American University of Beirut
Munib and Angela Masri Institute of Energy and Natural Resources

ASHRAE Shaping Tomorrow's Built Environment Today

ASHRAE Lebanese Chapter

2018 ASHRAE 3RD INTERNATIONAL CONFERENCE ON

Efficient Building Design

Material & HVAC Equipment Technologies

4-5 October 2018

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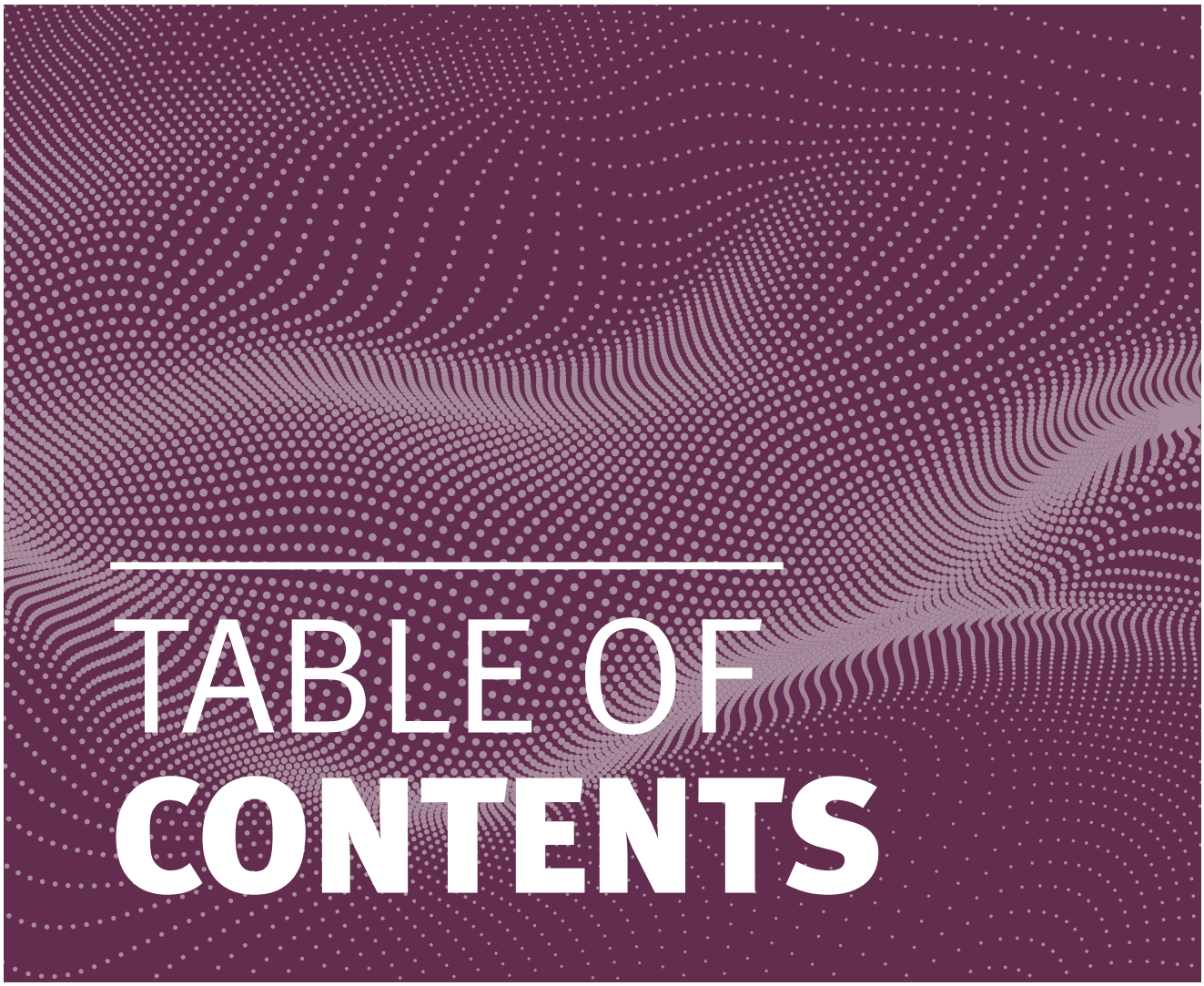
Efficient Building Design



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1 GENERAL INFORMATION

The Third International ASHRAE Conference on Efficient Building Design organizes 8 sessions with more than 35 presentations by local and international speakers over two days.
The Conference presents the latest research and development to improve building design and state-of-the-art technologies in building material and HVAC Equipment Technologies. The topics of the conference will include but are not limited to:

1. Alternative Energy Use in Buildings
2. Energy Efficiency, Comfort, and Climate
3. Energy Conservation Strategies I
4. Indoor Air Quality and Thermal Comfort
5. Modeling, Simulation, and Standards
6. Industrial Session
7. Heat Recovery and Applications
8. Energy Conservation Strategies II

In addition to the above, the conference hosts a number of presentations on new concepts and advances in HVAC design and industry.

2 ORGANIZERS

ASHRAE

ASHRAE founded in 1894, is a global society advancing human well-being through sustainable technology for the built environment. The Society and its members focus on building systems, energy efficiency, indoor air quality, refrigeration and sustainability within the industry. Through research, standards writing, publishing and continuing education, ASHRAE shapes tomorrow's built environment today. ASHRAE was formed as the American Society of Heating, Refrigerating and Air-Conditioning Engineers by the merger in 1959 of American Society of Heating and Air-Conditioning Engineers (ASHAE) founded in 1894 and The American Society of Refrigerating Engineers (ASRE) founded in 1904.

Munib and Angela Masri Institute of Energy and Natural Resources (MI) at AUB

MI provides a vehicle for promoting research and advanced study in the petroleum, water, and energy disciplines, as well as a focal point for collaborative research among scientists, engineers, and professionals in Lebanon and in the region at large. The institute serves as an interfaculty coordinating unit in AUB and a catalyst for advanced research in the sciences and engineering for the management and conservation of natural resources and energy.

The Lebanese ASHRAE Chapter

The Lebanese ASHRAE Chapter is representing ASHRAE in Lebanon and serves the local industries in all matters related to heating, refrigerating, air-conditioning as well as associated activities. The Lebanese ASHRAE Chapter holds lectures and seminars on a regular basis on different HVAC topics, and topics relevant to Lebanon and the region in order to contribute in the continuous training and education of the local engineers, in addition to keeping the country up to international standards.

3 CONFERENCE SPONSORS

The following companies and organizations are sponsoring the conference:

PLATINUM SPONSOR
Johnson Controls, www.johnsoncontrols.com/en_middleeast

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AHRI, www.ahrinet.org/Home
Dar Al-Handasah Consultants (Shair and Partners), www.dargroup.com/
Dunham Bush / Mase Gulf as Sole Agent in KSA, www.masegulf.com/

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Khatib and Alami, www.khatibalami.com
Trane, www.trane.com

HONORARY PARTICIPANT
United Nations Development Programme (UNDP) - Lebanon, www.lb.undp.org

The Executive Organizing Committee thanks the following platinum, gold, and silver sponsors for their support of the 2018 International Conference on Efficient Building Design:

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4 COMMITTEES

ORGANIZING COMMITTEE

- Ahmad El Bitar, President, Lebanese ASHRAE Chapter
- Bassam Elassaad, ASHRAE Life Member and Past Regional Chair for Europe
- Fadl Moukalled, American University of Beirut
- Kamel Ghali, American University of Beirut
- Nesreen Ghaddar, Conference Chair, American University of Beirut
- Samir Traboulsi, American University of Beirut, WAAAUB Council & Alumni Chapters Committee member
- Tony Giometti, Senior Manager of Conference Programs, ASHRAE
- Walid Chakroun, Kuwait University

SCIENTIFIC COMMITTEE

- Fadl Moukalled, American University of Beirut
- Kamel Ghali, American University of Beirut
- Mohamad Hosni, Kansas State University
- Samir Traboulsi, American University of Beirut, CEC Representative
- Walid Chakroun, Kuwait University
- William Bahnfleth, Pennsylvania State University

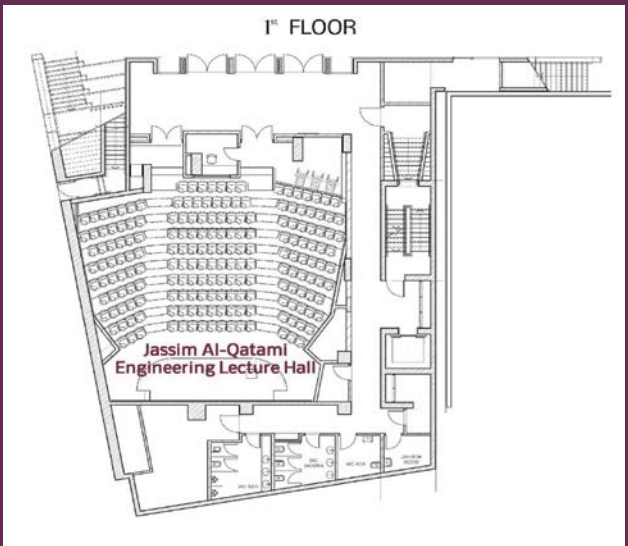
SUPPORT STAFF

- Austin Bradford, ASHRAE
- Christopher Preyor, ASHRAE
- Jasmine Farhat, American University of Beirut
- Mohamad Cherry, American University of Beirut
- Ragan McHan, ASHRAE
- Sandrine Assaad, American University of Beirut

