard 90.1 has been a benchmark and national model code for over 35 years and is indispensable for engineers and designers in the design of commercial buildings. Now with the publication of Standard 90.1-2016 it will significantly change the way buildings are built towards the new zero energy buildings. This seminar presents the major changes and shows the energy saving impacts from 90.1-2016. This session also highlights a new compliance path that enables a single, simple performance-based option for both minimum code requirements and above-code programs, leading to net zero energy buildings.

1. Advancing Standard 90.1 Envelope Requirements

***Leonard Sciarra, AIA, Member**, Gentler, Chicago, IL*

This presentation highlights the overall goals of Standard 90.1, specific goals set for 90.1-2016 edition. This presentation also covers the major changes of format, new climate zones, major changes in the envelope requirements and their applications in building design and construction.

2. Advancing Standard 90.1 Lighting and Power Requirements

***Eric Richman, Member**, PNNL, Richland, WA*

This presentation covers the major changes in lighting and power requirements of 90.1-2016. The presentation also provides insights into appropriate application of the major new requirements so engineers and designers will receive a better understanding of the design changes needed to meet the new requirements.

3. Advancing Standard 90.1 Mechanical Requirements

***Richard Lord, Fellow ASHRAE**, United Technologies Carrier Corp, Murfreesboro, TN*

This presentation covers the major changes in mechanical requirements of 90.1-2016, including equipment efficiency updates and system requirement changes.

4. Advancing Standard 90.1 Performance-Based Path to Achieving Net Zero Energy Buildings

***Michael Rosenberg, Fellow ASHRAE**, PNNL, Richland, WA*

Standard 90.1 has traditionally included two paths for compliance: the prescriptive path and performance path (also known as the Energy Cost Budget Method). The 2016 standard establishes a third path: a stable whole building performance method. This presentation provides an overview of this new fixed-baseline compliance path and explains its appropriate application and how this new path could encourage the innovative designs to eventually achieve net zero energy buildings. This presentation also summarizes the energy savings from Standard 90.1-2016.

Tuesday, June 27, 8:00 AM - 9:30 AM

Seminar 36

Using Nature, Keeping Control

Track: Controls NY PDH G

Room: 102AB

Sponsor: 1.4 Control Theory and Application, 4.5 Fenestration, MTG OBB

Chair: James Coogan, P.E., Associate Member, Siemens Industry, Inc., Buffalo Grove, IL

Moving toward sustainability, designers increasingly select systems that work with nature, rather than against it. Free cooling is routine today. Daylighting and daylight harvesting are moving into the mainstream. Natural ventilation for commercial spaces is uncommon, but it will grow. This session explores control systems for spaces with natural ventilation and natural light. When nontraditional systems are selected, they bring new control issues. Topics include control strategies, control devices, occupant interfaces and system architecture. Practical aspects of integrating new functions in a unified Building Automation System are discussed. Implications include the occupant's experience, along with costs of construction and operation.

1. Engaging Users in Natural Ventilation in Mixed Mode Buildings

***Glenn Friedman, P.E., Fellow ASHRAE**, Taylor Engineering, Alameda, CA*

Using natural ventilation is a primary strategy for low energy design. A common strategy is to combine natural ventilation with active heating and cooling systems resulting in mixed mode buildings which inherently have an additional level of control sophistication. This presentation tracks three case studies of the success and lessons learned from mixed mode buildings. The presentation reviews how occupants engage with and interpret mixed mode building operations including successes and learned experiences.

2. Reducing Uncertainty When Controlling Natural Ventilation
***Stephen Ray, Ph.D., P.E., Associate Member**, North Park University/SOM, Chicago, IL*

As more buildings strive towards net-zero energy consumption and seek to connect occupants with nature, natural ventilation is attracting more interest. This presentation explains the benefits of natural ventilation and the corresponding control design objectives. Challenges and lessons learned will be shared from a mid-rise office building, university dorms, several condos and academic buildings including sensing, occupant behavior, BAS interfacing, controlling night purge, tenant complexities and optimizing hybrid systems. The completed projects illustrate another practical key to success: designing control strategies that survive value engineering.

3. Integrated Room Control for HVAC, Lighting and Daylighting
***Klaus Jank**, Siemens BT, Buffalo Grove, IL*

Using natural light in buildings can save energy but only if systems are controlled to accomplish the savings. Natural light can enhance the occupant's impression of a space but only if they can adjust it to suit their preferences. A state-of-the art control system for lighting and dynamic shading handles diverse considerations: inputs from occupants, dynamic daylight conditions, thermal and electrical energy flows, scheduled and unscheduled use of the space. This presentation explains control features and the advantages of implementing them in an integrated BAS. Data from recent projects illustrates the benefits.

Tuesday, June 27, 8:00 AM - 9:30 AM

Seminar 37

Water Treatment: The Overlooked Aspect of Commissioning Hydronic Systems

Track: Commissioning: Optimizing New and Existing Buildings and their Operation 

Room: 203AB

Sponsor: 3.6 Water Treatment, 8.6 Cooling Towers and Evaporative Condensers
Chair: Helen Cerra, Member, ChemTreat, Inc., Glen Allen, VA

Proper water treatment is a key aspect of hydronic system performance and asset life. Commissioning water treatment systems when water is first introduced into a hydronic system provides corrosion protection, extended asset life and prevents other damage due to premature failure. These presentations describe commissioning requirements for various hydronic systems from a water treatment perspective.

1. Commissioning of Your Steam System's Water Treatment Program
***Todd Cornwell, Member**, AFCO, Raleigh, NC*

New steam boilers and hot water boilers need special attention paid to the application of water treatment during the startup/commissioning process. Proper cleaning and passivation during the startup will prevent equipment failures or poor energy performance. Steps to prevent mineral scale and corrosion should be implemented as soon as water is introduced into these systems. This seminar provides guidance (with checklist) on the steps required to prepare the boiler systems for service.

2. Proper Commissioning of Your Cooling System's Water Treatment Program
***Dan Weimar, Member**, Chem-Aqua, Inc., Irving, TX*

New cooling towers, evaporative condensers, fluid coolers, piping and chiller equipment must be commissioned properly to control waterside problems that will reduce equipment life, efficiency, reliability and safety. Proper startup and commissioning is especially important to reduce the potential for white rust corrosion in new cooling water systems containing galvanized metallurgy. This seminar explains the proper commissioning of new or retrofitted cooling water system construction projects and how to avoid costly damages and potential litigation due to uncontrolled water chemistry.

3. Potable Water and Other Indoor Aerosolizing Systems
***Tim Keane, Member**, Legionella Risk Management Inc., Chalfont, PA*

When building water system Legionnaires' disease outbreaks occur no matter how long after construction or renovation, commonly those involved in design and construction are named parties should subsequent litigation occur. And when building water system Legionnaires' disease outbreaks occur within one year of construction or renovation almost always those involved in design and construction are primary named parties should subsequent litigation occur. This seminar covers simple and easy steps to validate that critical commissioning steps of aerosolizing water systems have been completed and are properly documented to insure compliance with ASHRAE 188 and industry best practices.

Tuesday, June 27, 9:45 AM - 10:45 AM

Technical Paper Session 3

Research in HVAC Fundamentals

Track: Fundamentals and Applications 

Room: 102AB

Chair: Daniel Pettway, Life Member, Hobbs & Associates, Norfolk, VA

This session covers a breadth of research for HVAC applications including fault conditions as handled by building automation systems, air leakage in buildings and revised weather data.

1. Updating the ASHRAE Climate Design Data for 2017 (RP-1699) (LB-17-007)

***Michael Roth, Ph.D.**, Klimaat, Guelph, ON, Canada*

Under ASHRAE Research Project 1699 (RP-1699) we provide an update of the data used both in the "Climatic Design Information" chapter of the 2017 ASHRAE Handbook of Fundamentals and in ANSI/ASHRAE Standard 169, "Weather Data for Building Design Standards". A total of 8118 stations were successfully processed worldwide representing a 26% increase compared to 2013. Reported elements now include monthly average wind speed, wet bulb temperature return periods and monthly-average daily all-sky global horizontal solar radiation. A number of pre-screening and post-processing tools were developed in order to ensure a reliable and useful product.

2. Effects of Air Leakage on Buildings' Overall Thermal Resistances Based on U.S. Climate Zones (LB-17-008)

***Simon Pallin, Ph.D., Associate Member**[1], Michaela Stockdale[2], Phillip Boudreaux, Ph.D.[1] and Elizabeth Buechler[3], (1)ORNL, Oak Ridge, TN, (2)Tennessee Technological University, Cookeville, TN, (3)Tufts University, Medford, MA*

Air-leakage through building envelopes causes significant energy losses. Air-tightness codes do not account for air-leakage due to wind-driven pressure gradients and thermal resistance codes do not consider any air-leakage effects. Air-leakage needs to be included codes to understand the effects on thermal performance. We calculated effective thermal resistances in 103 locations considering air-leakage effects, to see effects on thermal performance. Simulations showed decreased thermal resistances and increased energy losses in every climate. Varying levels of thermal performance demonstrate relative importance of air-tightness in different climates. Results imply current codes do not accurately represent thermal performance and where air-tightness matters most.

3. Automatic Fault Detection and Diagnostics and Hierarchical Fault Suppression in ASHRAE (RP-1455) (LB-17-009)

***Reece Kiriu, P.E., Member** and Steven Taylor, P.E., Fellow ASHRAE, Taylor Engineering LLC, Alameda, CA*

This paper describes two of the unique elements of the advanced control sequences developed for ASHRAE Research Project 1455 (RP-1455): automatic fault detection and diagnostics (AFDD) and hierarchical alarm suppression. AFDD is a method used to identify fault conditions and provide possible diagnoses. Hierarchical fault suppression is a method based on hierarchical structure used to reduce the incidence of nuisance alarms. It is written by the members of the research team and is part of the deliverables for this research project. AFDD and hierarchical alarm suppression will further enhance the ability of DDC systems to make intelligent alarm distribution and management decisions.

Tuesday, June 27, 9:45 AM - 10:45 AM

Conference Paper Session 11

CFD for Smoke Management

Track: Building Life Safety Systems 

Room: 101B

Sponsor: 5.6 Control of Fire and Smoke

Chair: Paul Turnbull, Member, Siemens Building Technologies, Inc., Buffalo Grove, IL

Computational Fluid Dynamics (CFD) modeling is frequently used during the design phase of smoke control projects for building spaces that are too complicated to be done with hand calculations or zone models. Due to the extensive computing resources that would be required, CFD is generally not used to model entire buildings. This session covers three topics related to CFD models for smoke control system design. One paper explains how CFD models can be simplified in order to model large spaces, up to and including entire buildings. Another paper explains the use of CFD models for evaluating tenability within the space under consideration. The third paper walks through the design process of using a CFD model for smoke and heat spread, in combination with egress calculations, to determine a design which provides safe egress for occupants within a smoke-protected assembly seating area.

1. Tenability Analysis and Atrium Smoke Control (LB-17-C036)

***John Klote, P.E., Fellow Life Member**, John Klote Fire and Smoke Consulting, Leesburg, VA*

Tenability analysis along with computational fluid dynamics (CFD) are recognized methods of atrium smoke control analysis by NFPA 92, *Standard for Smoke Control Systems*. Tenability analysis evaluates the following threats to life: toxic gas exposure, heat exposure, thermal radiation exposure, and reduced visibility. In dense smoke, people see poorly and often become disoriented which prolongs exposure time of the other threats. Also falls from balconies can result from reduced visibility. This paper discusses these threats as they apply to atria smoke control and how tenability analysis can be incorporated in CFD simulations of atrium smoke control systems.

2. CFD Modeling of Full-Size Highrise Fire Smoke Spread and Control (LB-17-C037)

***Liangzhu Wang, Ph.D., P.E., Member**, Dahai Qi, Student Member, Shamim Mashayekh and Malek Soubra, Concordia University, Montreal, QC, Canada*

High-rise building fires often lead to disastrous and enormous losses if the fire smoke is not well controlled. This study uses the CFD model, Fire Dynamics Simulator (FDS) developed by the US National Institute of Standards and Technology (NIST), to model the fire smoke spreads and control strategies in a full-size high-rise building. The building is a 302-feet (92 meter) high-rise with two 20-story towers, three-story ground level parking spaces, two stairwells and one elevator shaft. The modeled fire smoke control system is a hybrid venting system with mechanical fan installed at the top of the stairwells. Neutral plane level, smoke temperature and smoke flow inside the building were studied based on the simulation.

3. Computational Fluid Dynamics (CFD) Analysis of Smoke Protected Seating (LB-17-C038)

***Jennifer L. Wiley, P.E.** and Michael J. Ferreira, P.E., JENSEN HUGHES Inc., Baltimore, MD*

The International Building Code and the Life Safety Code (NFPA 101) recognize that smoke-protected assembly seating, which is not subjected to smoke accumulation within or under a structure, subjects occupants to a lesser hazard from the accumulation of smoke and fumes during a fire event. The codes therefore have less-stringent requirements for design and layout of the means of egress for smoke-protected assembly seating, including reduced aisle widths per seat served and greater maximum travel distances. These less-stringent requirements provide increased use of space and flexibility in the design of assembly seating. This paper provides an overview of the use of CFD models in the design of smoke control systems for smoke-protected seating. Examples of smoke-protected seating in various settings, including arena seating and large theaters, are also discussed.

Tuesday, June 27, 9:45 AM - 10:45 AM

Conference Paper Session 12

Highly Efficient HVAC System Components

Track: HVAC&R Systems and Equipment 

Room: 101A

Chair: Stephanie Kunkel, JMT, Sparks, MD

Several methods are presented on highly energy efficient components for HVAC systems. These technologies incorporate ground source heat pumps, gas heat pumps and test parameters to determine efficiency. Implementing heat pump technology is a hot trend. These projects show new elements that can increase overall system efficiency beyond what is currently employed.

1. Application of TPRTs (Thermal Performance/Response Tests) in a Saturated Porous Formation (LB-17-C039)

Wonjun Choi, Ph.D., Member *and Ryozo Ooka, Ph.D., Member, University of Tokyo, Tokyo, Japan*

Thermal response tests (TRTs) are often conducted to inversely estimate the design parameters of borehole heat exchangers (BHEs); those are the effective thermal conductivity of ground and borehole thermal resistance. TRT can only provide the design parameters of a borehole heat exchanger, but it cannot provide the transient heat exchange rate of installed BHE which represents the actual performance of installed BHE. This paper proposes an estimation method of TPT that can provide both the thermal performance of BHEs and design parameters that usually obtained from TRT. Results showed that the performances of BHEs strongly depend on the inlet temperature. Additionally, transient heat exchange rates obtained from TPRTs provide valuable information on BHE performances that can be used for the design of BHEs.

2. Investigation of a Design and Operation Method for a Heat Recovery Ground Source Heat Pump System (LB-17-C040)

Takao Katsura, Ph.D.[1]*, Katsunori Nagano, Ph.D.*[1] *and Yasushi Nakamura, Ph.D.*[2]*, (1)Hokkaido University, Sapporo, Japan, (2)Nippon Steel & Sumikin Engineering, Tokyo, Japan*

The heat recovery ground source heat pump (HR-GSHP) system that has several types of GSHPs for different uses connected in the ground heat exchangers yields two types of heat recovery effects. The first one is the direct heat recovery effect obtained by operating the several types of GSHPs. The second one is the indirect heat recovery effect that utilizes the underground thermal storage effects and is brought by alternately operating the several types of GSHPs in the short term. By utilizing these two effects, the HR-GSHP can yield both energy saving effect and drastic reduction of the ground heat exchanger's total length. This paper investigates the design and operation method of the HR-GSHP system.

