2021 ASHRAE Virtual Annual Conference

June 28th - June 30th, 2021

Monday, June 28

Monday, June 28, 12:30 PM - 1:30 PM

Seminar 1 (Basic)

Fundamentals of Climate Change

Track: Fundamentals and Applications

Sponsor: 2.5 Global Climate Change, 4.2 Climatic Information , 2.10

Chair: Elizbaeth Tomlinson, P.E., Member, TKDA, St. Paul, MN

As climate change impacts our built environment today, ASHRAE members seek to improve the design of tomorrow's buildings. This June, ASHRAE is publishing the new Fundamentals chapter, Climate Change. Along with climate science and mitigation, the chapter introduces climate adaptation. Planning for tomorrow's climate is a hot topic for public and private owners, consultants and citizens. This session provides an industry update on building design and climate risk management. Presenters include leaders from ASHRAE's 2021 Fundamentals Handbook chapter Climate Change, US Army and International Code Council.

1. Notice: New 2021 Fundamentals Handbook Climate Change Chapter
***Elizabeth Tomlinson, P.E., Member**, TKDA, St. Paul, MN*

2. US Army Installation Climate Resilience
***Steve Dornbos, Ph.D.**, American Association for the Advancement of Science, Milwaukee, WI*

3. Adapting Codes and Standards to Address Changing Climate Risk
***Ryan Colker, J.D.**, International Code Council, Washington, DC*

Monday, June 28, 2:00 PM - 3:30 PM

Seminar 2 (Advanced)

Cleanroom Fan Energy Savings Through Variable Airflow

Track: Design, Control, and Operation of Critical Environments

Sponsor: 9.11 Clean Spaces, MTG.ACR

Chair: Vincent Sakraida, P.E., Associate Member, Skanska, Evansville, IN

This seminar presents the needed design steps for a cleanroom with variable airflow, cleanroom airflow and particulate CFD modeling that illustrates the impact cleanroom variable airflow has on airflow patterns and particulate generation. Speakers present the latest updates on the NEBB Cleanroom Performance Testing standard for testing variable airflow cleanrooms.

1. Real-Time Particle Concentration Sensing to Automatically Control Airflow Rate for Cleanrooms/Labs to Drastically Reduce Fan Energy Consumption
***Wei Sun, P.E., Fellow ASHRAE**, Engsysco Inc., Ann Arbor, MI*

2. CFD Analysis of ACH on Particle Removal Efficiency for Cleanrooms
***Kishor Khankari, Ph.D., Fellow ASHRAE**, AnSight LLC, Ann Arbor, MI*

3. Required Steps for Testing and Balancing a Variable Airflow Cleanroom
***Vincent Sakraida, P.E., Associate Member**, Skanska, Evansville, IN*

2:00 PM - 3:30 PM

Seminar 3 (Basic)

Research Programs and Funding Opportunities Part 1: U.S. Department of Energy (DOE) Building America and Advanced Research Projects Agency-Energy (ARPA-E)

Track: Research Summit

Sponsor: CRC

Chair: Kristen Cetin, Ph.D., P.E., Member, Michigan State University, Okemos, MI

The National Director of the U.S. Department of Energy (DOE) Building America program and Program Director at the Advanced Research Projects Agency-Energy (ARPA-E) provide an overview of current programs, including funding priorities and opportunities. Relevant core programs are also highlighted. Following the presentation, there will be a live Q&A. This session is geared towards researchers, young faculty and senior graduate students pursuing academic careers at U.S. institutions, but the information provided is valuable to principal investigators in any stage of their career. This is Part 1 of a 2 part series.

1. Arpa-E Investments in Building Energy Efficiency
***Marina Sofos, Ph.D.**, Advanced Research Projects Agency-Energy, Washington, DC*

2. U.S. Department of Energy Building America Program Overview
***Eric Werling, Member**, U.S. Department of Energy, Washington, DC*

2:00 PM - 3:30 PM

Seminar 4 (Intermediate)

Solving BACnet/SC Management Challenges with Managed BACnet

Track: HVAC&R Systems and Equipment

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

Chair: Carol Lomonaco, Member, Johnson Controls, Milwaukee, WI

BACnet has grown since its inception, to become the standard for control systems. As devices using the recently released BACnet/SC (Secure Connect) make their way to enterprise networks, challenges arise for BAS and IT. Challenges to interoperably and securely managing their fleet of devices. This seminar provides critical information on plans in the BACnet ecosystem to secure the entire BACnet stack. The seminar discusses stakeholders that will be involved in these systems and explains the components of a new initiative called Managed BACnet designed to provide an IT-centric holistic cybersecurity framework for building automation and control systems.

1. Evolution of Cybersecurity in BACnet from Inception to Mass Deployment
***James Lee**, Cimetrics, Inc., Boston, MA*

2. The Landscape of Stakeholders in Fully Managed and Secure Control Systems
***Anto Budiardjo**, Cimetrics, Inc., Asheville, NC*

3. Components of a Managed BACnet System You Need to Care about
***Ken Gilbert**, Automated Logic, Kennesaw, GA*

Monday, June 28, 4:00 PM - 5:00 PM

Panel 1 (Intermediate)

Maintaining Control during a Pandemic: Lessons Learned from Adapting Building Automation Systems to Meet Changing Recommendations

Track: Fundamentals and Applications

Sponsor: 1.4 Control Theory and Application

Chair: Elise Backstrom, Associate Member, Exyte U.S, Inc., Phoenix, AZ

Panelists speak to experience on changing control strategies and adapting building automation systems for the COVID pandemic, as well as discuss key take aways and lessons learned potentially applicable for future situations.

1. Panelist1
***Christopher Benson, P.E., Member**, The University of Utah, Salt Lake City, UT*

2. Panelist2

***JoeDon Breda, P.E.**, Ohio State University Medical Center, Columbus, OH*

3. Panelist3
***Anthony Bermudez**, Russell Sigler, Inc., Riverside, CA*

4:00 PM - 5:00 PM

Panel 2 (Basic)

What do Indoor Farmers Need and Want from their HVAC System?

Track: HVAC&R for Indoor Plants & Animals

Sponsor: 2.2 Plant and Animal Environment, MTG-CEA

Chair: Nadia Sabeh, Ph.D., P.E., Associate Member, Dr. Greenhouse, Inc., Sacramento, CA

Controlling the indoor plant environment is vital for producing healthy and productive crops indoors. The HVAC system must not only control temperature, humidity, and airflow, it also needs to stay within budget, fit within the building and site constraints, and be relatively easy to operate and maintain. Our group of panelists have grown a variety of plants in greenhouses, vertical farms, and repurposed buildings, all of which have unique design criteria and operating requirements.

1. I Grow Cannabis in an Old Orange Packing Facility in California
***Wayne Bishop**, 7 Points, Woodlake, CA*

2. I Grow Cannabis, Tomatoes, and Flowering Plants in Oklahoma
***Jay Whitney**, Alterra Wellness, Haskell, OK*

3. I Transformed a Target Store into a Vertical Farm
***Jake Counne**, Wilder Fields, Calumet City, IL*

4:00 PM - 5:00 PM

Forum 1 (Intermediate)

Is there a Magic Formula for Combining Multiple Air Cleaning Technologies to Improve Air Quality?

Track: HVAC&R Systems and Equipment

Sponsor: 2.3 Gaseous Air Contaminants and Gas Contaminant Removal Equipment, 2.9 Ultraviolet Air and Surface Treatment

Chair: Ashish Mathur, Ph.D., UVDI, Valencia, CA

There are multiple air cleaning technologies being used in the industry to improve IAQ in various combinations. These include particle filtration, activated carbon , photo-catalytic oxidation, UVGI and ionizers. With so many technologies to choose from and a lack of published literature or industry guidance, it becomes confusing for the design engineer to specify an appropriate technology combination. This workshop reviews how multiple air cleaning technologies are combined today and discusses the unanswered questions. The workshop also elicits industry feedback to determine what research/test methods/guidelines need to be developed to evaluate the combination of these technologies.

4:00 PM - 5:00 PM

Forum 2 (Intermediate)

Post Pandemic Resiliency Measures for Transportation Facilities

Track: Future Proofing - Renewable, Regenerative, and Resilient

Sponsor: 5.9 Enclosed Vehicular Facilities

Chair: Jesse Harder, P.E., Member, HNTB Corporation, Oakland, CA

With the emergence of COVID-19, transportation agencies must provide safe and healthy transit mobility. Appropriate safety measures, procedures and protocols, if implemented, can promote safe public transit and increase the resiliency of systems. The probability of contagion spread in an enclosed space can be determined with numerical modeling tools and testing. Effective measures aim to achieve a sustained reduction of the viral load in the air we breathe. This forum explores mechanical ventilation and air sanitization measures which are principal systems to support safe enclosed environments; in the transit industry this is especially applicable to enclosed vehicles, stations and facilities.

Monday, June 28, 7:00 PM - 8:30 PM

Seminar 5 (Intermediate)

Impact of IoT on Building Controls

Track: HVAC&R Systems and Equipment

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

Chair: Carol Lomonaco, Member, Johnson Controls, Milwaukee, WI

Commercial buildings have for some time been controlled by building management systems that monitor and control equipment. Newer to that market are enabled pieces of equipment with embedded factory installed IoT controls that can intelligently control themselves throughout their operation with minimal input from a supervisory controller or building management workstation software. With this comes the inclusion of intelligent sensors for temperature, humidity, etc. which facilitates this new technology and has created an opportunity for some buildings to operate even more efficiently. This IoT technology has opened buildings up to potential risks in security that need to be recognized.

1. Cybersecurity for the Connected Commercial Building
***Patrick Villaume, Member**, Patterson Kelley, East Stroudsburg, PA*

2. Cultural Changes Are Needed for IoT Cybersecurity in Commercial Buildings
***Fred Gordy, Member**, Intelligent Buildings, LLC, Villa Rica, GA*

7:00 PM - 8:30 PM

Seminar 6 (Basic)

Plant and Animal Environments: What Makes Them So Unique?

Track: HVAC&R for Indoor Plants & Animals

Sponsor: 2.2 Plant and Animal Environment, MTG-CEA

Chair: Nadia Sabeh, Ph.D., P.E., Member, Dr. Greenhouse Inc., Sacramento, CA

They are not human environments. Metabolic heat rates are different. Ventilation rates are different and so are the temperature and humidity targets. This seminar covers the unique considerations for designing and operating an HVAC system for a vertical farm, primary enclosure or animal shelter.

1. Why We Carrot All: Berry Important Conditions for Growing Plants Indoors
***Nadia Sabeh, Ph.D., P.E., Member**, Dr. Greenhouse Inc., Sacramento, CA*

2. Moooving Air and Making Cows (and other farm animals) Comfortable
***Morgan Hayes, Ph.D., Affiliate**, University of Kentucky, Lexington, KY*

3. Meow What? Addressing Unique Design Conditions for Companion Animal Spaces
***Niss Feiner, CHD, Member**, Delta-T Designs, Oro-Medonte, ON, Canada*

4. Ten Cardinal Parameters of Plant Health and Vitality
***Jesse Porter, Member**, InSpire Transpiration Solutions, San Francisco, CA*

5. 10 Cardinal Parameters of Plant Health and Vitality
***Robbie Batts, Affiliate**, InSpire Transpiration Solutions, San Francisco, CA*

Tuesday, June 29

Tuesday, June 29, 7:00 AM - 8:30 AM

Seminar 7 (Basic)

COVID-19 Particle Removal by Air Filter Devices

Track: Fundamentals and Applications

Sponsor: 2.4 Particulate Air Contaminants and Particulate Contaminant Removal Equipment

Chair: Kyung-Ju Choi, Ph.D., Member, Clean & Science, Louisville, KY

The COVID-19 virus attaches to mucus protein molecules in water droplets or to small particles that are larger than the virus itself. This seminar provides the basic principles of filtration to prevent COVID-19 spread and to describes the effectiveness of face coverings.

1. A Study of Viral Filtration Performance of Residential HVAC Filters
***John Zhang, Ph.D., Member**, 3M, St. Paul, MN*

2. Measuring the Performance of Community Face Coverings in Europe and Beyond
***Paolo Tronville, Ph.D., Fellow ASHRAE**, Politecnico di Torino, Torino, Italy*

3. Laboratory Test Data Comparison on Commonly Used Face Coverings
***Robert Singer, Member**, Blue Heaven Tech, Louisville, KY*

7:00 AM - 8:30 AM

Seminar 8 (Intermediate)

Energy Management Best Practices, Case Studies and Lessons Learned from Real-world Data Center Operation

Track: Design, Control, and Operation of Critical Environments

Sponsor: 9.9 Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment, 7.6 Building Energy Performance , TC 7.3, TC7.5

Chair: Eric Yang, P.E., Member, Energy System Group, Washington, DC

This session includes energy management best practices, case studies and lessons learned from real-world data center operation. Presentations address how controls systems, smart building technologies and data analytics are helping data centers operate more efficiently and reliably via real world examples and case studies. Common pitfalls in the data center operation are also discussed.

1. Harnessing the Power of Data Analytics for Reliable and Efficient Data Center Operations at LBNL's High-Performance Computing (HPC) Center
***Jingjing Liu, P.E., BEAP**, Lawrence Berkeley National Laboratory, Berkeley, CA*

2. Is Your Legacy Data Center Ready to Improve Energy Efficiency through the Use or Data Analytics, AI/ML and Intelligent Controls Optimization?
***John Dumler, P.E., Member**, Digital Realty, Atlanta, GA*

3. Classic Pitfalls to Avoid in Data Center Operation
***Mark Seymour, P.E., Member**, Future Facilities, London, United Kingdom*

Tuesday, June 29, 12:00 PM - 2:00 PM

Seminar 9 (Advanced)

Is More Better? Air Change Rate for Health Hazard Control in Critical Environments

Track: Design, Control, and Operation of Critical Environments

Sponsor: MTG.ACR, 9.6 Healthcare Facilities , 9.10 Laboratory Systems

Chair: James Bennett, Ph.D., Member, CDC/NIOSH, Cincinnati, OH

The impact of Air Change Rate (ACH) on contaminant control is intuitively positive. However, many indoor environments are greatly affected by variables that ACH may obscure. Airborne pathogen removal effectiveness in critical environments is one instance. The high-occupancy of aircraft cabins or the low-occupancy of operating or patient rooms both have high prescribed ACH but possibly differing levels of protection. While higher ACH is generally protective, negatives include faster build-up to maximum contaminant concentration, higher local velocities and turbulence for contaminant spread, and, exposure to younger more viable pathogens. These limitations will be explored in healthcare, transportation and industrial settings.

1. Moving Beyond More Is Better Toward Data-Driven Design and Commissioning
***Travis English, P.E., Member**, Kaiser Permanente, Anaheim, CA*

2. ACH: The Wrong Infection Control Parameter; Low RH: Too Long Ignored
***Douglas Walkinshaw, Ph.D., P.E., Fellow Life Member**, Indoor Air, Ottawa, ON, Canada*

3. Variables That Surpass ACH in Laboratory and Healthcare Environments
***Kishor Khankari, Ph.D., Fellow ASHRAE**, AnSight LLC, Ann Arbor, MI*

4. Looking Past Air Change Rate to Achieve Effective Ventilation
***James Bennett, Ph.D., Member**, CDC/NIOSH, Cincinnati, OH*

12:00 PM - 2:00 PM

Seminar 10 (Intermediate)

Occupants, Building Operation and Environment During COVID-19

Track: Future Proofing - Renewable, Regenerative, and Resilient

Sponsor: 2.1 Physiology and Human Environment

Chair: Shichao Liu, Ph.D., Associate Member, Worcester Polytechnic Institute, Worcester, MA

The COVID-19 pandemic has been momentously disrupting many facets of our daily life, including indoor environmental quality, the ways to design and operate building mechanic systems, psychological well-being, learning and even planning and operational performance due to social distancing. This seminar aims to share with stakeholders the insights of these influenced facets supported by data collection during COVID-19. A surge of research documenting, including the four talks in this seminar, prepare us better for future pandemics.

1. Impact of Noise on Occupants in Multi-Unit Residences during COVID-19
***Maedot Andargie**, University of Toronto, Ontario, ON, Canada*

2. Resilient Features of HVAC System Design and Operation during a Pandemic
***Chandra Sekhar, Ph.D., Fellow ASHRAE**, National University of Singapore, Singapore, Singapore*

3. How Indoor Environment and Stress Affect Online Learning during COVID-19
***Shichao Liu, Ph.D., Associate Member**, Worcester Polytechnic Institute, Worcester, MA*

4. The Role of Distance in Planning and Operational Performance for Voting Systems
***Jennifer Lather, Ph.D., Associate Member**, University of Nebraska-Lincoln, Omaha, NE*

12:00 PM - 2:00 PM

Seminar 11 (Intermediate)

The State of the Art of Thermally Driven Heat Pumping and Cooling System in the Age of Decarbonization

Track: Future Proofing - Renewable, Regenerative, and Resilient

Sponsor: 8.3 Absorption and Heat Operated Machines, 6.7 Solar Energy Utilization , TC6.7

Chair: William Ryan, Ph.D., P.E., Member, University of Illinois at Chicago, Chicago, IL

This seminar covers information on any absorption or other heat operated system used for cooling and/or heating, for domestic hot water, space conditioning or industrial applications and focuses on how these technologies can participate and can be correctly evaluated on both efficiency and environmental terms in a low carbon future.