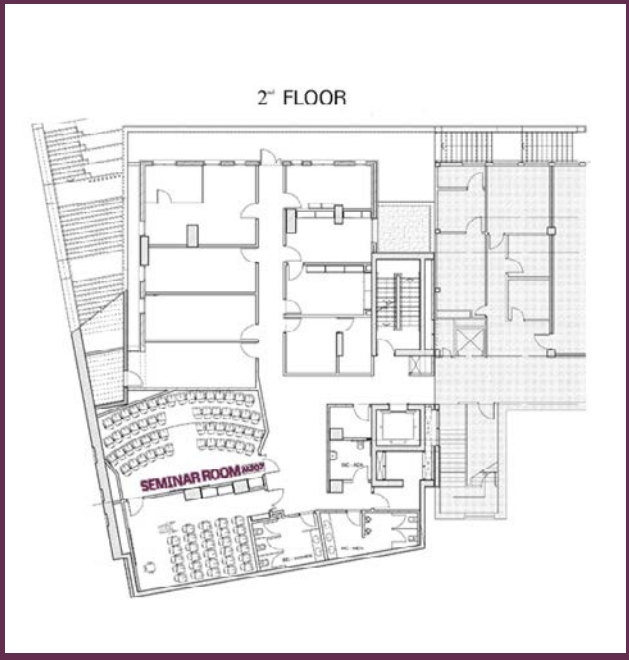
5 VENUES

CONFERENCE VENUE AND MAPS

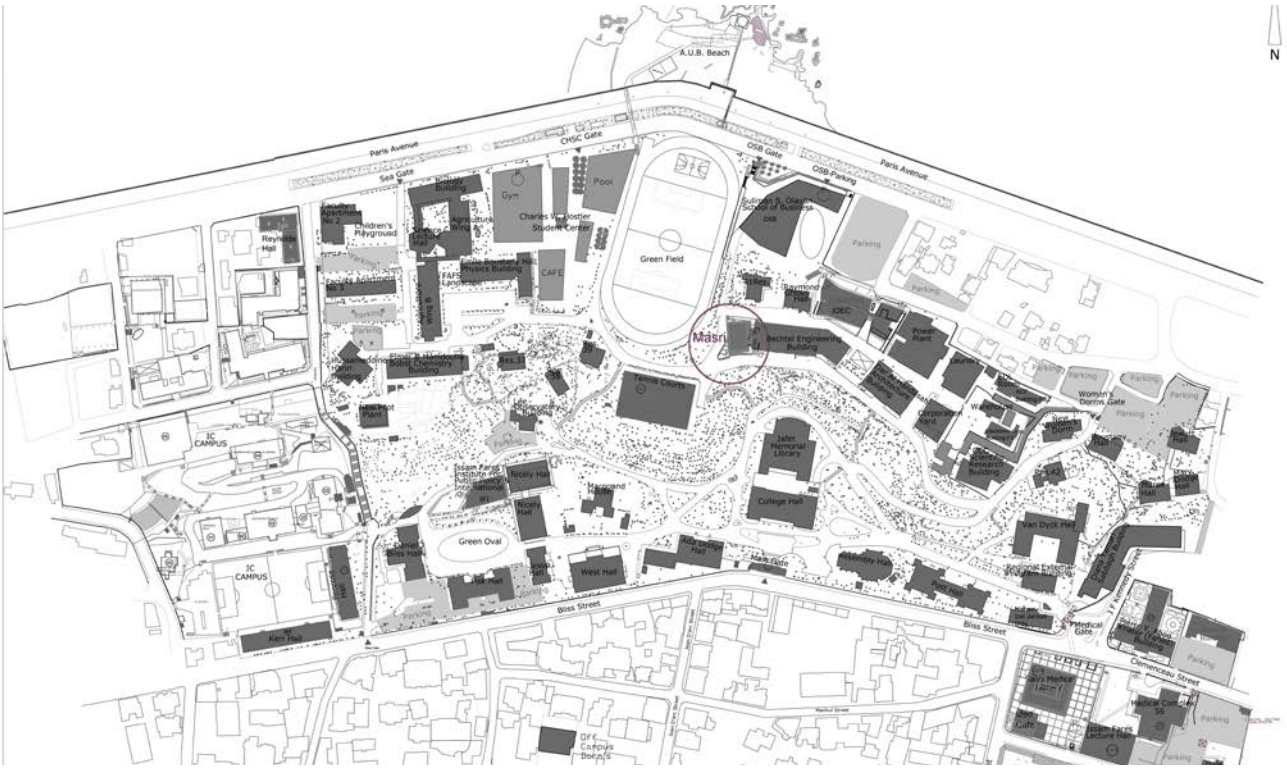
The Third International Conference on Efficient Building Design will take place on the 4th and 5th of October at the American University of Beirut.



The opening ceremony will be held in The Munib and Angela Masri Building, 1st floor, Jassim Al-Qatami Engineering Lecture Hall.



The technical sessions will be held in The Munib and Angela Masri Building, M207 on the 2nd floor, and the Jassim Al-Qatami Engineering Lecture Hall on the 1st floor.



Map of AUB campus: The conference location is in The Munib and Angela Masri Building marked with a purple circle. The closest entrances to the conference would be from Lower Campus at the OSB Gate on Paris Avenue while Main Gate on Bliss Street is the closest from Upper Campus.

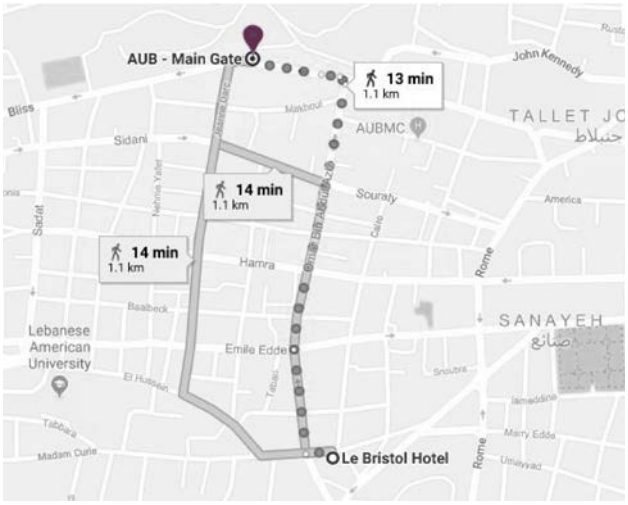
HOTEL VENUE

Le Bristol Hotel will be hosting the attendees for the Third International Conference on Efficient Building Design. Located in Verdun, Mme. Curie Street, Le Bristol Hotel offers world-class living against a gorgeous backdrop.
In the city's cosmopolitan heart, old-world charm bounces to life throughout Le Bristol Beirut with contemporary finishes, featuring room themes that range from Oriental to 1960s-inspired modern. Between sunset bicycle rides and candlelit dinners at Les Gourmandises Verdun, guests enjoy a proper Parisian experience in the Middle East, worthy of any world traveler.

COMPLIMENTARY SERVICES & AMENITIES:

1. Welcome In-room Le Bristol VIP homemade amenities
2. Free Shuttle to and from AUB Campus
3. Complimentary bike to roam the city
4. Personalized embroidered face towel
5. Early Check in & late checkout (subject to availability)
6. Daily crafted International breakfast
7. High speed Internet Access (Fiber Optic Connection)
8. In-room coffee, espresso & tea making facilities
9. Free access to our fitness room & our rooftop temperature controlled Pool & Jacuzzi

Le Bristol Hotel Beirut is a 13-minute walk to AUB, below is a map for additional information:



SPEAKERS' LOUNGE

Speakers and chairs of technical sessions can meet at the speakers' lounge in The Munib and Angela Masri Building (M401 and M501) and in Bechtel 537. If a presentation has not been submitted online, the speaker is asked to drop by the speakers' lounge to upload the presentation and have it checked for commercialization.

6 SOCIAL PROGRAM

- **Thursday, 4th of October, 2018; 8:30 PM**

Gala Dinner
Bristol Hotel– Golden Room
The event facility at Le Bristol is state-of-the-art and highlights the allure of the hotel as an ideal 21st century venue. The favorite destination of visiting dignitaries, Le Bristol is the prime location for national and international events.

- **Lunch**

Rooftop terrace of the Munib and Angela Masri Building

- **Lab Tours**

An optional lab tour can be arranged on the first day of the conference, Thursday October 4, 2018 at 1:15 PM, at the Irani Mechanical Engineering. Interested participants are requested to inform our staff at the registration booth by Thursday, October 4, 2018 at 9:30 am, at the latest.

- **Cultural Tour: Jeita & Byblos**

Date: Saturday, October 6, 2018
Time: 7:45 AM – 1:00 PM
Pick up Point: Le Bristol Hotel, Verdun
You can register for a one day tour at a special rate of $75 per person. Please don't hesitate to contact our registration desk before Friday October 5, 2018 at noon to reserve a seat in the guided tour. The tour includes transportation, entrance fees, and guided tour.

Registration

- Registration and pick up of registration package will take place on the first day of the conference at the entrance of the Munib and Angela Masri building from 8:00 am until 2:00 pm, and on the second day from 8:00 am till 12:00 pm.
- Onsite Registration outside the Masri Building is also possible at the Registration Desk.

Internet Access

Internet access will be available for free in the hotel venue and on campus at the American University of Beirut.

Photo-Release

Photographs will be taken at the International Conference for Efficient Building Design. By registering for this conference, you agree to allow ASHRAE to use your photo in any publications or website.

7 GENERAL SCHEDULE

ASHRAE, the Lebanese ASHRAE Chapter, the Munib and Angela Masri Institute of Energy and Natural Resources and the Department of Mechanical Engineering at AUB are honored to invite you to join their Opening Ceremony on October 4, 2018 at Jassim Al-Qatami Engineering Lecture Hall, AUB.

CONFERENCE OPENING CEREMONY [THE MUNIB AND ANGELA MASRI BUILDING, JASSIM AL-QATAMI ENGINEERING LECTURE HALL]

9:00 – 9:05 am	**Dr. Nesreen Ghaddar**, Conference Chair, American University of Beirut
9:05 – 9:15 am	**Mr. Ahmad El Bitar,** President, Lebanese ASHRAE Chapter
9:15 – 9:20 am	**Mr. Don Brandt** - ASHRAE Director-at-Large, representing ASHRAE President, Sheila Hayter
9:20- 9:30 am	**Dr. Alan Shihadeh,** Dean of the Maroun Semaan Faculty of Engineering and Architecture, American University of Beirut
9:30- 9:35 am	**Dr. Muhamad Harajli**, Provost, American University of Beirut
9:35- 9:43 am	**Trustee Munib Masri**, Chairman of the Engineering and Development Group, Edgo
9:43- 9:50 am	**Dr. Marleine Brax**, Director of the CNRS-L Geophysics Centre, representing Secretary General of the National Council for Scientific Research in Lebanon, Dr. Moueen Hamze

8 KEYNOTES & THEIR BIOGRAPHIES

Location
Jassim Al-Qatami Engineering Lecture Hall
Date
Thursday, October 4, 2018
Time
10:15 AM - 11:15 AM

Keynote Talk 1: INVERSE DESIGN OF INDOOR ENVIRONMENT BY CFD-BASED OPTIMAL METHODS

Qingyan "Yan" Chen, Ph.D
James G. Dwyer Professor of Mechanical Engineering
Editor-in-Chief, "Building and Environment"
School of Mechanical Engineering, Purdue University

Biography

Dr. Qingyan "Yan" Chen is the James G. Dwyer Professor of Mechanical Engineering at Purdue University, USA and Changjiang Chair Professor at Tianjin University, China. He serves also as the Editor-in-Chief of the international journal "Building and Environment". Chen was Principal Director of FAA Center of Excellence for Airliner Cabin Environmental Research in the United States and Founding Director of Tianjin Key Laboratory of Indoor Air Environmental Quality Control in China. Chen has published three books and over 400 journal papers, book chapters and conference papers and has been invited to deliver over 150 lectures internationally.

Google Scholar shows that his journal publications have been cited by more than 12,000 times and his H-index is 62.Dr. Chen has received the Distinguished Service Award from International Building Performance Simulation Association (IBPSA), the Oversea Chinese Contribution Award (Creative Talents) from All-China Federationof Returned Overseas, the John Rydberg Gold Medal from the Scandinavian Federation of Heating, Ventilating and Sanitary Engineering Associations, and the Willis J. Whitfield Award from the Institute of Environmental Sciences and Technology, Distinguished and Exceptional Service Awards from ASHRAE and CAREER award from the National Science Foundation in the United States. He is a fellow of ASHRAE and ISIAQ.