3. Retrofit of Commercial Buildings Using a Gas Heat Pump System (LB-17-C041)

Leticia De Oliveira Neves, Ph.D., Member[1]*, Bruno Scalet, P.E.*[2]*, Fernando Alves*[2]*, Tássia Marques*[2] *and Edson Kurotsu*[2]*, (1)University of Campinas, Campinas, Brazil, (2)CTE, São Paulo, Brazil*

In office buildings, the use of a Gas Heat Pump air-conditioning systems may be able to meet thermal demands with the same efficacy as a conventional electrical system while reducing energy demand of the whole building. This paper investigates technically, ambient and economically the substitution of a conventional air-conditioning system of an existing office building by a Gas Heat Pump air-conditioning system. The analysis was conducted through a data assembling of the potential of retrofit of operating office buildings in the city of Sao Paulo; through interviews with mechanical engineers and consultants; and through a case study developed in an existent office building, using computer simulation to evaluate energy performance of different air-conditioning scenarios.

Tuesday, June 27, 9:45 AM - 10:45 AM

Seminar 38

Not-in-Kind HVAC Technologies (Part 2)

Track: Fundamentals and Applications NY PDH G

Room: 103AB

Sponsor: Publication and Education Council

Chair: Pradeep Bansal, Ph.D., Fellow ASHRAE, ASHRAE STBE Editorial Board, Atlanta, GA

There is a strong need to develop not-in-kind technologies to replace conventional vapor compression refrigeration technology that can improve energy efficiency and environmental friendliness of residential and commercial building equipment. Such technologies will be critical to provide energy savings or other environmental benefits for space conditioning, water heating and refrigeration. This session presents material from two recently published papers from ASHRAE's archival journal, Science and Technology for the Built Environment, on the subject.

1. Elastocaloric Cooling: From Fundamental Thermodynamics to Solid State Air Conditioning

***Marvin Schmidt, Member**, Susanne-Marie Kirsch, Member, Stefan Seelecke, Dr.Ing., Member and Andreas Schütze, Dr.Ing., Member, Saarland University, Saarbrücken, Germany*

This presentation discusses fundamental thermodynamic concepts as well as experimental investigations of elastocaloric cooling processes and presents a concept of a potential elastocaloric air conditioning device. Various cooling cycles suitable for elastocaloric cooling are introduced and the process efficiencies are determined based on a graphical approach. The graphical method is validated experimentally with a specially designed scientific test setup, which enables the measurement of mechanical and thermal process quantities under various thermal boundary conditions. The results are compared with the values predicted by the graphical approach. Furthermore, a concept of a continuously operating elastocaloric air cooling device is introduced.

2. Magnetic Heat Pumps: An Overview of Design Principles and Challenges

***Paulo Trevizoli, Ph.D., Member**, Theodor Christiaanse, Student Member, Premakumara Govindappa, Student Member, Iman Niknia, Student Member, Reed Teyber, Student Member, Jader Barbosa and Andrew Rowe, Ph.D., Member, University of Victoria, Victoria, BC, Canada*

Active magnetic regeneration is one of the most promising alternative technologies for the development of heat pumps and cooling systems for applications near room temperature. Recently, numerous papers have reported on the development of magnetocaloric materials, magnetic circuits, prototypes and cycle optimization. This presentation examines some of the main challenges encountered in the current state of the art technology. It provides an overview of how design choices impact cooling power and work requirements from a system engineering perspective.

9:45 AM - 10:45 AM

Seminar 39

Chiller Retrofit Case Study: From Evaluating Options to Optimizing Operation

Track: Commissioning: Optimizing New and Existing Buildings and their Operation NY PDH G

Room: 203AB

Sponsor: 7.6 Building Energy Performance

Chair: Annie Smith, Associate Member, Ross & Baruzzini, St. Louis, MO

This seminar dives deep into evaluating the options for a replacement chiller retrofit. Options were evaluated using a feasibility study, a data-driven energy model, lifecycle cost analysis and detailed trend analysis. After installation, controls optimization strategies were used to bring further value to the project to ensure proper efficient operation and energy savings. Lessons learned concerning construction oversight, performance-based commissioning and the approach to the controls optimization are presented.

1. Case Study: Critically Evaluating Replacement Chiller Options beyond Lifecycle Cost Analysis

***Edmund Wong, P.E., Associate Member**, Arup, Los Angeles, CA*

This presentation covers the approach, methodology and lessons learned of a performance-based chiller retrofit project. The performance evaluation included a life-cycle cost assessment of replacement options that involved a data-driven energy model and an accurate understanding of the baseline energy consumption in the existing condition through a building survey and detailed trend analysis. Lessons learned from construction oversight and performance-based commissioning is also presented.

2. Post Chiller Retrofit: Ongoing Optimization Strategies for Continuous Improvement

***Jeff Landreth, P.E., BEAP and CPMP, Associate Member**, tk1sc, Los Angeles, CA*

The presentation covers the value of integrating ongoing controls optimization strategies as part of major retro-commissioning and retrofit projects. The presentation also follows up on the previous performance-based chiller retrofit project and how ongoing optimization strategies were implemented to further increase the value and energy savings of the retrofit project. This presentation includes the overall approach, methodology, results and lessons learned throughout this process, as well as provides an overall framework and approach to the controls optimization process for existing buildings.

Tuesday, June 27, 9:45 AM - 10:45 AM

Seminar 40

Delivering a Successful Critical Facility/Data Center Project by Fostering a Healthy Relationship between the Owner, Engineer and Commissioning Agent

Track: Commissioning: Optimizing New and Existing Buildings and their Operation NY PDH G

Room: 201A

Sponsor: 9.9 Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment, 7.9 Building Commissioning

Chair: Nick Gangemi, Life Member, Northern Air Systems, Rochester, NY

The presentations in this session discuss the independence as well as interdependencies between the Engineer of Record (EOR) and the Commissioning Agent (CxA) in partnering with the Owner to deliver a successful critical facility project. The presentations address both Greenfield and new construction projects as well as upgrades and renovations to existing facilities. The session presents both the EOR and CxA perspectives and discusses what information each requires from the other as well as what decisions and information both require from the Owner. The presentations will address all project phases of the project.

1. The EOR's Perspective on Delivering a Successful Critical Facility/Data Center Project By Fostering a Healthy Relationship with the Owner and Commissioning Agent

***Vali Sorell, P.E., Member**, Sorell Engineering, Charlotte, NC*

This presentation includes a discussion regarding the role of the EOR in bridging the process that begins with the owner, continues through design, construction and commissioning and ends with the delivery of a fully tested and operational facility. The discussion includes issues linking the EOR and the CxA, including how and when the CxA should be introduced into the design process, how the design and specifications should provide "hooks" to clearly designate to the contractors and subcontractors their own responsibilities to the CxA Team and the CxA Process and what can go wrong when those issues are omitted.

2. The CxA's Perspective on Delivering a Successful Critical Facility/Data Center Project by Fostering a Healthy Relationship with the Owner and Engineer

***Terry Rodgers, Member**, Primary Integration Solutions Inc, Charlotte, NC*

The presentation includes a discussion regarding the role of the commissioning agent and what information is required from both the Owner and EOR to facilitate a successful commissioning program. It also discusses how and why the CxA must remain independent of the EOR while also teaming with the EOR and the entire project team to facilitate a win-win outcome. The presentation explains how expanding the traditional scope of commissioning can be made to easily include leading the effort to deliver the needed FM/O&M programs, procedures and training.

9:45 AM - 10:45 AM

Forum 5

Future Smart Buildings: What Data Do We Need to Collect and How?

Track: Controls

Room: 202AB

Sponsor: 7.5 Smart Building Systems

Chair: Kristen Cetin, Ph.D., P.E., Associate Member, Iowa State University, Ames, IA

The future of smart buildings and smart homes face challenges of integrating data from multiple sources and systems for smart decisions to achieve better comfort and energy/cost savings. Future buildings also should be able to communicate and transact with the smart grid. What data should be collected and how should they be integrated using a common communication platform? This forum discusses the state of the industry (smart meters, smart thermostats, connected appliances, IoT, BEMOSS, VOLTTRON...) and determines a path that the ASHRAE community can contribute towards moving forward.

9:45 AM - 10:45 AM

Forum 6

Best Practices For Low Energy Residential Buildings Across the Globe

Track: Residential Buildings: Standards Guidelines and Codes

Room: 201B

Sponsor: 2.8 Building Environmental Impacts and Sustainability, AASA, MTG.HCDG Hot Climate Design Guide

Chair: Ashish Rakheja, P.E., Member, AEON Integrated Building Design Consultants LLP, Noida, India

ASHRAE Associate Society Alliance (AASA) has members from over 50 global HVAC&R societies. AASA also has a large representation from Developing Countries where due to rapid urbanization, the demand for homes is growing exponentially (India alone will add 50 billion sq. ft. of constructed space in next two decades). The Forum discusses the case studies and best practices followed in design of cost effective homes. This Forum has international flavor with representatives from more than 20 countries and provides an opportunity to the attendees to interact & learn from each other.

Tuesday, June 27, 11:00 AM - 12:30 PM

Conference Paper Session 13

Design, Commissioning and Fault Detection Considerations for New and Existing Buildings

Track: Fundamentals and Applications 

Room: 101B

Chair: Xiufeng Pang, LBNL, Berkeley, CA

As building performance targets continue to improve, commissioning, fault detection and alternative delivery methods have become more commonplace. This session focuses on these factors from a few different perspectives. A review of commissioning issues related to design-build projects is presented as is an analysis of integrating modeling into existing building projects. The strengths and weaknesses of automated fault detection along with potential for improvements to this technology is considered. Finally, an analysis of various building performance standards and impacts on retrofits to existing building stock is given.

1. Design-Build Commissioning: How to Enforce When the Contractor Is the Designer (LB-17-C042)

Michael Flemming, P.E., Associate Member[1] *and Bishara Mogannam*[2]*, (1)Interface Engineering, San Francisco, CA, (2)CTC Design, Santa Clara, CA*

One of the most important relationships in the commissioning process is between the commissioning agent, the owner and the engineer of record (EOR). A relationship that requires ongoing coordination with common goals defined from the beginning of the project. But what happens during Design-Build projects when the relationship between the EOR and contractors may result in different goals and can cause a conflict of interest? This paper provides a resource for all commissioning agents participating in a design-build project and offers guidelines to use to navigate from design to construction and to occupancy as effectively as possible.

2. IED and LCA in Design Processes for Refurbishment (LB-17-C043)

Mathilde Landgren, Ph.D. *and Lotte M.B. Jensen, Ph.D., Technical University of Denmark, Kgs. Lyngby, Denmark*

This paper addresses issues from DGNB refurbishment and explores how a design process can be streamlined to address refurbishment and still preserve the gains from IED. Registration of the existing conditions is a prerequisite for a good design process where the software tools developed to ensure low energy consumption and good indoor climate can be used, and 3D scanning is therefore making a new and important contribution. The paper includes case studies of both ideal and applied design processes from an architectural office that specializes in sustainable projects.

3. Using Pattern Matching and Principal Component Analysis Method for Whole Building Fault Detection (LB-17-C044)

Yimin Chen, Student Member*, Adam Reigner and Jin Wen, Ph.D., Member, Drexel University, Philadelphia, PA*

Automated fault detection and diagnosis (AFDD) methods, followed by corrections, have the potential to greatly improve a building and its system's performances. Existing AFDD studies mostly focus on component and sub-system AFDD. Much less effort has been spent on detecting and diagnosing faults that have a whole building impact. In this paper, an integrated data driven method: Pattern Matching Principle Component Analysis method, is developed and applied for whole building fault detection. Real building data that contains artificially injected faults and naturally occurred faults are used to evaluate the method's accuracy and false alarm rate. The method presents great potential to be a cost-effective and accurate whole building fault detection strategy.

4. Codes and Standards Options for Existing Buildings in BC (LB-17-C045)

James Montgomery, Ph.D., Member[1]*, Andrew Pape-Salmon, P.Eng., Member*[2] *and Toby Lau, P.E., Member*[3]*, (1)RDH Building Science Inc., Vancouver, BC, Canada, (2)BC Government, Building and Safety Standards Branch, Victoria, BC, Canada, (3)BC Hydro, Vancouver, BC, Canada*

This paper explores opportunities for, and impacts of potential regulated energy performance and emission reduction standards for existing buildings in British Columbia. It includes evaluation of four standards – Standard 100-2015, Standard 90.1-2010 (BC Building Code), National Energy Code of Canada for Buildings-2015 and retro-commissioning procedures. Standards are applied to the existing building stock, except low-rise residential buildings, at the time of existing building alterations or repairs that trigger the BC Building Code or Vancouver Building Bylaw.

Tuesday, June 27, 11:00 AM - 12:30 PM

Conference Paper Session 14

Low GWP Refrigerants: Is There a Tradeoff in Performance and Safety?

Track: Refrigeration

Room: 101A

Chair: Vikrant Aute, Ph.D., Member, University of Maryland, College Park, MD

The movement to low global warming potential (GWP) refrigerants is inevitable given the global consequences of climate change. However, will the use of low GWP refrigerants have an adverse effect on system efficiency and safety as well as building sustainability? This session examines heat transfer and pressure drop efficiencies as well as flammability concerns of some low GWP refrigerants.

1. Application of Safety Factors When Setting Charges Limits for A2L Flammable Refrigerants (LB-17-C046)

William Hansen, P.E., Member *and Stephen Kujak, Member, Trane, Ingersoll Rand, La Crosse, WI*

Today's societal demands to control climate change are forcing HVAC&R equipment designers to consider new lower GWP refrigerants, some of which are slightly flammable under certain conditions. This paper supports setting a safety factor as low as 2 to 1 (50% of LFL) when setting the charges limits for A2L flammable refrigerants depending on the HVACR products application refrigerant charge and application height. Computational fluid dynamic (CFD) analysis was performed to support the justification of setting the safety factor. Numerous fast leak scenarios, 4 min leaks, were evaluated at various heights, room areas and refrigerant charge sizes. Maximum refrigerant charges for a large number of ASHRAE 34 classified refrigerants will be summarized for comparison purposes at various LFL endpoints.

2. Impact of Next Generation Low GWP Refrigerants on Building Sustainability (LB-17-C047)

Stephen Kujak, Member[1]*, Tina Li Juan Hong, Ph.D.*[1]*, Xiuwei Yin*[2] *and Ted Xueyuan Yang*[3]*, (1)Trane, Ingersoll Rand, La Crosse, WI, (2)Ingersoll Rand, Tyler, TX, (3)Ingersoll Rand, Shanghai, China*

Demands to control climate change are forcing HVAC equipment designers to consider new lower GWP refrigerants to replace traditional higher global warming potential (GWP) refrigerants, for example R134a and R410A. Understanding the environmental tradeoffs of using these new low GWP alternatives in HVAC products is becoming well understood but what uncertainty remains in understanding how they impact the on building sustainability. This paper provides an understanding of the impacts on total building sustainability through using building model simulations employing products using new lower GWP alternatives R513A and R452B to replace R134a and R410A.