1. Design Optimization of a Thermally Integrated Solid Oxide Fuel Cell and Triple Effect Absorption Chiller
***Alejandro Lavernia, Student Member**, Advanced Power and Energy Program at University of California Irvine, Irvine, CA*

2. A Better Solution for Decarbonizing Building Heat?
***Michael Garrabrant, Member**, Stone Mountain Technologies, Johnson City, TN*

3. Ultra-Efficient Membrane-Based Ionic Liquid Dehumidification System
***Saeed Moghaddam, Ph.D.**, University of Florida, Nanoengineered Energy Systems (NES) Laboratories, Gainesville, FL*

4. Hybrid Design of a Distribution Warehouse in Coal Country USA
***Douglas Davis, Member**, Caribbean - Antilles Power Depot, Sab Juan, PR*

12:00 PM - 2:00 PM

Seminar 12 (Advanced)

Up, Down and All Around: Modeling Airflow in Indoor Plant and Animal Environments

Track: HVAC&R for Indoor Plants & Animals

Sponsor: 2.2 Plant and Animal Environment, 4.10 Indoor Environmental Modeling , MTG-CEA

Chair: Nadia Sabeh, Ph.D., P.E., Associate Member, Dr. Greenhouse, Inc., Sacramento, CA

The global human population is projected to reach nearly 10 billion people over the next 20 years. Indoor farming provides an innovative solution to help meet the growing demands for food, by allowing year-round production of crops and livestock in a controlled environment. Air distribution is essential for creating a healthy and productive environment for plants and animals, which are frequently produced in high densities. This session introduces the challenges of distributing conditioned air in plant and animal environments and presents strategies for creating uniform conditions based on simulation studies using computational fluid dynamics (CFD).

1. The Challenges of Distributing Air in an Indoor Plant Environment
***Nadia Sabeh, Ph.D., P.E., Associate Member**, Dr. Greenhouse, Inc., Sacramento, CA*

2. Analysis and Enhancement of Environmental Uniformity in CEA Production System
***Murat Kacira**, Dr. Greenhouse, Inc., Sacramento, CA*

3. Modeling Air Distribution in a Vertical Farm Using Computational Fluid Dynamics
***Christian Rohr**, CPP Wind Engineering Consultants, Windsor, CO*

4. Ventilation Challenges for Animal Environments
***Joe Zulovich, Ph.D., P.E., Affiliate**, University of Missouri, Columbia, MO*

5. Animal Processing Facilities: Increasing Effectiveness of HVAC Air Distribution Using CFD
***Steven Thomasson, Member**, Price Industries, Winnipeg, MB, Canada*

Tuesday, June 29, 3:00 PM - 4:00 PM

Seminar 13 (Intermediate)

Update on Progress of the Task Force on Building Decarbonization

Track: Future Proofing - Renewable, Regenerative, and Resilient
Chair: Don Brandt, Member, Trane, Inc. (Retired), Phoenix, AZ
The Task Force on Building Decarbonization was formed by President Chuck Gulledge and President Elect Mick Schwedler in Feb of 2021 under the leadership of presidential members Don Colliver and Tom Phoenix. We have broken the members down into 12 teams to tackle the responsibilities to which we have been assigned, including providing recommendations on best practices, identifying existing and developing new resources, and bringing ASHRAE's technical expertise to the policy discussion. This seminar addresses how ASHRAE is bringing its unique perspective to address one of our industry's most challenging climate questions of the 21st century.

1. Placeholder1
***Placeholder Speaker**, ASHRAE, Atlanta, GA*
2. Placeholder2
***Placeholder Speaker**, ASHRAE, Atlanta, GA*

Tuesday, June 29, 4:00 PM - 5:00 PM

Panel 3 (Basic)

All Animals Are Not Created Equal

Track: HVAC&R for Indoor Plants & Animals
Sponsor: 2.2 Plant and Animal Environment
Chair: Morgan Hayes, Ph.D., Affiliate, University of Kentucky, Lexington, KY
Ventilation for animal spaces are challenging and vary significantly between species. This panel allows engineers who focus on environmental control animal spaces to discus their approaches and targets when building environments for these animals.

1. Animal Energetics/Beef Production
***Tami Brown-Brandl, Ph.D.**, University of Nebraska, Lincoln, NE*
2. Swine Production
***Brett Ramirez, Ph.D., Member**, Iowa State University, Ames, IA*
3. Poultry Production
***Richard Gates**, Iowa State University, Ames, IA*
4. Economics/Dairy Production
***Joe Zulovich, Ph.D., P.E., Affiliate**, University of Missouri, Columbia, MO*

4:00 PM - 5:00 PM

Panel 4 (Intermediate)

Is Controlled Environment Agriculture the Future of Secure and Sustainable Food Production?

Track: HVAC&R for Indoor Plants & Animals
Sponsor: 2.2 Plant and Animal Environment
Chair: Nadia Sabeh, Ph.D., P.E., Associate Member, Dr. Greenhouse, Inc., Sacramento, CA
How will we feed 9 Billion people on earth in 2050 in the face of climate variability, water scarcity, soil depletion and mass migrations? Will space travelers carry their food or grow their food on long missions to Mars and beyond? This panel of experts discusses the challenges and opportunities of using controlled environment agriculture (CEA) to secure food production with fewer resources and in more extreme conditions.

1. The Future of Growing Food for Humans on Earth and in Space
***Gene Giacomelli**, University of Arizona, Tucson, AZ*
2. Securing Food Production in the North Arctic
***Corey Ellis**, The Growcer, Ottowa, ON, Canada*

3. Cultivating Insects to Feed 9 Billion
***Lydia Palma Miner, Ph.D.**, Dr. Greenhouse Inc., Sacramento, CA*

4:00 PM - 5:00 PM

Panel 5 (Basic)

To Serve Humanity: The Efforts of ASHRAE Chapters to Help Reduce Risks of Building Related COVID-19 Transmissions

Track: Future Proofing - Renewable, Regenerative, and Resilient

Sponsor: 7.3 Operation and Maintenance Management, Environmental Task Force

Chair: Sonya Pouncy, Member, Building Vitals, Detroit, MI

The ASHRAE mission is "to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration and their allied fields." How do we do that, in general? And, how do we do that in the face of a foe like COVID-19? Panelist members from 5 chapters and 3 countries discuss their chapters' efforts to be a technical resource to their local communities as they respond to pandemic. Panelists share their strategies, what worked and what didn't, as well as future planned efforts to raise the profile and reliance on ASHRAE at local community levels.

1. Brazil Chapter's Experience
***Felipe Accorsi, Member**, LG Electronics, Porto Alegre, Brazil*

2. Toronto Chapter's Experience
***Doug Cochrane, P.E., Member**, Independent, Toronto, ON, Canada*

3. Gold Coast Chapter's Experience
***John M Constantinide, P.E., Member**, Independent, Merritt Island, FL*

4. Montreal Chapter's Experience
***Audrey Dupuis, Member**, Pageau Morel, Montreal, QC, Canada*

5. Detroit Chapter's Experience
***Sonya Pouncy, Member**, Building Vitals, Detroit, MI*

4:00 PM - 5:00 PM

Panel 6 (Intermediate)

Walking the Talk: Achieving Verified Net Zero Goals and Why It Matters

Track: Future Proofing - Renewable, Regenerative, and Resilient

Chair: Selina Holmes, U.S. Green Building Council, Washington, DC

In 2020, a year when public health and safety was paramount, net zero goals also rose to the forefront as many prioritized climate action in their COVID-19 recovery strategies. In the first nine months of 2020, the number of net zero emissions commitments roughly doubled totaling 823 cities, 101 regions and 1,541 companies. This panel discussion focuses on buildings as the top contributor to global CO2 emissions and USGBC's LEED Zero program. Panelists discuss the impact and cost of strategies implemented by building projects to achieve LEED Zero certification in water, energy, carbon and waste.

1. Walking the Talk: Achieving Verified Net Zero Goals and Why It Matters Panelist 1
***Emma Hughes**, U.S. Green Building Council, Washington, DC*

2. Walking the Talk: Achieving Verified Net Zero Goals and Why It Matters Panelist 2
***Guido Petinelli**, Petinelli Inc., Curitiba, Brazil*

3. Walking the Talk: Achieving Verified Net Zero Goals and Why It Matters Panelist 3
***Chris Ladner**, Entegrity, Little Rock, AR*

Tuesday, June 29, 7:00 PM - 8:30 PM

Seminar 14 (Intermediate)

Reducing Ozone: A Critical Factor in Improving IAQ

Track: Fundamentals and Applications

Sponsor: 2.3 Gaseous Air Contaminants and Gas Contaminant Removal Equipment

Chair: Kyung-Ju Choi, Ph.D., Member, Clean & Science, Louisville, KY

Ozone has adverse health effects such as lung diseases, asthma and increased mortality. Moreover, ozone oxidation byproducts such as carbonyls, formaldehyde and secondary organic aerosols can be more harmful than ozone itself. ASHRAE Standard 62.1-2019: Ventilation for Acceptable Indoor Air Quality, requires the minimum ozone removal efficiency to be 40%, and that the

ozone concentration limit be lowered down to 100 ppb. It is critically important to reduce the ozone concentration in indoor environments.

1. Performance of Ozone Removal Air Cleaning Devices
***Mengjia Tang**, The University of Texas at Austin, Austin, TX*
2. Beyond Ozone: Cleaning Outdoor Air for IAQ
***Chris Muller, Member**, Muller Consulting, Lawrenceville, GA*
3. Ozone Emission Sources and Surface Removal in Indoor Environments
***Jialei Shen, Student Member**, Syracuse University, Syracuse, NY*
4. Impact of Operating Conditions on Performance of Ozone Removal Air Cleaning Devices
***Atila Novoselac, Member**, University of Texas at Austin, Austin, TX*

Wednesday, June 30

Wednesday, June 30, 7:00 AM - 8:30 AM

Seminar 15 (Intermediate)

Development of Reference Building Information Model (BIM) Test Cases for Improving Usage of Software Interoperability Schemas

Track: Future Proofing - Renewable, Regenerative, and Resilient
Sponsor: 1.5 Computer Applications, MTG.BIM Building Information Modeling
Chair: Stephen Roth, P.E., Member, Carmel Software, San Rafael, CA
This seminar discusses the results of ASHRAE RP-1810 "Development of Reference Building Information Model (BIM) Test Cases for Improving Usage of Software Interoperability Schemas". The key objective of this research project was to develop a series of standardized test cases for BIM and building performance software tool vendors to employ so as to ensure that valid modelling data can be used by other building performance software. This research project also included the development of a robust, accessible, web-based validation software tool for simple data validation and basic model checking.

1. Why BIM and BEM Software Interoperability Is More Important Than Ever and the Research behind It
***Stephen Roth, P.E., Member**, Carmel Software, San Rafael, CA*
2. Discuss Why Schema Validation Is so Important for Successful BIM to BEM Workflows
***Weili Xu, Ph.D., Associate Member**, BuildSimHub, Pittsburgh, PA*
3. Discuss the Overall Goals of ASHRAE RP-1810 and How They Were Accomplished
***Krishnan Gowri, Ph.D., BEMP, Fellow ASHRAE**, Intertek Building Science Solutions, Bothell, WA*

Wednesday, June 30, 11:30 AM - 1:30 PM

Seminar 16 (Intermediate)

Fault Detection and Diagnosis in Guidelines and Specifications and Their Application

Track: Future Proofing - Renewable, Regenerative, and Resilient
Sponsor: 7.5 Smart Building Systems
Chair: Liping Wang, Ph.D., P.E., Member, University of Wyoming, Laramie, WY
Common faults in building systems can result in high maintenance costs, occupant discomfort, and energy waste. Fault detection and diagnosis (FDD) in building systems detect and identify operational faults based on the analysis of measured system behaviors. This seminar updates attendees on the FDD resources in ASHRAE Guideline 36 and Energy Management and Information System from Lawrence Berkeley National Lab and demonstrates the implementation of the fault auto-correction algorithms in FDD software products and field testing results.

1. New Resources for Fault Detection and Diagnostics Application in Commercial Buildings
***Guanjing Lin, Ph.D., Associate Member**, Lawrence Berkeley National Laboratory, Berkeley, CA*
2. Guideline 36: Automatic Fault Detection and Diagnostics for VAV AHU
***Justin Mezzadri**, Carrier, Charlotte, NC*
3. Development and Implementation of Fault-Correction Algorithms in Fault Detection and Diagnostics Tools
***Yimin Chen**, Lawrence Berkeley National Lab, Berkeley, CA*

11:30 AM - 1:30 PM

Seminar 17 (Intermediate)

Grid-Interactive Buildings: Impacts on Energy Use and Comfort

Track: Research Summit

Sponsor: 7.5 Smart Building Systems, 1.4 Control Theory and Application , 7.6 Building Energy Performance

Chair: Michael Brambley, Ph.D., Fellow Life Member, Pacific Northwest National Laboratory, Richland, WA

As more variable renewable wind and solar photovoltaic power generation is added to the electric power grid, management of building power demand will likely be increasingly looked upon as one of the ways to compensate for the variability of both solar and wind power. This seminar explores approaches being used currently and under development to control building demand for this purpose with a special focus on impacts on energy consumption, efficiency and comfort in grid-interactive buildings. This seminar includes two presentations on commercial buildings and one on homes.

1. Using Electricity Markets to Value Tradeoffs between Energy Consumption and Flexibility
***David Blum, Ph.D.**, Lawrence Berkeley National Laboratory, Berkeley, CA*

2. What Are the Impacts on the HVAC System When It Provides Frequency Regulation?: A Comprehensive Case Study with a Medium Office Building
***Zheng O'Neill, Ph.D., P.E., Member**, Texas A&M University, College Station, TX*

3. Demand Reduction and Energy Impacts in Grid-Interactive Homes
***Austin Rogers, Ph.D., Affiliate**, Pacific Northwest National Laboratory, Richland, WA*

11:30 AM - 1:30 PM

Seminar 18 (Intermediate)

Update on the ANSI Z9.5 Laboratory Ventilation Standard

Track: Design, Control, and Operation of Critical Environments

Sponsor: 9.10 Laboratory Systems

Chair: James Coogan, P.E., Associate Member, Siemens Smart Infrastructure, Chicago, IL

need to rework this --- The Laboratory Ventilation Standard, ASSP Z9.5, is in revision, with publication expected in 2022. The seminar discusses the version currently in public review. One speaker explores what changes will mean for organizations using the standard. The session also addresses the relationship to other standards.

1. Changes in the Standard from the View of a Safety Officer
***Markus Schaufele**, Northwestern University, Evanston, IL*

2. ANSI Z9.5 and Ductless Hood Performance Requirements
***Kenneth Crooks**, Erlab, Inc., Rowley, MA*

3. Relationships between Z9.5 and Other Standards
***James Coogan, P.E., Associate Member**, Siemens Smart Infrastructure, Chicago, IL*

Wednesday, June 30, 2:00 PM - 3:00 PM

Seminar 19 (Basic)

Infrared Heating and Grow Facilities

Track: HVAC&R for Indoor Plants & Animals

Sponsor: 6.5 Radiant Heating and Cooling, 2.2 Plant and Animal Environment

Chair: Devin Abellon, P.E., Member, Uponor, Centennial, CO

This seminar explains the effectiveness of Infrared Radiant heat systems for large areas such as grow facilities, aircraft hangars, distribution centers, manufacturing areas and warehouses. Infrared heating has an added benefit over forced air heating in that, there is the infrared factor. This, along with re-radiance, is described in detail during this seminar.

1. Infrared Heating
***Kevin Mahoney**, Specified Air, Comstock Park, MI*

2. Applying Gas-Fired Infrared Radiant Heat in Greenhouses, Including Cannabis Greenhouses
***Don Larsson, Member**, Specified Air Solutions, Virginia Beach, VA*

2:00 PM - 3:00 PM

Seminar 20 (Basic)

Leadership Skills and Management Skills: You Need Both!

Track: Professional Development

Sponsor: 1.7 Business, Management & General Legal Education

Chair: Pam Duffy, P.E., Member, Spark One Solutions, LLC, Dallas, TX

Many engineers never receive formal leadership or people management training. Developing yourself to become the leader and manager you have the potential to be will change everything for you, your team and your business. It will add to your effectiveness, subtract from your weaknesses, divide your workload and multiply your impact. Get 20 lessons in leadership and management in 60 minutes from two ASHRAE Distinguished Lecturers.

1. Ten Lessons to Develop Your Leadership in 30 Minutes
***Karine Leblanc, Member**, USACD, Industry, CA*

2. Ten Tips to Becoming a Better Manager
***Pam Duffy, P.E., Member**, Spark One Solutions, LLC, Dallas, TX*

2:00 PM - 3:00 PM

Seminar 21 (Basic)

Research Programs and Funding Opportunities Part 2: U.S. Department of Energy (DOE) Building Technologies Office (BTO) and the National Science Foundation (NSF)

Track: Research Summit

Sponsor: CRC

Chair: Kristen Cetin, Ph.D., P.E., Member, Michigan State University, East Lansing, MI

Representatives from the National Science Foundation (NSF) Civil, Mechanical and Manufacturing Innovation Division (CMMI), and from the U.S. Department of Energy Building Technologies Office provide an overview of current programs, including funding priorities and opportunities. Relevant core programs are also highlighted. Following the presentation, there will be a live Q&A. This session is geared towards researchers, young faculty and senior graduate students pursuing academic careers at U.S. institutions, but the information provided will be valuable to principal investigators in any stage of their career. This is Part 2 of a 2 part series.

1. Research Programs, Initiatives and Opportunities at Doe's Building Technologies Office
***Amir Roth**, Department of Energy, Washington, DC*

2. Research Overview and Funding Opportunities within the National Science Foundation
***Caglar Oskay**, National Science Foundation, Washington, DC*

2:00 PM - 3:00 PM

Seminar 22 (Intermediate)

Smoother Workflow for Controls Sequence Delivery: Standardizing and Digitizing the Process of Controls Sequences

Track: Fundamentals and Applications

Sponsor: 1.4 Control Theory and Application, 2.8 Building Environmental Impacts and Sustainability

Chair: Taraneh Shoorideh, P.E., Member, P2S Inc, Long Beach, CA

This session includes two talks, connected with the mutual theme of making the design, programing, implementation and delivery of control system standard and digitize, and overall smoother. The first speaker describes Guideline 36-High-Performance Sequence of Operation for HVAC system and lessons learned from implementation of this guideline. The second speaker describes the new efforts from ASHRAE 231P and DOE to develop a tool and process to digitize the controls delivery.