Location
Jassim Al-Qatami Engineering Lecture Hall
Date
Thursday, October 4, 2018
Time
2:45 PM - 3:45 PM

Keynote Talk 2: DESIGN OF INDOOR ENVIRONMENT BY CREATING SHARED VALUES

Arsen Melikov, Professor, PhD

International Centre for Indoor Environment and Energy
Department of Civil Engineering
Technical University of Denmark

Biography

Professor Melikov is leading the advanced air distribution and microenvironment research at the International Centre for Indoor Environment and Energy, Technical University of Denmark. His teaching and research areas cover advanced air distribution in rooms and vehicle compartments, airborne cross-infection, impact of indoor environment on people's health, comfort and performance, personally controlled environment, heat and mass transfer, indoor climate measurements and instruments. The results of his research are included in engineering handbooks and guidelines as well as in International, European and national standards. He has been principle investigator of 60 research projects sponsored by government and private organizations in numerous countries. He has coordinated several international research projects sponsored by the European Community. New HVAC technologies and measuring instruments have been developed based on his collaboration with industry.

He has supervised 28 PhD students and 98 MSc students. Many of his students have received national and international awards for their work.

Prof. Melikov is author and co-author of 50 technical reports, chapters in books and more than 380 scientific papers published in 15 languages. He is member of four societies of HVAC engineers. He has been and is member of national and international technical and standardization committees. He has organized and chaired international conferences, symposiums, seminars and workshops. He is member of editorial and review board of numerous international journals. He has given 50 invited lectures. He has received numerous awards. He is Fellow of ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) and Fellow of ISIAQ (International Society of Indoor Air Quality and Climate). He is Honorary Member of SHASE (The Society of Heating, Air Conditioning and Sanitary Engineers of Japan) and Honorary Member of BULSHRAE (The Bulgarian Society of Heating, Refrigerating and Air-Conditioning Engineers).

Location
Jassim Al-Qatami Engineering Lecture Hall
Date
Friday, October 5, 2018
Time
9:30 AM - 10:30 AM

Keynote Talk 3: OVERVIEW OF LOW GWP REFRIGERANT OPTIONS AND THE CURRENT STATE OF GLOBAL REGULATION

William F. McQuade, P.E., LEED® AP, FASHRAE
Executive Director, Global Energy and Sustainability Policy
Building Efficiency
Johnson Controls

Biography

Bill McQuade is the Executive Director of Global Industry Relations and Regulatory Policy at Johnson Controls International. He has spent the past 25+ years working for the York International/Johnson Controls organizations in various technical and managerial positions ranging from research engineer to senior management positions related to the strategic application of advanced technology and R&D efforts. He has a BSME, MSME, and MBA from Penn State University. While working at York/Johnson Controls, he has been awarded 11 US and International patents related to large building air-conditioning equipment. Bill's has many industry affiliations including the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) where he is currently on the Board of Directors. He was elevated to the honorary grade of Fellow in 2013 and received its Distinguished Service Award in 2012.
He has participated in the development of international environmental treaties and agreements including those concerning climate and ozone, He has provided input to the US, EC, and Chinese governments regarding ozone and climate regulation and legislation. He was selected by the US Department of State and US EPA to serve as an industry representative on the Indo-US Task Force on HFCs. Also, he has served as an expert on the US Department of Energy HVAC Roadmap Collaboration Team (Oak Ridge National Lab). Finally, he has been invited to speak as an expert on refrigerants at various World Bank, United Nations (UNEP) and HVAC&R industry technical meetings.

Location
Jassim Al-Qatami Engineering Lecture Hall
Date
Friday, October 5, 2018
Time
2:15 PM - 3:15 PM

Keynote Talk 4: HOW TO MAXIMIZE THE HISTORICAL OPPORTUNITY TO IMPROVE COOLING EFFICIENCY

Dan Hamza-Goodacre

Executive Director, Kigali Cooling Efficiency Program

Biography

Dan Hamza-Goodacre is the Executive Director of the Kigali Cooling Efficiency Program. Dan has over 20 years of experience working on climate change and sustainable development in the public and private sectors. His work spans all major continents. Previously Dan was Director of Buildings and Industry at ClimateWorks. Before working in philanthropy, Dan was with PwC, where he was the Deputy CEO of the Climate and Development Knowledge Network (CDKN), a global program supporting developing country responses to climate change. Dan held various posts at Defra, (the U.K. Environment and Agriculture Ministry), including: Head of the Secretary of State's office; co-founder of the UK's Adapting to Climate Change Program; Adaptation Policy Lead on the UK Climate Change Act and Sustainable Agriculture Advisor. Dan also worked for the UK Foreign Office as a Climate Attaché. He is a regular speaker and moderator at conferences and events and has written widely on climate and development. Dan has an MSc in International Development from Bristol University, where he also was a lecturer and researcher in global environmental politics. In his early career Dan lived and worked in the rainforests of Latin America. He volunteers regularly in schools in support of their 'green' teams.

DESIGNING FOR IAQ: COMPLYING WITH REQUIREMENTS OF STANDARD 62.1 (MENA)

Time: 8:00 – 17:00
Date: Wednesday, October 3
Location: Bechtel 537

Course Summary: This course focuses on the basic requirements of ASHRAE Standard 62.1-2016, Ventilation for Acceptable Indoor Air Quality. The newest version of the standard includes a major change to the scope of the standard by which residential occupancies are moved from ASHRAE Standard 62.1 to 62.2. This course provides an overview of the requirements of the new standard with emphasis on changes from the previous version and practical application of the standard to modern VAV systems. New requirements to the indoor air quality procedure for determining minimum ventilation rates are discussed. In the 2016 version, changes were made in determining air class for laboratory exhaust systems and the use of sensors for demand control ventilation, and these changes are discussed as well. The course presents sample calculations for code review and for physical operation.

Instructors: Hassan Younes, Member ASHRAE, BEAP, BEMP, HBDP, CPMP, HFDP, OPMP; and Donald Brandt, CEM, Member ASHRAE, BEAP

STANDARD 90.1: HVAC/MECHANICAL AND APPENDIX G (MENA)

Time: 8:00 – 17:00
Date: Wednesday, October 3
Location: Bechtel 536

Course Summary: This course focuses on the major requirements of ASHRAE Standard 90.1-2016, including incorporated addenda. The ASHRAE Standard 90.1: HVAC/Mechanical and Appendix G (MENA) course will cover highlights of the envelope, mechanical, HVAC, and lighting requirements in Appendix G and its new compliance path and performance rating method. Baseline building conditions and climate zone information on many cities in the region will also be provided.

Instructors: Samir Traboulsi, Ph.D., P.Eng., Fellow Life Member ASHRAE;
and Donald Brandt, CEM, Member ASHRAE, BEAP

Keynote and Paper Sessions - Thursday, October 4, 2018 - Masri Building

Time	ASHRAE Paper/Keynote Talk Number	Title	Presenting Author	Room Number
Keynote Talk 1 | Chair: Prof. Fadl Moukalled				
10:15 - 11:15	**Inverse design of indoor environment by CFD-based optimal methods**		**Qingyan "Yan" Chen**	**Jassim Al-Qatami Engineering Lecture Hall**
Session 1 – Alternative Energy Use in Buildings | Chair: Dr. Samir Traboulsi; Co-Chair: Mr. Ahmad El-Bitar				
11:15 - 11:45	36	Establishment of a Sustainable Energy Action Plan: Case Study of Union of Municipalities	Sabine Saad	Jassim Al-Qatami Engineering Lecture Hall
11:45 - 12:15	57	Energy Comparison of Air Conditioning Split System VS. Solar Absorption Systems with Optimization for a Prototype Educational Building	Hesham Safwat	
12:15 - 12:45	55	Contributing Algorithms of Energy Efficiency and Renewable Energy in the Residential, Commercial, and Industrial Sectors	Georges El-Jamal	
12:45- 13:15	19	Benefits from Combination of Centralized Ventilation System and Decentralized Conditioning Units	Maciej Danielak	
Session 2 – Enegy Efficiency, Comfort, and Climate | Chair: Dr. Issam Srour; Co-Chair: Fouad Azizi				
11:15 - 11:45	48	Holistic Approach to Energy Performance of Green Built Environment	Essam E. Khalil	M207
11:45 - 12:15	32	Transition Engineering the Water-Electricity Nexus Operating in Building Services and Urban Heat Islands - Concept Design - Is Air-Conditioning Really Necessary?	Eric Peterson	
12:15 - 12:45	25	Design Optimization for Maintaining Occupants' Outdoor Thermal Comfort	Haneen Hamdan	
12:45- 13:15	15	Prediction and Control of Noise and Vibration within a Sport Facility	Ghina Annan	

Keynote Talk 2 | Chair: Prof. Kamel Ghali				
15:45 - 16:15	**Design of Indoor Environment by Creating Shared Values**		**Arsen Melikov**	**Jassim Al-Qatami Engineering Lecture Hall**
3- Energy Conservation Strategies I | Chair: Dr. Aram Yeretzian; Co-Chair: Dr. Ghassan Chehab				
15:45 - 16:15	24	A Four Step Approach for Energy Conservation and Retrofitting Interventions for Residential Buildings	Mohamad Hajj Hassan	Jassim Al-Qatami Engineering Lecture Hall
16:15- 16:45	37	Investigation of Thermal Comfort in a Space Conditioned by Liquid Desiccant Membrane Chilled Ceiling/ Displacement Ventilation System	Racha Seblany	
16:45- 17:15	53	Interrelationship Between Architectural and Mechanical Aspects of the Building Envelope Design	Hadi Maamoun	
17:15- 17:45	14	Hygrothermal engineering Analysis of Walls and Roofs in Hot and Humid Climates	Ghina Annan	
4- Indoor Air Quality and Thermal Comfort | Chair: Dr. Nesreen Ghaddar; Co-Chair: Carine Habchi				
15:45 - 16:15	35	Mathematical modelling of hybrid cooling vest integrated with Bio-heat model for assessing cooling effect on humans in hot conditions	Ragheb Raad	M207
16:15- 16:45	64	Effect of Inter-Segmental Ventilation on the Segmental Heat Losses by Means of Electric Circuit Analogy	Nagham Ismail	
16:45- 17:15	5	Numerical Study on PCM-Desiccant Cooling Vest to Improve Cooling and Performance of Workers in Hot Humid Conditions	Mariam Itani	
17:15- 17:45	62	Quantifying Losses Due to Thermal Discomfort: An Agent Based Modeling Approach	Mohamad Awada	