3. Predicted Heat Transfer and Pressure Drop Performance of Low Global Warming Potential R410A Alternatives (LB-17-C048)

Jordan Morrow, Student Member*, Melanie Derby, Ph.D., Member and Xi Chen, Kansas State University, Manhattan, KS*

There is significant interest in the adoption of low global warming potential (GWP) refrigerants. However, the heat transfer performance of these refrigerants is not well documented. This paper investigates alternate R410A refrigerants such as R32 and R452B. Fewer than 10 papers have been located which report heat transfer and pressure drop data for R32 and no papers have been located which report heat transfer and pressure drop data for R452B. The predicted performance of low GWP R410A alternatives will be compared to baseline values for R410A and impact on evaporator and condenser design will be discussed.

4. Performance of an Air-Cooled Chiller with R410A Alternatives R452B and R32 (LB-17-C049)

Kenneth Schultz, Ph.D., Member[1] *and Gurudath Nayak, Ph.D.*[2]*, (1)Ingersoll Rand, La Crosse, WI, (2)Ingersoll Rand, Bangalore, India*

In recent years, the HVAC&R industry has been evaluating low global warming potential (GWP) alternatives to refrigerants such as R410A because of rising concerns over climate change due to their high direct GWPs. The industry is working to identify candidates that optimize performance, safety (flammability), and environmental impacts (GWP). R452B and R32 are two of the candidates under consideration. This paper presents measurements of system performance made on an R410A-based 100 RT air-cooled packaged water chiller with R410A (as baseline), R452B, and R32 refrigerants. The chiller comprised scroll compressors, a brazed plate evaporator, and microchannel condenser.

Tuesday, June 27, 11:00 AM - 12:30 PM

Seminar 41

Designs and Policies for Affordable Zero Net Energy Homes and Sustainable Communities

Track: Net Zero Energy Buildings: The International Race to 2030 NY PDH G

Room: 201B

Sponsor: 2.8 Building Environmental Impacts and Sustainability, Residential Building Committee

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

New homes and communities represent an opportunity for economical design options for zero net energy performance. This seminar explores the concept of design for affordability and for homes and communities and provides an overview of codes, standards and policies that influence affordability and market penetration. Home design incorporates integrated layout and system packages to maximize benefit-cost ratio. Community design incorporates building design and layout of the streets and community spaces for optimal solar orientation and building performance. Success stories are described along with a discussion of public policies intended to encourage zero net energy buildings.

1. Affordable Zero Net Energy Home Design Strategies

***George Koertzen**, Habitat for Humanity of San Joaquin County, Inc., Stockton, CA*

Design for affordability incorporates thoughtful floor plans, thermal envelope, water distribution systems and HVAC systems to minimize costs and maximize benefit to cost ratio. This presentation provides detailed information on key design elements of affordable high performance homes. Case studies of successful application of these principles in affordable ZNE homes are summarized, along with insights on creative approaches and challenges when trying to apply cost-effective solutions to real-world affordable new construction.

2. Challenges and Opportunities in the Design of Sustainable Communities

***Judi Schweitzer**, Schweitzer and Associates, Lake Forest, CA*

Turning zero energy ready homes into zero net energy homes, neighborhoods and communities can be facilitated or complicated by builder development strategies, community involvement, local ordinances and siting constraints. This presentation highlights cooperative and integrated design and siting strategies between developers and community agencies that can increase the penetration of affordable ZNE homes using guiding principles related to costs and benefits of sustainable development. Win/win/win combinations of individual home designs and community plot plans and infrastructure with high benefit-cost ratios for sustainable communities are highlighted, along with case studies of several new sustainable communities.

3. Zero Net Energy Policies: Opportunities and Challenges in California

***Sue Kristjansson**, Southern California Gas Co., Los Angeles, CA*

California has set goals that all new homes will be zero net energy (ZNE) by 2020 and new businesses will be ZNE by 2030. These goals drive California energy policy and building industry responses and influence regional and national initiatives. This presentation summarizes California's ZNE codes, standards and policies and their impact on the private sector and consumers and highlights challenges when trying to provide cost-effective ZNE homes. Examples of high performance buildings, design challenges, advanced available technology and ongoing efforts to provide breakthrough design options in response to the California ZNE goals are highlighted.

11:00 AM - 12:30 PM

Seminar 42

Integrate Your Body: Human Physiological Response as a Potential Driving Factor in IEQ Controls

Track: Fundamentals and Applications NY PDH G

Room: 102AB

Sponsor: 2.1 Physiology and Human Environment, 1.5 Computer Applications

Chair: Mark Jackson, Ph.D., McCree Consulting, Grand Praire, TX

Modern technologies help provide a high potential for sensing and integrating human factors, such as an individual's real-time environmental preference and his/her physiological responses within a building system control context. Based on its technical merit, Human-Building Integration (HBI) becomes an emerging research domain for establishing novel thermal comfort models and adopting advanced computational algorithms. Accordingly, a better understanding of the principle of HBI is essential for optimizing a HVAC system's performance by using the human body as a component of an integrated building system. This seminar addresses pertinent HBI technical features and their potential for real-world application.

1. Thermal Comfort in Health Care: The Need for Physiological Feedback

***Rodrigo Mora, Ph.D., Associate Member**, British Columbia Institute of Technology, Burnaby, BC, Canada*

Thermal comfort quality impacts health care workers' outcomes and patients' well-being. However, unlike any other type of indoor environments there is often a great variability in activity levels and health condition among occupants in a health care space that makes it difficult to achieve acceptable conditions for certain groups of occupants without sacrificing other groups. This seminar examines types of wearable sensors, their requirements and mappings in assessing individual thermal comfort and how such individual comfort data can be used to drive the operation of personalized and room indoor climate systems in real-time.

2. Using Occupants' Control Behavior with Internet-Connected Personal Comfort System to Predict Individuals' Thermal Preference

***Joyce Kim, Student Member**, University of California, Berkeley, Berkeley, CA*

Occupants interact with thermal control devices available in buildings to address their comfort needs/desire; hence, the resulting behavior is an expression of one's thermal preference. The new generation Personal Comfort System(PCS) with wireless connectivity offers a continuous stream of individuals' heating and cooling usage data along with occupancy and environmental measurements in real time. This presentation summarizes findings from a field study of 40PCS heated and cooled chairs in an office building and reports the predictive performance of personal comfort models developed from continuous PCS data. Proposed models show an improvement of individuals' comfort predictions by 20-30% compared to PMV.

3. Bio-Sensing Environmental Control: Data-Driven Thermal Sensation Prediction as a Function of Local Body Skin Temperature

***Joon-Ho Choi, Ph.D., Associate Member**, University of Southern California, Los Angeles, CA*

Since the human body is governed by the thermoregulation principle to balance the heat flux between the ambient thermal condition and the body itself, skin temperature has a significant role in maintaining the physiological principle. Therefore, the author investigated the potential use of skin temperature and its technical parameters to establish a thermal sensation. This seminar discusses optimally combined skin temperature information collected from selected body areas, and examines how much reliable and applicable the designated skin temperatures are for estimating individual thermal sensations.

Tuesday, June 27, 11:00 AM - 12:30 PM

Seminar 43

Making Displacement and Natural Ventilation Work in High Heat Gain Applications

Track: Fundamentals and Applications NY PDH G

Room: 103AB

Sponsor: 4.10 Indoor Environmental Modeling

Chair: Wangda Zuo, Ph.D., Member, University of Miami, Coral Gables, FL

Designing an effective displacement ventilation or a natural ventilation in high heat gain applications are very challenging. This seminar discusses how to use computational fluid dynamic models to support the design of displacement and natural ventilation systems for buildings with high heat gain. Experts from both academia and industry share their successful stories as well as lessons learned in real world applications.

1. CFD Ventilation Study of an Aluminum Foundry

***Duncan Phyfe, Associate Member** and Marty Kozlak, ARL, Alden, MA*

In this case study, CFD was used to evaluate roof modifications of an aluminum foundry. The study shows the strategies used to provide an efficient and effective computational model that will provide the key data needed to evaluate the large space and make the right modifications to maintain air temperature limits. The modeler's understanding of fluid dynamics will be a critical element towards applying appropriate strategies in the development of the CFD model to provide a robust design evaluation tool. Care must be taken in specification of the inputs to a CFD model, and interpretation of results and associated implications.

2. Natural Ventilation Modeling of High Heat Gain Auditoria

***Malcolm Cook, Member**, Faisal Durrani, Ph.D. and James J. McGuirk, Ph.D., Loughborough University, Loughborough, United Kingdom*

Natural ventilation is characterized by low driving pressures leading to the need for large ventilation openings. In addition, natural ventilation systems must remove sufficient heat to ensure thermally comfortable conditions. This is particularly challenging in high heat gain spaces such as raked-seat auditoria where heat gains can be as high as 90W/m2. This presentation talks through the design and CFD modeling of a 500-seat theatre in the UK which harnesses buoyancy-driven displacement ventilation to deliver a comfortable and 'atmospheric' performance space. Two modeling techniques are used: traditional Reynolds Averaged Navier Stokes and Large Eddy Simulation.

3. Push It to the Limit: Using Displacement Ventilation for High Heat Gain Applications

***Mike Koupriyanov, P.E., Associate Member**, Price Industries Limited, Winnipeg, MB, Canada*

Displacement ventilation (DV) has a become a commonly used system in a broad range of applications due to its energy saving potential and superior indoor air quality. There are various rules of thumb that dictate the maximum cooling load that the system can handle. Although using the system for higher cooling loads is not recommended, there are cases where it is still advantageous to do so. This seminar explores the performance of a DV system outside of its normal operating range using CFD. Design guidance will be provided and application-specific trade-offs will be explored.

4. Natural Ventilation Potential Maps of North America for Removing High Heat Gains

***Leon Wang, Ph.D., P.E., Member**, Jun Cheng, Student Member and Ali Katal, Concordia University, Montréal, QC, Canada*

Natural ventilation is an efficient way of removing high internal heat gains for buildings and its energy saving potentials however depend on many parameters. This presentation reports a series of GIS maps for natural ventilation potentials of North America, similar to the well-known solar potential maps. These maps provide key graphical information of energy saving potentials of both single sided and cross natural ventilation in terms of total hours suitable for natural ventilation and associated energy savings for over 50 cities in the US and 10 cites in Canada.

Tuesday, June 27, 11:00 AM - 12:30 PM

Seminar 44

Optimization of Existing Buildings Is Much More than Retro Commissioning

Track: Commissioning: Optimizing New and Existing Buildings and their Operation NY PDH G

Room: 202AB

Sponsor: 7.9 Building Commissioning, 7.6 Building Energy Performance

Chair: Wade H. Conlan, P.E., Member, Hanson Professional Services, Orlando, FL

Optimization of the building systems through the Retro Commissioning Process starts well before the CxP interrogates the BAS system and doesn't end when the report is issued. This seminar starts by working through the creation of an energy roadmap for your building or campus to plan your savings. A case study on a 30,000 ton chiller plant serving a campus expands on that optimization process and shows real implementation and results of the RetroCx process. Finally, the seminar discusses the process on finding, and more importantly, implementing energy savings measures with buy-in from the Owner and Operators.

1. Campus Energy Management: You Need a Plan

***Nathaniel Boyd, P.E., CPMP, Member**, Hanson Professional Services, Orlando, FL*

Taking on an energy management program of a large campus or portfolio of properties can be a daunting task. Rather than "putting out fires" by approaching projects independently, this study analyzes a strategic, deliberate approach to achieving institutional energy cost reduction through a repeatable, stepwise roadmap plan that involves financial planning, needs assessments, prioritization and implementation of audits, retro-commissioning and measures. Setting up your plan allows you to actually predict the impact of the optimization process.

2. How to RetroCommission a 30,000 ton Chiller Plant

***Lee Riback, Member**, McKinstry, Dallas, TX*

Seriously, how do you approach RetroCx of a 30,000 ton chiller plant? We will take a deep dive into a University of Arizona campus chilled water plant that includes 22 chillers and 300 ice storage tanks. The discussion covers the process and findings of the work which includes the load management and chiller staging to improve plant efficiency. It also covers the field modifications completed at the plant to implement the RetroCx measures. Finally it discusses the OnGoing Monitoring based Cx that has further optimized the plant.

3. Taking the "Retro" out of Retro-Commissioning

***Benjamin Skelton, P.E., CPMP and BEMP, Member**, Cyclone Energy Group, Chicago, IL*

How you look for optimization opportunities and present the value takes special care to ensure buy-in from owners and operators. This study focuses on how to hunt down measures, present them with confidence, ensure successful implementation and verify results. Specific examples from large commercial buildings are presented.

11:00 AM - 12:30 PM

Seminar 45

The Use of Pollution Control Units and Technologies to Control Grease, Smoke and Odor from Commercial Kitchens

Track: HVAC&R Systems and Equipment NY PDH G

Room: 201A

Sponsor: 5.10 Kitchen Ventilation, 5.4 Industrial Process Air Cleaning (Air Pollution Control)

Chair: Derek Schrock, Member, Halton Company, Scottsville, KY

This seminar provides an overview of the updated requirements for certifying pollution control units and guidance for how these requirements may impact future codes and standards. Electrostatic precipitators will be presented with a focus on the balance between cost and performance and their effectiveness at smoke and odor control. Additional presentations will show how electrostatic precipitators can be used effectively to clean emissions in challenging applications, such as highly-populated urban areas with mixed-use areas. The use of ozone to clean odor from commercial cooking emissions will also be discussed.

1. Safety Requirements of Pollution Control Units: The Timely Release of New UL8782

***Mark Skierkiewicz, P.E., Member**, UL, LLC, Northbrook, IL*

Pollution Control Units have been used in the marketplace for several years. However, with increasing pollution control regulation, and the boom of mixed-use (residential / commercial) complexes, there has been a significant increase in the use of these products. This led to a stronger demand for standardized safety requirements. This session focuses on the timely development and publication of UL8782, Outline of Investigation for Pollution Control Units for Commercial Cooking Operations released January 30, 2017. This session also reveals plans for inclusion of these requirements into the appropriate ASHRAE Standards and installation Codes.

2. Pollution Control Technologies: Rising to the Challenge
***Chris Lowell, Member**, Air Scrubbers, Sanford, NC*

Pollution control units (PCUs) utilized for commercial kitchen exhaust is increasingly more common due to tighter environmental regulation, as well as a greater propensity to install foodservice establishments in population-dense and mixed-use areas. This presentation explains the process of selecting and applying the scrubbing device for commercial kitchen exhaust air.

3. Electrostatic Pollution Controls: Performance and Maintenance Considerations
***Russ Robison, Member**, Gaylord Industries, Tualatin, OR*

Balancing performance, capital costs and cost of operations; Electrostatic Precipitator based pollution control units have been providing reliable cost effective smoke and odor abatement for nearly four decades. This presentation focuses on the performance deliverables of these units and where the application of this technology makes great sense.

4. The Use of Ozone Generators in CKV Exhaust
***Mark Tilles, Associate Member**, AirMaid/Interzon, Stockholm, Sweden*

The use of ozone generators in CKV exhaust treatment is a new technology recently introduced to North America, yet one that has been in widespread use throughout Europe for about a decade. Although ozone is already applied in many areas of science and industry, this presentation focuses upon its use in CKV. Topics covered include methods of production, benefits realized, limitations and code-compliance requirements for grease applications.