1. Using Guideline 36 and Getting Better at It
***Jim Coogan, P.E., Member**, Siemens Building Technology, Buffalo Grove, IL*

2. Digitizing the Process of Controls Sequence Design and Delivery
***Paul Ehrlich, P.E., Member**, Building Intelligence Group, Portland, OR*

Conference Paper Session (On-Demand)

Conference Paper Session 1 (Intermediate)

Impact of COVID-10 on Energy Consumption and Grid-Interactive Efficient Buildings

Track: Future Proofing - Renewable, Regenerative, and Resilient

This session begins with a discussion of the impacts of COVID-19 on the energy usage and performance of residential buildings. The third paper focuses on the climate analysis for future heat waves, which can have catastrophic effects causing mortality, grid failures, and increase in electricity consumption. The remainder of the papers focus on topics related improving building design method and performance, such as electrification of space heating, model-based operational optimization, characterization of grid interactive building stock, and threat assessment. The session concludes with findings from the development and implementation of a novel DC-powered picogrid to optimize residential energy consumption.

1. Investigation of the Impacts of COVID-19 on the Electricity Consumption of a University Dormitory (VC-21A-C001)
Zhihong Pang, Student Member *and Zheng O'Neill, Ph.D., P.E., Member, Texas A&M University, College Station, TX*

2. Impacts of COVID-19 on Residential Building Energy Usage and Performance (VC-21A-C002)
Emily Kawka, Student Member *and Kristen Cetin, Ph.D., P.E., Member, Michigan State University, East Lansing, MI*

3. A Flexible and Generic Functional Mock-up Unit Based Threat Injection Framework for Grid-Interactive Efficient Buildings (VC-21A-A001)
Yangyang Fu, Ph.D., Member[1]*, Zheng O'Neill, Ph.D., P.E., Member*[1]*, Jin Wen, Ph.D., Member*[2] *and Veronica Adetola, Ph.D., Member*[3]*, (1)Texas A&M University, College Station, TX, (2)Drexel University, Philadelphia, PA, (3)Pacific Northwest National Laboratory, Richland, WA*

4. Design and Implementation of a DC-Powered Local Weather Station Picogrid for Optimal Energy Management in a Residential Building (VC-21A-C003)
Jonathan Ore, Student Member[1]*, Aaron Farha, Student Member*[1]*, Davide Ziviani, Ph.D., Member*[2] *and Eckhard Groll, Dr.Ing., Fellow ASHRAE*[2]*, (1)Purdue University, United States of America, West lafayette, IN, (2)Purdue University, West Lafayette, IN*

5. Electrifying Space Heating in Existing Commercial Buildings: Opportunities and Challenges (VC-21-C004)
Christopher Perry, P.E., Member[1] *and Steven Nadel*[2]*, (1)American Council for an Energy Efficient Economy (ACEEE), Washington, DC, (2)American Council for an Energy Efficient Economy, Washington, DC*

6. Implementation and Calibration of Grey-Box Models to Optimize Operation of Educational Buildings in Canada (VC-21A-C005)
Navid Morovat, Student Member[1]*, José Agustín Candanedo, Ph.D., Member*[2] *and Andreas K Athienitis, Fellow ASHRAE*[1]*, (1)Concordia University, Montreal, QC, Canada, (2)CanmetENERGY-Varennes, Montreal, QC, Canada*

7. Institutional Climate Analysis for Future Heat Wave Scenarios: Sandia National Laboratories California Site (VC-21A-C006)
Daniel Villa, P.E., Member*, Sandia National Laboratories, Albuquerque, NM*

8. Methodology for Defining Diverse Populations of Grid Interactive Buildings (VC-21A-C007)
Hayden Reeve, Dr.Eng, Member[1]*, Robert Pratt*[2] *and Ankit Singhal*[2]*, (1)PNNL, Seattle, WA, (2)Pacific Northwest National Laboratory, Richland, WA*

Conference Paper Session 2 (Intermediate)

Thermal Storage, Solar Energy Utilization and Building Performance

Track: Future Proofing - Renewable, Regenerative, and Resilient

The papers in this session focus on the use of thermal storage and photovoltaics to improve equipment operation and building energy efficiency. The first and second paper present the analysis of a novel building integrated photovoltaic system with a thermoelectric generator and phase change material. The third paper discusses the dynamic analysis of a solar heat pump water heater. The remainder of the papers focus on building energy savings technologies such as use of solar reflective walls, improved rooftop solar reflectivity, and double skin façade integrating photovoltaics.

1. Phase-Change Material Design for Thermoelectric Generator Assisted Building Integrated Photovoltaic (VC-21A-C008)
Jinyoung Ko, Student Member *and Jae-Weon Jeong, Ph.D., Member, Hanyang University, Seoul, Korea, Republic of (South)*

2. A Case Study on Retrofitting an Old Office Building into a Net Zero Energy Building in Florida Climate (VC-21A-C009)
Kwame Amoah, Ph.D., BEAP, Member[1]*, Troy Nguyen, Ph.D., P.E., BEMP, Member*[2] *and Najafi Hamidreza, Ph.D., BEAP, Member*[2]*, (1)University of Northern Iowa, Cedar Falls, IA, (2)Florida Institute of Technology, Melbourne, FL*

3. Numerical analysis of Building Integrated Photovoltaic design with Thermoelectric Generator and Phase Change Material (VC-21A-C010)
Yong-Kwon Kang[1], *Soo-Jin Lee*[2] *and Jae-Weon Jeong, Ph.D., Member*[1], *(1)Hanyang University, Seoul, Korea, Republic of (South), (2)Ewha Womans University, Seoul, Korea, Republic of (South)*

4. Simulation Analysis of the Dynamic Performance of a Solar Heat Pump Water Heater Operating in Medellin, Colombia (VC-21A-C011)
Santiago Valencia-Cañola, P.Eng.*, Cesar A. Isaza-Roldán, Ph.D., Associate Member, Carlos A. Bustamante-Chaverra, Ph.D., Carolina Mira-Hernández, Ph.D. and David A. Oliva-Patiño, P.Eng., Universidad Pontificia Bolivariana, Medellín, Colombia*

5. The Role of Rooftop Radiative Properties in Urban Cooling and Energy Savings for Different Climate Zones (VC-21A-C012)
Jyothis Anand, Student Member *and David Sailor, Arizona State University, tempe, AZ*

6. The Role of Solar-Reflective Walls and Roofs in Old Residential Buildings Energy Saving- a Case Study (VC-21A-C013)
Roja Rastegar, Ph.D. *and Jae Chang, Ph.D., University of Kansas, Lawrence, KS*

Conference Paper Session 3 (Intermediate)

Air Quality and Handling in Mission Critical Facilities

Track: Design, Control, and Operation of Critical Environments

Air quality and flow control are a key consideration in mission critical environments such as data centers, healthcare facilities and clean rooms. This session begins with an introduction of latest air-mover technologies and the requirements for improved fan performance continue to grow with demand for higher HVACR energy efficiencies. This is followed by a discussion of temperature controlled air-flow in healthcare facilities, and the impact of exhaust grilles on the air quality and flow patterns. The last paper focuses on the development of digital twin of a data center to improve its design, control and operation.

1. Air Considerations in Imaging (X-Ray) Rooms (VC-21A-C014)
Travis English, P.E., Member*, Kaiser Permanente, Anaheim, CA*

2. Development of Detailed Server Digital Twin Models for Enabling a Data Center Digital Twin for Design, Control and Operation (VC-21A-C015)
Yuanchen Hu, Ph.D., ***Dustin Demetriou, Ph.D., Member*** *and John Madalengoitia, IBM, Poughkeepsie, NY*

3. EC Fan Array Implementation – How to Capture the Energy Savings without Sacrificing Power Quality (VC-21A-C016)
Anthony Hoevenaars, P.Eng., Member[1] *and* ***Joseph Landrette***[2]*, (1)Mirus International, Brampton, ON, Canada, (2)EBM Papst Inc., Farmington, CT*

4. Effect of Exhaust Grille Position on Air Quality and Flow Patterns in Clean Rooms (VC-21A-C017)
Essam Khalil, Ph.D., P.E., Fellow ASHRAE*, Taher AbouDief, Dr.Eng, Ahmed Abou Zeid, Dr.Eng and Hesham Metwally, P.Eng., Cairo University, Cairo, Egypt*

5. The Efficacy of Temperature-Controlled Air Flow in Maintaining Ultraclean Conditions throughout the or (VC-21A-C018)
Clemens Bulitta, M.D.[1]*,* ***Kathy Warye, Associate Member***[2] *and Peter Hojerback*[3]*, (1)Technical University of Applied Sciences Amberg-Weiden, Amberg-Weiden, Germany, (2)Infection Prevention Partners, Sonoma, CA, (3)Avidicare, Lund, Sweden*

Conference Paper Session 4 (Intermediate)

Design Considerations for Cannabis Processing and Indoor Agriculture

Track: HVAC&R for Indoor Plants & Animals

Indoor plant growing has become very popular, particularly in regions where cannabis usage has been legalized. It allows for optimal growing conditions year-around but can be energy intensive and often requires maintaining tight temperature and humidity control. This session begins with a review of cannabis drying methods followed by comprehensive review and analysis of HVAC technologies for use in controlled environment agriculture. The fourth paper explores evaporative cooling systems in the cold chain to extend the storage period of perishable products. The last paper presents the findings on the use of non-infrared selective solar films in greenhouses for heating energy savings in winter.

1. Comparative Energy Analysis of Dehumidification Technologies for Indoor Cannabis Operations (VC-21A-C019)
Josh Spalding, Associate Member*, Quest, Los Angles, CA*

2. Demystifying the Unorthodox Drying Methods of Cannabis (VC-21A-C020)
Daniel Dettmers, Member*, Quest Dehumidifiers, Madison, WI*

3. Selecting Optimal HVAC Systems for Indoor Grow Room Based on Performance and Energy Usage (VC-21A-C021)

Bryce Cox, P.E., Member[1]*, Joshua Gess, Ph.D., Member*[1] *and Adam Boyd*[2]*, (1)Oregon State University, Corvallis, OR, (2)ColeBreit Engineering, Corvallis, OR*

4. Using NIR-Selective Solar Films in Greenhouses for Heating Energy Savings in Winter (VC-21A-C022)
Julian Wang, Ph.D.*, Enhe Zhang and Qiuhua Duan, Penn State University, University Park, PA*

5. Design, Fabrication and Evaluation of Integrated Evaporative Cooling System for the Storage of Fruits and Vegetables (VC-21A-C023)
Yoftahe Tewodros[1] *and Belachew Assalf, Ph.D.*[2]*, (1)none, chantilly, VA, (2)Norwegian Institute of Bioeconomy Research (NIBIO), AAS, Norway*

Conference Paper Session 5 (Intermediate)

Energy Audits, Buildings Efficiency and Fault Diagnosis

Track: Design, Control, and Operation of Critical Environments

Energy audits and modeling enables tracking of energy use and guides implementation of conservation measures to accelerate energy savings. The first paper describes the energy analysis savings as obtained by the application of energy audits to buildings on a University campus. The second paper presents parametric energy simulation of single-pane glazing systems with condensation effects. The third paper explores strategies to optimize air-handler operation to improve occupant comfort, reduce loads and save energy. The last paper presents a comparative study between the use of static vs. dynamic Bayesian Network for building HVAC fault diagnosis.

1. Impact of Crops Growth on the Theoretical Energy Demand and Sensible Heat Ratio of a Controlled-Environment Agriculture Space (VC-21A-C024)
Marie-Hélène Talbot, P.Eng., Student Member *and Danielle Monfet, Ph.D., École de technologie supérieure, Montreal, QC, Canada*

2. Dynamic Bayesian Network for Fault Diagnosis (VC-21A-A002)
Ojas Pradhan, Student Member[1]*, Jin Wen, Ph.D., Member*[1]*, Yimin Chen, Ph.D.*[2]*, Teresa Wu, Ph.D.*[3] *and Zheng O'Neill, Ph.D., P.E., Member*[4]*, (1)Drexel University, Philadelphia, PA, (2)Lawrence Berkeley National Laboratory, Berkeley, CA, (3)Arizona State University, Tempe, AZ, (4)Texas A&M University, College Station, TX*

3. Energy Audit and Modeling of High Energy Consuming, Multi-Purpose Buildings at a University Campus (VC-21A-C025)
Devashis Shrestha*, Michael Ohadi, Ph.D., Fellow ASHRAE and Farah Singer, University of Maryland, College Park, MD*

4. Parametric Energy Simulation with Considerations of Condensation Effects on Glazing Systems (VC-21A-C026)
Julian Wang, Ph.D.*, Qiuhua Duan and Laura Hinkle, Penn State University, University Park, PA*

5. Utilizing Data Trending to Optimize Air Handler Setpoint Resets (VC-21A-C027)
Bryan Lang, P.E., Member*, ETC Group, LLC, Tempe, AZ*

Conference Paper Session 6 (Intermediate)

Minimizing the Spread of Airborne Contaminants

Track: Fundamentals and Applications

Recently due to the pandemic, the understanding and minimizing the spread of air-borne contaminants has gathered significant attention. This session presents the latest research on simulation-based understanding airflow patterns in indoor spaces and their impact on thermal comfort and flow path of airborne contaminants. The investigation into the effect of coughed and sneezed droplet sizes on the spread of contaminants in aircraft and subway cabins is discussed. A framework for evaluating currently installed ventilation devices is provided to identify and minimize the risk of infection due to cross contamination is presented.

1. CFD Analysis of Airflow Patterns and Flow Path of Airborne Contaminants in Indoor Spaces (VC-21A-C028)
Kishor Khankari, Ph.D., Fellow ASHRAE*, AnSight LLC, Ann Arbor, MI*

2. COVID-19 Cross Contamination through Energy Recovery Ventilation Devices (VC-21A-C029)
Hoy Bohanon, P.E., BEAP, Life Member[1] *and* ***Marwa Zaatari, Ph.D., Associate Member***[2]*, (1)Hoy Bohanon Engineering, PLLC, Clemmons, NC, (2)D ZINE Partners, Austin, TX*

3. Testing of Granular Air Cleaning Media for Ozone Removal in Ashrae Standard 145.1 Setup (VC-21A-C030)
Marzieh Namdari, Student Member[1]*, Chang-Seo Lee, Member*[1]*, Fariborz Haghighat, Ph.D., Fellow ASHRAE*[1] *and Ali Bahloul, Ph.D.*[2]*, (1)Concordia University, Montreal, QC, Canada, (2)IRSST, Montreal, QC, Canada*

4. The Effect of the Coughed and Sneezed Droplet Sizes and Exhaled Speed on Spreading COVID-19 inside the Aircraft Cabins (VC-21A-C031)
Essam Khalil, Ph.D., P.E., Fellow ASHRAE *and Hassan Kotb, P.Eng., Cairo University, Cairo, Egypt*

5. Investigation on Airflow Characteristics and Thermal Comfort in METRO Cabin (VC-21A-C032)

***Essam Khalil, Ph.D., P.E., Fellow ASHRAE**, Khaled Affify, P.E. and Taher Abou Dief, Dr.Eng, Member, Cairo University, Cairo, Egypt*

Conference Paper Session 7 (Intermediate)

Building Equipment and Design Considerations for Cold and Extreme Climates

Track: Fundamentals and Applications

Providing adequate heating capacity in cold climates at the appropriate coefficient of performance is quite challenging especially at extreme ambient conditions. Furthermore, the resilience of thermal energy systems is critical in extremely hot and cold climates and the metrics for quantifying such resilience are not well understood. This session presents studies in characterizing resilience of thermal energy systems for extreme climates, building envelopes in cold climates, and different equipment options for use in cold climate. The session concludes with the presentation of a thermoelectric cement which is a novel thermo-electric material that can harvest the large indoor and outdoor temperature difference to generate electricity.

1. Building Envelope Characteristics in Cold Climates (VC-21A-001)
***Lyle Axelarris**[1], Aaron Cooke[2], Craig Fredeen[3], Robbin L. Garber-Slaght, P.E., Associate Member[4], Emmett Leffel[5], Lorne Ricketts, P.Eng., Associate Member[6] and William B. Rose, Fellow ASHRAE[7], (1)Design Alaska, Anchorage, AK, (2)Cold Climate Housing Research Center, Anchorage, AK, (3)Cold Climate Engineering, LLC, AK, (4)Cold Climate Housing Research Center, Fairbanks, AK, (5)Alaska Thermal Imaging LLC, AK, (6)RDH Building Science Inc., Vancouver, BC, Canada, (7)University of Illinois at Urbana-Champaign, Champaign, IL*

2. Thermal Energy System Resilience: Temperature Decay in Cold/Arctic Climates: Part I (VC-21A-002)
***Bjorn Oberg**[1], Angela Urban[2], Emmett Leffel[3], Jonathan Goebel[1], Matthew Perry[4], Dragos Vas[2] and Richard Liesen, Ph.D., Member[5], (1)US Army Corps of Engineers, Champaign, IL, (2)US Army Engineer Research and Development Center, Champaign, IL, (3)Alaska Thermal Imaging LLC, AK, (4)Alaska Center for Energy and Power, Anchorage, AK, (5)US Army Corps of Engineers, Newark, OH*

3. Thermal Energy System Resilience: Thermal Decay Test (TDT) in Cold/Arctic Climates, Part II Modeling (VC-21A-003)
***Richard Liesen, Ph.D., Member**[1], Brianna Morton[1], Brandy Diggs-McGee[2] and Alexander Zhivov, Ph.D.[3], (1)US Army Corps of Engineers, Newark, OH, (2)USACE ERDC CERL, Champaign, IL, (3)US Army Corps of Engineers, Champaign, IL*

4. Thermoelectric Characteristics of Graphene and Aluminum Doped Zinc Oxide Nanopowder Enhanced Cement Composite for Low-Temperature Applications (VC-21A-A003)
***Xiaoli Liu, Student Member** and Ming Qu, Ph.D., Associate Member, Purdue University, West Lafayette, IN*

5. Cold Climate Heat Pump Capital Costs with and without Electrical Resistance Backup (VC-21A-C033)
***Thomas Stief, Student Member**, Mahsa Safari, Ph.D., Hugh Johnson, Jin Wen, Ph.D., Member and Patrick Gurian, Ph.D., Drexel University, Philadelphia, PA*

6. Performance Evaluation of 3-Pipe Engine Driven Gas Heat Pump VRF System in Cold Climate (VC-21A-C034)
***Farzin M.Rad, Ph.D., P.E., Member** and Aqeel Zaidi, P.Eng., Enbridge Gas Inc., Toronto, ON, Canada*

Conference Paper Session 8 (Intermediate)

Improvements in Vapor Compression Systems through Modeling and Experimentation

Track: Fundamentals and Applications

Vapor compression cycles are at the heart of most heating and cooling equipment. This session explores various component and system efficiency enhancement options for vapor compression systems. The first three papers present modeling and experimental research focusing on improving heat exchangers such as evaporator and condensers. The fourth paper investigates the impact of incorporating phase change material with the insulation foam used in refrigerators. The last paper presents a new in-situ method for measuring oil circulation ratio in real time in a transport refrigeration system, that is non-invasive and requires minimal human intervention.