Keynote and Paper Sessions - Friday, October 5, 2018 - Masri Building

Time	ASHRAE Paper/Keynote Talk Number	Title	Presenting Author	Room Number
Keynote Talk 3 | Chair: Prof. Walid Chakroun				
9:30 - 10:30	**Overview of Low GWP Refrigerant Options and the Current State of Global Regulation**		**William F. McQuade**	**Jassim Al-Qatami Engineering Lecture Hall**
5- Modeling Simulation, and Standards | Chair: Dr. Nesreen Ghaddar; Co-Chair: Mr. Youssef Ghoussoub				
11:00 - 11:30	10	A Comparative Assessment of the Performance of Cooling Systems for Large Scale High-Density Data Centers using CFD Simulations	Khaled Abu Howeij	M207
11:30 - 12:00	12	A Full Three-Dimensional Simulation of an Industrial Baking Oven	Mohamad Al Nasser	
12:00 - 12:30	54	CFD-Optimized Radiant Cooling with Dedicated Outdoor Air System (DOAS) for High Ceilinged Spaces in Hot and Dry Climates	Youssef Ghoussoub	
6 - Industrial Sessions | Chair: Mr. Mazen Hussein; Co-Chair: Mr. Bassam Elassaad				
11:00 - 11:20	Interlinkage between the HPMP and Energy Efficiency in the RAC and Domestic Refrigeration Sectors		Mazen Hussein	**Jassim Al-Qatami Engineering Lecture Hall**
11:20 - 11:40	International Developments Towards Integrating Refrigerant Management and Energy Efficiency Programmes		UNDP Representative	
11:40 - 12:00	How Countries Begin Preparing to Implement the Kigali Amendment		Walid Chakroun	
12:00 - 12:20	Impact of Energy Efficiency of AC Equipment on Rating Green Buildings		Samir Traboulsi	
12:20 - 12:40	Enhancing Energy Efficiency in the RACHP Sectors: Decision XXIX/10 of the Montreal Protocol		Bassam Elassaad	
12:40 - 13:00	Q&A			

**Keynote Talk 4	** Chair: Prof. Nesreen Ghaddar			
14:15 - 15:15	**How to Maximize the Historical Opportunity to Improve Cooling Efficiency**		**Dan Hamza-Goodacre**	**Jassim Al-Qatami Engineering Lecture Hall**
**7 - Heat Recovery and Applications	** Chair: Dr. Mohamad Ahmad; Co-Chair: Dr. Mariam Itani			
15:30 - 16:00	26	High Solar Combi-Plus System using PCM Storage: KSA Case Study	Mohamad Hmadi	Jassim Al-Qatami Engineering Lecture Hall
16:00 - 16:30	50	Sustainable Design in Metro Stations	Anne Beh	
16:30 - 17:00	16	Energy Performance and Occupant Comfort in an Office Building: Co-Simulation of an Agent-Based Behavior Model with EnergyPlus	Mohamad Awada	
17:00 - 17:30	33	Principles of Split Mass Flow and Heat Shifting Psychrometrics Toward Efficient Comfort Management	Peter Phillips	
**8- Energy Conservation Strategies II	** Chair: Dr. Kamel Ghali; Co-Chair: Mr. Mahmoud Al-Hindi			
15:30 - 16:00	20	World Class Energy Efficient HVAC System for New 'Twisty Tower' in South Africa	Pieter de Bod	M207
16:00 - 16:30	3	Energy Conservation for an Office Building in a Hot Climate	Hari Dalal	
16:30 - 17:00	8	A Simplified Personalized and Displacement Ventilation Model for Predicting Passive Contaminant Spread in Office Spaces	Douaa Al-Assaad	
17:00 - 17:30	7	Feasibility Assessment for Retrofitting an Energy-Efficient Hospital Building through Energy Modelling and Field Investigation	Fu Jen Wang	

Technical Sessions - Thursday, October 4

10:15 - 11:15 | Keynote Talk 1: Inverse Design of Indoor Environment by CFD-Based Optimal Methods

Dr. Qingyan "Yan" Chen; James G. Dwyer Professor of Mechanical Engineering, Editor-in-Chief, "Building and Environment" School of Mechanical Engineering, Purdue University

Room: Jassim Al-Qatami Engineering Lecture Hall

Chair: Dr. Fadl Moukalled, AUB

11:15 - 13:15 | Technical Paper Session 1: Alternative Energy Use in Buildings

Room: Jassim Al-Qatami Engineering Lecture Hall

Chair: Dr. Samir Traboulsi

Co-Chair: Mr. Ahmad El-Bitar

1. Establishment of a Sustainable Energy Action Plan: Case Study of Union of Municipalities
Sabine Saad, Student Member ASHRAE; Adel Mourtada, DrEng; Marwan El Brouche, PhD; Mazen Ghandour, DrEng

2. Energy Comparison of Air Conditioning Split System VS. Solar Absorption Systems with Optimization for a Prototype Educational Building
Hesham Safwat, PhD, Member ASHRAE; Fady Anees

3. Contributing Algorithms of Energy Efficiency and Renewable Energy in the Residential, Commercial and Industrial Sectors
Georges El-Jamal, PhD, Member ASHRAE; Chantal Maatouk, PhD; Mazen Ghandour, PhD; Adel Mourtada, PhD; Fouad Kaddah, PhD

4. Benefits From Combination of Centralized Ventilation Systems and Decentralized Conditioning Units
Maciej Danielak, PhD

11:15 - 13:45 |Technical Paper Session 2: Energy Efficiency, Comfort, and Climate

Room: M207

Chair: Dr. Issam Srour

Co-Chair: Dr. Fouad Azizi

1. Holistic Approach to Energy Performance of Green Built Environment
Essam E Khalil, PhD, PE

2. Transition Engineering the Water-Electricity Nexus Operating in Building Services and Urban Heat Islands - Concept Design - Is Air-Conditioning Really Necessary?
Eric Laurentius Peterson, PhD, PE

3. Design Optimization for Maintaining Occupants' Outdoor Thermal Comfort
Haneen I. Hamdan, ME, Balsam A. Nehme, ME

4. Prediction and Control of Noise and Vibration within a Sport Facility
Ghina Annan, PE, Dar Al Handasah (Shair and Partners); Balsam A. Nehme, Dar Al Handasah (Shair and Partners)

14:45 - 15:45 | Keynote Talk 2: Design of Indoor Environment by Creating Shared Values

Dr. Arsen Melikov; International Centre for Indoor Environment and Energy, Department of Civil Engineering, Technical University of Denmark

Room: Jassim Al-Qatami Engineering Lecture Hall

Chair: Dr. Kamel Ghali, AUB

15:45 - 17:45 | Technical Paper Session 3: Energy Conservation Strategies I

Room: Jassim Al-Qatami Engineering Lecture Hall

Chair: Dr. Aram Yeretzian

Co-Chair: Dr. Ghassan Chehab

1. A Four Step Approach for Energy Conservation and Retrofitting Interventions for Residential Buildings
Mohamad Hajj Hasan; Mohamad Abbas; Bahaa Mneymneh; Issam Srour, PhD

2. Investigation of Thermal Comfort in a Space Conditioned by Liquid Desiccant Membrane Chilled Ceiling/ Displacement Ventilation System
Racha Seblany, MS; Nesreen Ghaddar, PhD, Member ASHRAE; Kamel Ghali, PhD, Member ASHRAE; Nagham Ismail, PhD; Marco Simonetti, PhD; Fracastoro Giovanni Vincenzo, PhD; Joseph Virgone, PhD; Assaad Zoughaib, PhD

3. Interrelationship Between Architectural and Mechanical Aspects of the Building Envelope Design
Hadi Maamoun, Member ASHRAE

4. Hygrothermal Engineering Analysis of Walls and Roofs in Hot and Humid Climates
Ghina Annan, PE, Dar Al Handasah (Shair and Partners); Balsam A. Nehme, Dar Al Handasah (Shair and Partners)

15:45 - 17:45 | Technical Paper Session 4: Indoor Air Quality and Thermal Comfort

Room: M207

Chair: Dr. Nesreen Ghaddar

Co-Chair: Carine Habchi

1. Mathematical Modeling of Hybrid Cooling Vest Integrated with Bio-Heat Model for Assessing Cooling Effect on Humans in Hot Conditions
Ragheb Raad; Mariam Itani, PhD; Nesreen Ghaddar, PhD, Member ASHRAE, Kamel Ghali, PhD, Member ASHRAE

2. Effect of Inter-Segmental Ventilation on the Segmental Heat Losses by Means of Electric Circuit Analogy
Nagham Ismail, PhD; Nesreen Ghaddar, PhD, Member ASHRAE; Kamel Ghali, PhD, Member ASHRAE

3. Numerical Study on PCM-Desiccant Cooling Vest to Improve Cooling and Performance of Workers in Hot Humid Conditions
Mariam Itani, PhD; Rana Bachnak; Nesreen Ghaddar, PhD, Member ASHRAE; Kamel Ghali, PhD, Member ASHRAE

4. Quantifying Losses Due to Thermal Discomfort: An Agent Based Modeling Approach
Mohamad Awada; Issam Srour, PhD

Technical Sessions - Friday October 5
9:30 - 10:30 | Keynote Talk 3: Overview of Low GWP Refrigerant Options and the Current State of Global Regulation
Mr. William F. McQuade; PE, LEED AP, Fellow ASHRAE Executive Director, Global Energy and Sustainability Policy, Building Efficiency, Johnson Controls
Room: Jassim Al-Qatami Engineering Lecture Hall
Chair: Dr. Walid Chakroun, Kuwait University
11:00 - 12:30 | Technical Paper Session 5: Modeling, Simulation, and Standards
Room: M207
Chair: Dr. Nesreen Ghaddar
Co-Chair: Mr. Youssef Ghoussoub
1. A Comparative Assessment of the Performance of Cooling Systems for Large Scale High-Density Data Centers Using CFD Simulations Khaled Abou Hweij; Adnan Akhdar 2. A Full Three-Dimensional Simulation of an Industrial Baking Oven Mohamad Al Nasser; Iyad Fayssal, PhD; Fadl Moukalled, PhD 3. CFD-Optimized Radiant Cooling with Dedicated Outdoor Air System (DOAS) for High Ceilinged Spaces in Hot and Dry Climates Youssef Ghoussoub; Adnan Akhdar
11:00 - 13:00 | Session 6: Industrial Sessions
Room: Jassim Al-Qatami Engineering Lecture Hall
Chair: Mr. Mazen Hussein, National Ozone Unit
Co-Chair: Mr. Bassam Elassaad
1. Interlinkage between the HPMP and Energy Efficiency in the RAC and Domestic Refrigeration Sectors Mazen Hussein 2. International Developments Towards Integrating Refrigerant Management and Energy Efficiency Programmes UNDP Representative 3. How Countries Begin Preparing to Implement the Kigali Amendment Walid Chakroun, PhD 4. Impact of Energy Efficiency of AC Equipment on Rating Green Buildings Samir Traboulsi, PhD 5. Enhancing Energy Efficiency in the RACHP Sectors: Decision XXIX/10 of the Montreal Protocol Bassam Elassaad

14:15 - 15:15 | Keynote Talk 4: How to Maximize the Historical Opportunity to Improve Cooling Efficiency