Tuesday, June 27, 11:00 AM - 12:30 PM

Seminar 46

Updates in the Air Distribution Systems Design Procedure: Expansion of Air Diffusion Performance Index (ADPI) Method

Track: Fundamentals and Applications NY PDH G
Room: 203AB
Sponsor: 5.3 Room Air Distribution
Chair: David John, P.E., Member, Stan Weaver & Co., Tampa, FL

This session covers the history of ADPI and the recently completed RP 1546 Expansion and Updating of the Air Diffusion Performance Index Method conduct at the University of Texas. The session consists of four presentations: Background of using ADPI in diffuser selection process, Updated ADPI tables for cooling operation, Additional development of the effective draft temperature for heating, Findings from the research to ensure ventilation effectiveness in overhead heating applications and Effect of return air placement in heating applications. A preview of the updates which will be included in the ASHRAE Application Handbook Room Air Distribution Chapter is included.

1. Updates in Air Diffusion Performance Index (ADPI) Diffuser for Cooling Operation
***Atila Novoselac, Ph.D., Member**, University of Texas at Austin, Austin, TX*

The current diffuser selection guide described in ASHRAE handbook-fundamentals provides the correlation between diffuser characteristics, such as throw length and types, and its performance to distribute supply air and thereby to optimize space air diffusion. However, the current guideline considers only five diffuser types and the range of sensible cooling loads that is up to four times larger than those we find in today's energy efferent buildings. This presentation shows the updated ADPI-based guideline that includes 15 diffuser types at lower cooling loads, typical for today's buildings. The new guideline shows the minimum airflow set-point for a VAV systems.

2. A New Air Diffusion Performance Index (ADPI) for Heating Operation
***Atila Novoselac, Ph.D., Member**, University of Texas at Austin, Austin, TX*

The performance of air distribution using overhead mixing diffusers is evaluated using ADPI. The ADPI methods is often used for selection of diffusers used for both cooling and heating. However, the current diffuser selection guide confines the application to only cooling mode. This presentation introduces a new ADPI for heating mode and specify the criteria of diffuser selection from the perspectives fluid dynamics and occupant thermal comfort based on ASHRAE Standard-55. The presentation covers the development of the effective draft temperature for heating applications and the resulting ADPIs curves with various diffuser types.

3. Connection between Air Diffusion Performance Index (ADPI) and Ventilation Effectiveness (EV): Effects of Diffuser Adjustment and Return Air Placement
***Hideyuki Amai**, University of Texas at Austin, Austin, TX*

This presentation provides fundamental design data that supports optimal diffuser selection in mixing ventilation with heating and cooling operation. It shows how diffuser adjustment, room-supply air temperature differences and return air grille location impact ADPI and E_V. The study points out connections between ADPI and E_V and shows similarities and differences for heating and cooling operation. It presents the operation characteristic that provide good E_V while maintaining acceptable ADPI. Also, it shows how diffuser adjustment may improve E_V. Furthermore, the presentation shows the cases where return air location may have a significant effect on ADPI and E_V.

4. The History of Air Diffusion Performance Index (ADPI) and the Results of Research Project RP 1546 Expansion and Updating of the Adpi Method
***David John, P.E., Member**, Stan Weaver & Co., Tampa, FL*

The effective draft temperature was experimentally developed in 1949 in Sweden. This is the current equation used to calculate ADPI for cooling. In 1972 Nevins and Miller presented an ASHRAE paper which determined that boundaries for ADPI to obtain a 70% occupant comfort level. After 33 years, this method needed many updates as buildings and air distribution systems changed. The ASHRAE RP 1546 updated and confirmed the ADPI predicted comfort levels using Standard 55. It produced the effective draft temperature equation for heating. Furthermore, it developed ADPI values that can predict thermal mixing in heating.

Tuesday, June 27, 1:30 PM - 3:00 PM

Debate 3

Fellow's Debate: There is No Purpose in a Code of Ethics

Track: Fundamentals and Applications
Room: 203AB
Sponsor: 1.7 Business, Management & General Legal Education, College of Fellows (Primary sponsor)
Chair: Larry Spielvogel, P.E., Fellow Life Member, Consulting Engineer, Bala Cynwyd, PA, Paducah, KY

Members sign up to the ASHRAE Code of Ethics, but do they apply them? A very small number of complaints are made.

Participants
Samir Traboulsi, Dr.Ing., P.Eng., Fellow Life Member, Thermotrade/Ranec, Beirut, Lebanon, E. Mitchell Swann, P.E., Member, MDCSystems, Paoli, PA, Kathleen Lacey, J.D., Ukleja Center for Ethical Leadership at California State University, Long Beach, Long Beach, CA, Don Beaty, P.E., Fellow Life ASHRAE, DLB Associates, Eatontown, NJ, William Murphy, Ph.D., P.E., Fellow Member, University of Kentucky, and Peter Simmonds, Ph.D., Fellow ASHRAE, Building and Systems Analytics LLC, Marina Del Rey, CA

Tuesday, June 27, 3:15 PM - 4:45 PM

Seminar 47

Zero Energy Healthcare Buildings: Current Status and Future Efforts

Track: Net Zero Energy Buildings: The International Race to 2030 NY PDH G
Room: 203AB
Sponsor: 9.6 Healthcare Facilities, 2.8 Building Environmental Impacts and Sustainability, TC 7.6
Chair: David Eldridge Jr., P.E., Member, Grumman/Butkus Associates, Evanston, IL

Hospitals have traditionally been high energy users. Recent research has shown that hospitals can be designed and operated as 'Net Zero Energy Buildings' or even positive energy, contributing to their local community's low carbon goals, in a cost effective and sustainable manner. This seminar collects reports from European research, UK energy targets and discussion of North American ambitions to reduce toward zero. Cost effective technologies exist but need to be adopted and applied in new and existing facilities to achieve NZEB in this challenging sector. Support such as a new ASHRAE design guide on NZE Hospitals is discussed.

1. Toward NZE Hospitals in North America
***Heather Burpee**, University of Washington Integrated Design Lab, Seattle, WA*

North American hospitals are high energy users due to their intense usage and environmental control required for healthcare. However there are techniques which could be applied to existing and new hospitals to achieve net zero energy usage based on a low energy and efficiency approach complemented by renewable energy systems. This presentation considers what steps need to be taken to reach NZE outcomes and highlights potential risks and concerns which are peculiar to hospital buildings.

2. Owner Perspective on Potential for NZE Healthcare Facilities
***Travis English, P.E., Member**, Kaiser Permanente, Anaheim, CA*

This presentation discusses the owner's perspective for potential of NZE in US hospitals at national scale. It discusses ideas from the US market contrasted to international viewpoints. How does the US perspective vary from the international perspectus? What do we need to be looking at to move the national portfolio to NZE? What are the biggest uses and how do we address them cost effectively? What is the cost and economic viability of NZE deployments and conversions? What synergies do NZE have with resilience that can make the economics more viable or feasible?

3. European Research Study into NZE Hospitals
***Wim Maassen**, Royal Haskoning DHV, Rotterdam, Netherlands*

This presentation addresses the project “nZEB Hospital Buildings” undertaken in cooperation with the Eindhoven University of Technology and supported by TVVL and REHVA to give information and insight in nZEB developments that will occur in the near future and what the consequences of these developments are for hospital buildings and in particular for building services. Hospitals consume approximately 1% of the primary energy in the Built Environment. Majority of energy is used by the building and building services. The study considers future scenarios of required building performances, functions/usage of the buildings, technological innovations and business case parameters.

4. Strategies for NZE Hospitals in the UK
***Francis Mills, CEng, Life Member**, Frank Mills Consulting, Leyland, United Kingdom*

The UK has committed to low carbon targets, 80% total reduction by 2050. This will require buildings including hospitals to become "Net Zero" and even positive contributors toward this target. Research has shown that massive reductions are possible and that with the appropriate strategies there can be cost benefits which would help to ease the financial pressures on the NHS. By embracing low carbon energy as a resource and of value to the community, hospitals could start to see an income stream from their waste energy.

Tuesday, June 27, 5:00 PM - 6:00 PM

Seminar TC

TC Seminar Ductless Car Park Ventilation: Global Trends and Design Practices

Track: Fundamentals and Applications
Room: Bixby 3
Sponsor: 5.9 Enclosed Vehicular Facilities
Chair: Yoon Ko, Ph.D., Member, National Research Council Canada, Ottawa, ON, Canada

OPEN SESSION: No badge required; no PDHs awarded; presented during the TC's meeting. As cars are parked within an underground parking structure, CO and other exhaust fumes are emitted into the atmosphere. There is a need for an efficient ventilation system that can remove these toxins, circulate fresh air into the garage, and assist fire fighters in the case of a fire emergency. This seminar introduces ductless car park presentation.

1. Ductless Car Park Ventilation: Global Trends and Design Practices
***Troy Goldschmidt, Member**, Greenheck, Schofield, WI*

As cars are parked within an underground parking structure, CO and other exhaust fumes are emitted into the atmosphere. There is a need for an efficient ventilation system that can remove these toxins, circulate fresh air into the garage, and assist fire fighters in the case of a fire emergency. There are two options for this task: ducted or ductless ventilation.
Ducted ventilation is heavily used in the US and other global markets. While this has been the standard for many years, innovations in the field of ventilation have shifted the conventional ventilation system towards ductless designs.

Wednesday, June 28

Wednesday, June 28, 8:00 AM - 9:30 AM

Technical Paper Session 4

Advances in Domestic Water Heating

Track: Fundamentals and Applications 

Room: 103AB

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

This session covers recent improvements in the design of residential and commercial water heating. Two of the presentations discuss recent ASHRAE research regarding sizing criteria of domestic water heating systems in hotels. The remaining presentations cover a comparison of large capacity electric instantaneous water heaters to lower capacity storage type and the test conditions for residential water heaters.

1. The Dependence of Water Heater Energy Factor on Deviations from Nominal Test Conditions (LB-17-010)

***William Healy, Member**, National Institute of Standards and Technology, Gaithersburg, MD*

An analytical study is carried out to assess the impact of corrections to nominal test conditions on the measured energy factor for residential water heaters. While test conditions are specified in the method of test, the difficulty in exactly achieving these test conditions in the laboratory necessitates a computational approach to correct the results to nominal conditions. This paper examines the magnitude of those corrections for a range of water heaters of various fuel type, heating method, and size across a number of potential draw volumes during a 24 hour simulated use test.

2. Tankless Electric Water Heater Diversified Electrical Demand in Residential Applications (LB-17-011)

***Carl C. Hiller, Ph.D., P.E., Fellow ASHRAE**, Applied Energy Technology, Davis, CA*

The impact of the high power requirements of large residential tankless electric resistance water heaters on electric system distribution wiring, transformers, breakers, and other equipment is an area of concern for both electric utilities and builders. This study analyzes how probable and worst case diversified electrical demand of large (28 kW) residential tankless electric water heaters compares to that of 4.5 kW storage water heaters in residential applications as a function of number of households on a given electrical distribution circuit.

3. Hot Water Use in Hotels, Results of ASHRAE Research Project 1544, Part 4 of 6: Comparison of Travel and Business Hotel Hot Water System Monitoring Results (RP-1544) (LB-17-012)

***Russell Johnson, Member**[1] and Carl C. Hiller, Ph.D., P.E., Fellow ASHRAE[2], (1)Johnson Research LLC, Pueblo West, CO, (2)Applied Energy Technology, Davis, CA*

Information on hotel hot water use patterns has been limited until now, resulting in most hotel hot water systems being designed using extremely old hot water use data (45-80 years old) that predate the introduction of water and energy efficient fixtures and appliances. In recognition of this fact, ASHRAE funded research project 1544 “Establishing Benchmark Levels and Patterns of Commercial Hot Water Use – Hotels” to both develop a monitoring methodology that could be duplicated by others to collect hot water use data from a larger number of hotels and to obtain updated hot water use information from at least two hotels. This paper compares hot water use results collected for a “travel” hotel which had neither meeting rooms nor food service and a “business” hotel which had both.

4. Hot Water Use in Hotels, Results of ASHRAE Research Project 1544, Part 5 of 6: Updated Hotel Hot Water System Design Techniques (RP-1544) (LB-17-013)

***Carl C. Hiller, Ph.D., P.E., Fellow ASHRAE**[1] and Russell Johnson, Member[2], (1)Applied Energy Technology, Davis, CA, (2)Johnson Research LLC, Pueblo West, CO*

This is the fifth paper in a series of technical papers written to describe results of ASHRAE research project 1544. This paper builds on information presented in the project final report, the three previously published papers to present information on using the updated data to select water heating systems for hotels of any desired size and compares results of this sizing method to other hotel hot water system sizing methods described in the ASHRAE Service Water Heating Handbook Chapter through the use of examples.

Wednesday, June 28, 8:00 AM - 9:30 AM

Conference Paper Session 15

Building Energy and Consumption

Track: HVAC&R Systems and Equipment 

Room: 101A

Chair: Rachel Romero, P.E., Member, NREL, Golden, CO

Quantification of the potential for thermal load management is a first step towards its deployment and its contribution to the development of more sustainable cities. This session identifies the improvements in efficiency for 50 commercial buildings in Singapore that have undergone chiller plant retrofitting and introduces the framework of the national building energy consumption database and analyzes energy use characteristics of office buildings across the country. Also proposed is a novel unsupervised non-intrusive building energy disaggregation technique using 15-minute interval whole-building energy consumption and weather data.

1. Quantification of the Potential for Advanced Thermal Control Strategy over a Range of Buildings Characteristics (LB-17-C050)

Solène Goy, Student Member[1]*, François Maréchal*[2] *and Donal Finn*[1]*, (1)University College Dublin, Energy Institute, Dublin, Ireland, (2)Ecole Polytechnique Fédérale de Lausanne, Industrial Process and Energy Systems Engineering (IPESE), Lausanne, Switzerland*

Thermal load management studies have been carried out at small and large scale, covering all the range from a single building to the country level, although prior research provides valuable information on the possible energy management schemes and gains, the large scale studies typically suffer shortcomings. This paper addresses those shortcomings focusing on the existing building stock. It describes a comprehensive tool to estimate the potential for thermal load management at large scale accounting for the buildings passive storage potential. The paper also describes the application to a 10 buildings case-study in Geneva (Switzerland) and quantifies the associated gains.

2. The Impact of Chiller Plant Retrofit on Energy Consumption for Commercial Buildings in Singapore (LB-17-C051)

Siew Eang Lee, Ph.D.*, Chirag Deb and Junjing Yang, Ph.D., Associate Member, National University of Singapore, Singapore, Singapore*

Energy efficiency in buildings is one of the key measures to tackle global energy and emission concerns. The large share of air conditioning in commercial buildings makes air conditioning systems as primary targets for retrofitting. This paper studies 50 commercial buildings in Singapore that have undergone chiller plant retrofitting. The energy audit reports from these buildings are studied in detail to gather data related to building energy consumption and chiller plant efficiency (measured in kW/RT). The energy utilization index (EUI) which is measured as the total energy per square meter is analyzed for these buildings before and after retrofitting.