1. Phase Change Material Incorporated Refrigeration Insulation for Refrigerator Energy Savings (VC-21A-C035)
*Sania Shaik, Sheldon Shi and **Weihuan Zhao**, University of North Texas, Denton, TX*

2. Numerical Investigation of Heat Transfer Enhancement in Double Pipe Heat Exchanger Using Twisted Tape Inserts (VC-21A-C036)
***Essam Khalil, Ph.D., P.E., Fellow ASHRAE**, Samir AbouHodaima, Dr.Eng, Ahmed Hwary, P.Eng. and Mohamed El-Shabrawy, Dr.Eng, Cairo University, Cairo, Egypt*

3. Dynamic Behavior of Vapor Compression Refrigeration System UNDER Different Geometrical Parameters of Condenser (VC-21A-C037)
***Sambhaji Kadam, Ph.D.**[1], Ibrahim Galal Hassan[2], Aziz Mohammad Rahman, Ph.D.[3], Athanasios Papadopoulos[4] and Panos Seferlis, Ph.D.[5], (1)Texas A and M University at Qatar, Doha, Qatar, (2)Texas A & M University at Qatar, Doha, Qatar,*

(3)Texas A&M University at Qatar, Doha, Qatar, (4)Centre for Research and Technology Hellas, Thessaloniki, Greece, (5)Chemical Process and Energy Resources Institute, Thermi, Thessaloniki, Grenada

4. Experimental Results and Model Calculations of Evaporator's Heat Recieving Performance Using Low Pressure Refrigerant (VC-21A-C038)
Koichi Todoroki, Ph.D., Associate Member *and Minoru Yoshikawa, System Platform laboratories, NEC, Kawasaki-city, Kanagawa, Japan*

5. In-situ Oil Circulation Ratio (OCR) Measurement using Separation Method in a Transport Refrigeration System with R404A and POE32 (VC-21A-004)
Vatsal Shah, Student Member*, Orkan Kurtulus, Travis Horton, Ph.D., Member, Eckhard Groll, Dr.Ing., Fellow ASHRAE and James Braun, Ph.D., Fellow ASHRAE, Purdue University, West Lafayette, IN*

Conference Paper Session 9 (Intermediate)

Launching into HVAC Design Engineering

Track: Professional Development

There are significant job opportunities in North America for students, recent graduates, and career-changers from science, technology, engineering and math (STEM) backgrounds interested in careers in heating, ventilation, and air conditioning (HVAC) fields. However, many are not familiar with this field, the types of careers it offers and where to identify these opportunities. This session will introduce this field and present discussion on the opportunities available in this area.

1. Launching into HVAC Design Engineering, Part I (VC-21A-C039)
Brian Rock, Ph.D., P.E., Fellow ASHRAE*, The University of Kansas, Lawrence, KS*

2. Launching into HVAC Design Engineering, Part II (VC-21A-C040)
Brian Rock, Ph.D., P.E., Fellow ASHRAE*, The University of Kansas, Lawrence, KS*

Conference Paper Session 10 (Intermediate)

Improvements and Advancements in Heat Exchanger Technologies in HVAC&R Applications

Track: HVAC&R Systems and Equipment

In recent years there have been significant advancements in heat exchanger technologies for use in a broad range of HVAC&R applications. As building efficiency and load flexibility become increasingly important, advanced technologies can play a critical role in addressing these needs. In this session, a diversity of heat exchanger-focused efforts will be discussed for use in applications including: phase change materials in a heat exchanger for residential thermal energy storage, plate heat exchanger performance evaluation, rectangular plain fin heat exchanger performance under wet conditions, advanced three-fluid heat and mass exchanger effectiveness evaluation, shape morphing elements on heat exchanger fins, and alternatives to avoid heat exchanger corrosion in natural gas furnace applications.

1. Effect of Inclination Angle on the Airside Performance of the Rectangular Plain Fin Heat Exchangers Under Wet Condition (VC-21A-C041)
M Muneeshwaran and ***Chi-Chuan Wang, Ph.D., Fellow ASHRAE****, National Chiao Tung University, Hsinchu, Taiwan*

2. De-Icing in Heat Pump Fins Using Shape Morphing (VC-21A-C042)
Aman Thakkar, Student Member*,* ***Jiacheng Ma****, James Braun, Ph.D., Fellow ASHRAE, Travis Horton, Ph.D., Member and Andres F. Arrieta, Ph.D., Purdue University, West Lafayette, IN*

3. Effectiveness of Advanced Three-Fluid Heat and Mass Exchanger (VC-21A-C043)
Zhiming Gao*[1], Zhiyao Yang, Student Member[2], Navin Kumar, Ph.D.[1], Kyle Gluesenkamp, Ph.D., Member[3], Ahmad Abu-Heiba[1] and Van Baxter, Fellow Life Member[1], (1)Oak Ridge National Laboratory, Oak Ridge, TN, (2)Purdue University, West Lafayette, IN, (3)Oak Ridge National Laboratory, Oak RIdge, TN*

4. Clean and High-Efficiency Natural Gas Furnace with Advanced Acidic Gas Trap Technology (VC-21A-C044)
Zhiming Gao*[1], Ayyoub Mehdizadeh Momen, Ph.D., Member[1], Josh Pihl[1], Anthony C. Gehl[1], Zhang Mingkan, Ph.D.[1], Dino Sulejmanovic[1], Lingshi Wang[1], Xiaobing Liu, Ph.D., Member[1], Tim LaClair[1] and Kyle Gluesenkamp, Ph.D., Member[2], (1)Oak Ridge National Laboratory, Oak Ridge, TN, (2)Oak Ridge National Laboratory, Oak RIdge, TN*

5. Locally Measured Heat Transfer Coefficient with Simultaneous Visualization of Evaporating Fluid Flow in the Plate Heat Exchanger (VC-21A-C045)
Abdel-Rahman D. Farraj, Student Member *and Pega Hrnjak, Ph.D., Fellow ASHRAE, University of Illinois at Urbana-Champaign, Urbana, IL*

6. Additively Manufactured Polymer-Encapsulated Phase-Change Material Heat Exchangers for Light Commercial and Residential Thermal Energy Storage (VC-21A-C046)

Thomas Freeman, Student Member[1], *Kashif Nawaz, Ph.D., Member*[2], *Raj M. Manglik, Ph.D., Fellow ASHRAE*[3], *Rafael Rodriguez, Ph.D., P.E., Member*[1] *and Sandra Boetcher, Ph.D., Member*[1], *(1)Embry-Riddle Aeronautical University, Daytona Beach, FL, (2)Oak Ridge National Laboratory, Oak Ridge, TN, (3)University of Cincinnati, Cincinnati, OH*

Conference Paper Session 11 (Intermediate)

Advanced Controls, Technologies and Fault Detection for Chillers and Chilled Water System Applications

Track: HVAC&R Systems and Equipment

Chillers and chilled water systems are commonly used in commercial building HVAC applications. These systems are complex and include a range of different HVAC equipment for operation. This session will cover efforts to model and optimize chilled water pumps, improve chiller efficiency, identify chiller deficiencies, and reduce pump energy consumption. The results of these efforts work towards more efficient and reliable HVAC components and systems.

1. Model-Free Optimal Control Method for Chilled Water Pumps Based on Multi-Objective Optimization: Engineering Application (VC-21A-C047)
Shunian Qiu*, Zhenhai Li, Ph.D. and Zhengwei Li, Ph.D., Tongji University, Shanghai, China*

2. Effect of Lowering Condenser Water Temperatures in the Chiller Efficiency (VC-21A-C048)
Vinicius Cruz Sr., Associate Member*, Johnson Controls Hitachi, Brasilia, Brazil*

3. Pump Speed Control Strategies (VC-21A-C049)
Pedro Cabral, Affiliate[1] *and Diogo Monteiro*[2]*, (1)IST, University of Lisbon, Lisbon, Portugal, (2)Independent researcher, Geneva, Switzerland*

4. Utilizing New Technology and Analytics to Identify Chiller Deficiencies (VC-21A-C050)
Greg Jimmie, Member*, ETC Group, Tempe, AZ*

Conference Paper Session 12 (Intermediate)

Advancements in the Design, Controls and Fault Detection of Air Handing Units and Ventilation Equipment

Track: HVAC&R Systems and Equipment

Air Handling Units are a central part of HVAC systems used in residential and commercial buildings today. Similarly, ventilation systems are also critical, ensuring sufficient outdoor air is supplied to interior spaces. However, such systems can be complex to design, and in addition, require consideration of energy efficiency. This session will cover air handling unit design and fault analysis, and ventilation systems energy recover and dehumidification.

1. How to Design a Variable Air Volume Central Hospital Air Handling System (VC-21A-C051)
Travis English, P.E., Member*, Kaiser Permanente, Anaheim, CA*

2. Experimental Analysis of Energy Recovery Performance of a Hollow Fiber Membrane Dehumidification-Based Ventilation System (VC-21A-C052)
Hye-Jin Cho, Student Member *and Jae-Weon Jeong, Ph.D., Member, Hanyang University, Seoul, Korea, Republic of (South)*

3. An Experimental Study on Dehumidification Performance of a Vacuum-Based Membrane Dehumidifier (VC-21A-C053)
Seong-Yong Cheon *and Jae-Weon Jeong, Ph.D., Member, Hanyang University, Seoul, Korea, Republic of (South)*

4. High Performance Heat- and Energy-Recovery Ventilators: What to Consider When Selecting Equipment (VC-21A-C054)
Jessica DeWitt, Member[1], *Ben Larson*[2], *Louis Starr*[3] *and Jeff Rigotti*[3], *(1)Cadeo Group, Seattle, WA, (2)Larson Energy Research, Seattle, WA, (3)Northwest Energy Efficiency Alliance, Portland, OR*

5. Effect of Sensor Redundancy on Model-Based Fault Detectability for Air Handling Units (VC-21A-C055)
Narges Torabi, P.Eng., Student Member[1], *Burak Gunay*[2] *and Liam O'Brien, Ph.D.*[1], *(1)Carleton University, Ottawa, ON, Canada, (2)Carleton University, Canada*

Conference Paper Session 13 (Intermediate)

Grid-Interactive, Flexible, and Low-Carbon Buildings and Building Systems

Track: Research Summit

As the electric grid increasingly uses renewable energy resources to provide electricity, the electricity produced is also more variable. To address this variability, advanced technologies and controls in buildings are needed to be able to produce and/or store energy on site, and adjust loads from energy consuming devices and equipment, while minimally impacting occupants in buildings. In this session advancements and research in technologies and controls to support this functionality are explored.

1. Fire Smoke Control for Building Integrated Photovoltaic (BIPV) (VC-21A-A004)
*Dahai Qi, Ph.D.[1], **Monireh Aram, Student Member**[1] and Yoon Ko, Ph.D., Member[2], (1)Université de Sherbrooke, Sherbrooke, QC, Canada, (2)National Research Council Canada, Ottawa, ON, Canada*

2. Aggregation of Lighting Related Demand Response for the Entire Mid-Continent Independent System Operator Region (VC-21A-C056)
***Soham Vanage, Student Member**[1], Niraj Kunwar, Student Member[2], Emily Kawka, Student Member[1] and Kristen Cetin, Ph.D., P.E., Member[1], (1)Michigan State University, East Lansing, MI, (2)Iowa State University, Ames, IA*

3. Optimizing Ice Thermal Storage As a Distributed Resource (VC-21A-A005)
***Karl Heine, Student Member**, Colorado School of Mines, Golden, CO*

4. A Hardware-in-the-Loop Approach for Laboratory Performance Verification of Flexible Building Equipment in a Typical Commercial Building (VC-21A-A006)
***Zhelun Chen, Ph.D., Associate Member**[1], Jin Wen, Ph.D., Member[1], Steven T. Bushby, Fellow ASHRAE[2], Caleb Calfa[3], Yangyang Fu, Ph.D., Member[3], Gabriel Grajewski[1], Yicheng Li[1], L. James Lo, Ph.D., Member[1], Zheng O'Neill, Ph.D., P.E., Member[3], W. Vance Payne, Ph.D., Member[2], Amanda Pertzborn, Ph.D., Associate Member[2], Zhiyao Yang, Ph.D., Member[3] and Yun Zhang, Student Member[1], (1)Drexel University, Philadelphia, PA, (2)National Institute of Standards and Technology, Gaithersburg, MD, (3)Texas A&M University, College Station, TX*

5. Framework for Assessing Grid-Level Impacts of Building Participation in Flexibility Services (VC-21A-A007)
***Soham Vanage, Student Member**[1], **Niraj Kunwar, Associate Member**[2], Rajaz Amitava[3], Emily Kawka, Student Member[1], Abigail Morton[3], Cody Newlun[3], Yu Wang, Ph.D.[3], Kristen Cetin, Ph.D., P.E., Member[1] and James McCalley, Ph.D.[3], (1)Michigan State University, East Lansing, MI, (2)Oakridge National Laboratory, Oakridge, TN, (3)Iowa State University, Ames, IA*

6. Numerical Model Validation for a Novel Dual-Purpose Underground Thermal Battery (VC-21A-A008)
***Liang Shi, Student Member**[1], Ming Qu, Ph.D., Associate Member[1], Xiaobing Liu, Ph.D., Member[2] and Lingshi Wang[2], (1)Purdue University, West Lafayette, IN, (2)Oak Ridge National Laboratory, Oak Ridge, TN*

7. Decarbonization of a Residential Community in Golden, CO (VC-21A-A009)
***Paulo Cesar Tabares-Velasco, Ph.D., Associate Member**, **Daniel Safronov**, Hamood Al-Harthi and Jon Salas Navarro, Colorado School of Mines, Golden, CO*

Conference Paper Session 14 (Intermediate)

Research Advancements in Residential Building Applications

Track: Research Summit

While commercial buildings have historically received much of the research-focused attention in HVAC&R applications, there is an increasing focus on improving the efficiency, indoor air quality, and performance of residential buildings and building systems. This session will cover research results, analysis and modeling specifically focused on residential building applications. Topics include applications in indoor air quality, CCHP, ventilation, and moisture modeling.

1. Application of a Moisture Balance Model to Estimate Internal Moisture Generation Rates in New Homes in the Southeastern US (VC-21A-C057)
***Eric Martin**, Bereket Nigusse, Ph.D., Associate Member and Tanvir Khan, Ph.D., FSEC Energy Research Center at the University of Central Florida, Cocoa, FL*

2. Ventilation and Indoor Air Quality in Residential Bedrooms (VC-21A-C058)
***Hagen Fritz, Student Member**, Kerry Kinney, Ph.D., David Schnyer, Ph.D. and Zoltan Nagy, Ph.D., Associate Member, The University of Texas at Austin, Austin, TX*

3. CFD Ventilation Modeling For The Evaluation of Indoor Air Quality In Tiny Homes (VC-21A-C059)
***Jaya Mukhopadhyay, Ph.D., Member**, Patrick William Henry Hodges and Ryan Anderson, Montana State University, Bozeman, MT*

4. Analysis of a Residential Fuel Cell Combined Cooling, Heating and Power System (VC-21A-A010)
***Brent B. Skabelund, Student Member** and Ryan J. Milcarek, Ph.D., Member, Arizona State University, Tempe, AZ*

Conference Paper Session 15 (Intermediate)

State-of-the-art Materials and HVAC&R Technologies in Commerical Buildings

Track: Research Summit

Commercial buildings are increasingly built and retrofitted to improve energy performance and reduce climate and carbon impacts. To so to requires careful consideration of the materials used to construct the building and their impact on performance and indoor environmental conditions, as well as the ability to assess, in the design and operational phases, the HVAC system performance. This session includes a review of both materials and HVAC&R state of the art technologies used in buildings today, followed by research efforts to improve the modeling and evaluation of the performance of buildings using new materials and HVAC&R equipment.

1. Materials Health in HVAC Equipment and Systems (VC-21A-C060)
Lydia Stensberg, Member[1], *Nicole Moes, Member*[2], *Erin McConahey, P.E., HBDP, Fellow ASHRAE*[3], *Frances Yang*[4] *and Sara Tepfer*[4], *(1)Arup, Washington, DC, (2)Arup, Houston, TX, (3)Arup, Los Angeles, CA, (4)Arup, San Francisco, CA*

2. HVAC System-Level Energy Performance: Exploring the Doe Commercial Prototype Building Models (VC-21A-C061)
Scott West, P.E., BCxP, BEAP and BEMP, Member*, Harrison French & Associates, Fort Worth, TX*

3. Energy Analysis of Water Sprayed-Condenser Assisted HVAC System of Two Different Sprayed Type (VC-21A-C062)
Beom-Jun Kim, Student Member*, Jae-Weon Jeong, Ph.D., Member, Hye-Jin Cho, Student Member and Li-hua Lin, Hanyang University, Seoul, Korea, Republic of (South)*

4. A Quantitative Review of the State-of-the-Art of Conventional and Alternative Hvac&r Technologies (VC-21A-C063)
Zechao Lu, Student Member*, Junyoung Kim, Student Member, James Braun, Ph.D., Fellow ASHRAE and Davide Ziviani, Ph.D., Member, Purdue University, West Lafayette, IN*

5. Energy Performance Comparison of Separate Sensible and Latent Cooling Loads and Total Cooling System (VC-21A-A011)
Tomas Venegas, BEMP, Associate Member[1], *Ming Qu, Ph.D., Associate Member*[1], *Liang Shi, Student Member*[1], *Zhiyao Yang, Student Member*[1] *and Kashif Nawaz, Ph.D., Member*[2], *(1)Purdue University, West Lafayette, IN, (2)Oak Ridge National Laboratory, Oak Ridge, TN*

6. Openstudio Validation of a Clt Building in Colorado (VC-21A-A012)
Gabriel Flechas, Student Member *and Paulo Tabares Velasco, Ph.D., Associate Member, Colorado School of Mines, Golden, CO*

Conference Paper Session 16 (Intermediate)

Occupant Comfort: Advancements and Improvements in Modeling and Evaluation of Thermal and Acoustical Comfort

Track: Research Summit

Buildings are designed for occupants, as people spend nearly 90% of their time in buildings. Therefore residential and commercial buildings must consider occupant comfort when they are designed and operated. However, some buildings face challenges in achieving the desired design and operation to ensure occupants are comfortable. This session will cover research focused on assessing acoustic comfort and discomfort, comfort cooling using ceiling fans, and thermal comfort evaluation in children.