Mr. Dan Hamza-Goodacre; Executive Director, Kigali Cooling Efficiency Program

Room: Jassim Al-Qatami Engineering Lecture Hall

Chair: Dr. Nesreen Ghaddar, AUB

15:30 - 17:30 | Technical Paper Session 7: Heat Recovery and Applications

Room: Jassim Al-Qatami Engineering Lecture Hall

Chair: Dr. Mohamad Ahmad

Co-Chair: Dr. Mariam Itani

1. High Solar Combi-Plus System Using PCM Storage: KSA Case Study
Mohamad Hmadi; Adel Mourtada, PhD, PE

2. Sustainable Design in Metro Stations
Steven Lai, Member ASHRAE; Anne Beh; William Xie, CEng; Hadi Wijaya, PE, CEng; K.W Ang, PE, CEng

3. Energy Performance and Occupant Comfort in an Office Building: Co-simulation of an Agent-Based Behavior Model with EnergyPlus
Mohamad Awada; Mohamad Hajj Hassan; Daoud Kiomjian; Issam Srour, PhD; Hiam Khoury, PhD

4. Principles of Split Mass Flow and Heat Shifting Psychrometrics Toward Efficient Comfort Management
Peter Phillips, Member ASHRAE

15:30 - 17:30 | Technical Paper Session 8: Energy Conservation Strategies II

Room: M207

Chair: Dr. Kamel Ghali

Co-Chair: Mr. Mahmoud Al-Hindi

1. World Class Energy Efficient HVAC System for New 'Twisty Tower' in South Africa
Pieter J. de Bod, PE, Member ASHRAE

2. Energy Conservation for an Office Building in a Hot Climate
Hari Dalal, Member ASHRAE

3.A Simplified Personalized and Displacement Ventilation Model for Predicting Passive Contaminant Spread in Office Spaces
Douaa Al-Assaad; Carine Habchi, PhD; Nesreen Ghaddar, PhD, Member ASHRAE; Kamel Ghali, PhD, Member ASHRAE

4. Feasibility Assessment for Retrofitting an Energy-Efficient Hospital Building through Energy Modelling and Field Investigation
Fu-Jen Wang, PhD, PE, Fellow ASHRAE; Cheng-Shu Kuo , PhD; Hung-Wen Lin, PhD, Member ASHRAE; Pei-Yu Yu, PhD; Chen-Pu Wang, Student Member ASHRAE

11 ABSTRACTS

KEYNOTE LECTURES

INVERSE DESIGN OF INDOOR ENVIRONMENT BY CFD-BASED OPTIMAL METHODS

Qingyan "Yan" Chen, Ph.D
James G. Dwyer Professor of Mechanical Engineering
Editor-in-Chief, "Building and Environment"
School of Mechanical Engineering, Purdue University

Abstract
The inverse design approach is new to indoor environment research and building design community, though it has been used in other industries including automobile and airplane design. Inverse design concept uses the desired indoor environment as the design objective and inversely determines the systems required to achieve the objective. This presentation discusses a number of backward and forward methods for inverse design. Backward methods can be used to identify contaminant sources in an enclosed environment. However, these methods cannot be used to inversely design a desired indoor environment. Forward methods, such as the computational-fluid-dynamics (CFD)-based genetic algorithm method, the CFD-based adjoint method, and the CFD-based proper-orthogonal-decomposition method, show the promise in the inverse design of airflow and heat transfer in an enclosed environment. This lecture provides some exciting design examples of inverse design of indoor environment, discusses the pros and cons of each design method, and shows the best approach in using the methods for designing indoor environment.

DESIGN OF INDOOR ENVIRONMENT BY CREATING SHARED VALUES

Arsen Melikov, Professor, PhD
International Centre for Indoor Environment and Energy
Department of Civil Engineering
Technical University of Denmark

Abstract
Indoor environment affects occupants' health, comfort and performance. Energy used for heating, cooling, ventilating and air conditioning of buildings is substantial. Yet, in many buildings indoor environment is mediocre. Today ambitious energy saving goals has been adopted in many countries. In order to move closer to the goals, energy saving is achieved by reduction of ventilation air supplied to spaces. However, energy saving strategy is dangerous because it will affect negatively occupants' health. In public buildings, for example in offices, it will contribute to decrease of work performance. On the opposite, an increase of the outdoor clean air supplied to spaces has positive impact on health and performance, but one of the negative consequences is an increase of energy consumption. It is also possible to continue with the present design practice but is this the right choice?
Ventilation based on total volume air distribution in spaces is not always an efficient way to provide high-quality indoor environments at the same time as low-energy consumption. This talk justifies the need for improving the present air distribution design in spaces, and in general the need for a paradigm shift from the design of collective environments to the design of individually controlled environments. The focus is on advanced air distribution in spaces, its guiding principles and its advantages and disadvantages. Examples of advanced air distribution solutions in spaces for different use, such as offices, hospital rooms, vehicle compartments, are presented. The potential of advanced air distribution, and individually controlled micro-environment in general, for achieving shared values, that is, improved health, comfort, and performance, energy saving, increased flexibility of space use, reduction of healthcare costs and improved well-being is demonstrated. Performance criteria are defined and further research in the field is outlined.

OVERVIEW OF LOW GWP REFRIGERANT OPTIONS AND THE CURRENT STATE OF GLOBAL REGULATION

William F. McQuade, P.E., LEED® AP, FASHRAE
Executive Director, Global Energy and Sustainability Policy
Building Efficiency
Johnson Controls

Abstract
Over the next 5 years, our industry will be experiencing an unprecedented amount of change. Transitions to low GWP refrigerants, requirements for cybersecurity, a global focus on resilience, a system approach to energy efficiency, and the internet of things (IoT) are just some examples of future trends that will have a significant effect on the mechanical systems within the built environment. This presentation will provide a global overview of coming trends and identify many of the opportunities and risks that will accompany them.

HOW TO MAXIMIZE THE HISTORICAL OPPORTUNITY TO IMPROVE COOLING EFFICIENCY

Dan Hamza-Goodacre
Executive Director, Kigali Cooling Efficiency Program

Abstract
In 2016 the Kigali Amendment to the Montreal Protocol was agreed by 197 nations. The agreement fixed a timetable to reduce super polluting F-gases used in cooling and for the first time the door was also opened to improving cooling efficiency in tandem with the F-gas transition. How this will happen is not yet clear but efforts are already underway, in particular driven by a new philanthropically supported global initiative – the Kigali Cooling Efficiency Program (K-CEP). Working in 38 developing countries (including Lebanon), and in partnership with the UN, World Bank and other cooling experts, K-CEP's methodology supports institutions, policies, finance and access to cooling in order to help speed and scale cooling efficiency.

Paper No.: ICEBD-MET: 2018-36

Establishment of a Sustainable Energy Action Plan: Case Study of Union of Municipalities

Sabine Saad, Student Member ASHRAE; Adel Mourtada, DrEng; Marwan El Brouche, PhD; Mazen Ghandour, DrEng

While climate change mitigation and adaptation strategies are the world's most prominent issue today, Lebanon, the Southern Mediterranean country, is trying to develop an integrated plan for urban development, energy supply, and environmental management. For years, the central authority in Lebanon has been unable to provide a steady production and distribution of electrical energy or even invest in the existing renewable resources.

This has lead local authorities, or municipalities, to design their own plans despite the lack of accurate data and the absence of supporting measures initiated by the State. In the framework of the Covenant of Mayors (CoM) applications in the South Mediterranean region through the CES-MED program, it has been noticed that several Lebanese applicants wish to commit to the Covenant but are obstructed by many barriers which we shall highlight and evaluate in this paper. The paper also presents a complete case study of the Union of Municipalities of Shouf–Soueijany encompassing eight different municipalities. The case study establishes that the calculation of the total amount of greenhouse gas (GHG) emissions resulting from the overall energy consumption of the 8 municipalities (the Baseline Emission Inventory or BEI) will enable the union to comply with the CoM through the implementation of a Sustainable Energy Action Plan (SEAP). In order to identify the nature of the entities emitting CO2 in the scope of the municipal union, we have resorted to onsite data collection. The unavailability of official reliable statistics and references has made data collection and the determination of a baseline year a significant obstacle to the research.

Paper No.: ICEBD-MET: 2018-57

Energy Comparison of Air Conditioning Split System VS. Solar Absorption Systems with Optimization for a Prototype Educational Building

Hesham Safwat, PhD, Member ASHRAE; Fady Anees

This paper aims to study solar energy in Egypt and its potential utilization in solar thermal cooling (absorption technique). The paper includes a detailed proposed solar absorption cooling system for one building located at the British University in Egypt with maximum cooling load of 141.3 ton. Of refrigeration. The building cooling loads at different months were calculated using the hourly analysis program (HAP). A detailed design using a design software (TRNSYS) is introduced to model the system and for optimization. A cost analysis is finally included to compare the running costs of both the proposed cooling system and the current system. The paper shows that more than 80% energy savings can be achieved using the solar thermal cooling system compared to ordinary split air-conditioning units.

Paper No.: ICEBD-MET: 2018-55

Contributing Algorithms of Energy Efficiency and Renewable Energy in the Residential, Commercial and Industrial Sectors

Georges El-Jamal, PhD, Member ASHRAE; Chantal Maatouk, PhD; Mazen Ghandour, PhD; Adel Mourtada, PhD; Fouad Kaddah, PhD

Renewable energies (RNE) and energy efficiency (EE) are considered as twin pillars in the energy strategic battle to decrease fossil energy consumption. The combined potential of energy efficiency and renewable energy to reshape energy future is substantial. The energy consumption profile of an industry process or facility is considered to be an energy footprint and a main axis in its life. The aim of this paper is to highlight to the existing energy profile of a facility or industry process and to elaborate different steps to reduce it by exposing an innovative algorithm (methodology), contributing between EE and RNE, to achieve a low energy profile in residential, commercial and industrial sectors.

Paper No.: ICEBD-MET: 2018-19

Benefits from Combination of Centralised Ventilation System and Decentralised Conditioning Units

Maciej Danielak, Kampmann GmbH, Germany

Each building needs to have regulated temperature as well as needs to be ventilated. These two requirements come from one of most important function of the building: create comfortable indoor climate. A human being need fresh air to stay healthy and fit. The building need to be thermal conditioned from one side to protect the construction and the mass of the building and because of thermal indoor comfort for a user's. The both needs relate to energy consumption but also with a place (volume) in a building. So, there are both investments cost and consumption costs. Benefits for both can bring the system witch splits those to needs – hygienic and caloric – and bring a combination between centralized ventilation system and decentralized conditioning system. In this the air exchange is provided by a single bidirectional ventilation unit. The temperature is adjusted on this system by decentralized equipment in the inside of the room and not via the central ventilation unit (air handling unit). This combines the unbeatable efficiency of decentralized units with the heat recovery capability of a ventilation unit. The basic system will be presented and compared. The central-decentral system will be described in detail and all the benefits for the building energy consumption and other system component like BMSystem, architecture will be mentioned. The presentation will present a separately working centralized ventilation unit and decentralized conditioning units with are connected into one system.