3. Unsupervised Non-Intrusive Building Energy Disaggregation (LB-17-C052)

Mohammad A. Hossain, Student Member*, Ethan M. Pickering, Jack Mousseau, Arash Khalilnejad, Rachel A. Swanson, Roger H. French and Alexis R. Abramson, Case Western Reserve University, Cleveland, OH*

Commercial buildings alone are responsible for 36% of the total United States electricity consumption, and on average 30% of this electricity consumption is wasted. One of the greatest challenges in improving building energy efficiency lies in the ability to do simple and non-intrusive disaggregation. Building energy disaggregation extracts system and equipment level energy signals from a whole building's energy consumption data. This paper proposes a novel unsupervised non-intrusive building energy disaggregation technique using 15-minute interval whole-building energy consumption and weather data. The proposed disaggregation technique consists of an analysis loop with three steps.

4. Analysis of Energy Consumption in Office Buildings Based on the National Building Energy Database in Korea (LB-17-C053)

Haeng Pil Jo*, Hye Gi Kim and Sun Sook Kim, Ph.D., Member, Ajou University, Suwon, Korea, Republic of (South)*

Benchmarking energy use can help building owners and managers to assess building energy performance and to identify energy efficiency opportunities. Energy consumption data makes it easy to understand the energy use characteristics of each building, and can promote occupants' awareness of building energy efficiency when providing an energy performance index developed from this data. As a way of improving energy efficiency in the building sector, the Korean government has developed a nation-wide integrated energy consumption database with more than six million building records. This paper introduces the framework of the national building energy consumption database and to analyze energy use characteristics of office buildings across the country.

Wednesday, June 28, 8:00 AM - 9:30 AM

Conference Paper Session 16

Dynamic HVAC Controls

Track: Controls 

Room: 101B

Chair: Geoff Bares, P.E., Member, ASHRAE, Plainfield, IL

Conventional control approaches relying only on local feedback control can lead to unnecessary energy use. Dynamic scheduling of HVAC systems using access control data and model predictive control (MPC) algorithms are becoming more popular for building HVAC supervisory control. This session evaluates the former, as well as compare operational outcomes of a homegrown control strategy with that of a standardized best practice control strategy. As a whole, this session provides insight on dynamic HVAC controls and how they could help conserve energy.

1. An Implementation Framework of Model Predictive Control for HVAC Systems: A Case Study of EnergyPlus Model-Based Predictive Control (LB-17-C054)

Zhiang Zhang, Student Member *and Khee Poh Lam, Ph.D., Carnegie Mellon University, Pittsburgh, PA*

Model predictive control (MPC) is becoming a popular algorithm for building HVAC supervisory control. One type of MPC for HVAC supervisory control is EnergyPlus Model-based Predictive Control (EPMPC), where an EnergyPlus model is used in MPC algorithm to predict future building performance. EPMPC could reduce the development cost of MPC by reusing the EnergyPlus model that is often developed during the design phase of a project. However, MPC, especially EPMPC, is much more complex and computation-intensive compared to traditional HVAC control logic; also, it needs to constantly acquire updated forecast data as inputs for computation, such as weather forecast data and occupancy schedule forecast data. Therefore, implementation of MPC to real HVAC systems is difficult. In this paper, a software framework of MPC for HVAC supervisory control is developed to facilitate implementation of MPC.

2. Dynamic Scheduling of HVAC Systems' Occupied Period using Access Control Data (LB-17-C055)

Bianca Howard, Ph.D.*, Salvador Acha, Ph.D., Nilay Shah, Ph.D. and John Polak, Ph.D., Imperial College London, London, United Kingdom*

Intelligent building management systems aim to maintain thermal comfort and reduce energy consumption by learning occupant's habits and behaviors. A component of these systems is dynamic scheduling, which ensures the HVAC system is only in use when the building is occupied. This paper develops dynamic schedules of building occupancy for an office building in London and estimate the effectiveness through a building simulation.

3. Comparing Guideline 36 Single Duct VAV Terminal Reheat Strategy with a Similar, Homegrown Approach (LB-17-C056)

Andrew Windham, Ph.D., Associate Member*, Appalachian State University, Boone, NC*

ASHRAE Guideline 36 aims to standardize a set of best practices for HVAC control. This paper compares a single-duct VAV terminal reheat strategy developed and implemented at Appalachian State University with the dual maximum strategy included in Guideline 36. The two strategies are similar but they differ in the details of implementation. The Appalachian State strategy controls the reheat valve with the zone temperature. Discharge air temperatures are monitored and when that temperature reaches 90 F, the VAV damper modulates to cap the discharge air temperature at the 90 F setpoint. Using numerical analysis and actual performance data, this study looks at the implications of this variation and compare operational outcomes with those established for the dual maximum strategy outlined in Guideline 36 and other energy conservation standards.

4. Field Performance of a MPC Coordinating Multiple Rooftop Units (LB-17-C057)

DONGHUN KIM, Ph.D. *and James E. Braun, Purdue University, West Lafayette, IN*

Small and medium sized commercial buildings, such as retail stores, restaurants and factories, often utilize multiple roof top units (RTUs) to provide cooling and heating for open spaces. A conventional control approach for these buildings relies on local feedback control, where each unit is cycled on and off using its own thermostat. Because a thermostat operates regardless of the overall building's behavior, the conventional control approach could result in unnecessary energy use and high electrical peak demand via poor coordination among the units. The control solution is not site-specific and provides reduced energy consumption and peak demand with low sensor requirements. This paper provides recent results of long-term performance of the RTU Coordinator at field sites for small/medium commercial buildings.

Wednesday, June 28, 8:00 AM - 9:30 AM

Seminar 48

Achieving Net Zero: Design Strategies and Modeling Techniques

Track: Net Zero Energy Buildings: The International Race to 2030 NY PDH G

Room: 102AB

Sponsor: 7.1 Integrated Building Design, 1.5 Computer Applications

Chair: Krishnan Gowri, Ph.D., Fellow ASHRAE, Autodesk, Bothell, WA

This seminar brings together leading industry experts in energy design and modeling to discuss state-of-the-art strategies, tools and techniques to achieve net zero energy design goals. An overview of the future codes, standards and voluntary programs trending towards net zero are discussed with an emphasis on the metrics, compliance methods and technologies. Results from California state energy efficiency studies to achieve net zero by 2030 are presented along with a case study on achieving net zero for retrofits. ASHRAE members will gain knowledge of industry trends, technologies and modeling insights for high performance building design.

1. Trending Towards Net Zero: Codes, Standards and Voluntary Programs

***Krishnan Gowri, Ph.D., Fellow ASHRAE**, Autodesk, Bothell, WA*

This presentation provides a summary of leading codes, standards and voluntary programs including ASHRAE 90.1, 189, IgCC, CEC Title 24, AIA 2030 and Federal Executive Order 13514 - all aimed at high performance and net zero building design. Primary metrics, design tools and evaluation methods to meet the net zero design goals will be discussed. Attendees are provided with resources for learning about these new programs and databases available on recently completed net zero buildings.

2. Scenario Analysis for ZNE Modeling

***Charles Eley, P.E., BEMP, Member**, Eley Consulting, San Francisco, CA*

As zero net-energy becomes our goal, we have a fixed energy target (e.g. zero) that is verified after the building is constructed and operated. The assumptions on operating conditions are no longer neutral as they are with the two-model approach used for code compliance; they are critically important. This presentation introduces the concept of an energy services index (ESI) and recommends that the energy modeling workflow include scenario analysis for a range of energy services that the building could potentially deliver in the future. For future ESI's that are more demanding, opportunities for additional renewable energy are identified.

3. The Technical Feasibility of Zero Net Energy Buildings in California

***Wyatt Kennedy, P.E.**, Arup, San Francisco, CA*

The California Public Utility Commission and California Energy Commission have set a Zero Net Energy (ZNE) 2020 target for new residential construction and a ZNE 2030 target for new commercial construction. This presentation outlines the technical feasibility of reaching ZNE goals for 12 "prototypical" buildings. An energy modeling study has been completed that determined integrated packages of energy efficiency features and on-site renewable energy systems that could move these prototypical buildings as close as reasonably possible to ZNE. This study's central finding is that ZNE buildings will be technically feasible for much of California's new construction market in 2020.

4. Aiming for Zero-Net-Energy at an Existing Supermarket

***Rob Best**, Arup, San Francisco, CA*

This presentation discusses key approaches and initial analytical findings from a project to retrofit an existing operational supermarket to near zero-net-energy (ZNE). The project, partially funded by a California Energy Commission (CEC) grant, seeks to investigate and implement proven pre-commercial strategies for an existing supermarket in the San Francisco Bay Area. The presentation discusses initial energy estimates for the retrofit design and the design's consideration of industry shifts towards ZNE in supermarkets, such as building electrification and thermal and electrical storage. The presentation also discusses the project's use of parametric modeling and analysis to optimize the retrofit strategies.

Wednesday, June 28, 8:00 AM - 9:30 AM

Seminar 49

Direct Expansion Ground Source Heat Pump: Reviewing Issues, Advancements and Advantages

Track: HVAC&R Systems and Equipment NY PDH G

Room: 203AB

Sponsor: 6.8 Geothermal Heat Pump and Energy Recovery Applications

Chair: Xiaobing Liu, Ph.D., Member, ORNL, Oak Ridge, TN

Direct expansion ground source heat pump (DX-GSHP) technology uses refrigerant as primary working fluid in ground heat exchangers (GHE). It is the oldest type of ground coupled heat pump and potentially the most efficient vapor compression-based air conditioning systems that are not commonly used due to several design and operational issues. This seminar covers the history and status of DX-GSHP, operational issues, ongoing studies on trends in GHE design and use of natural refrigerants and common myths surrounding DX-GSHP technology.

1. Performance and Reliability of Direct-Expansion Ground-Coupled Heat Pumps

***Demba Ndiaye, Ph.D., P.E., BEMP, Member**, University of North Carolina at Charlotte, Charlotte, NC*

Direct Expansion Ground-Coupled Heat Pumps are potentially the most efficient vapor compression-based air conditioning system, but are not very popular due to the numerous operational and design issues they are plagued with: shortage of field studies, oil return to the compressor, expansion valve hunting, refrigerant flow mal-distribution in parallel loops, high pressure drops and gains in the ground heat exchanger, variable speed operation of the compressor, lack of reliable numerical models of the ground heat exchanger and of the whole system and lack of generalized design guidelines. This seminar discusses these issues and possible solutions to them.

2. Status and Trends in DX Bore Field Dimensioning

***Louis Lamarche, Ph.D.**, Ecole de Technologie SUperieure, Montreal, QC, Canada*

In a classical Secondary Loop (SL) GSHP, the ground loop is sized independently and simply to exchange enough heat with the ground. In a DX system however, the ground loop is an integral part of the heat pump and clear design metrics is less obvious. Therefore, good design can become technology-dependant and other constraints like oil-return or valve hunting plays a role as much as thermal performance. Recent research has brought some new guidelines to improve global knowledge on this technology. This presentation discusses recent trends in ground loop design based on experimental observations and theoretical modeling.

3. Direct Expansion Ground Source Heat Pump Using Carbon Dioxide As Refrigerant

***Parham Eslami Nejad, Ph.D.**, Natural Resources Canada, Varennes, QC, Canada*

Although the detrimental environmental impacts of conventional refrigerants have raised global concern, due to the worldwide growing energy demand, high energy efficiency of heat pumps still remains a great incentive for using this technology in residential and commercial buildings. Over the last decade, several studies have been conducted to replace synthetic refrigerants with natural ones. Among the candidates, CO_2 has been attracting more attention due to being environmentally benign and safe together with superior heat transfer characteristics. This seminar presents some field operation results, modeling advancements and system and GHE performance improvements of DX-GSHP using CO_2 as refrigerant.

8:00 AM - 9:30 AM

Seminar 50

High Efficiency Commercial Refrigeration Systems with Natural Refrigerants

Track: Refrigeration

Room: 201A

Sponsor: 10.7 Commercial Food and Beverage Refrigeration Equipment, Refrigeration Committee, TC8:1 Positive Displacement Compressors; TC3.1 Refrigerants and Secondary Coolants

Chair: Georgi Kazachki, Ph.D., Fellow ASHRAE, Dayton Phoenix Group, Inc., Dayton, OH

Commercial refrigeration systems have been some of the largest contributors to refrigerant leaks, second to automotive air-conditioning. For this reason, they became the most intensely studied application for natural refrigerants, such as ammonia and carbon dioxide. These systems went through a substantial evolution in the last 10-15 years to accommodate ammonia and CO2 specific properties (safety class B2 for ammonia and low critical temperature and high pressures in certain conditions for CO2) and, at the same time, to be cost and efficiency competitive with the HFC systems. The seminar demonstrates the outcome of this evolution through the featured presentations.

1. Doing It All Efficiently with CO2 Refrigeration Anywhere in the World

***Klaas Visser, P.E., Affiliate**, KAV Consultants Pty Ltd, Kangaroo Flat, Australia*

This presentation examines the benefits of Evaporative Condensers/Gas Coolers (EC/GCs) where the cooling medium temperature is the Ambient Wet Bulb Temperature (AWBT) and not the ambient dry bulb temperature as is the case with air cooled gas coolers. A 1% incidence AWBT of 28°C is not exceeded in 98% of the world's climates. At a AWBT of 28°C it is relatively easy to achieve a gas cooler CO_2 exit temperature 31°C and even 30°C at part load. This means that efficient CO_2 refrigeration may be operated all over the world with the use of EC/GCs.

2. Design and Performance Validation of Ultralow Charge Ammonia Cascade System for Retail Food Environment
***Karthick Kuppusamy**, Heatcraft-Kysor/Warren, COLUMBUS, GA*

Natural refrigeration technology in supermarkets is driven by growing global concerns around energy and environment. Energy efficiency, safety and reliability are key characteristics of supermarket system design. A field test is carried out on a Supermarket with ammonia system as top cycle catering to MT and LT refrigeration loads. The entire system is designed with state-of-the-art energy efficient features and ultra-low ammonia charge @ 0.75 Lbs / TR. A brief overview of design considerations and test results are presented. Superior efficiency of ammonia is demonstrated in a side by side energy study with HFC that is validated by third party.

3. Opportunities for Utilizing Two-Phase Ejectors to Increase Efficiency of Commercial Refrigeration Systems Using Natural Refrigerants
***Stefan Elbel, Ph.D., Member**, Creative Thermal Solutions and University of Illinois at Urbana-Champaign, Urbana, IL*

The low GWP of natural refrigerants makes them great candidates for commercial refrigeration. An important characteristic of transcritical CO2 cycles are the substantial throttling losses that negatively impact energy efficiency at high ambient temperatures. This presentation introduces numerous ways of improving COP at demanding outdoor conditions, and the emphasis will be on utilizing two-phase ejectors. A variety of cycle options exist that allow integration of ejectors, including utilization of the recovered energy to unload the compressor, to provide cooling at different temperature levels and to improve efficiency by using the ejector to drive refrigerant overfeed in liquid recirculation cycles.

4. Packaged Ammonia/CO2 Systems for Refrigeration
***Scott Mitchell, Associate Member**, Southern California Edison, Irwindale, CA*

This presentation provides the final results from field testing of a packaged ammonia/carbon dioxide system installed in Irvine, CA. The unit was one of the first of its kind installed in North America and provides a glimpse at how natural refrigerants can be applied to systems where they previously were not used. The project was featured in a Feb 2016 ASHRAE Journal article.