1. The Use of Ceiling Fans in Reverse-Flow Mode for Comfort Cooling: Physiological Aspects and Relationship with International Standards (VC-21A-C064)
Francesco Babich, Ph.D., Associate Member[1], *Wilmer Pasut, Ph.D., Associate Member*[2] *and Annamaria Belleri, Ph.D.*[1], *(1)Eurac Research, Bolzano, Italy, (2)Ca' Foscari, University of Venice, Venice, Italy*

2. Acoustic Impact on Work and Study Spaces Caused By Multi-Functional Use of an Atrium in an Educational Building (VC-21A-C065)
Nadia Sultana*,* ***Marco A. Rico Thirion, P.Eng.****, Marianne F. Touchie, P.E., Associate Member and Maedot S. Andargie, University of Toronto, Toronto, ON, Canada*

3. Evaluating Thermal Comfort of Children: A Perspective on Commonly Used Methods (VC-21A-C066)
Nour Youssef, Student Member *and Katherine D'Avignon, Ph.D., Member, École de technologie supérieure, Montreal, QC, Canada*

Seminars (On-Demand)

Seminar 23 (Intermediate)

Additive Manufacturing Of Heat Exchangers: Performance, Challenges And Opportunities

Track: Research Summit

Sponsor: 8.4 Air-to-Refrigerant Heat Transfer Equipment, 1.3 Heat Transfer and Fluid Flow

Chair: Kishan Padakannaya, Johnson Controls, Norman, OK

Manufacturing of heat exchangers for the HVAC&R industry, although well established, is capital and labor intensive. Additively manufactured heat exchangers are emerging as an alternative technology to traditional manufacturing. In this seminar, we present some ongoing research highlighting recent developments improving heat exchanger performance and producing more compact designs. The current high cost of 3D printing is addressed by exploring intermediate enhanced conventional manufacturing strategies. Process techniques are also presented that improve the performance of additively manufactured heat exchangers.

1. Performance Evaluation of Shape Optimized Air-to-Refrigerant Heat Exchangers Fabricated Using Additive and Conventional Manufacturing Techniques
***Vikrant Aute, Ph.D., Member**, University of Maryland, College Park, MD*

2. Opportunities and Challenges for Additively Manufactured Heat Exchangers for Air Heating and Cooling Applications
***Kashif Nawaz, Ph.D., Member**, Oak Ridge National Laboratory, Oak Ridge, TN*

3. Enhancement of Additively Manufactured Hxs By Roughness and Topology Modification
***Kevin Uvodich**, University of Illinois at Urbana-Champaign, University of Illinois at Urbana-Champaign, IL*

4. Design, Additive Manufacturing, and Performance of Heat Exchangers with Novel Flow Path
***Kashif Nawaz, Ph.D., Member**, Oak Ridge National Laboratory, Oak Ridge, TN*

Seminar 24 (Intermediate)

Airside Economizers to Minimize Energy Use in Indoor Plant Environments

Track: HVAC&R for Indoor Plants & Animals

Sponsor: 2.2 Plant and Animal Environment

Chair: Justin Schoonbaert, P.Eng., Associate Member, Solution Air, Winnipeg, MB, Canada

Indoor farming is one method to meet the growing demands of food; this opportunity provides increased yields indoor by controlling the indoor plant environment (IPE). However, controlling both sensible and latent loads in indoor plant environment can be very energy intensive. Energy efficient HVAC systems, including airside economizers help reduce annual energy use and costs of IPE. Performed studies investigated the use of enthalpy-controlled economizers for multiple locations in ASHRAE climate zones 0-8. Lettuce, Cannabis and strawberries were evaluated, the research proved the ability to use OA depends on location, crop type and density.

1. Airside Economizers to Minimize Energy Use in Indoor Plant Environments
***Nadia Sabeh, Ph.D., P.E., Associate Member**, Dr. Greenhouse, Inc., Sacramento, CA*

Seminar 25 (Basic)

American Geophysical Union Headquarters: Net-Zero Case Study

Track: Future Proofing - Renewable, Regenerative, and Resilient

Chair: Roger Frechette, P.E., Interface Engineering, Washington D.C., DC

This presentation focuses on a methodology and approach to urban renovation projects seeking to achieve a "Net-Zero Energy" or "Positive Energy" result. The presentation touches on architectural and engineering strategies currently being used in Net-Zero Energy buildings across the country. A compelling case study will be offered for the newly renovated American Geophysical Union Headquarters. The course describes the process used to distill available sustainable options down to select strategies to achieve the Net-Zero goal. The course addresses opportunities and challenges associated with the design, permitting, construction and commissioning of Net-Zero projects.

1. American Geophysical Union Net-Zero Case Study
***Roger Frechette, P.E.**, Interface Engineering, Washington D.C., DC*

Seminar 26 (Basic)

Application of Computational Fluid Dynamics to HVACR Compressor Design

Track: HVAC&R Systems and Equipment

Sponsor: 8.2 Centrifugal Machines, 8.1 Positive Displacement Compressors

Chair: Matt Cambio, Member, Trane Technologies, La Crosse, WI

Computational Fluid Dynamics (CFD) has been a modeling tool available to engineers for more than 40 years. In recent time computational hardware and commercially available codes has moved CFD from a research tool to a design tool. In addition engineers are continually taking on more complex problems. CFD provides insights that are not possible to obtain through testing or other types of models. This session provides examples of how CFD is used in the design process to improve compressor performance and reliability.

1. Modified Cut-Cell Method Applied to CFD Simulations of Positive Displacement Compressors
***Davide Ziviani, Ph.D., Member**, Center for High Performance Buildings, Purdue University, West Lafayette, IN*

2. Effects of Liquid Carryover on the Performance of a Centrifugal Compressor
***Chaitanya Halbe, Ph.D.**, Carrier Corporation, Bloomfield, CT*

3. Application of 3D CFD to a Scroll Compressor with Vapor Injection
***Joe Ziolkowski**, Trane Technologies, La Crosse, WI*

Seminar 27 (Intermediate)

Application of Low GWP Refrigerants in Centrifugal Chillers

Track: HVAC&R Systems and Equipment

Sponsor: 8.2 Centrifugal Machines, MTG.LowGWP Lower Global Warming Potential Alternative Refrigerants

Chair: Mark Rogan, P.E., Member, Artic Chiller Group, Stuarts Draft, VA

Presenters will share results of recent investigations into the application of alternate refrigerants for chillers with centrifugal-type compressors. Single component and multi-component refrigerant blends are considered; all have significantly lower GWP than the baseline refrigerants they are intended to replace.
Analysis includes energy efficiency and associated impact on life cycle climate performance.

1. Alternative Refrigerants for Centrifugal Chillers
***Phillip Johnson, P.E., Member**, Daikin Applied, Staunton, VA*

2. New Refrigerants for Centrifugal Chillers
***Stephen Kujak, Member**, Trane, La Crosse, WI*

Seminar 28 (Advanced)

Application of Machine Learning in Future Proofing Building Operation

Track: Future Proofing - Renewable, Regenerative, and Resilient

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

Chair: Jin Wen, Ph.D., Member, Drexel University, Philadelphia, PA

Advanced building control and operation provide the smartness for a building to address the many challenges faced by the industry. High-fidelity energy forecasting model, as a core component of model-predictive-control and energy analytics, is critical for advanced building operation. Data-driven energy forecasting modeling, especially those that use machine learning methods, receives great interest recently due to its cost-effectiveness and scalability. This seminar presents several case studies using various machine learning methods to demonstrate the effectiveness and performance of machine learning enabled energy forecasting and their application in advanced building operation used for future proofing operation.

1. Estimation of HVAC Energy Consumption Using Feature Selection and Machine-Learning Approaches
***Zheng O'Neill, Ph.D., P.E., Member**, Texas A&M University, College Station, TX*

2. Short-Term Load Forecasting to Enable Better Control of Buildings-to-Grid Integration
***Bing Dong, Ph.D., Associate Member**, Syracuse University, Syracuse, NY*

3. A Learning Framework for Load Forecast for Smart Residential Buildings
***Helia Zandi**, Oak Ridge National Laboratory, Knoxville, TN*

Seminar 29 (Intermediate)

Applying Machine Learning and AI Data-driven Controls: Case Studies, Challenges and Lessons Learned

Track: HVAC&R Systems and Equipment

Sponsor: 7.6 Building Energy Performance, 7.5 Smart Building Systems , TC 1.4, TC 7.3

Chair: Eric Yang, P.E., Member, Energy System Group, Washington, DC

This track includes innovative control strategies and lessons learned from real-world energy management practice. Presentations will address how machine learning, artificial intelligence, FDD and data analytics are helping buildings operate more efficiently.

1. Applying Machine Learning to Enhance Building Performance at US Army Reserve Centers
***Emily Windel**, PNNL, Richland, WA*

2. Data Education for Operators: Why It Matters
***Michael Bobker, Member**, CUNY Institute for Urban Systems, New York, NY*

Seminar 30 (Intermediate)

Approaches and Applications of Occupant Information Modeling

Track: Research Summit

Sponsor: MTG.OBB Occupant Behavior in Buildings, MTG.BIM Building Information Modeling

Chair: Na Luo, Ph.D., Lawrence Berkeley National Laboratory, Berkeley, CA

Energy-related occupant behavior in buildings is a key issue for building design optimization, energy diagnosis, performance evaluation, and building energy simulation. Occupant information modeling is significant for understanding the occupant behavior in buildings. This seminar provides an overview of key objectives and state-of-art research topics related to occupant information modeling and discusses how to integrate occupant information into the building design and operation stages to improve both the building energy performance and the occupant comfort. The seminar will also cover methods, tools and data to facilitate the occupant information modeling.

1. Why Do Building Occupants Matter? Objectives of the EBC Annex 79
***Andreas Wagner, Ph.D.**, Karlsruhe Institute of Technology, Karlsruhe, Germany*

2. Modeling Occupant Data for Supporting Privacy Risk Assessments
***Jens Hjort Schwee**, University of Southern Denmark, Odense, Denmark*

3. Extending the Brick Schema to Represent Metadata of Occupant Data
***Na Luo, Ph.D.**, Lawrence Berkeley National Laboratory, Berkeley, CA*

4. Simulating Occupant Comfort and Behavior for Geb Load Flexibility Emulation
***Jin Wen, Ph.D., Member**, Drexel University, Philadelphia, PA*

Seminar 31 (Basic)

Back to Basics: The Right Compressor for the Job

Track: HVAC&R Systems and Equipment

Sponsor: 8.1 Positive Displacement Compressors

Chair: Margaret Mathison, Ph.D., Member, Iowa State University, Ames, IA

This seminar provides an overview of the types of compressors available for HVAC&R applications, leaving attendees with an improved understanding of the capabilities and limitations of different designs. Speakers explain the operating characteristics of some of the most common compressors, including rolling piston, scroll, and centrifugal machines. They use similarity analysis to explore the appropriate application of each. Speakers also address how changes in refrigerants impact compressor operation, which proves especially important to understand as the industry continues to move towards low-GWP refrigerants.

1. Governing Principles of Compressor Design and Choice
***Matt Cambio, Member**, Trane Technologies, La Crosse, WI*

2. Performance Evaluation of Low-GWP Refrigerants in 1-100 Ton Scroll Compressors
***M. Mohsin Tanveer, Student Member** and Craig Bradshaw, Ph.D., Member, Oklahoma State University, Stillwater, OK*

3. Effects of Low-GWP Refrigerants on Hermetic Rolling Piston Compressors
***Davide Ziviani, Ph.D., Member**, Center for High Performance Buildings, Purdue University, West Lafayette, IN*

4. Electrification of Heating and Centrifugal Compressor Design
***Chris Thilges**, Trane Technologies, La Crosse, WI*

Seminar 32 (Intermediate)

Building Envelopes and their Resilience to Natural Disasters

Track: Future Proofing - Renewable, Regenerative, and Resilient

Sponsor: 4.4 Building Materials and Building Envelope Performance

Chair: Andre O. Desjarlais, Member, Independent Consultant, Montague, MI

In 2020 there were 22 weather/climate disaster events with losses exceeding $1 billion each to affect the United States. Overall, these events resulted in the deaths of 262 people, $95 billion in damage and significant economic effects on the areas impacted. Buildings account for a large percentage of the economic damage, and with the number of major disasters increasing, the impact on our building envelopes will multiply. This seminar includes presentations that discuss efforts underway to understand why our buildings are damaged during these events and what we are doing to try to reduce the impact.

1. There Was a Windstorm, Where Is My RTU?
***David Roodvoets**, Independent Consultant, Montague, MI*

2. Research & Resilient Construction – an Insurance Perspective
***Larry Stevig, AIA**, Building Research Unit of State Farm's Enterprise Research, Bloomington, IL*

3. Singin' in the Wind-Driven Rain
***Jay Crandell, P.E., Associate Member**, Ares Consulting, Shady Side, MD*

Seminar 33 (Intermediate)

Commissioning and Cultivation

Track: HVAC&R for Indoor Plants & Animals

Sponsor: 2.2 Plant and Animal Environment, 5.3 Room Air Distribution , MTG-CEA

Chair: James Megerson, P.E., Member, Design Mechanical Inc., Kansas City, KS

It's generally accepted that well commissioned buildings will operate better. This becomes more important when dealing with indoor agriculture facilities. There are many systems in these buildings that must operate congruently and in symphony to provide an indoor grow environment that promotes plant propagation and vitality. In addition to building systems, it is important to commission the growing process before plants are introduced into the space. This session presents the different life support systems for plants that must work in concert. Speakers compare and clarify the differences between whole building and horticulture commissioning related to these buildings.

1. Whole Building Commissioning for Cultivation
***Donald Hill, P.E., Member**, Accutec Service, Inc., Lee's Summit, MO*

2. Horticulture Commissioning
***Michael Zartarian**, Zartarian Engineering, Boston, MA*

Seminar 34 (Intermediate)

Computational Wind Engineering: Good, Bad and Ugly

Track: Fundamentals and Applications

Sponsor: 4.3 Ventilation Requirements and Infiltration

Chair: John Carter, Member, CPP, Windsor, CO

Computational wind engineering (CWE) is a specialized sub-set of the engineering application of computational fluid dynamics. The increasing availability of commercial CFD codes, combined with increasing computing power, is both a blessing and a curse to this application. It is a blessing in allowing for CWE to develop into a strong field within wind engineering, and a curse in that it has led and will continue to lead to the use of CFD for CWE without the required basic knowledge. "The judicial presumption of innocence does not hold in CFD. CFD results are wrong, until proven otherwise." Blocken, 2014.

1. Hybrid Computational/Physical Model Simulation of Wind Flow and Dispersion in the Built Environment
***Robert Meroney, Ph.D.**, Colorado State University, Fort Collins, CO*

2. Do's and Don't's When Modeling Flows Around Buildings Using CFD
***Duncan Phillips, Ph.D., P.E., Member**, Rowan Williams Davies & Irwin, Guelph, ON, Canada*

3. The Application of CFD for Dispersion Modeling: Is It Anything More Than Pretty Pictures?
***Christian Rohr**, CPP Wind Engineering Consultants, Windsor, CO*

Seminar 35 (Intermediate)

Considerations for District Energy Systems Utilizing Geothermal Heat Pumps

Track: Future Proofing - Renewable, Regenerative, and Resilient

Sponsor: 6.2 District Energy, 6.8 Geothermal Heat Pump and Energy Recovery Applications

Chair: Steve Tredinnick, Burns & McDonnell, Downers Grove, IL

Geothermal heat pumps (GHP) have seen wide spread application in the United States as well as other locations with favorable conditions. They have proven to be efficient where accepted design guidance has been followed. At present, there is considerable interest in using GHP in district energy systems, yet little experience exists with these types of applications and no accepted design guidance is available. This session highlights some of the issues that must be considered in design of such systems and will introduce some of the factors that must be looked if designs are to be efficient and cost effective.

1. District Geo: Just Moving Btus Around, Ma'Am.
***Lisa Meline, P.E., Member**, Meline Engineering Corporation, Sacramento, CA*

2. Buried Distribution Systems for Geothermal Heat Pump Based District Heating and Cooling
***Gary Phetteplace, Ph.D., P.E., Member**, GWA Research LLC, Lyme, NH*

3. Efficient GSHP District Energy Requires Efficient Building HVAC Systems
***Steven Kavanaugh, Ph.D., Fellow Life Member**, Energy Information Services, Northport, AL*

Seminar 36 (Intermediate)

Cybersecurity And The Built Environment

Track: Fundamentals and Applications

Sponsor: Cybersecurity MTG (not listed in dropdown above)

Chair: David J. Branson, P.E., Fellow ASHRAE, Compliance Services Group, Inc., Lubbock, TX

Cybersecurity has become a critical facet of sharing sensitive data across networks. The ASHRAE Cybersecurity Multidisciplinary Task Group has been formed to address Industry concerns on this topic. This seminar introduces some cybersecurity challenges for Industrial Internet of Things (IIoT) soft appliances and the rationale behind standards and guidelines development.