Paper No.: ICEBD-MET: 2018-48

Holistic Approach to Energy Performance of Green Built Environment

Essam E Khalil, PhD, PE

The global energy crisis coupled with the threats of climate change bring into sharp focus both opportunities and challenges for developing countries. Developed and developing countries have to better address the increasing energy demands of growing economies, as well as address energy poverty issues often highlighted by extreme disparities in income. They also need to deal with the real and potential impacts of climate change and energy efficiency improvement. In addition to these challenges is the global imperative to reduce carbon emissions in order to prevent climate change. While developing nations have thus far been sheltered from obligations to reduce carbon emissions, one cannot anticipate that this situation will continue for long. Holistic approach to energy performance in built environment had been a key tool to improve the overall energy performance. Within this context nations need to follow a very different development path from that established by first world countries. This development path is a low energy, low carbon and generally a resource efficient one.

Paper No.: ICEBD-MET: 2018-32

Transition Engineering the Water-Electricity Nexus Operating in Building Services and Urban Heat Islands – Concept Design – Is Air-Conditioning Really Necessary?

Eric Peterson, Adjunct Professor, Victoria University, Visiting Research Fellow, University of Leeds, U.S.A

After firstly determining if passive design cannot be expected to serve at a given development site, it is appropriate to determine what mode of building services would be expected to provide comfortable conditions, as ventilation or evaporative cooling may satisfy without resorting to air-conditioning. Consequently, there are broadly three modes of building services which may be recommended to provide coolth in summer if passive means will not suffice, and similarly another three modes of building services that may be required in to maintain comfort in winter if passive means will not suffice. I suggest that leading winter building service modes are humidification, moderate air-source heat pumping, and icing-heating. The icing-heating condition could be partially managed by defrosting of air-source heat pumps, but may recommend a ground-source or combustion heat-source. For the purposes of the present study there are seven operating modes ranging from direct expansion (DX) air-conditioning in summer to icy-heating in winter. Balancing comfort and economy, the criteria for the more extreme conditions were taken to be satisfied if the defined criteria are not to exceed more than 10 days per year – inspired by the Australian approach to setting comfort design conditions with only daily min/max observations – where the average of the tenth highest daily max was used to determine the design dry bulb. So I propose that if mean daily conditions show that air-conditioning is desirable only nine days in a year, then it is not deemed necessary in that location. But if in that location there were at least ten days in a year where evaporative cooling or air-conditioning were desirable, then evaporative cooling would be the suggested system. And finally, passive design may be acceptable for comfort if there were less than ten days in-total in which any of the active modes of cooling were desired. Results include a tabulation of the medians from 157 countries. Larger federations such as USA, Canada, Russia, China, and Australia were not summarized as provincial climatic variability is vast. The highest dry bulb threshold T_{Vhot} arises from ASHRAE 55 standard for comfort and the next two are the most common base temperatures of cooling and heating degree days, and Ticing is the upper whole degree associated with freezing up of air-source heat pumps together with ΔT_{ice}=5K of degrees that dewpoint is below drybulb. The highest wetbulb T_{Vhumid} is the author's suggested limit for the suitability of ventilation to manage humidity without air-conditioning, and the lowest webbulb threshold T_{dry} is where the air may be too dry for comfort. The wetbulb T_{humid} is threshold of evaporative cooling.

Paper No.: ICEBD-MET: 2018-25

Design Optimization for Maintaining Occupants' Outdoor Thermal Comfort

Haneen I. Hamdan, ME, Balsam A. Nehme, ME

The purpose of this study is to benefit from SPMV model and develop an in-house tool that predicts thermal comfort of a person present outdoors and directly subjected to the outside environmental conditions such as wind and direct sun radiation. By conducting an hourly assessment of outdoor thermal comfort, the tool allows for identifying critical hours of the day when discomfort due to external conditions might occur. Moreover, the work presents case studies considered and further simulated to assess the impact and optimize the implementation of various potential adequate design measures onto the individuals' thermal comfort in an external environment.

Paper No.: ICEBD-MET: 2018-15

Prediction and Control of Noise and Vibration within a Sport Facility

Ghina Annan, Balsam A. Nehme, Dar Al-Handasah, Lebanon

The prediction and control of noise and vibration during sport events has created a tough challenge for sport facilities, as full compliance to minimum standard requirements and city regulations are now mandatory. This dictates designers to achieve suitable reverberation time and utilize desirable while controlling undesirable discrete reflections within occupied spaces and maintaining proper with equally distributed sound energy levels. As such, design aspects shall include all specifications, from room volume and shaping, to the selection and placement of finish materials for walls, floors and ceilings and implementation of reflectors and diffuse elements. Unwanted noise and vibration invade an enclosure by mechanical transmission through solid structure of wood, steel, concrete, or masonry.

The noise due to HVAC systems can be transmitted to a room by the air in the ducts or by the metal of the ducts themselves or both, while having the vibration travel great distances through these solid structures with minimal losses. Similarly, water pipes and plumbing fixtures tend to have significant sound carrying abilities. This paper highlights the acoustics, noise and vibration criteria applicable to a sports' facility located in Dubai, and further optimize the acoustic performance of its walls, floors, doors and finishes in occupied and technical spaces to meet the minimum standard requirements.

Paper No.: ICEBD-MET: 2018-24

A Four Step Approach for Energy Conservation and Retrofitting Interventions for Residential Buildings

Mohamad Hajj Hasan; Mohamad Abbas; Bahaa Mneymneh; Issam Srour, PhD

This paper presents a utility data analysis for a residential building and the estimated energy saving results from the use of practical retrofitting energy efficient systems. A four step approach is used to: (1) collect the utility data to estimate an actual baseline for energy consumption, (2) conduct an energy audit to determine the existing operating conditions of major energy use equipment, (3) model the building in Autodesk-Revit then export the data into Elite-Chvac (Commercial Heating Ventilation and Air Conditioning) for heat load analysis, and (4) prepare a comprehensive list of energy conservation measures. Several scenarios for possible interventions to the building's cooling, lighting and hot water systems are proposed and evaluated in order to assess the effectiveness of various energy conservation techniques. Based on the results of these simulations, it is concluded that it is possible to reach an overall 44% reduction in energy consumption.

Paper No.: ICEBD-MET: 2018-37

Investigation of Thermal Comfort in a Space Conditioned by Liquid Desiccant Membrane Chilled Ceiling/ Displacement Ventilation System

Racha Seblany, MS; Nesreen Ghaddar, PhD, Member ASHRAE; Kamel Ghali, PhD, Member ASHRAE; Nagham Ismail, PhD; Marco Simonetti, PhD; Fracastoro Giovanni Vincenzo, PhD; Joseph Virgone, PhD; Assaad Zoughaib ,PhD

Chilled ceilings combined with displacement ventilation (DV) have gained popularity due to their efficiency in terms of providing thermal comfort and high air quality, with minimal noise and good energy savings. Chilled ceilings can be replaced by liquid desiccant membrane systems integrated with DV system (LDMC-C/DV) to operate at lower ceiling temperatures and to directly dehumidify the indoor environment for improved performance. Thermal comfort is a major concern in any air conditioning system as it is directly related to the health of the occupants. Therefore, the effect of low ceiling temperatures in LDMC-C/DV environments on comfort needs to be investigated. For this purpose, a validated mathematical model of the dehumidifier panel will be integrated with a steady-state DV space model. The integrated model is used to represent the mass and energy balances inside the space and at the two sides of the dehumidifier panel. A parametric study will be carried out under different air supply conditions to predict the air conditions (temperature and relative humidity) in a space conditioned by the LDMC-C/DV system. Accordingly, the thermal comfort of the occupants inside the space is assessed based on the PMV value for different DV supply conditions and inlet desiccant solution temperatures. It was found that at low ceiling temperatures the relative humidity in the space rises but thermal comfort can still be realized under specified DV supply conditions.

Paper No.: ICEBD-MET: 2018-53

Interrelationship between Architectural and Mechanical Aspects of the Building Envelope Design

Hadi Maamoun, Member ASHRAE

The building envelope plays an important role in maintaining interior thermal comfort and in minimizing uncontrolled moisture and air movement into a building. An effective building envelope design works towards minimizing heat transfer and preventing moisture and condensation problems. Because some of these considerations are not always apparent to Architects, the interaction between Architects and Mechanical engineers is crucial in creating a problem free design. This paper aims to show the relationship between the architectural and mechanical aspects of the envelope design. This paper also details how the integrative design is implemented during the early design phases supported by several building envelope case studies for airports, hotels and institutional facilities. For each case study, a thermal and moisture diffusion analysis is conducted to evaluate the thermal effectiveness of the proposed envelope design and to assess the potential of surface or interstitial condensation within the layers. Different scenarios are also simulated under various climatic conditions during the year and even during a single day to determine the operational behavior of the assembly, the optimal ordering of the assembly layers, the need of some features within the envelope such as vapor barrier and several other critical issues.

Paper No.: ICEBD-MET: 2018-14

Hygrothermal Engineering Analysis of Walls and Roofs in Hot and Humid Climates

Ghina Annan, Balsam A. Nehme, Dar Al-Handasah, Lebanon

Moisture damage in buildings is common, where the consequences can be catastrophic, and the remedial measures expensive. Factors influencing condensation risk include exterior climate conditions, interior environment, thermal and vapor properties of the structure and the heating, ventilation and air conditioning system. Condensation can occur on building surfaces or can be interstitial, causing serious problems if left unchecked; such as crumbling or soft spots in drywall, decay in wood framing or corrosion of steel, paint peeling, damage to the insulation inside the walls, and mold and mildew problems. Research shows that several human health illness is attributed to damp indoor air quality such as cough, wheeze, asthma and dyspnea. Controlling moisture is crucial to ensure healthy indoor air quality, occupant comfort and to avoid the deterioration of building structures. Hygrothermal engineering is the combined effect of temperature and humidity transport through the building components, influenced by the envelope material composition and the surrounding climate. This work is concerned with the assessment of the possibility of condensation in the building structure using WUFI® Pro, a software that performs a transient two-dimensional heat and moisture transport in multi-layered building components using real climatic conditions. Typical walls and roofs used in hot and humid climates, such as typical climates across the United Arab Emirates, are investigated for possible condensation and accordingly building materials are selected with appropriate water and thermal transmission characteristics.

Paper No.: ICEBD-MET: 2018-35

Mathematical Modeling of Hybrid Cooling Vest Integrated with Bio-Heat Model for Assessing Cooling Effect on Humans in Hot Conditions

Ragheb Raad; Mariam Itani, PhD; Nesreen Ghaddar, PhD, Member ASHRAE, Kamel Ghali, PhD, Member ASHRAE

Workers in hot environments are exposed to increased irritability and to excessive sweating. They are also very likely to lose some of their concentration. This environment will therefore reduce their ability to do physical work and as a result, affect their performance and efficiency. Not to mention that physical work burns additional energy creating extra metabolic heat that adds to the tally. Cooling methods such as cooling vests are therefore necessary to increase the performance and output of the workers. The main objective of this study is to develop a computational model for an evaporative cooling vest and integrate it with a validated bioheat model. Such a vest improves the thermal comfort of the workers, thus allowing them to efficiently perform outdoor physical activities at elevated air temperatures. The vest's model is based on the formulation of the direct evaporative cooling technique. The borders of the channel are represented by an outer insulated layer and a highly hygroscopic material for the inner layer adjacent to the skin. Ventilation fans located at the lower back are used to blow ambient air into the vest. A mathematical model of the cooling technique is developed and it is coupled with the bioheat model which allows studying the workers' thermal response to the proposed vest. These computations would predict the variation of the torso and mean skin temperature as well as sweat rate and overall thermal comfort during outdoor physical activities and under specific ambient conditions. In this study, the model is tested under a moderate activity level and it is then compared to the case where no cooling is present. The results showed that the proposed system would decrease the torso and mean skin temperatures as well as improve overall thermal comfort of subjects wearing the vest.