Wednesday, June 28, 8:00 AM - 9:30 AM

Seminar 51

It's a Breeze! Understanding the Fundamentals of Air Flow Around Buildings and Its Effect on Ventilation and Air Quality

Track: Fundamentals and Applications NY PDH G
Room: 202AB
Sponsor: 4.3 Ventilation Requirements and Infiltration
Chair: Martin Stangl, P.Eng., Member, RWDI Consulting Engineers, Guelph, ON, Canada

Wind behaves in unusual ways when it interacts with buildings. Although unseen, it can impact HVAC equipment and indoor environmental quality. Chemicals, odors, and contaminants emitted from buildings are often carried by the wind directly back into the building – a potentially dangerous situation. This seminar gets back to basics by providing an overview of the wind flow around buildings and dispersion modelling techniques described in Chapter 24 of the Fundamentals, and Chapter 45 of the Applications Handbooks. Also presented is a practical application of these concepts by examining the design considerations and control of high performance laboratory exhaust systems.

1. Air Flow Around Buildings and Its Effect on Ventilation and Air Quality
***Michael Ratcliff, Ph.D., P.E., Member**, RWDI, Redlands, CA*

The outdoor wind and air flow around buildings affect the indoors in several ways. Wind is the primary driver for natural ventilation by exerting pressures (both positive pressure and negative suction) on building surfaces. Wind also can cause building exhausts to migrate outdoors to nearby air intakes and pedestrian locations, creating poor air quality indoors. This presentation focuses on approach wind conditions, the air flow patterns around buildings and wind pressures exerted on buildings. These effects are the fundamental starting place for more detailed ventilation and air quality analyses. Also discussed are modeling methods using CFD and wind tunnel similarity.

2. Dispersion Modeling Techniques for Exhaust Stack Design
***Brad Cochran, P.E., Member**, CPP Wind Engineering & Air Quality Consultants, Fort Collins, CO*

There are four types of dispersion models; graphical, analytical, computational and physical. Each one of these models has its appropriate applications, but misapplying a model can result in either an inadequate exhaust design or in an excessive effort (i.e., fees). Therefore, this presentation provides the audience with guidelines on how and when each of these models should be utilized, what the limitations are of each model, and some insight in how to determine if models are being properly utilized.

3. Engineered Lab Exhaust Design Application
***Nathan Ho, P.E., Associate Member**, P2S Engineering, Inc., Long Beach, CA*

Laboratory exhaust systems are a central element of high performance science and technology facilities. Air quality, energy efficiency, and operational reliability are deeply impacted by the performance and design of the laboratory exhaust system. This presentation focuses on the design process, considerations, fan basics and control of high performance lab exhaust systems. Brief design application examples will be included to connect fundamentals with practice. The objectives of this presentation are to provide guidance on design team collaboration, insights on lab exhaust design fundamentals and share examples of application.

Wednesday, June 28, 8:00 AM - 9:30 AM

Seminar 52

The New 90.2

Track: Residential Buildings: Standards Guidelines and Codes 

Room: 201B

Sponsor: 7.6 Building Energy Performance, SSPC 90.2; Residential Building Committee

Chair: Theresa A. Weston, Ph.D., Member, DuPont Building Innovations, Richmond, VA

Standard 90.2 Energy-Efficient Design of Low- Rise Residential Buildings has undergone a major revision which was released in the Public Review conducted at the end of 2016. This seminar discusses the new direction of the standard to become an accurate, flexible performance-based tool to enable user creativity in meeting the performance objectives residential building energy performance that is at least 50% more efficient than the energy efficiency defined by the 2006 IECC.

1. Standard 90.2 in a Diverse Residential Marketplace

***Chris Mathis, Member**, Mathis Consulting, Asheville , NC*

Residential buildings are responsible for over 22% of total US energy use. Recognizing the role of residential buildings on energy demand, environmental impact and economic development, ASHRAE has been working to revise Standard 90.2 to better address these and other topics. Concurrently, ASHRAE has engaged a diverse array of residential stakeholders within and outside of ASHRAE to determine the scope of needs in the residential marketplace, and to determine ASHRAE's role in addressing those needs. This presentation explores the diversity of residential stakeholders ASHRAE seeks to engage and the possible opportunities for 90.2 to impact the residential built environment.

2. Standard 90.2 Performance and Flexibility

***Philip Fairey, Member**, Florida Solar Energy Center, Cocoa, FL*

This presentation describes the performance approach which is the core of 90.2. Performance-based energy calculation tools have long been elements of building code compliance and beyond code programs. However, these building energy modeling tools have often been varied and inconsistent in their default assumptions, modeling rule sets and calculation approaches. To address these concerns, the SSPC 90.2 has developed very detailed rules governing the energy modeling and analyses necessary to determine compliance. More importantly, 90.2 provides a mechanism by which any residential building design can be easily evaluated against these performance objectives.

3. Illuminating the ASHRAE 90.2 Lighting Requirements

***Theresa A. Weston, Ph.D., Member**, DuPont Building Innovations, Richmond, VA*

This presentation gives an overview of the advanced lighting technologies and strategies, from lamps to control systems, to help deliver even greater levels of lighting energy savings than current minimum code.

Wednesday, June 28, 9:45 AM - 10:45 AM

Technical Paper Session 5

Building System Analysis

Track: HVAC&R Systems and Equipment 

Room: 103AB

Chair: Jaya Mukhopadhyay, Ph.D., Member, Montana State University, Bozeman, MT

This session presents a unique opportunity to explore two areas of building systems investigation. One presenter investigates occupant behavior and their interactions with various building components. Secondly, attendees hear about improved indoor air quality by using alternative desiccant technology.

1. Interpreting Occupant-Building Interactions for Improved Office Building Design and Operation (LB-17-014)

***Sara Gilani, Student Member** and William O'Brien, Ph.D., Member, Carleton University, Ottawa, ON, Canada*

Knowledge of occupants' interactions with building components and systems and how indoor environments are influenced in response to occupant behaviors is highly beneficial to operate and maintain existing building more efficiently and to design new buildings to be more comfortable and energy-conscious. This paper provides insight in this regard. To this end, occupant behaviors and energy flows are being monitored in an academic building in Ottawa, Canada. The paper presents results of this monitoring campaign on occupants' presence and behaviors, indoor environmental conditions, and energy demands in various offices.

Wednesday, June 28, 9:45 AM - 10:45 AM

Conference Paper Session 17

Analyzing, Improving and Innovating Thermal Comfort

Track: Fundamentals and Applications 

Room: 101B
Chair: Peng Yin, Ph.D., Associate Member, University of Louisiana at Lafayette, Lafayette, LA

Achieving thermal comfort while answering the ventilation requirements of an occupied space often presents design challenges. This conference paper session discusses how thermal comfort may be achieved or affected by spatially adaptive supply air, radiant heating and humidification.

1. Experimental Study of Energy Savings Using a Household Humidifier (LB-17-C058)
Kevin Anderson, Ph.D., P.E., Member *and Patricia Wassem, California State Polytechnic University at Pomona, Pomona, CA*

This paper describes experimental results obtained from running a household dehumidifier overnight and comparing the temperature and humidity changes before and after turning on the dehumidifier, and comparing these changes to the amount of energy used to run the dehumidifier. This work is being performed in response to sustainability goals proposed by the United Nations call for "off-the-shelf" sustainable technologies in third world nations. The objective is to test the energy-saving qualities of dehumidifiers as a method of home heating. The data reduction of the household humidifier first calculates the amount of energy in the form of heat that is generated by the dehumidifier by comparing the change in temperature, time, kWh, and humidity, and applying these changes to the equation for the change in enthalpy in atmospheric air.

2. Improving Thermal Comfort via Spatially Adaptive HVAC (LB-17-C059)
Robert Bailey, Ph.D., P.E., Member*, Matthew Kalensky and Charles Wilson, Loyola University Maryland, Baltimore, MD*

This paper presents a new, interior-space, environmental conditioning strategy, referred to as spatially adaptive heating, ventilating, and air conditioning (HVAC), where supply air locations within a room are repositioned in response to changing thermal loads or other room conditions. In order to quantitatively examine the technical merits of this concept, a computational fluid dynamics (CFD) model of a typical office was created using SOLIDWORKS Flow Simulation software and benchmarked using full-scale, experimental, velocity and temperature data from the literature. In light of promising results, a one-fifth scale model office was constructed to examine additional scenarios not covered experimentally in the literature and to validate computer simulations of these scenarios. Initial results from the scale model tests are described, and preliminary engineering concepts for achieving supply register relocation are presented. In addition, the opportunities, challenges, limitations, and potential for energy savings associated with this new strategy are discussed.

3. Cooling Performance Analysis and Optimization of a Room with Radiant Panel Using CFD (LB-17-C060)
Abdullah Karimi, Affiliate *and Reza Ghias, Ph.D., Member, Southland Industries, Dulles, VA*

Radiant systems are increasingly being used for heating and cooling spaces due to its benefits like better energy efficiency, improved thermal comfort and IAQ. In addition, the radiant systems reduce the ductwork and are aesthetically pleasing. However, the effectiveness of radiant systems for optimal design need detailed study of impact of several parameters. In this paper, detailed CFD simulation of a typical room with radiant panel for cooling has been performed. Typical heat loads from human, lights and computer are considered in the model. Different scenarios of return diffuser location, on floor and on ceiling, are considered. Impact of radiation and buoyancy are modeled in the simulation and typical thermal boundaries are applied for walls, roof and floor. The detailed temperature and flow distribution obtained from simulation are used to evaluate and optimize the cooling system, supply flow requirements and diffuser locations.

Wednesday, June 28, 9:45 AM - 10:45 AM

Conference Paper Session 18

Thermal Storage

Track: HVAC&R Systems and Equipment 

Room: 101A

Chair: Marija Todorovic, P.Eng., Fellow ASHRAE, University of Belgrade, Belgrade, Serbia

Thermal storage systems are energy efficient, resource efficient and reduce load on power plants during peak times. Therefore, employing thermal storage systems reduces carbon footprint and positively affects climate change. This session discusses methods of operating and optimizing thermal storage systems for both heating and cooling. These presentations also indicate rate of return for improvement projects, COP and costs of operation.

1. Experimental Performance Study on a CO_2 Heat Pump System with Thermal Storage (LB-17-C061)

Fang LIU, Ph.D., P.E., Member*, Weiquan Zhu and Yang Cai, Shanghai University of Electric Power, Shanghai, China*

The experimental performances of a dual-mode CO_2 heat pump system coupled with hot and cold thermal storage is investigated in this paper. This combined system was tested by controlling compressor frequency, expansion valve opening and hot and cold circulation water flow rates. Experimental results show that high compressor frequency benefits the combined system performances. Expansion valve opening affects the thermal stratification of thermal storage tanks very slightly. Low hot and cold water flow rates are good for the thermal stratification of thermal storage tanks although high water flow rates can enhance the COP of heat pump system; and thermal stratification in thermal storage tanks is one of the most important impact factors on the COP of heat pump.

2. Integrated Optimisation of PV and Storage Systems for UK Non-Domestic Buildings (LB-17-C062)

Salvador Acha, Ph.D., Member*, Arthur Mariaud, Ned Ekins-Daukes, Ph.D. and Nilay Shah, Ph.D., Imperial College London, London, United Kingdom*

Growing concerns about climate change, new decarbonization agenda, research for energy independence and geopolitical evolutions have led countries and industries to rethink their energy consumption. In this research for sustainability, major stakeholders in the UK food retail market are investigating pathways to reduce their carbon footprint. Low-carbon energy production technologies such as photovoltaic systems coupled with battery storage constitute potential solutions, also driven by rising electricity bills. The purpose of this paper is to develop an end-user optimization model assessing potential benefits of photovoltaic systems associated with battery storage for commercial buildings integration.

3. Efficient Interaction between Energy Demand, Surplus HEAT/Cool and Thermal Storage (LB-17-C063)

Trond Thorgeir Harsem, P.Eng. *and Janne Grindheim, M.D., BEAP and HFDP, Norconsult AS, Sandvika, Norway*

This paper discusses new methods for the operation of interacting simulating models. These methods provide tools to step into optimization of combinations of integrated energy systems. The main design issues that are addressed are hydronic flow system and the sizing of storage systems. The hydronic layout is important with respect to utilization of exergy i.e. water temperature, but the research also shows the importance of control strategies on energy savings. A proposed new hydronic layout and control design are described in this paper, as applied to heating, cooling and storage systems.

Wednesday, June 28, 9:45 AM - 10:45 AM

Seminar 53

Control System Best Practices: How to Make Your Control System Project a Success Part 1

Track: Controls 

Room: 201A

Sponsor: 1.4 Control Theory and Application

Chair: Kris Kinney, Member, Highwoods Properties, Raleigh, NC

Understanding an owner's needs, effectively controlling the mechanical systems, capturing the products, networking and sequences to produce contract documents is the control designers challenge. Learn the best practices of how to successfully design the control sequence, network architecture and a truly useful dashboard and communicate the requirements to the control contractor. The control contractor is challenged with making the system work while complying with the requirements of the contract documents. In this sometimes conflicting environment, the contractor often has to make some decisions. Learn how the contractor handles this dilemma and make the project a success.

1. Effective Design of Building Control Systems

***Frank Shadpour, P.E., HFDP, Fellow ASHRAE**, SC Engineers, Inc., San Diego, CA*

The professional engineer has to focus on multiple aspects of a project including, safety, identifying operational and mechanical processes, specifications, control system design and construction, control system installation and system maintenance. How these parts are merged to satisfy the owner's requirements and are conveyed from schematic design to construction and ultimately operated by the end-user is an interactive process. Integrating the right steps and checks in the process sets the basis for an effective and working design.

2. What Owners and Engineers Should Know about Control Systems for Successful Implementation

***Larry Fisher, Life Member**, ECT Services (Retired), Louisville, KY*

Early coordination with owner and engineer allows the controls integrator to understand the mechanical equipment design, owners' capabilities and development of a "Controls Responsibility Matrix". There are many ingredients for a successful controls system including coordinating other building trades, integrating with different protocols, installation quality and owner training expectations. The controls integrator will be a life partner with the owner, unlike the bricks and mortar type contractors, so specifying controls is a totally different concept. This presentation introduces the Controls Responsibility Matrix and the relationship for building a successful controls system.

9:45 AM - 10:45 AM

Seminar 54

Hot Water Distribution Systems in Residential Buildings

Track: Fundamentals and Applications 

Room: 201B

Sponsor: 6.6 Service Water Heating Systems

Chair: James D. Lutz, P.E., Member, Hot Water Research, Oakland, CA

This seminar presents recent research on the performance of hot water distribution systems and parts. One presentation is about unexpected results of laboratory testing of flow rates and pressure drop across plumbing fittings. The second presentation discusses measurements of energy and water losses in a residential hot water distribution system using a PEX home-run manifold configuration.

1. Energy and Water Losses in a Residential a PEX Home-Run System

***Tania Ullah, Associate Member**, National Institute of Standards and Technology, Gaithersburg, MD*

This presentation examines measurements of energy and water losses in a residential hot water distribution system using a PEX home-run manifold.