1. Cybersecurity Considerations for an Indoor Air Quality Iiot Appliance
***David J. Branson, P.E., Fellow ASHRAE**, Compliance Services Group, Inc., Lubbock, TX*

Seminar 37 (Intermediate)

Data-Driven Computational Fluid Dynamics

Track: Design, Control, and Operation of Critical Environments

Sponsor: 4.10 Indoor Environmental Modeling

Chair: Duncan Phyfe, Associate Member, Alden Research Laboratory, Holden, MA

Humans are on a never-ending quest for speed; this desire even applies to our analysis tools. This seminar session will look at various approaches being taken for faster solutions in Computational Fluid Dynamics (CFD) analysis. The increased speed of solution will allow for wider usage, along with the ability to look at larger and more complex models. The urban environment provides an extremely complex and unpredictable flow pattern that is tamed through machine learning. Similarly, artificial intelligence can be used to speed up air distribution models for indoor spaces.

1. Artificial Intelligence for Indoor Airflow Simulation
***Wangda Zuo, Ph.D., Member**, University of Colorado, Boulder, CO*

2. Using Wind Tunnel Measurements to Validate External Flow Simulations
***Goncalo Pedro, Ph.D.** and Duncan Phillips, Ph.D., P.E., Member, Rowan Williams Davies & Irwin, Guelph, ON, Canada*

3. Accelerating RANS Simulations Using a Data-Driven Framework for Eddy-Viscosity Emulation
***Himanshu Sharma, Ph.D.**, Pacific Northwest National Laboratories, Richlan, WA*

4. Estimating Urban Wind Power Potential Based on Machine Learning with City Fast Fluid Dynamics Training Data
***Leon Wang**, Concordia University, Montreal, QC, Canada*

Seminar 38 (Intermediate)

Data-Driven Control of Residential and Commercial Buildings for Energy and Cost Savings

Track: Research Summit

Sponsor: 7.5 Smart Building Systems, 7.6 Building Energy Performance

Chair: Kristen Cetin, Ph.D., P.E., Member, Michigan State University, East Lansing, MI

Data-driven and model-predictive control (MPC) of buildings and building systems provides significant opportunities to reduce energy and greenhouse gas emissions from the built environment, and support load modulation for grid resilience. Ongoing research efforts in the U.S. work towards the development and demonstration of such methods for residential and commercial buildings. This session covers ongoing efforts at universities and national laboratories across the country.

1. Model Predictive Control or Deep Reinforcement Learning-Based Control for Commercial Building Energy System
Yangyang Fu, Ph.D., Member*, Drexel University, Philadelphia, PA*

2. Optimal Precooling Using a Data-Driven Thermal Model in Residential Buildings
Junke Wang, Student Member*, University of Oklahoma, Norman, OK*

3. Load Management Using Reinforcement Learning
Helia Zandi, Member*, Oak Ridge National Laboratory, Oak Ridge, TN*

4. Data-Driven Optimization, from Today's Products to Research
Jessica Graderson*, Lawrence Berkeley National Laboratory, Berkeley, CA*

Seminar 39 (Basic)

Demand for Variable Speed Equipment in Data Center Applications

Track: HVAC&R Systems and Equipment

Sponsor: 1.11 Electric Motors and Motor Control, 5.1 Fans , 5.1 Fans

Chair: Nicolas S. Rosner, P.E., Member, Eaton, City of Industry, CA

Data center is a fast-growing niche in the HVAC&R industry and Data Center mechanical equipment design requires both redundancy and energy efficiency. The purpose of this presentation is to identify the needs of a Data Center end-user, including critical equipment. ECM and VFD fan arrays will be presented. Speakers will also discuss Custom Air Handler system design with an emphasis on variable speed technology. Top industry experts will explain equipment considerations. Participants will understand equipment solutions in this critical segment of the industry.

1. Fan Array Technology - Efficiency, Basics, Inductions Motors with VFDs and Ecms
Tom A. Bise, Associate Member*, Johnson Controls, York, PA*

2. Custom Air Handlers
George Paich, Associate Member*, Alliance Air Products, San Diego, CA*

3. Data Center Mechanical Equipment Design, Redundancy, and Variable Speed Applications
Tim Chadwick, P.E., Member*, AlfaTech, San Jose, CA*

Seminar 40 (Intermediate)

Demystifying Controlled Environments for Agriculture

Track: HVAC&R for Indoor Plants & Animals

Sponsor: 2.2 Plant and Animal Environment, 5.3 Room Air Distribution , MTG-CEA

Chair: Nadia Sabeh, Ph.D., P.E., Associate Member, Dr. Greenhouse, Inc., Sacramento, CA

With cannabis becoming legal in nearly every US state and many countries around the globe, there are more indoor grow facilities being built. It is important for engineers and contractors to be aware of the unique requirements associated with Controlled Environments for Agriculture (CEA) facilities. The HVACD systems do not follow the conventional wisdom experienced with typical buildings. Knowing how plants thrive and produce and how that is dependent on space temperature and humidity is extremely important. The paradigm CEA is realizing that we are trying to create the perfect outdoor day for growing inside the building, every day.

1. Programming and Architecture for Controlled Environments for Agriculture
Brian Anderson, AIA*, Anderson Porter Design, Cambridge, MA*

2. Hvacd for Controlled Environments for Agriculture
James Megerson, P.E., Member*, Design Mechanical Inc., Kansas City, KS*

3. Purpose Built for CEA
Adrian Giovenco, Member*, Inspire Transpiration Solutions, Berkeley, CA*

Seminar 41 (Intermediate)

Displacement vs Mixing Ventilation: How to Use Them to Mitigate Indoor Virus Transmission

Track: Design, Control, and Operation of Critical Environments

Sponsor: 4.10 Indoor Environmental Modeling

Chair: Wangda Zuo, Ph.D., Member, University of Colorado, Boulder, CO

The airborne transmission of viruses (including COVID-19) via aerosols is a reality that will affect the way ventilation systems are designed for years to come. This seminar evaluates the impact of mixed and displacement ventilation methods on mitigating indoor virus transmission for different indoor environments. Some novel improvements over the conventional design are also proposed to improve the indoor air quality.

1. Displacement Vs Mixing Ventilation: Which Is Better to Limit Airborne Virus Transmission Risk in an Office Environment
***Duncan Phillips, Ph.D., P.E., Member**, Rowan Williams Davies & Irwin, Guelph, ON, Canada*

2. Airborne Transmission of Infectious Aerosols in a Typical Classroom
***Mike Koupriyanov, P.E., Associate Member**, Price Industries Limited, Winnipeg, MB, Canada*

3. Wall-Mounted Displacement Induction Ventilation System for Reducing Virus Transmission in Classrooms
***Qingyan Chen, Ph.D., Life Member**, Purdue University, West Lafayette, IN*

Seminar 42 (Intermediate)

Experimental Study on the Effect of Enhanced Tube Characteristics on Fouling Behavior and Fouling Prediction Model

Track: Fundamentals and Applications

Sponsor: 8.5 Liquid-to-Refrigerant Heat Exchangers, 1.3 Heat Transfer and Fluid Flow

Chair: Kashif Nawaz, Ph.D., Member, Oak Ridge National Laboratory, Oak Ridge, TN

Implementation of enhanced tubes in heat exchangers design has led to the improvement in the thermal efficiency of refrigeration, heating, and air conditioning systems. However, available fouling prediction models are not accurate enough to predict the effect of tube enhancement and water quality on fouling progression inside tubes. This seminar will highlight the result of the experimental study conducted as part of ASHRAE RP-1677 on evaluating the effect of enhanced tube characteristics and water quality on the fouling behavior and propose a model that can predict the fouling by considering the sticking probability and deposit bond strength in different geometries.

1. Investigation on Fouling of Enhanced Tubes Used in a Cooling Tower Water System Based on a Long-Term Test
***Chao Shen, Ph.D., Member**, Harbin Institute of Technology, Harbin, China*

2. Experimental Study on the Fouling Prediction Model, Sticking Probability and Deposit Bond Strength of Fouling in Enhanced Tubes
***Chao Shen, Ph.D., Member**, Harbin Institute of Technology, Harbin, China*

3. Performance Degradation Due to the Fouling of Heat Exchangers for Evaporative Cooling Applications
***Kashif Nawaz, Ph.D., Member**, Oak Ridge National Laboratory, Oak Ridge, TN*

Seminar 43 (Advanced)

Fault Prevalence Types and Impacts by Building Types and System Types

Track: Design, Control, and Operation of Critical Environments

Sponsor: 7.5 Smart Building Systems

Chair: Piljae Im, Ph.D., Member, Oak Ridge National Laboratory, Oak Ridge, TN

The lack of comprehensive studies on prevalence of various faults in commercial buildings has been a major barrier for building owners and operators to deploy AFDD in their buildings. This seminar presents the results of recent large-scale studies investigating the prevalence of faults in HVAC systems in commercial buildings as well as the impacts of the various fault scenarios on unitary air conditioner and high performance control sequences in handling those faults. The seminar will also discuss the challenges of this type of study and the implication of the results.

1. Quantifying HVAC Fault Prevalence Using the Largest Standardized Fault Dataset Assembled to Date
***Eliot Crowe**, Lawrence Berkeley National Laboratory, Berkeley, CA*

2. Impacts of Faults on Unitary Air Conditioners
***Yifeng Hu, P.E., Student Member**, University of Nebraska - Lincoln, Omaha, NE*

3. Performance of High-Performance Control Sequences in Handling Various Faults

***Xing Lu, Student Member**, Texas A&M University, College Station, TX*

Seminar 44 (Basic)

Findings from the Big-Box Efficiency Project: Integrating Pre-Commercial Technologies to Drive Deep Energy Savings at a Big Box Retailer in Southern California

Track: Future Proofing - Renewable, Regenerative, and Resilient

Chair: John Woolsey, P.E., Member, Center for Sustainable Energy, San Diego, CA

The Big-Box Efficiency Project is a partnership with the California Energy Commission, a big box retailer, IOU, and non-profit, to evaluate impacts of installing an integrated suite of precommercial energy efficiency technologies in an existing big-box retail store. The goal is to achieve greater than 20% savings in electric consumption, in support of California's aggressive greenhouse gas reduction goals. This session focuses on the innovative technologies used to drive deep energy efficiency savings in big-box retail and opportunities to further build resiliency through the integration of these types of technologies with on-site generation, storage and demand-response.

1. Pursuing Deep Energy Savings at a Walmart in Southern California Using Pre-Commercial Technologies
***John Woolsey, P.E., Member**, Center for Sustainable Energy, San Diego, CA*

Evaluating and Implementing Cutting-Edge Efficiency Projects to Meet Sustainability Targets in Big-Box Retail
***Yogesh Mardikar**, Walmart, Betonville, AR*

Seminar 45 (Intermediate)

Fume Hood Testing and the State of the Industry

Track: Design, Control, and Operation of Critical Environments

Sponsor: 9.10 Laboratory Systems

Chair: Robert Weidner, P.E., Member, Gannett Fleming, Inc., Camp Hill, PA

People working in laboratories rely on proper performance of fume hoods to protect them from exposure to hazardous airborne chemicals. The ASHRAE 110 Method of Testing Performance of Laboratory Fume Hood has been used for more than 25 years and the results have been used to improve fume hood design, lab safety and energy efficiency. This session will review the results of Research Project 1573 for a new tracer gas option that is more environmentally conscious, discuss upgrades to the ASHRAE 110 Standard and also discuss other fume hood safety testing protocols from around the world.

1. Results of Ashrae Research Project 1573-TRP to Identify an Environmentally Friendly Air Tracer for Testing Fume Hood Performance
***Thomas Smith, Member**, 3Flow, Cary, NC*

2. Ashrae 110 Revisions
***Jim Coogan, P.E., Member**, Siemens Building Technology, Buffalo Grove, IL*

3. International Standards for Performance Testing of Fume Hoods
***Brad Cochran, P.E., Member**, CPP Wind Engineering & Air Quality Consultants, Fort Collins, CO*

Seminar 46 (Intermediate)

Future Fuels for Decarbonization of the Built Environment

Track: Future Proofing - Renewable, Regenerative, and Resilient

Sponsor: 6.10 Fuels and Combustion

Chair: Alex Fridlyand, Ph.D., Associate Member, Gas Technology Institute, Des Plaines, IL

Renewable fuels are gases, liquids, and solids that can be synthesized from renewable energy sources such as wind, solar, and biomass. As a form of high-density energy storage and carrier, these fuels can often be a drop-in replacement or a blending component for fossil derived alternatives. In this form, renewable fuels can utilize the already built infrastructure and help decarbonize difficult-to-electrify segments of the built environment and yield immediate environmental benefits. This seminar will review cases studies and ongoing research on the applications of renewable fuels.

1. Renewable Gas for a Path Towards Carbon Neutrality
***James Leidel, Member**, DTE, Detroit, MI*

2. Hydrogen Renewable Fuel for Decarbonization at Scale and Energy Storage
***Paul Glanville, P.E., Associate Member**, Gas Technology Institute, Des Plaines, IL*

3. Liquid Renewable Fuels for Greenhouse Gas Reduction
***Thomas Butcher, Ph.D., Fellow ASHRAE**, Brookhaven National Laboratory, Upton, NY*

Seminar 47 (Intermediate)

Future Proofing the Built Environment with Renewable, Regenerative and Resilient Combined Heat and Power Systems

Track: Future Proofing - Renewable, Regenerative, and Resilient

Sponsor: 1.10 Cogeneration Systems

Chair: Blake Ellis, P.E., Member, Burns & McDonnell, Overland Park, KS

In response to the drive for renewable energy and a growing need for energy resilience, CHP offers the best of both worlds. The original motivators of CHP were based on its energy efficiency which resulted in reduced fuel use, emissions and operating costs, while the resilience benefits were accepted as a side benefit. With a reordering of priorities and the move to renewable sources of energy, CHP technology has evolved to meet the challenge. This seminar will explore renewable energy driven CHP technologies, how CHP is key to energy resilience and why CHP's energy efficiency trumps many other RE options.

1. Regenerative & Resilient CHP
***Gearoid Foley, Member**, Integrated CHP Systems Corp., Princeton, NJ*

2. Hybrid Microgrid (CHP, PV & Storage) Case Study
***Dragos Paraschiv, Associate Member**, Humber College Institute of Technology and Advanced Learning, Knoxville, TN*

3. Renewable CHP
***Richard Sweetser, Life Member**, Exergy Partners Corp., Herndon, VA*

Seminar 48 (Intermediate)

Grid-Interactive Efficient Buildings for Renewable Energy Integration and Decarbonization

Track: Future Proofing - Renewable, Regenerative, and Resilient

Sponsor: 7.5 Smart Building Systems

Chair: Donghun KIM, Ph.D., Lawrence Berkeley National Laboratory, Berkeley, CA

The rapid penetration of photovoltaics, batteries and thermal energy storages increases the complexity of building systems. The increasing pressure of the clean energy and renewable portfolio standards and the growing need for load flexibility and grid services have also imposed additional challenges on building operators. The paradigms of the grid-interactive efficient building and building to grid integration are promising pathways for renewable energy integration and decarbonization. This session will discuss and present the corresponding recent efforts on building operation strategies and smart grid approach.

1. Hierarchical Model Predictive Control for Resilient Operation of a Residential Community with Local Distributed Energy Resources
***Xin Jin, Ph.D., Member**, National Renewable Energy Laboratory, United States of America, Golden, CO*

2. Smart Grid and Renewable Energy Integration
***Shihab Kuran, Ph.D.**, Power Edision, Watchung, NJ*

3. Which Signals Should Grid-Interactive Building Model Predictive Controllers Follow?
***Greg Pavlak, Ph.D., Member**, Penn Sate University, State College, PA*

4. Field Demonstration of Model Predictive Control for Integrated Thermal Energy Storage Cooling Plant with Solar Pvs
***Donghun KIM, Ph.D.**, Lawrence Berkeley National Laboratory, Berkeley, CA*

Seminar 49 (Intermediate)

Hands-on Demonstration: Automating Control Sequence Selection and Evaluation

Track: Future Proofing - Renewable, Regenerative, and Resilient

Sponsor: 1.4 Control Theory and Application

Chair: Ed Morris Jr., Member, Carrier Corporation, Rockfall, CT

Properly designed and delivered control sequences are a key element for the delivery of high-performance commercial buildings. Unfortunately, this is hard to achieve using the current process. Work completed in ASHRAE Guideline 36 and being developed in the US DOE labs and in ASHRAE standard 231P, has the potential to offer dramatic improvements. This workshop will take participants through the tools and process being developed and demonstrate how they can be used from system concept through project delivery.

1. Introduction to the Digital Control Design and Delivery Process
***Paul Ehrlich, P.E., Member**, Building Intelligence Group, Portland, OR*

2. Getting Started Using Controls Modeling Tools to Design and Simulate Optimized Sequences.
***Milica Grahovac, Dr.Ing., Member**, Lawrence Berkeley National Laboratory, Berkeley, CA*

3. How Controls Design Tools and Simulation Work for an Experienced Controls Designer.
***Jamie Nickels, Member**, Facility Dynamics Engineering, Glen Allen, VA*

Seminar 50 (Intermediate)

Holistic Envelope and HVAC Design and Retrofit Considerations in Hot and Humid Locations

Track: Fundamentals and Applications

Sponsor: 4.4 Building Materials and Building Envelope Performance

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

'Hot and humid' can be scary, especially when they happen at the same time. Retrofit, design and operation of buildings is particularly challenging due to moisture and mold issues, but many ASHRAE members face this every day. Thus, this seminar presents guidelines and shares lessons learned from three fantastic case studies in hot and humid locations: from discussing principles needed for energy efficient humidity control in residential construction, use of unconditioned outdoor air to prevent mold growth and improve indoor air quality, to key steps in retro-fit ventilation options. Join us to learn more about it!