Paper No.: ICEBD-MET: 2018-64

Effect of Inter-Segmental Ventilation on the Segmental Heat Losses by Means of Electric Circuit Analogy

Nagham Ismail, PhD; Nesreen Ghaddar, PhD, Member ASHRAE; Kamel Ghali, PhD, Member ASHRAE

The flow characteristics and heat transfer in the presence of inter-connection between clothed segments are studied for the walking clothed upper human body part in cross wind. The aim of the work is to develop a computationally effective model to estimate the clothing ventilation and heat transfer of the inter-connected upper human body part. The model is based on the analogy between (i) the air flow in the microclimate air layer and an electric circuit composed of resistance and inductance elements, and between (ii) the heat losses from the human body and the thermal electric circuit resistance. The two developed model are coupled allowing the estimation of segmental heat losses generated at constant skin temperature. The coupled ventilation circuit and heat circuit models predicted both the segmental clothing ventilation rate and heat loss for different walking speeds and external wind. The developed model of the segmental ventilation and heat transfer from the clothed human segment were validated by conducting experiments on a walking thermal manikin at constant skin temperature using tracer gas method placed in an environmental chamber under windy conditions. The segmental ventilation and heat losses measured from the thermal manikin experiment were compared to the results of the ventilation-heat circuit model. Good agreement was observed between the ventilation-heat circuit model and the experimental data with a maximum error of 16 % which is still within the experiment standard deviation range. Results show that the segmental heat losses for the arm and the trunk attain its minimum for the lowest relative velocity and its maximum for the highest relative velocity. Evidently, when the relative velocity increases, the trunk and arm ventilation increase leading to an increase in segmental heat losses. The main reason is that the penetrated air is coming from the ambient condition. It is slightly heated in the fabric nodes and enter to the microclimate air layer leading to significant heat losses from the heated skin.

Paper No.: ICEBD-MET: 2018-5

Numerical Study on PCM-Desiccant Cooling Vest to Improve Cooling and Performance of Workers in Hot Humid Conditions

Mariam Itani, PhD; Rana Bachnak; Nesreen Ghaddar, PhD, Member ASHRAE; Kamel Ghali, PhD, Member ASHRAE

People working in a hot humid environment are exposed to heat strains due to the high ambient conditions as well as hindered cooling by sweat evaporation from the human body. This causes heat accumulation in the human body and an increase in the core temperature affecting the comfort of the workers and eventually their productivity. Passive cooling vests containing phase change material (PCM) have been designed to provide cooling for the body. However, the presence of PCM packets creates a barrier in the path of sweat evaporation, and in humid conditions, condensation might happen on the surface of the packets. A combination of PCM and solid desiccant packets was used to minimize the risk of condensation and provide a drier microclimate in the cooling vest. The aim of this study is to integrate a validated fabric-PCM-Desiccant model with a validated Bioheat model and assess the human thermal response upon wearing the PCM-Desiccant vest. The fabric-PCM-Desiccant model is based on heat and mass balances that predict fabric, PCM, desiccant and micro and macro climate air temperatures, as well as micro and macro climate air humidity contents. The bioheat model divides the human body into 25 segments including upper and lower segments of the trunk, that are represented by 8 skin nodes. The bioheat model predicts segmental skin temperatures and heat losses, as well as, mean skin and core temperatures and sweat rate. Thus, an integrated model would allow designing a PCM-Desiccant cooling vest capable of sufficiently cooling the body while maintaining a drier microclimate. The integrated model would also allow assessing the effect of the PCM-Desiccant vest on skin temperature, microclimate temperature, and microclimate humidity content. In this study, a comparison is done between predicted skin and microclimate temperatures and microclimate humidity content when using a PCM-Desiccant vest and when using a PCM-Only cooling vest in hot humid conditions. Then, the effect of different PCM melting temperatures on the human thermal responses and the performance of the PCM-Desiccant vest is examined to give a recommended vest design. It is expected that the PCM-Desiccant cooling vest would provide a cool and less humid microclimate than that in a PCM-Only cooling vest, thus improving thermal comfort of the worker in hot humid environments.

Paper No.: ICEBD-MET: 2018-62

Quantifying Losses Due to Thermal Discomfort: An Agent Based Modeling Approach

Mohamad Awada; Issam Srour, PhD

This paper presents a framework that employs an agent based model (ABM) to examine and understand the impact of occupants' thermal behavior in a commercial building. The proposed simulation framework has two main objectives. The first objective is to model and understand the behavior of occupants in their workplace environment while taking into account the influence of thermal conditions on the behavioral decision-making. The four main behaviors that are studied correspond to the agent's adjusting of clo level, shades use, thermostat use, and personal fan use. The second objective is to quantify the financial and profitability losses due to thermal discomfort in an air-conditioned office by examining the effect of thermal dissatisfaction on productivity, absenteeism and complaint rates. Simulated agents in the proposed ABM framework behave according to the Fogg Behavior Model, where two main elements must converge at the same time for a certain behavior to occur; motivation and ability.

Paper No.: ICEBD-MET: 2018-10

A Comparative Assessment of the Performance of Cooling Systems for Large-Scale High-Density Data Centers Using CFD Simulations

Khaled Abou Hweij, Dar Al Handasah; Adnan Akhdar

The increasing demand for storage, networking and high-performance computing has led to a significant growth in the size, energy density and complexity of data centers which drives the need for efficient cooling strategies to cope with the rising energy demands. Thus, thermal performance and efficiency of cooling systems in data centers has become indispensable to ensure that the servers operate within reliable thermal limits for the ever-increasing servers' power density while minimizing as much as possible the energy consumption of the cooling system which constitutes a large portion of the total consumption of data center. This paper will use computational fluid dynamics (CFD) simulations in order to study and compare the performance of current and emerging cooling strategies in efficient air distribution and thermal management of the heat dissipation from the servers.

Specifically, the performance of a traditional and widespread computer room air conditioning (CRAC) system with underfloor plenum will be compared against emerging systems such as Chiller-Door Units (CDU) and In-Row system without raised floors. For this purpose, a detailed investigation of airflow delivery is carried out on full-scale three-dimensional models of a large and high-density data center to comparatively assess the resultant thermal distributions of the considered cooling systems and establish the fundamental benefits and drawbacks of each system. In summary, the findings indicate that there is significant potential to increase efficiency while still maintaining uniformly delimited hot and cold regions in front of the sever cabinets by moving the cooling energy closer to the heat source to avoid losing cooling capacity by mixing with the hotter air inside the stratified layer above the cabinets.

Paper No.: ICEBD-MET: 2018-12

A Full Three-dimensional Simulation of an Industrial Baking Oven

Mohamad Al Nasser; Iyad Fayssal, PhD; Fadl Moukalled, PhD

Forced convection baking ovens are widely used in the baking industry for their high efficiency and effective heat transfer over radiation-based ovens. The aim of this study is to model and simulate an industrial baking oven as a prior step to optimize the operation of the oven (airflow management) and baking process, and reduce the required fuel consumption. This may help in compensating for the expected rising energy costs and meeting the mandatory industrial standards. A full scale three-dimensional model of an industrial oven is developed and analyzed using the ANSYS FLUENT computational fluid dynamics package that adopts a finite volume approach for the discretization of the governing conservation equations. The oven, which is composed of a heat exchanger, a fan, a baking chamber, and rotary racks, was first constructed using the SOLIDWORKS software and then imported to the design modeler in ANSYS. The computational domain was covered with a mesh of size 14 million elements. Initially, single phase simulations to predict the hydrodynamic and thermal fields were conducted for the sake of establishing an idea about the velocity and temperature distribution of the air circulating inside the oven. The results were validated with available experimental data. Temporal and spatial variations of the velocity field, recirculation zones, and temperature distribution will be presented and analyzed in terms of contour plots. Preliminary results indicate that some improvements in performance may be achieved by slightly modifying the design of the oven.

Paper No.: ICEBD-MET: 2018-54

CFD-Optimized Radiant Cooling with Dedicated Outdoor Air System (DOAS) for High Ceilinged Spaces in Hot and Dry Climates

Youssef Ghoussoub, Dar Al-Handasah; Adnan Akhdar

The increasing demand for sustainable and energy efficient buildings, and fast-track delivery of projects with limited design time, has driven the need for advanced design tools to accurately assess and optimize ever more complex and diversified design strategies to find ways to reduce loads, boost efficiency, and utilize renewable resources. Computational Fluid Dynamics (CFD) proved to be a solid and flexible platform for design development and validation to meet such challenges within tight schedules, and deliver state-of-the art designs for high performance buildings.

This paper will present the use of computational fluid dynamics (CFD) simulations at Dar Al-Handasah to develop an innovative air-conditioning system for high-ceilinged spaces in hot and dry climates based on radiant cooling coupled with a dedicated outdoor air system (DOAS). Specifically, the performance effectiveness of the proposed cooling strategy in establishing a comfortable thermal environment is compared against a conventional overhead supply ceiling diffusers system by conducting a detailed investigation of airflow delivery and temperature distribution in a typical transient high-ceilinged assembly hall during full load and part load conditions. Moreover, to analyze accurately the performance of the compared VAC designs, several parameters have been considered such as the supply air flow rate and temperature, the air distribution layout, radiant floor temperature and heat loads. The findings indicate that the proposed cooling strategy based on a combination of radiant cooling with DOAS helped achieve a thermally uniform environment with markedly improved thermal comfort conditions and reduced energy use as compared to the conventional design and the study concludes with a set of recommendations to optimize the air conditioning system energy use and thermal comfort levels in such spaces.

Paper No.: ICEBD-MET: 2018-26

High Solar Combi-Plus System using PCM Storage: KSA Case Study

Mohamad Hmadi; Adel Mourtada, PhD, PE

Based on the increasing worldwide tendency towards sustainability and the“go green” movement, the idea was targeted towards developing a standalone “High Solar Combi Plus System” (HSC+) that can provide all thermal energy loads of cooling, heating, and domestic hot water for any building throughout the year without the use of an auxiliary source of energy. The high solar combi-plus system consists of evacuated tube heat pipe solar collector panels, thermal energy storage in the form of a phase change material (PCM) to maintain the stability of the system, a hot water driven lithium bromide absorption chiller, the heating, and the domestic hot water systems.