2. Pressure Drop and Flow Rates in Residential Water Piping

***Gary Klein, Associate Member**, Gary Klein and Associates, Inc., Rancho Cordova, CA*

This seminar presents the results of pressure drop testing of pipe, with and without fittings and compares these results to the numbers found in standard engineering reference manuals. A selection of copper, CPVC and PEX piping from 1/4 - 3/4 inch nominal and commonly available elbows at velocities from 1-12 gpm have been tested. The method of tests and the results are presented. Come learn whether these are higher or lower and discuss the implications of not having good numbers for the future of safe, efficient and high performance plumbing design.

Wednesday, June 28, 9:45 AM - 10:45 AM

Seminar 55

Research Updates on Radiant Cooling and Heating Systems

Track: Research Summit 
Room: 202AB

Sponsor: 6.5 Radiant Heating and Cooling

Chair: Paul Raftery, Ph.D., Affiliate, Center for the Built Environment, Berkeley, CA

Radiant cooling and heating systems are gaining in popularity and applications as they have the potential to provide energy efficiency and thermal comfort benefits. However, there are many unanswered questions regarding appropriate best practice for design, sizing and control. This seminar reports on recent research on the topic, including the effects of direct solar on radiant chilled floors and the effects of night-time precooling of thermally massive radiant systems.

1. New Method for the Design of Radiant Floor Cooling Systems with Direct Solar Radiation

***Jingjuan Feng, Ph.D., Associate Member**, Taylor Engineering, Alameda, CA*

This presentation explains a new method for designing radiant floor cooling systems that accounts for the effects of direct solar radiation.

2. Design Cooling Load Calculations Comparison between TABS and Air Systems

***Eleftherios Bourdakis, Student Member**, Technical University of Denmark, Kongens Lyngby, Denmark*

This presentation compares the differences in cooling loads between high and low thermal mass radiant systems and all-air systems.

9:45 AM - 10:45 AM

Seminar 56

Urban-scale Building Energy Modeling, Part 6

Track: Commissioning: Optimizing New and Existing Buildings and their Operation 
Room: 102AB

Sponsor: 1.5 Computer Applications, 4.7 Energy Calculations

Chair: Joshua New, Ph.D., Member, ONRL, Oak Ridge, TN

Development of urban-scale building energy models is becoming increasingly tractable for many applications including city-wide energy supply/demand strategies, urban development planning, electrical grid stability and urban resilience. This seminar has assembled several researchers with capabilities in the field of urban-scale energy models to discuss an overview of the field as well as the data, algorithms, workflow and practical challenges addressed in their applications involving creation of useful models of individual buildings at the scale of a city, urban or metropolitan area.

1. Agent Based Modeling to Estimate the Adoption of Energy Efficient Building Technologies

***Ralph Muehleisen, Ph.D., P.E., Member**, ANL, Lemont, IL*

Agent based modeling (ABM) is a bottom-up method of modeling complex systems that simulates the actions and interactions of autonomous agents. ABM is being used to look at consumer adoption of technologies ranging from cosmetics to electric vehicles and are often used as a replacement for diffusion models. This seminar presents the use of ABM to estimate the adoption of energy efficient building technologies. In the model, building owners make decisions based on a wide variety of economic and non-economic factors. A study of the nationwide adoption of hot water heating technology is shown.

2. Virtual Reality UBEM

***Drury Crawley, Ph.D., BEMP, Fellow ASHRAE**, Bentley Systems, Inc., Washington, DC*

With the advent of urban scale reality models, creating community, campus or Urban Building Energy Models (UBEM) has become as easy as a few hours of capturing photos with a drone. Combining the virtual model with benchmarking, facility, utility, management data and BIM models allows data to be easily queried. This presentation demonstrates several examples of how UBEM can visualize and report on benchmarking, utility and facility management data at the community, campus or urban scale. Virtual navigation of a campus and several cities will demonstrate how UBEM can be used to measure, analyze and report readily available urban data.

Wednesday, June 28, 9:45 AM - 10:45 AM

Workshop 9

How to Design, Construct and Operate Net Zero Hospitals AND Save Money

Track: Net Zero Energy Buildings: The International Race to 2030 NY PDH G

Room: 203AB

Sponsor: 9.6 Healthcare Facilities, 2.8 Building Environmental Impacts and Sustainability, SSPC 170

Chair: Francis Mills, CEng, Life Member, Frank Mills Consulting, Leyland, United Kingdom

Hospitals are high energy users and produce a lot of carbon emissions. However recent research has shown that hospitals can be designed and operated as 'Nett Zero Energy' or even Positive energy and this can be done without diverting funds from Healthcare. This workshop invites ASHRAE members to take part in a brainstorming session to see what are the best methods toward Nett Zero and what differences apply between different locations, countries and climate regions. Issue such as local Standards, codes and traditions will be raised and any other potential obstacles to the ZERO target.

1. How to Achieve Net Zero Energy Hospitals

***Wim Maassen**, Royal Haskoning DHV, Rotterdam, Netherlands*

Research in Europe has shown thatnthere are cost effective strategies to achieve Nett Zero Hospitals. This will be discussed in terms of its relevance to all countries.

2. Strategies to Net Zero Hospitals

***Frank Mills, Member**, Low Carbon Design Consultants, Liverpool, United Kingdom*

The UK Low energy hospital study and other studies show that Nett Zero can be cost effective and beneficial.

Wednesday, June 28, 11:00 AM - 12:30 PM

Technical Paper Session 6

Airside HVAC Advances

Track: HVAC&R Systems and Equipment NY PDH G

Room: 103AB

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

This session covers research on airside HVAC systems. Presentations include using natural ventilation for healthcare applications, modeling fan terminal units, minimum airflow rates and energy recovery for labs.

1. Differential Pressure Rise Measurements and Impact in EnergyPlus Modeling for Series VAV Fan Powered Terminal Units Using PSC Motors (LB-17-016)

***John Bryant, Ph.D., P.E., Member**, Texas A&M University, College Station, TX*

When modeling an HVAC system using fan powered terminal units with EnergyPlus, the user must enter values for fan total pressure rise and fan/motor efficiency. A recent study found that for an 8 inch inlet (203 mm) series fan powered terminal unit, the fan total pressure was considerably lower than values commonly recommended in online training sources. Values in that study were on the order of 0.25 in. w.g. (63 Pa) and not 1.5 or even as much as 3 in. w.g. (374 – 747 Pa). Manufacturer's performance data were used to verify and extend VAV fan powered terminal unit total pressure rise measurements as determined in a previous study.

2. ASHRAE SSPC 170 Natural Ventilation Task Group: Position Paper on Natural Ventilation in Health Care Facilities (LB-17-017)

***Travis English, P.E., Member**[1], Paul Ninomura[2], Heather Burpee[3], Jeremy Fauber, P.E., Member[4] and Arash Guilty[5], (1)Kaiser Permanente, Anaheim, CA, (2)Indian Health Service, Seattle, WA, (3)University of Washington Integrated Design Lab, Seattle, WA, (4)Heapy Engineering, Dayton, OH, (5)Mazzetti, Denver, CO*

The current version of ASHRAE Standard 170 procludes natural ventilation in all spaces in healthcare facilities. This work-group suggests it should be allowed in most healthcare spaces, except for Operating Rooms, Procedure Suites, Sterile Core areas, Interventional Radiology or Cardiology Spaces, Airborne Isolation Areas, and Protective Environments. Natural or mixed-mode ventilation designs may offer some benefits. Among the most likely are energy reduction and enhanced occupant satisfaction. Less likely benefits may include enhanced indoor air quality and a more beneficial microbiome. When considering natural ventilation in health care, designers must fully address the fundamental challenges of space appropriateness, climate appropriateness, acoustics, security, and outdoor air quality. Projects implementing natural ventilation should anticipate commissioning challenges.

3. Redesigning the HVAC System of a University Laboratory Building (LB-17-018)

***James Mathias, Member**, Navya Madineedi and Justin Harrell, Southern Illinois University Carbondale, Carbondale, IL*

The energy consumption of the heating and cooling coils of the air handling units of an educational building with multiple laboratories has been evaluated and suitable energy recovery methods were assessed in an attempt to reuse the energy lost in the exhaust air stream and promote energy conservation while complying with the current building codes. The HVAC system of Life Sciences II (LS II) building of Southern Illinois University Carbondale, is a constant air volume (CAV), 100% outside air (OA) system due to the many laboratories in the building. It is one of the most energy intensive buildings on campus.

4. Energy and Control Performance Investigation of Air Handling Units with Return Air Bypass (LB-17-019)
Gang Wang, P.E., Member[1]*, Xuejing Zheng*[2]*, Esber Andiroglu*[1] *and Li Song, Ph.D., P.E., Member*[3]*, (1)University of Miami, Coral Gables, FL, (2)Tianjin University, Tianjin, China, (3)University of Oklahoma, Norman, OK*

The adoption of energy efficient standards significantly cut the energy consumption in buildings by reducing envelope heat transfer and internal heat gain. These energy efficiency measures reduce not only the electrical load but also the cooling load as well as the supply airflow rate. As a result, additional reheat is typically required to maintain the minimum airflow setpoint under partial space cooling loads for conventional air handling units (AHUs) and may degrade the effectiveness of energy efficient measures. The AHUs with return air bypass (RAB) provides an alternative to reduce additional reheating and overcooling at the minimum airflow rate with good space humidity control. The purpose of this paper is to investigate the energy and control performance of the AHUs with RAB under different operating conditions through simulations.

11:00 AM - 12:30 PM

Conference Paper Session 19

Ventilation: A Critical Element from Design through Operation

Track: Fundamentals and Applications NY PDH G

Room: 101B

Chair: Anil Parekh, Member, HBC – CanmetENERGY, Ottawa, ON, Canada

From energy recovery and exhaust hoods, to occupancy and operable windows, this session explores some of the many variables that influence our buildings' ventilation systems.

1. Motorized Windows: A New Approach to Saving Energy in Office Buildings (LB-17-C064)
Niraj Chandra, P.Eng., Member[1] *and Udit Sapre*[2]*, (1)Government of Canada, Gatineau, QC, Canada, (2)Carleton University, Ottawa, ON, Canada*

Mechanical ventilation accounts for a significant portion of the total energy consumption in large office buildings. The air needs to be transported over large distances through ducts, it requires filtration and needs heating and cooling to condition the ventilated space. Most offices in North America have closed windows, and manually opening these windows for natural airflow is discouraged as this can interfere with the operation of the building's HVAC system. The recent drive for energy efficiency has created renewed interest in using natural ventilation to reduce energy consumption. This paper suggests a new approach to natural ventilation by using motorized windows controlled by the Building Automation System (BAS) in existing buildings. This paper presents a detailed breakdown and analysis of the simulation results, including an economic feasibility analysis of the application of BAS-controlled motorized windows.

2. Experimental Study on Influence of Overhang of Exhaust Hood on Ventilation Requirements (LB-17-C065)
Toshiya Iwamatsu, Ph.D., Associate Member[1] *and Wataru Urabe*[2]*, (1)Central Research Institute of Electric Power Industry, Komae, Japan, (2)Central Research Institute of Electric Power Industry, Tokyo, Japan*

The purpose of this research is to elucidate the influence of overhang of an exhaust hood on the capture and containment of the exhaust hood. The capture and containment performance depends on capturing and containing the thermal plume from cooking appliances. Larger exhaust hood openings seem more able to capture thermal plumes even if they expand due to air disturbance. However, provided that the ventilation rate is the same, the face velocity of exhaust hoods is low of the larger exhaust hood openings. This may prevent containment of the thermal plume from cooking appliances. We prepared an electric fryer and an electric noodle cooker. These devices are typical cooking appliances whose thermal plumes are weak and strong, respectively. The capture efficiencies of exhaust hoods were revealed, including the parameters of overhang length of exhaust hood and ventilation rate.

3. Ventilation and Corresponding CO_2 Levels in High School Classrooms (LB-17-C066)
Leigh Lesnick, Student Member*, Atila Novoselac, Ph.D., Member and Richard Corsi, Ph.D., P.E., University of Texas at Austin, Austin, TX*

The K-12 education system is the largest public enterprise in the United States. Public K-12 schools employ approximately three million staff and enroll more than fifty million students. Public schools have an expenditure that includes funds for salaries, benefits, transportation, materials and energy use. Of these expenditures, energy use is often targeted for reduction, which sometimes results in reduced ventilation. While saving energy is desirable, it must be achieved without compromising student health. Lack of proper ventilation can result in a decrease of students' attention and can cause health-related issues. This paper evaluates how the type of heating, ventilation, and air conditioning (HVAC) systems installed in schools and HVAC operation conditions affect temporal and spatial distributions of carbon dioxide (CO_2) concentration in classrooms.

4. The Effects of Temperature and Humidity on the Permeation Properties of Membrane Transport Media Used in Energy Recovery Ventilators (LB-17-C067)

Steven Rogak, Ph.D., P.E.[1], *Amin Engarnevis, Student Member*[1], *Sarah Romani*[1], *Alexander Sylvester, Student Member*[1], *Ryan Huizing, P.Eng.*[2] *and Sheldon Green, Ph.D., P.E.*[1], *(1)University of British Columbia, Vancouver, BC, Canada, (2)dPoint Technologies, Vancouver, BC, Canada*

This paper discusses a systematic experimental study of the effects of operating conditions (i.e. relative humidity and temperature of working air streams) on the transport of water vapor and CO2 (as a major indoor air contaminant) through a series of standard polymeric materials suitable for membrane media used in ERVs'. Results are reported for the permeation experiments of binary mixtures of water vapor and CO2 in five commercial polymers of two major types (glassy and rubber). The selectivity of water vapor over CO2 was also evaluated from permeation experiments. In general, the permeability results suggest that ERV exchangers using polymer membranes can achieve high latent effectiveness (i.e. very high water vapor permeability) over a wide range of operating temperature and relative humidity while maintaining very low CO2 permeability and very low EATR crossover rates (<1%) accordingly.

Wednesday, June 28, 11:00 AM - 12:30 PM

Conference Paper Session 20

District and Central Plant Efficiency

Track: HVAC&R Systems and Equipment NY PDH G

Room: 101A

Chair: Steven Taylor, P.E., Fellow ASHRAE, Taylor Engineering LLC, Alameda, CA

Commonly, buildings exceeding the plant static pressure level experience negative pressure in their tallest parts, allowing air into the system that reduces heat transfer efficiency, causes noise, increases corrosion and consumes much more pumping power. One study sets out to investigate the effect of the wind speed and direction on cooling towers thermal performance. More than 40% of the data center energy consumption is attributed to the cooling system, majority of the CWS are overdesigned to accommodate the maximum projected heat load. A decentralized pumping system is an alternative system that only circulates the minimum water required by the respective terminal unit and can reduce excess pressure loss associated with centralized pumping systems.

1. Comparison of the Energy Saving Potential between Centralized and Decentralized Pumping Systems under Various Flow Conditions (LB-17-C068)

Mingzhe Liu*, Ryozo Ooka, Ph.D., Member, Wonjun Choi, Ph.D., Member and Shintaro Ikeda, University of Tokyo, Tokyo, Japan*

In most HVAC systems, water is usually delivered by several centralized pumps, which may reduce the pumping system's energy efficiency because of unnecessary pressure loss. A decentralized pumping system is an alternative system that only circulates the minimum water required by the respective terminal unit and can reduce the excess pressure loss. This paper verifies the performance of the decentralized pumping system by conducting an experiment comparing centralized and decentralized pump systems under various water flow conditions in terms of their energy consumption in water delivery and their energy saving potential.