1. Relative Humidity Control Needs to be Accounted for in Energy Rated and Near Zero Energy Homes in Warm Moist Climates
***Chuck Withers**, Florida Solar Energy Center, Cocoa, FL*

2. Using Unconditioned Outdoor Air to Improve Indoor Air Quality in a Hot and Humid Climate
***Peter Adams, P.Eng., Member**, Morrison Hershfield Ltd, Toronto, ON, Canada*

3. Top Priorities for Improving Energy-Efficient Relative Humidity Control in Existing Small Commercial Buildings Located in Humid Climate Zones
***Chuck Withers**, Florida Solar Energy Center, Cocoa, FL*

Seminar 51 (Basic)

How To Run an Effective Meeting

Track: Professional Development

Sponsor: 7.2 HVAC&R Construction & Design Build Technologies, 9.8 Large Building Air-Conditioning Systems , Communications Committee

Chair: Schopplein-Anderson Schopplein, P.E., Member, University Mechanical & Engineering Contractors, El Cajon, CA

Ever wondered how to make your meetings more efficient? Why are some meetings efficient while others feel like a waste of your time? This seminar helps teach you the skills to run better in person meetings, virtual meetings, and how to properly implement Robert's Rules of Order. Whatever type meeting you are leading, learn how to be more efficient, productive and effective.

1. Leading Successful Engaging and Productive Meetings
***Karine Leblanc, Member**, US Air Conditionings Ditstributors, City of Industry, CA*

2. Robert's Rules of Order
***Timothy Wentz, P.E., HBDP, Presidential Member**, University of Nebraska-Lincoln, Lincoln, NE*

3. Effective Virtual Meetings
***Pam Duffy, P.E., Member**, Spark One Solutions, LLC, Dallas, TX*

Seminar 52 (Advanced)

Latest Developments in Low-GWP Refrigerants and Systems for Refrigeration

Track: HVAC&R Systems and Equipment

Sponsor: 10.7 Commercial Food and Beverage Refrigeration Equipment, 3.1 Refrigerants and Secondary Coolants , REF-CPCC, TC8.1, TC10.6

Chair: Georgi Kazachki, Ph.D., Fellow ASHRAE, Cryotherm, Raleigh, NC

The last years witnessed unprecedented development and implementation of new environment-friendly refrigerants and associated refrigeration technologies with constantly improving energy efficiency and acceptable cost and return on investments. This seminar provides the stage for presenting the broad variety of refrigeration technologies demonstrating the application of refrigerants with low-GWP, natural refrigerants, refrigerants with low flammability limits, flammable refrigerants and also refrigeration technologies with enhanced efficiency.

1. Distributed Scroll Booster for Supermarket Refrigeration

***Mike Saunders, Member**, Emerson, Dayton, OH*

2. Performance Evaluation of a Multi-Temperature Refrigerated Container Using R744 Technology
***Neal Lawrence, Ph.D., Associate Member**, Creative Thermal Solutions, Urbana, IL*

3. Dynamic Analysis of Multi-Evaporator Transcritical CO2 Refrigeration Systems with Expansion Work Recovery
***Riley Barta, Ph.D., Member**, Technical University of Dresden, Dresden, Germany*

4. Sorting through Lubricants and Low GWP Refrigerants for Commercial Refrigeration Applications
***Joe Karnaz, DSc, Member**, Shrieve Chemical, Houston, TX*

5. Case Study Demonstrating the Energy Efficiency Improvements with the Use of HC (R-290) and Variable Speed Compressor Technology in Self-Contained Frozen Island Merchandisers
***Mike Devine**, Tecumseh Product Company, Ann Arbor, MI*

Seminar 53 (Basic)

Lessons in Collaboration from Cx Agents

Track: Professional Development

Sponsor: 7.9 Building Commissioning

Chair: Michael Flemming, P.E., Associate Member, Interface Engineering, San Francisco, CA

Engineers and design professionals face challenges that reach beyond their technical capabilities to ensure that sustainable and energy efficient features along with client project goals are maintained in projects. As projects progress from conceptual design through occupancy all industry professional must be able to balance technical and interpersonal challenges to meet project goals while ensuring that project teams remain collaborative instead of confrontational. This session focuses on lessons learned by Commissioning Providers who in many cases act as mediators between design, construction and building owners with the goal of ensuring that parties remain collaborative and that project goals are met.

1. The Art of Moving Projects Forward
***Michael Flemming, P.E., Associate Member**, Interface Engineering, San Francisco, CA*

2. Tailoring Value for the Customer
***Steven Klekas, P.E., BCxP, Member**, University of Utah, SLC, UT*

3. Making the Invisible Visible: A Balanced Perspective
***Soph Davenberry**, National Energy Management Institute Committee, Falls Church, VA*

Seminar 54 (Intermediate)

New Trends in Environmental Control for Poultry and Swine Production Housing

Track: HVAC&R for Indoor Plants & Animals

Sponsor: 2.2 Plant and Animal Environment

Chair: Morgan Hayes, Ph.D., Affiliate, University of Kentucky, Lexington, KY

Housing for poultry and swine is constantly improving. These improvements in environmental control occur due to changes in animal housing style, availability of new ventilation equipment, and concerns with biosecurity for the animals.

1. Environmental Control for Swine Facilities: Improved Biosecurity and Production
***Brett Ramirez, Ph.D., Member**, Iowa State University, Ames, IA*

2. New and Recent Trends in Ventilation and Environment Control in Poultry Production Facilities
***Richard Gates**, Iowa State University, Ames, IA*

Seminar 55 (Advanced)

Next Generation Equipment Rating: The Load-Based Testing Approach

Track: HVAC&R Systems and Equipment

Sponsor: 8.11 Unitary and Room Air Conditioners and Heat Pumps

Chair: Davide Ziviani, Ph.D., Member, Center for High Performance Buildings, Purdue University, West Lafayette, IN

This seminar will provide an overview of the load-based testing and rating approach for unitary air conditioners and heat pumps and will highlight shortcomings of the current AHRI 210/240 rating standard. Speakers will explain the fundamentals of the load-based testing methodology, how the testing procedure has been developed and why such approach has the potential to better capture field performance of unitary equipment under different climate conditions, building types and variable speed operation. Speakers will also address the need for validation and repeatability of the testing results as well as convergence criteria

1. Dynamic Load-Based Testing for Unitary Equipment – a Step-By-Step Tutorial

***Andrew Hjortland, Ph.D., Member**, Johnson Controls, Inc., Norman, OK*

2. Validation of a Load-Based Testing Method for Performance Assessment of Residential Heat Pumps
***Parveen Dhillon, Student Member** and James Braun, Ph.D., Fellow ASHRAE, Purdue University, West Lafayette, IN*

3. Representativeness Field Testing Plans
***Christopher Dymond, Member**[1] and Rick Huddle, P.E.[2], (1)NEEA, Portland, OR, (2)Cadeo Group, Portland, OR*

4. Mapping the Performance of Residential Air Conditioners Using Load-Based Testing to Enable Climate and Building Specific Ratings
***James Braun, Ph.D., Fellow ASHRAE** and Parveen Dhillon, Student Member, Purdue University, West Lafayette, IN*

Seminar 56 (Intermediate)

Occupant-centric Performance Metrics

Track: Research Summit

Sponsor: MTG.OBB Occupant Behavior in Buildings

Chair: Han Li, Associate Member, Lawrence Berkeley National Laboratory, Berkeley, CA

Occupant behaviors have significant impacts on building operations and indoor environmental quality (IEQ), while occupants' comfort and wellbeing are influenced by building design and operations. Understanding the building performance from occupant-centric perspectives is crucial to inform building design and operations given the increasing needs for energy efficiency and demand flexibility. This seminar will provide an overview of the occupant-centric building performance metrics, discuss their categories, targets, quantification methods, and implications. Existing and prospective use cases such as performance benchmarking, building code and standard compliance, and occupant-centric building controls, will also be discussed.

1. Occupant-Centric Key Performance Indicators for Building Design and Operations
***Han Li, Associate Member**, Lawrence Berkeley National Laboratory, Berkeley, CA*

2. Occupant-Centric Metrics - a Better Indicator of Sustainability
***Liam O'Brien, Ph.D.**, Carleton University, Ottawa, ON, Canada*

3. Metrics for Occupant-in-the-Loop Controllers
***Zoltan Nagy, Ph.D., Associate Member**, The University of Texas at Austin, Austin, TX*

4. Measuring Success When Seeking to Satisfy Heterogeneous Occupants
***Clinton Andrews, Ph.D., P.E., Member**, Rutgers University, New Brunswick, NJ*

Seminar 57 (Intermediate)

Overview of the New Section on Multi-scale Building Energy Modeling in Chapter 19 of 2021 Fundamentals Handbook

Track: Fundamentals and Applications

Sponsor: 4.7 Energy Calculations

Chair: Tianzhen Hong, Ph.D., Fellow ASHRAE, Lawrence Berkeley National Laboratory, Berkeley, CA

A new section on multi-scale building energy modeling (BEM) was developed for Chapter 19 of the 2021 Fundamentals Handbook. This seminar provides an overview of BEM's use across five scales: sub-building, building, district, urban, and regional and national. Each scale of BEM aims to provide insights into: (1) What are the problems and use cases this scale tries to address? (2) What are modeling approaches and available tools for this scale? (3) What data sources, models and standards are available to support this scale of modeling? and (4) What are modeling and simulation challenges at this scale?

1. Modeling Nationwide Building Stocks for Energy Efficiency, Flexibility, and Decarbonization
***Jared Langevin, Ph.D.**, Lawrence Berkeley National Laboratory, Berkeley, CA*

2. Regional Building Stock Modeling Approaches and Applications
***Eric Wilson**, NREL, Boulder, CO*

3. Urban Scale Building Energy Modeling
***Xuan Luo**, LBNL, United States of America, Berkeley, CA*

4. Modelica-Based Modeling from District Energy Systems to Buildings and Control Sequences
***Michael Wetter, Ph.D., Member**, Lawrence Berkeley National Laboratory, Berkeley, CA*

Seminar 58 (Advanced)

Performance of Alternative Low GWP A2L Refrigerants in Evaporators

Track: HVAC&R Systems and Equipment

Sponsor: 1.3 Heat Transfer and Fluid Flow, MTG.LowGWP Lower Global Warming Potential Alternative Refrigerants , 8.5 Liquid-to-Refrigerant Heat Exchangers

Chair: Pratik Deokar, Ph.D., Member, Rheem Manufacturing Company, Lewisville, TX

There has been a continuous effort to evaluate the performance of alternative refrigerants, which can substitute conventional working fluids like R410A, in current HVAC&R systems to have reduced environmental impact. This seminar highlights the performance of low GWP and A2L refrigerants and blends under flow boiling or evaporation inside internally enhanced tubes, small size channels, and plate heat exchangers. The seminar helps to identify the potential of Artificial Neural Network to predict the boiling heat transfer coefficients for the new refrigerants. This session will benefit engineers to design improved heat exchangers for their new or existing systems.

1. Heat Transfer Coefficient and Pressure Drop during Flow Boiling of A2L Refrigerants
***Claudio Zilio, Ph.D.**, Dept. Fisica Tecnica, University of Padova Italy, Padova, Italy*

2. Evaporation of Low GWP A2L Refrigerants in Small Diameter Tubes and Plate Heat Exchanger
***Akio Miyara, Ph.D.**, Saga University, Saga-shi, Japan*

3. Thermal-Hydraulic Performance Evaluation of Refrigerants Under Flow-Evaporation
***Kashif Nawaz, Ph.D., Member**, Oak Ridge National Laboratory, Oak Ridge, TN*

Seminar 59 (Intermediate)

Performance of low GWP refrigerants in plate heat exchangers

Track: HVAC&R Systems and Equipment

Sponsor: 8.5 Liquid-to-Refrigerant Heat Exchangers, 1.3 Heat Transfer and Fluid Flow

Chair: Kashif Nawaz, Ph.D., Member, Oak Ridge National Laboratory, Oak Ridge, TN

Plate heat exchangers are extensively adopted in HAVC systems due to their smaller footprint, limited refrigerant charge, higher efficiency, and lower cost. This seminar will highlight the experimental and theoretical work on condensation and boiling of low GWP refrigerants inside a plate heat exchanger. It will provide heat transfer and fluid flow analysis by comparing the two conventional prediction approaches. Moreover, the effect of various parameters such as fouling, corrosion, and particle aggregation on the extended performance of a plate heat exchanger will be discussed. Lastly, a comprehensive performance correlation for plate heat exchangers will be presented.

1. An Overview of the Long-Term Performance Degradation of Heat Exchangers
***Kashif Nawaz, Ph.D., Member**, Oak Ridge National Laboratory, Oak Ridge, TN*

2. Low-GWP Heat Transfer and Fluid Flow in Plate Heat Exchangers
***Simone Mancin, Ph.D.**, University of Padova, Padua, TN, Italy*

3. Development of Generalized Performance Correlation for Thermal-Hydraulic Performance of Plate Heat Exchanger
***Tariq Saeed Khan, Ph.D., Member**, Higher College of Technology, Dubai, United Arab Emirates*

Seminar 60 (Basic)

Putting Life Into Life Cycle Cost Analysis: Real World Costs Commonly Overlooked

Track: Fundamentals and Applications

Sponsor: 7.3 Operation and Maintenance Management

Chair: Matthew Mullen, P.E., Member, EMCOR Services New England Mechanical, South Windsor, CT

Life Cycle Cost Analysis is routinely used to evaluate engineering alternatives. Proper analysis requires understanding Life Cycle Cost principles and must include all potential costs, not just first cost and energy costs. This seminar will provide an update on life cycle cost techniques, provide real world examples of overlooked costs that can dramatically alter the results, and the impact of COVID-19 building modifications on original life cycle cost analyses.

1. Back to Basics and Beyond: Life Cycle Costing for Decision-Making in the 21st Century
***Sonya Pouncy, Member**, Building Vitals, Detroit, MI*

2. Experience and Total Costs of Ownership: The Whole Truth, and Nothing but the Truth.
***Don Gariepy, Member**, University of North Carolina at Charlotte, Charlotte, NC*

3. The Impact of COVID-19 Changes to a Building's Life Cycle Costs
***Aaron Sorrell**, GSA - PBS - Design and Construction Division, Boston, MA*

Seminar 61 (Intermediate)

Quantifying and Minimizing Exposure to Airborne Infectious Diseases in Different Indoor Environments

Track: Future Proofing - Renewable, Regenerative, and Resilient

Chair: Eric Martin, FSEC Energy Research Center at the University of Central Florida, Cocoa, FL

Existing evidence strongly suggests that viral infectious diseases can be transmitted via an airborne route across distances in indoor environments. Accordingly, sharing indoor space in the presence of infected individuals poses a major risk in the transmission of the disease. This session will present results of two recently completed research projects. The first project quantified emissions from speaking in a physically distanced conference with overhead HVAC. The second project tested the effectiveness of low-cost interventions to isolate a contagious person from the rest of the occupants in a single family home.

1. Lab Home Testing of Residential Isolation Space Control to Minimize Infectious Disease Transmission in Existing Single-Family Homes
***Tanvir Khan, Ph.D.**, FSEC Energy Research Center at the University of Central Florida, Cocoa, FL*

2. Experiments to Measure Dispersion of Simulated Emissions from Speaking in a Physically-Distanced Meeting with Overhead HVAC
***Haoran Zhao, Ph.D.** and **Brett Singer, Ph.D., Member**, LBNL, Berkeley, CA*

Seminar 62 (Advanced)

RANS vs LES: Modeling Airflow in Built Environment

Track: Research Summit

Sponsor: 4.10 Indoor Environmental Modeling

Chair: Wangda Zuo, Ph.D., Member, University of Colorado, Boulder, CO

RANS (Reynolds-averaged Navier-Stokes) and LES (Large Eddy Simulation) are two most popular computational fluid dynamics methods in modeling airflows for built environment. To help users decide which approach to be used in their applications, this seminar illustrates their pros and cons via various examples.

1. Numerical Prediction of Time-Dependent Flows in Natural Ventilation
***Malcolm J. Cook, Ph.D., Member**, Faisal Durrani, Ph.D. and James J. McGuirk, Ph.D., Loughborough University, Loughborough, United Kingdom*

2. Comparing Unsteady RANS and LES with Lagrangian Particle Modeling in a Mechanically Ventilated Space
***Shichao Liu, Ph.D., Associate Member**, Worcester Polytechnic Institute, Worcester, MA*

3. The Difference between LES/DES and RANS for Outdoor Simulations
***Goncalo Pedro, Ph.D.**, Rowan Williams Davies & Irwin, Guelph, ON, Canada*

4. LES Vs RANS for Modeling Indoor Air Flow
***Vimaldoss Jesudhas, Ph.D.**, RWDI, Guelph, ON, Canada*

Seminar 63 (Advanced)

Radiant Cooling with Direct Solar Heat Gain

Track: Fundamentals and Applications

Sponsor: 6.5 Radiant Heating and Cooling

Chair: Peter Simmonds, Ph.D., Fellow ASHRAE, Building and Systems Analytics LLC, Emneth, CA, United Kingdom

This seminar presents several methods of accounting for solar radiation to radiant cooled floors. Design and operation methods will be presented.

1. Studying the Effects of Solar Radiation on Radiant Cooled Floors
***Daniel Nall, P.E., HBDP, CPMP and BEMP, Fellow Life Member**, Daniel Nall, Consultant, LLC, Princeton, NJ*

2. "Opportunities to Achieve Even Greater Energy Performance and Comfort with High Thermal Mass Radiant Systems - Improving the Standard Design Procedure for Load Calculations, Equipment Sizing, and Control"
***Jonathan Woolley, Ph.D., Member**, Emanant Systems, Colrain, MA*

3. Incorporating the Effects of Solar Radiation into the Design and Operation of Radiant Cooled Floors
***Peter Simmonds, Ph.D., Fellow ASHRAE**, Buildings and Systems Analytics LLC, Emneth, CA, United Kingdom*

Seminar 64 (Intermediate)

Selecting the Right UVC Disinfection Strategy for Your Application

Track: HVAC&R Systems and Equipment

Sponsor: 2.9 Ultraviolet Air and Surface Treatment

Chair: Henry Greist, Member, Lennox Industries, Inc., Ocala, FL

This seminar will focus on the various applications that will help guide the engineer, contractor and end-user to select the appropriate UV equipment that will have the greatest impact for reducing the transmission of pathogens in the space. This will include the use of upper air UVC fixtures, mobile UVC disinfection equipment (UVC robots) and UVC HVAC systems designed for air handler and airstream disinfection. The seminar will present various examples of common applications and discuss which UV strategy can be implemented for desired results.