The sequence of operation and control for such a system was described in four modes: solar regeneration mode, solar source only mode, solar and storage mixing mode, and the storage source only mode. In order to study its validity and reliability, a mathematical model was developed for its different components. These models were then coupled with a fully programmed calculator developed using “Visual Basic ©”. This calculator was capable of finding the optimized combination between the solar collectors and PCM thermal energy storage, together with all annual hourly simulation results from the consumption of the building and the collected solar radiation, to the PCM thermal energy storage level. Furthermore, a villa in Riyadh KSA designed according to Saudi Arabia Thermal Standard was taken as a case study. The thermal and electrical consumption baselines were simulated hourly using the “Design Builder” Program, and then input in the calculator. The results showed that only 80m2(861 ft2) solar collectors and 3.5 m3 (925 gal) PCM storage were enough for running this system continuously throughout the year without the need for any other auxiliary source of energy. Finally, the feasibility of the novel system shows that although the very low electrical tariff in KSA deters its usage, adopting this system in the Country’s Energy Policy will help the government decrease 12.7% of the overall electrical consumption in the country.

Paper No.: ICEBD-MET: 2018-50

Sustainable Design in Metro Stations

Steven Lai, Member ASHRAE; Anne Beh; William Xie, CEng; Hadi Wijaya, PE, CEng; K.W Ang, PE, CEng

In addressing the Global Energy Crisis, engineers have the social responsibility to find and implement practical solutions. This paper discusses the sustainable heating, ventilation and air-conditioning (HVAC) design concepts that can be applied in metro systems. The use of Platform Screen Door (PSD) along the underground station platform to isolate the station from the tunnel has a positive impact on the overall energy consumption of the metro systems in tropical regions (e.g. Singapore, Thailand, Malaysia, etc.) and subtropical regions (e.g. Hong Kong, Guangzhou, Shanghai, etc.). During cooler months, the concept of free cooling by introducing more outdoor air in seasoned countries can further reduce energy consumption as well as improving indoor air quality. To contribute on sustainable development, engineers should participate in the overall planning of the metro stations with other stakeholders. Effective use of space is a key strategy in mitigating the challenge of land scarcity in developed urban cities. This planning may include (1) utilizing the space created incidentally due to metro construction by converting it to commercial areas instead of backfilling it, (2) integrate development above metro stations or (3) connecting the metro stations to nearby developments to mitigate impact to the aboveground traffic.For sustainable design, Central Chiller Plant can be considered for adjacent stations and their connecting developments. Apart from saving initial cost and running cost, this approach also saves the overall land space. To further release space above ground for other usage, open top vent shafts can be designed to reduce the size of the aboveground structure. There are other sustainable designs in metro systems that are related to HVAC design. Taking the lighting system for example, the use of "Light without Fitting" (LwF) concept with Light-emitting Diode (LED) lighting is an ongoing trend to bring a new aesthetic experience to the public. It not only reduces the lighting energy consumption, but also reduces the cooling load requirement.
Examples from various projects in Singapore and Hong Kong will be referenced in this paper. Other sustainable measures e.g. Variable Speed Drive (VSD) for pumps and cooling towers, outdoor air control, regenerative energy, etc. which have been used in metro systems are also covered in this paper.

Paper No.: ICEBD-MET: 2018-16

Energy Performance and Occupant Comfort in an Office Building: Co-simulation of an Agent-based Behavior Model with EnergyPlus

Mohamad Awada; Mohamad Hajj Hasan; Daoud Kiomjian; Issam Srour, PhD; Hiam Khoury, PhD

There is a lack of consensus in the literature regarding the interplay between energy efficiency and occupant comfort. Some sources argue that energy-efficient buildings are congruent with improved occupant comfort, while others state that energy efficiency efforts have a dampening effect on occupant comfort. This lack of agreement is rooted in the fragmented nature of the building industry that requires conducting energy simulations during the design phase when little is known about the building envelope and the behavior of the occupants. Although design parameters are considered central for energy modeling, behavioral aspects are of paramount importance as well and their impact on energy performance should also be considered. Therefore, this paper co-simulates an Anylogic agent-based model of occupant comfort and behavior with an EnergyPlus building energy model. To that end, a hypothetical case study of an office building is developed to identify the optimal position to place the office furniture that can balance comfort levels and energy consumption. Provided with three control features (thermostat, Clo level and internal shades), the thermal comfort level of an occupant is assessed according to the employees' Predicted Mean Vote (PMV). The findings generated by modeling multiple scenarios indicate that comfort levels are not the sole triggers of behavior and that the agent behavior emerges as a result of the autonomy agents have over a set of control parameters within their environment.

Paper No.: ICEBD-MET: 2018-33

Principles of Split Mass Flow and Heat Shifting Psychrometrics toward Efficient Comfort Management

Peter Phillips, Member ASHRAE

When designing energy efficient buildings much attention is devoted to reducing building fabric, internal sensible heat loads and ventilation heat loads. Latent heat loads from people and ventilation are beginning to dominate our thinking toward satisfying our concepts of occupant comfort and mold control building wellness. The paper discusses the merits of split mass flow psychrometrics (SMFP) and cold cooling heat exchangers to disconnect the sensible and latent cooling processes. In association with SMFP, heat shifting within either air mass stream can provide further disconnection of the cold cooling process from the saturation curve to enhance occupant comfort management and control of the potential for mold growth within ducting systems.

Paper No.: ICEBD-MET: 2018-20

World Class Energy Efficient HVAC System for New 'Twisty Tower' in South Africa

Pieter J. de Bod, PE, Member ASHRAE

The international auditing firm Pricewaterhouse Coopers (PwC) in South African has taken occupation of the brand new modern office building in November 2016, a project that deserves global recognition. The new iconic 26 storey PwC head office is showcasing on the global prospectus with a beautiful "twisty" high rise tower architectural design which gently twists through in height with the top and ground floor rotated by 30 degrees. Keeping South Africa's environmental challenges of water scarcity and limited electricity supply in mind, the new energy efficient air-conditioning system is a low water and electricity consumption 4 pipe chilled and hot water system. Using two new state of the art water cooled chillers plus three new multifunction 4-pipe units', the carbon footprint of the building is substantially reduced compared to most other buildings in the area. At the same time the annual on-site water consumption is also reduced. The efficient building design hosts numerous innovative and energy saving technologies which contributes to the measured low energy consumption as well as the excellent occupancy comfort and environmental quality.

Paper No.: ICEBD-MET: 2018-3

Energy Conservation for an Office Building in a Hot Climate

Hari S. Dalal, Member ASHRAE, The Associated Engineering Partnership

Kuwait is located in Middle east region. The weather is very hot. During summer the Ambient temp becomes 52 °C db, and relative humidity varies between 40 % to 60%. Kuwait area is also very dusty due to sand dust. HVAC design is a very challenging today. ASHRAE 90.1 – is a standard guidelines related to energy saving. Year after year the power requirement
becoming less to save energy as well carbon dioxide generation to control the environment. Ministry of electricity and water (MEW) have formulated some guidelines in this aspect. Façade glazing, Thermal Energy storage (TES) , Energy Recovery Unit (ERU) etc will play related to Energy savings. Manufacturer also trying to improve Energy Efficiency Ratio (EER) of products like chillers, fans etc and they are concentrating on development of product by research and development. Noise reductions also Energy Conservation for an Office Building in A Hot Climate , Kuwait In this paper, An office building have been considered. Office area is air conditioned by Underfloor system. To reduce HVAC plant capacity, Thermal storage – Chilled water by Indirect interface system have been considered. The influence of following parameters like UFAD (Underfloor air distribution system}, Facade glazing factor like "U" (Overall Heat Transfer coefficient}, SHGF (Solar Heat Gain Factor} , Thermal Energy Storage (TES) for Partial loading , ERU (Energy Recovery Unit) etc. will be discussed and the contribution as percentage of energy saving will be presented.

Paper No.: ICEBD-MET: 2018-8

A Simplified Personalized and Displacement Ventilation Model for Predicting Passive Contaminant Spread in Office Spaces

Douaa Al-Assaad; Carine Habchi, PhD; Nesreen Ghaddar, PhD, Member ASHRAE; Kamel Ghali, PhD, Member ASHRAE

The purpose of this work is to develop a mathematical multi-layer, multi-plume model of passive contaminant spread for office spaces equipped with displacement ventilation (DV) coupled with a personalized ventilation system (PV). The model studies the transport of species and therefore predicts occupant risk of infection in typical office spaces. The particle concentrations in the thermal plumes and the surrounding air are separately evaluated in each air layer in the space. The PV is taken into account in the occupant breathing zone and affects the species' concentration in the rising thermal plume. The temperatures and concentrations at each layer are computed by solving the energy and mass balance equations. On the other hand, the temperature and concentration at the breathing zone are calculated by discretizing the PV jet into vertical control volumes and performing energy and mass balance at each PV layer. The model is then validated experimentally in a climatic chamber equipped with a DV+PV system and a heated cylinder representing an occupant in a typical office space. Validation of the model is performed for a DV flow rate of 60 L/s (127.13 CFM) and a supply temperature of 19°C (66.2°F) along with a typical PV flow rate of 3.5 L/s (7.41 CFM) and supply temperature of 22°C (71.6°F). Good agreement is obtained between measured and predicted values by the model with maximum errors of 7.44% for temperature and 4.47% for concentration found in the macroclimate air.

Paper No.: ICEBD-MET: 2018-7

Feasibility Assessment for Retrofitting an Energy-efficient Hospital Building through Energy Modelling and Field Investigation

Fu-Jen Wang, PhD, PE, Fellow ASHRAE; Cheng-Shu Kuo , PhD; Hung-Wen Lin, PhD, Member ASHRAE; Pei-Yu Yu, PhD; Chen-Pu Wang, Student Member ASHRAE

The objective of this study, including field investigations and energy modelling, is to evaluate the feasibility of retrofit for energy performance of a hospital in Taiwan. This hospital consumes around 8500000 kWh annually with 37490 m2 floor area including twelve stories and two floors of basements. The current facility systems of this hospital present relevant signs of degradation and obsolescence with high energy consumption. The retrofitting plan of facility systems for this hospital is assessed and conducted to improve energy performance accordingly. Based on ASHRAE procedures for commercial building energy audits (PCBEA), field study and energy audits were conducted to collect information of building geometry, building materials, space types, density and activities of people, capacity of HVAC system, loads and operating schedules of lighting and other facilities. The energy consumption baseline can be derived through PCBEA and BEMS (building energy management system) data. Energy modelling using Energy Plus code has been conducted extensively to evaluate the energy saving approaches. The results reveal that the energy saving strategy of increasing chiller water supply temperature 1□ could obtain 1% of annual energy saving, while increasing room set point 1□ may reach 2% saving of annual energy consumption. Besides, applying the insulation film for glass also presents about 0.8% of annual energy saving through energy modelling. The retrofit feasibility has also been evaluated in terms of annual savings and payback period of the investment. The procedural investigation of building energy consumption should provide valuable information for facility engineers facing energy saving concerns.

12 PAPER CITATION IN THE PROCEEDINGS

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