2. CFD Investigation on Parameters Affecting the Thermal Performance of Mechanical Draft Cooling Towers in District Cooling Plants (LB-17-C069)

E. M. ElBialy, Ph.D. *and Essam E. Khalil, Fellow ASHRAE, Cairo University, Cairo, Egypt*

District cooling means producing cooled water in a centralized plant and distributing it in pipelines to a number of buildings to cool the air in each building's air conditioning system. This paper investigates the effect of the wind speed and direction on cooling towers' thermal performance. Moreover, the distance between stacks, cooling tower fan speed, and effect of wind barriers were also simulated. A three-dimensional Computational Fluid Dynamics (CFD) model of a power plant cooling towers is utilized to assess the effect of flow circulation air on entering air wet bulb temperature under different ambient conditions and orientations.

3. Large Campus Loop Performance Improvement, Negative Pressure Issue (LB-17-C070)

Robert Henry, P.E.*, Hui Chen, P.E., BEAP, BEMP, CPMP, HBDP and OPMP, Member, Homer Bruner, Member, Klayton Wittler, Elijah Crosby and James Riley, Texas A&M University, College Station, TX*

Texas A&M University's Main campus has its heating and cooling district to provide needs of both heating hot water (HHW) and chilled water (CHW) to over 230 buildings. Commonly, buildings exceeding the plant static pressure level experience negative pressure in their tallest parts, allowing air into the system that reduces heat transfer efficiency, causes noise, and increases corrosion. The negative pressure also results in consuming much more pumping power due to the requirement of lifting water above plant static pressure to above top building coil. This paper identifies the reason for the negative pressure, and a pressure distribution analysis was performed on the campus thermal loop.

4. Evaluating and Improving the Chilled Water System of a Data Center Using Flow Network Modeling (LB-17-C071)

Amir Radmehr, Ph.D.[1], *John Fitzpatrick*[2] *and Kanchan Kelkar, Ph.D.*[3], *(1)Innovative Research, Inc., Plymouth, MN, (2)University of Rochester, Rochester, NY, (3)Innovative Research, LLC, Plymouth, MN*

Chiller plants are commonly used to provide cooling water to data centers. While chiller plants are designed for the maximum projected heat load, majority of data centers produce a fraction of the design load. Chiller plants that operate at partial load may not perform efficiently. Evaluating the performance of a working chiller plant is challenging because of the limited data available at the site. Moreover, it is not possible to know how the system will perform after making an adjustment to improve the efficiency. This paper illustrates the use of a scientific approach based on the Flow Network Modeling (FNM) technique for improving the operating efficiency of a real-life data center in Rochester, NY.

11:00 AM - 12:30 PM

Seminar 57

Dampness and Mold in Homes: Update on Health Effects and Environmental Assessments that Are Useful for Physicians

Track: Residential Buildings: Standards Guidelines and Codes 
Room: 203AB

Sponsor: 1.12 Moisture Management in Buildings, Environ Health // SSPC 62.1 // SSPC 62.2

Chair: Elliott Horner, Ph.D., Member, UL Environment, Marietta, GA

Six recent peer-reviewed papers summarized the current state of knowledge regarding exposure to indoor mold colonization. New information on innate immunity interaction with microbial products offers a plausible mechanism in place of the "all mycotoxin" vs "only allergen" choice. Included in these papers is guidance for clinicians working with an Indoor Environmental Professional (IEP) and guidance for IEPs on what makes a clinically useful and relevant assessment report. The collaboration of IEP and clinician may become routine if the clinician requests assessments when appropriate and if the IEP reports are helpful. Some insurers are already considering the benefit/cost.

1. Key Elements of Relevant and Useful Home Assessments

***Kevin Kennedy, MPH, CIEC, MS, Associate Member**, Children's Mercy Hospitals and Clinics, Kansas City, MO*

Significantly, information on the home environmental is now recognized as often important to the clinical management of respiratory disease. Guidance is presented for clinicians regarding questions they should be asking patients regarding residential conditions associated with dampness and mold, and how clinicians should work with Indoor Environmental Professionals (IEP). Key components are identified that should be included by an IEP in an environmental report if the report is to be useful to a clinician. The importance is stressed of an IEP avoiding making medical inferences and of a clinician not making conclusions about the building.

2. Finally Getting to the Cause: What Is Damp and Mold Doing to Residents?

***Jay Portnoy, M.D.**, Children's Mercy Hospital, Kansas City, MO*

The effects and clinical management of patients with respiratory disease that are exposed to indoor mold colonization are still not fully understood. A recent effort by a Working Group of the American Academy of Allergy compiled six peer-reviewed papers covering responses to fungal products and health effects related to exposure and clinical management. Recent information on the innate immune system and the interaction with various microbial components sheds light on the prevailing controversy of whether health effects associated with damp buildings are due to mycotoxins or allergens. Other microbial products are now seen as likely factors to these respiratory effects.

3. Residential Dampness Assessment: Elements of a Useful Report

***Elliott Horner, Ph.D., Member**, UL Environment, Marietta, GA*

If a home assessment is justified and requested, the report from the Indoor Environmental Professional (IEP) must provide accurate, useful and actionable information. An outline is provided including the necessary criteria for a report. These criteria include, ¨a rationale for each specific activity/measurement/sample, ¨ observations supported by objective evidence, ¨ conclusions prepared by the on-site investigator and incorporating data collected with ¨ priority assignments to any recommendations provided.

Wednesday, June 28, 11:00 AM - 12:30 PM

Seminar 58

Acoustic Performance Standards for Residential Buildings and When They Fall Short

Track: Residential Buildings: Standards Guidelines and Codes 
Room: 201B

Sponsor: 2.6 Sound and Vibration

Chair: Erik Miller-Klein, P.E., Member, A3 Acoustics, LLP, Seattle, WA

This session provides a summary of the current residential building codes and standards, explores areas where occupant complaints are not addressed by existing codes and highlights a new International Organization for Standardization (ISO) standard on the classification of residential buildings based on acoustic performance.

1. Status of Acoustical Standards and Codes in the USA for Residential Buildings

***Cathleen Novak, Associate Member**, Veneklasen Associates, Santa Monica, CA*

Acoustical standards and codes for residential construction are adopted by municipalities that cover the basic level of performance. Though these standards are not always sensibly applied or do they ensure acoustical comfort for the space. Some standards and codes only require referencing design guides and the actual installation and application does not meet the performance intent. This presentation discusses the current state of acoustical standards and codes and the current limitations of these documents.

2. Where Current Standards and Codes Fall Short: Tones and Unsteady Noise from MEP Systems
***Roman Wowk, Associate Member**, Papadimos Group, San Francisco, CA*

Industry standards and building codes that address noise from mechanical, electrical and plumbing (MEP) systems typically limit noise levels but do not adequately address tones or unsteady conditions such as fluctuating or impulsive noise. Such conditions may be difficult to quantify but are a recurring theme when it comes to noise complaints in occupied buildings. This presentation uses recent project examples where discrete tones or unsteady noise from MEP systems resulted in complaints but still complied with current standards and building codes and provides a basic guide to help the practicing engineer recognize and avoid these problems.

3. ISO 19488: Acoustic Classification for Residential Buildings
***Jason Swan, Member**, Sandy Brown Associates, LLP, London, United Kingdom*

The International Organization for Standardization (ISO) has a new standard, 19488, that will create an acoustics label for dwellings, similar to Energy Efficiency Ratings. This will give a residential building a grade of A to F based on its performance in achieving five key acoustic design parameters, including interior noise and exterior noise intrusion. This will help home buyers make decisions about what to buy and will impact the mechanical system design. This seminar summarizes the standard and provides basic recommendations for ensuring internal and external noise levels can be achieved.

Wednesday, June 28, 11:00 AM - 12:30 PM

Seminar 59

Don’t Be Scared: CFD for Everyday Design

Track: Fundamentals and Applications NY PDH G
Room: 202AB
Sponsor: 4.10 Indoor Environmental Modeling
Chair: James W. VanGilder, P.E., Member, Schneider Electric, Andover, MA

CFD is no longer exotic technology used only by ivory-tower experts. It is commonly employed by engineers for routine design of indoor environments ranging from commercial spaces to data centers. This seminar highlights the practical side of CFD through examples such as assessing thermal comfort in general occupied spaces to determining the optimal throw angle for a chilled beam system to using sensitivity analysis to create a robust data center design that performs well under imprecisely-known IT configurations and heat loads.

1. Using CFD Modeling for HVAC System Design
***Steven Thomasson**, Price Industries Limited, Winnipeg, MB, Canada*

This presentation focuses on the use of computational fluid dynamics (CFD) modeling to predict the performance of an air distribution system inside the built environment. The presentation provides an introduction to CFD and how it can be used effectively to study thermal comfort and indoor air quality. A broad range of examples will demonstrate how CFD can be used to tackle common design challenges in the indoor environment including thermal comfort optimization, enhancement of indoor air quality and air volume reduction, all with the aim of reducing the size and energy usage of the air distribution systems.

2. Practical Applications of CFD for Optimizing Chilled Beam Performance
***Ramin Rezaei, Associate Member**, Southland Industries, Dulles, VA*

Chilled beam systems have been used in Europe for many years, but they've only started to be used recently in the United States. In this study, the effect of the active chilled beam systems on flow and temperature distribution in a typical room with occupants has been investigated using CFD. This presentation explains how a detailed three-dimensional analysis helped find an optimum throw angle for mixed supply air ensuring the thermal comfort level and reducing draft risk in the room.

3. Garbage In, Garbage Out: Is Conceptual Data Center CFD Design Any Use?
***Mark Seymour, CEng, Member**, Future Facilities Ltd, London, United Kingdom*

CFD is commonly used for data center design and operational planning. It provides confidence in routine and innovative designs and enables change in a risk averse operational environment. Yet still more do not take advantage of this technology. One barrier is that accurate prediction for an operational data center requires detailed models. In contrast the designer often doesn’t know what the IT configuration will be. So will garbage in be garbage out? This seminar uses simplified studies to show that sensitivity analysis enables the designer to identify efficient and effective designs perform well despite the uncertainties in IT load/configuration.

Wednesday, June 28, 11:00 AM - 12:30 PM

Seminar 60

Power Trends Update: Aligning Future Facility Capability and ITE Power

Track: Fundamentals and Applications NY PDH G

Room: 102AB

Sponsor: 9.9 Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment

Chair: Nick Gangemi, Life Member, Northern Air Systems, Rochester, NY

This seminar presents critical information to improve alignment between future data center needs and IT equipment power and cooling requirements. In today's environment, customers are pivoting to purpose built IT equipment solutions designed for a specific type of workload resulting in distinct power ranges and power trend trajectories. In order to obtain more accurate power range projections, this update to the ASHRAE Datacom Equipment Power Trends and Cooling Applications delineates ITE power ranges and power trend trajectories as a function of workload type, server features and configuration, as well as server size. In this update, this segregation is discussed.

1. Datacom Equipment Workloads, Configurations and Applications

***Matt Archibald, Associate Member**, Lenovo, NY, NY*

In today's environment volume servers are commonly designed for specific workload types. As a result, in the updated edition of the ASHRAE Datacom Equipment Power Trends and Cooling Applications publication, volume servers and their corresponding power trends are segregated into eight unique workload types. This is a significant change from the 2nd edition which delineated the power trends only by server size and the number of sockets. In addition, servers are no longer one size and one configuration fits all. These purpose-built servers include specific features and components sized to meet a customer's workload requirements.

2. Datacom Equipment Power Trends

***Susan Smith, Member**, Intel Corp, Hillsboro, OR*

Volume servers are becoming aligned to specific workload types and server configurations to meet customers' needs. This translates to an increase in server configurations and potentially significantly different power ranges and power trend trajectories even in the same server size. The distinction of servers by workload type and size provides greater accuracy in projecting the power ranges and trends as compared to server size and number of sockets as in the 2nd Edition of the ASHRAE Datacom Equipment Power Trends. This session discusses the updated power trends over the next decade as a function of eight unique workload types.

3. Data Center Solutions and Examples

***Jerrod Buterbaugh**, Lenovo, New York, NY*

The increasing volume server power trends are making it increasing difficult to properly plan for future space, power and cooling needs in the data. This seminar provides assets to help facility planners better understand how to properly apply the updated ASHRAE Datacom Equipment Power Trends and Cooling Applications data. It discusses trends in airflow requirements and how these relate to the data center capabilities for both air and liquid cooling. Examples of how to use these updated guidelines are presented.

11:00 AM - 12:30 PM

Seminar 61

Do You Know What You Are Breathing?: Indoor Air Contaminants

Track: Fundamentals and Applications NY PDH G

Room: 201A

Sponsor: 2.3 Gaseous Air Contaminants and Gas Contaminant Removal Equipment, 2.4 Particulate Air Contaminants and Particulate Contaminant Removal Equipment

Chair: Kyung-Ju Choi, Ph.D., Member, Clean & Science, Louisville, KY

Indoor air contaminants such as PM2.5, dust, smoke, formaldehyde, radon, NOx, SOx, O3, VOCs, sVOCs such as phthalate, odor, airborne allergens, mold, bacteria and viruses have been linked to adverse health effects. This seminar provides information that helps assess the impact of the indoor air contaminants as well as understand current methods of removing them by means of air cleaning devices.

1. Fate and Transport of Phthalates in Indoor Environments and the Influence of Temperature: A Case Study

***Chenyang Bi** and Ying Xu, Ph.D., Associate Member, The University of Texas at Austin, Austin, TX*

A case study in a test house was conducted to investigate the fate and transport of benzyl butyl phthalate (BBzP) and di-2-ethylhexyl phthalate (DEHP) in residential indoor environments and the influence of temperature. Total airborne concentrations of phthalates were sensitive to indoor temperatures, and their steady-state concentration levels increased by a factor of three with

an increase in temperature from 21 to 30 ºC. Strong sorption of phthalates was observed on interior surfaces, including dust, dish plates, windows, mirrors, fabric cloth and wood.

2. Impact of Residential HVAC Filters on Indoor Air Quality

John Zhang, Ph.D., Member*, 3M Personal Care Division, St. Paul, MN*

Filtration and ventilation are commonly used to remove or dilute airborne contaminants and improve indoor air quality. This presentation concentrates on the effectiveness of residential HVAC filters for reducing air contaminants in residential buildings. To assess the efficacy of residential HVAC filters, efficiencies and pressure drops of filters of different MERV levels were first measured according to ASHRAE 52.2. Then an indoor air quality (IAQ) model was applied to characterize health-relevant indoor aerosols in different residences with various combinations of filter types and ventilation conditions. Modeling results are discussed in the presentation.

3. Effectiveness of Residential Air Cleaning Devices in Removal of Particulate and Gaseous Pollutants: A Review

Thad Ptak, Ph.D., Member*, A. O. Smith Corporation, Milwaukee, WI*

Indoor air pollution is an environmental health risk. The methods of reducing concentration of indoor contaminants vary, depending on the design of the air cleaning device, its location and on the contaminant phase. Air cleaning devices can be categorized by the type of contaminant that they remove, particulate and gas phase. This presentation covers recent studies of various filtration methods and their effectiveness in removal of particulate and gas phase pollutants. Test methods used to assess the performance of air cleaning devices are presented and their applicability to various contaminants is discussed.