1. Mobile UVC Systems for Whole Room Disinfection a
***Katja Auer, Member**, American Ultraviolet, Lebanon, IN*

2. Mobile UVC Systems for Whole Room Disinfection B
***Ashish Mathur, Ph.D.**, UVDI, Valencia, CA*

3. Upper Room Germicidal UV—a Robust Intervention for Mainstream Control of Airborne Pathogens
***Richard Vincent, Member**, Mount Sinai School of Medicine, New York, NY*

4. UV-C Applications in HVAC Systems
***William Bahnfleth, Ph.D., P.E., Presidential Fellow ASHRAE**, Penn State, University Park, PA*

5. Conclusion – Applications/Customer's Needs
***Brian Hafendorfer, P.E., Member**, Gray Engineering, Lexington, KY*

Seminar 65 (Intermediate)

Sound and Vibration Issues with Mission Critical Facilities

Track: Design, Control, and Operation of Critical Environments

Sponsor: 2.6 Sound and Vibration

Chair: Patrick Marks, P.E., Fellow ASHRAE, Johnson Controls, New Freedom, PA

Whether it is a hospital, a data center or another mission critical facility, these projects present their own unique sound and vibration control challenges. This seminar will highlight specific noise and vibration concerns unique to data centers and health care facilities and will review successful case studies of applications.

1. Data Center Sound and Vibration Control Issues
***Paul Bauch, Member**[1] and Patrick Marks, P.E., Fellow ASHRAE[2], (1)Johnson Controls, York, PA, (2)Johnson Controls, New Freedom, PA*

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

3. Noise Control That Focuses on Care and Safety in Healthcare
***Erik Miller-Klein, P.E., Member**, Tenor Engineering Group LLC, Seattle, WA*

Seminar 66 (Advanced)

Stack Effect and Wind Induces Building Pressure Mitigation Strategies in Tall Buildings

Track: Fundamentals and Applications

Sponsor: 9.12 Tall Buildings

Chair: Peter Simmonds, Ph.D., Fellow ASHRAE, Buildings and Systems Analytics LLC, Emneth, CA, United Kingdom

From previous designs and research, we know that outdoor conditions vary with height. Supertall buildings are taller than 300m and Mega Tall buildings are taller than 600m. At these heights, the outside climate can have both a positive and a negative effect on the space conditions within the building. This seminar will investigate the fluctuation of pressure differentials within the building, especially in relation to stair shafts and elevator shafts, over the height of the building

1. The Impact of Uncontrolled Building Pressure on HVAC Systems Design & Performance of Tall Buildings
***Mehdi Jalayerian, P.E., Member**, Environmental Systems Design, Inc., Chicago, IL*

2. Retrofit of a Tall Building Ventilation System to Address MUA Shortages
***Duncan Phillips, Ph.D., P.E., Member**, Rowan Williams Davies & Irwin, Guelph, ON, Canada*

3. Climate Effects on the Performance of Supertall and Mega Tall Building
***Peter Simmonds, Ph.D., Fellow ASHRAE**, Buildings and Systems Analytics LLC, Emneth, CA, United Kingdom*

Seminar 67 (Intermediate)

Standards and Regulations Affecting HVAC Systems Used in the US Controlled Environment Agriculture Market

Track: HVAC&R for Indoor Plants & Animals

Sponsor: 2.2 Plant and Animal Environment

Chair: Daniel Dettmers, Member, Quest Dehumidifiers, Madison, WI

The purpose of this seminar is to update the HVAC&R community on current and pending regulations effecting the cannabis industry and the rest of the Controlled Environmental Agriculture (CEA) industry, from full indoor growing to greenhouses and more. The focus will be on the HVAC system and anything that effects the sizing and selection of the HVAC system. We will also discuss gaps in current and proposed building standards, equipment rating standards, codes and regulations for the CEA industry as identified by the speakers, members of ASHRAE TC2.2 and other industry experts.

1. California Title 24's Controlled Environment Horticulture Regulation
***Kyle Booth, Member**, Energy Solutions, Boston, MA*

2. Energy Policies Regulating U.S. Cannabis Production Facilities
***Gretchen Schimelpfenig, P.E., Associate Member**, Resource Innovation Institue, Portland, OR*

3. Regulation in the Greenhouse Industry
***Jessica Walker**, ACME Engineering & Manufacturing, Muskogee, OK*

Seminar 68 (Advanced)

Strategies to Optimize Critical Exhaust Systems

Track: Design, Control, and Operation of Critical Environments

Sponsor: 9.10 Laboratory Systems, 1.4 Control Theory and Application

Chair: James Coogan, P.E., Associate Member, Siemens Smart Infrastructure, Chicago, IL

IAQ for laboratories and other spaces with airborne hazards depends on functioning exhaust systems to remove contaminated air. Manifolded exhaust systems, serving multiple, independent VAV air flow control terminals are the norm. Ganged fans with redundant equipment, operate in unison or in stages, often at varying speed to eject effluent clear of air intakes. This seminar explores ways to make exhaust systems perform and some pitfalls to avoid.

1. Optimization Strategies of the Exhaust Fan System
***Robert Kraft, Associate Member**, Greenheck, Schofield, WI*

2. Optimization Strategies of the Exhaust Flow Control System:
***Paul Fuson**, Siemens Smart Infrastructure, Buffalo Grove, IL*

Seminar 69 (Basic)

The Basics of Steam Boiler Water Treatment

Track: HVAC&R Systems and Equipment

Sponsor: 3.6 Water Treatment

Chair: William Pearson II, Member, BPEARSON Consulting LLC, Leland, NC

Steam boilers are used to generate steam for many purposes. The first trials and explosions started in the late 1700's and the first patented boiler was not until 1867. Steam boilers brought about the industrial revolution by providing room/building heat, building materials (lumber from saw mills), trains, ships and many other uses. Today healthcare, educational and institutional facilities use steam for building heat, domestic hot water, and humidification where desired. Effective water treatment and operation can help not only optimize operating costs and increase reliability of the boilers themselves but also the steam network as a whole.

1. Steam Boilers - the Truth or Consequences
***Dan Weimar, Member**, Chem-Aqua, Inc., Irving, TX*

2. Protecting Your Steam Network
***Henry Becker**, Earthwise Environmental, Chicago, IL*

3. Steam Boiler Pre-Treatment: It's Not Just Chemicals!
***Joseph Ham, Member**, DuBois Chemicals, Sharonville, OH*

Seminar 70 (Intermediate)

The Challenges Encountered When Commissioning Tall Buildings

Track: HVAC&R Systems and Equipment

Sponsor: 9.12 Tall Buildings, 7.9 Building Commissioning

Chair: Francis Kohout, P.E., Member, Cyclone Energy Group, Chicago, IL

The design and operation of tall buildings presents many unique challenges including air and water pressurization control and the impacts of stack effect. This seminar discusses approaches to commissioning tall building systems, techniques for testing and verifying operation, and present lessons learned from a variety of buildings. It will also include an evaluation of changes to the systems that may be needed over time and how commissioning with analytics is a valuable tool.

1. Commissioning Processes and Lessons Learned for Tall Buildings
***Benjamin Skelton, P.E., Member**, Cyclone Energy Group, Chicago, IL*

2. Commissioning Processes and Lessons Learned for Tall Building
***John Bell, BCxP**, RWDI, Toronto, ON, Canada*

Seminar 71 (Intermediate)

The Continuing Evolution of the ASHRAE Data Center Environmental Guidelines

Track: Design, Control, and Operation of Critical Environments

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

Chair: Joseph Gangemi, Life Member, Data Aire, Orange, CA

To address the growing emphasis on energy efficiency of data centers, TC 9.9 has been evolving the Thermal Guidelines on a regular basis as data becomes available. A historical perspective is given including the latest change to the recommended envelope based on research of high humidity and gaseous pollutants as it affects the reliability of IT equipment. Another environmental envelope has been added to the existing 4 air-cooling classes to accommodate high density racks. With increasing high density racks the IT industry will be deploying more liquid cooling products. With these trends the water-cooling classes have been expanded and renamed.

1. History of the Ashrae Thermal Guidelines and It Equipment Power Trends
***Dustin Demetriou, Ph.D., Member**, IBM, Poughkeepsie, NY*

2. Research on High RH and Gaseous Pollutants Impact on It Equipment Reliability
***Roger Schmidt, Ph.D., P.E., Member**, IBM, Poughkeepsie, NY*

3. Expanded Guidelines for Data Center and It Air Cooling
***Paul Artman**, Lenovo, Raleigh, NC*

4. Liquid Cooling White Paper and Updates to the Ashrae Water Cooling Classes
***Dave Moss**, Dell Inc., Round Rock, TX*

Seminar 72 (Basic)

Understanding the Basics of Controls, the Key to Becoming a Great Engineer for YEA!

Track: Fundamentals and Applications

Sponsor: 1.4 Control Theory and Application

Chair: Michelle Shadpour, Member, SC Engineers, Inc., San Diego, CA

Control systems are a fundamental component of any HVAC systems, and yet many engineers view it as mysterious black box. This seminar covers the basics to understanding controls, reviews essential concepts to effective designs and allows the audience to apply what they have learned through guided examples. Whether you are drafting the controls diagrams, writing the sequence of operations, or implementing the requirements of the drawings, understanding the basics of controls is essential to ensuring a project success.

1. Controls 101: The Fundamentals and Introduction to Direct Digital Control (DDC)
***Jim Coogan, P.E., Member**, Siemens Building Technology, Buffalo Grove, IL*

2. Starting with the End in Mind. How to Write Sequences of Operations for Block Programming
***Israa Ajam, Associate Member**, Yearout Energy, San Antonio Texas, TX*

Seminar 73 (Intermediate)

Using Artificial Intelligence to Optimize Building Performance

Track: Future Proofing - Renewable, Regenerative, and Resilient

Sponsor: 1.5 Computer Applications

Chair: Abhishek Khurana, Voyager Buildings, Toronto, ON, Canada

Commercial buildings drive a significant portion of global energy consumption and GHG emissions. It is often unperceived that one of the largest contributors of this energy usage comes from buildings' HVAC systems. In fact, 45% of commercial buildings' energy consumption comes from HVAC and 30% of it is usually wasted. Artificial Intelligence is revolutionizing building management by pre-emptively changing how HVAC systems behave and offering a low-cost, high-impact solution to improve commercial energy management. Adding a layer of artificial intelligence on top of the building's existing automation system can reduce emissions and operating costs while increasing occupant comfort.

1. Using Artificial Intelligence to Optimize Building Performance
***Jean-Simon Venne**, BrainBox AI, Montreal, QC, Canada*

Seminar 74 (Intermediate)

Water Systems in Resilient Buildings

Track: Future Proofing - Renewable, Regenerative, and Resilient

Sponsor: 3.6 Water Treatment

Chair: Joseph Ham, Member, DuBois Chemicals, Sharonville, OH

The shutdown of buildings as a result of the COVID pandemic magnified the importance of understanding the impact that stagnant water can have on the overall building health and take careful consideration the health of your occupants before re-opening. The purpose of this seminar is to review studies and best practices that support the Epidemic Task Force and SSPC 188 guidelines to not only maintain our buildings water systems and, but also to reopen them safely after a prolonged shutdown.

1. Legionella and Pathogens in Building Water Systems: A Party in Our Pipes?
***Janet Stout, Ph.D., Member**, Special Pathogens Laboratory, Pittsburgh, PA*

2. Impact of Stagnation on Building Water Quality: Commissioning and Low Usage in New Buildings
***Emilie Bedard**, Polytechnique Montreal, Montreal, QC, Canada*

3. Flushing and Disinfection of Stagnant Building Water Systems
***Ron George, Member**, Plumb-Tech Design & Consulting Services,, Newport, MI*

Seminar 75 (Intermediate)

What Are Effects of Building Models on the Performance of Model Predictive Controls

Track: Future Proofing - Renewable, Regenerative, and Resilient

Sponsor: 7.5 Smart Building Systems

Chair: Zheng O'Neill, Ph.D., P.E., Member, Texas A&M University, College Station, TX

The use of Model Predictive Control (MPC) in buildings has gained significant attention over the years to address challenges related to intelligent building operation, energy management and resilience, including reduction and shifting in response to electric grid signals for grid-interactive efficient buildings. One of the primary obstacles to implement the MPC at a large scale is to produce building and HVAC models that are accurate enough for control optimization with the least implementation cost. This seminar will present three case studies that help address this challenge for MPC applications in commercial and residential buildings

1. Impact of RC Model Accuracy on Model Predictive Control Performance.
***Andreas Athienitis, Ph.D., P.E., Fellow ASHRAE**, Concordia University, Montreal, QC, Canada*

2. The Effects of Envelope Model Accuracy on the Performance of MPC for Building HVAC
***David Blum, Ph.D., Member**, Lawrence Berkeley National Laboratory, Berkeley, CA*

3. Effects of Resistance-Capacitance Model Accuracy on the Performance of Model Predictive Control in Residential Buildings
***Xin Jin, Ph.D., Member**, National Renewable Energy Laboratory, United States of America, Golden, CO*

Seminar 76 (Intermediate)

What is Hot in Energy Storage? Integration and Effective Utilization of Thermal Energy Storage into the Built Environment

Track: Research Summit

Sponsor: 6.9 Thermal Storage

Chair: Spencer Dutton, Ph.D., Lawrence Berkeley National Laboratory, Berkeley, CA

Energy storage is a hot topic these days. The utilization of thermal energy storage into our built environment provides opportunities to achieve deep reductions in HVAC peak cooling and heating loads, reduced HVAC energy costs to users, enabling electrification of heating energy use, while also improving grid reliability and supporting utilization of renewable electricity. This session presents three projects focused on the modeling of and real world implementation of thermal energy storage, looking at both applications within a single building and at community-scale.

1. Community-Scale Energy Flexibility Via Ice Storage in Urbanopt
***Karl Heine, Student Member**, Colorado School of Mines, Golden, CO*

2. Integrated HVAC Systems for Small and Medium Commercial Buildings
***Dre Helmns, Ph.D.**, Lawrence Berkeley National Laboratory, Berkeley, CA*

3. Thermal Energy Storage Dispatch for Minimizing Other Energy Storage Needs
***Chuck Booten, Ph.D., Associate Member**, National Renewable Energy Laboratory, Golden, CO*

Seminar 77 (Intermediate)

What is New on Walls? Advances in Ventilated Cavities

Track: Research Summit

Sponsor: 4.4 Building Materials and Building Envelope Performance

Chair: Paulo Cesar Tabares - Velasco, Associate Member, Colorado School of Mines, Golden, CO

Having ventilation in the air space behind a brick veneer wall assembly is important for the control of moisture, but also impact the heat transfer of the assembly. This seminar will present the latest research on air-spaces behind cladding from an ASHRAE Research Project and CFD modeling to help understand and quantified the how wall heat transfer is affected by having ventilation in the air space.

1. Impact of Air-Flow on Thermal Performance of Air-Spaces behind Cladding (ASHRAE 1759-RP)
***Mohammad Rahiminejad**, École polytechnique fédérale de Lausanne, Lausanne, Switzerland*

2. The Impact of Air Flow on the Thermal Resistance of a Ventilated Residential Brick Veneer Wall
***Nate Huygen, Ph.D.**, National Brick Research Center, Anderson, SC*

Seminar 78 (Intermediate)

Work Smarter Not Harder: 3D CFD Not Required!

Track: Fundamentals and Applications

Sponsor: 4.10 Indoor Environmental Modeling

Chair: Mohammad Heidarinejad, Ph.D., P.E., Associate Member, Illinois Institute of Technology, Chicago, IL

This session aims to highlight smart indoor environmental modeling approaches. With the advances in computational and storage resources, it appears a 3D modeling is the first starting point to model indoor environments. However, a 3D modeling approach may not be the best solution to understand the underlying airflow and thermal mechanisms in indoor environments. Therefore, this session will demonstrate computational cost effective real-world case solutions to (i) model a building for natural ventilation,(ii) evaluate a gas turbine enclosure cooling system eductor, (iii) demonstrate cross ventilation, and (iv) estimate SARS-CoV-2 airborne transmission risks in buildings.

1. A Simplified Network Flow Model of a Building Using an Atrium for Natural Ventilation
***Duncan Phillips, Ph.D., P.E., Member**, Rowan Williams Davies & Irwin, Guelph, ON, Canada*

2. Evaluation of a Gas Turbine Enclosure Cooling System Eductor with 2D CFD
***Duncan Phyfe, Associate Member**, Alden Research Laboratory, Holden, MA*

3. Sub-Zonal Approximation of Natural Ventilation Performance in a Simple Building Scenario
***James Lo, Ph.D., Member**, Drexel University, Philadelphia, PA*

4. Estimating Sars-Cov-2 Airborne Transmission Risks in Multizone Buildings By Contam
***Liangzhu (Leon) Wang, Ph.D., P.E., Member**, Concordia University, Montreal, QC, Canada*

Seminar 79 (Advanced)

Working Fluid and Application Considerations for Ultra Low Temperature Refrigeration

Track: Fundamentals and Applications

Sponsor: 3.4 Lubrication

Chair: Christopher Campo, Associate Member, Shrieve Chemical, SPRING, TX

Today with the current covid crisis, ultra-low refrigeration has been brought to the forefront. But it is not only important for vaccine storage, it is vital to other medical, industrial and food processing industries. And due to environmental concerns transitioning from current refrigerants to the next generation low GWP is a priority and will require evaluation. Beyond system and compressor reliability other concerns including lubricants and material choice need to be considered. This seminar will discuss the different types of ultra-low refrigerant systems and the importance of lubricant and material selection.

1. Working Fluid and Application Considerations for Ultra-Low Temperature Refrigeration
***Wayne Zhang**, Thermo Fischer Scientific, Asheville, NC*

2. Lubricants for Low Temperature Applications
***Christopher Seeton, Ph.D., Member**, Shrieve, The Woodlands, TX*