Second International Conference on Energy and Indoor Environment for Hot Climates

Outdoor Cooling Technologies, Challenges, and Opportunities for the Hot Climates

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Sunday, February 26

Sunday, February 26, 9:30 AM - 10:30 AM

Keynote

Keynote 1

Room: Main Hall

Can International Standards for Indoor Environmental Quality be Applied in Hot Climates?

Bjarne W. Olesen, Ph.D., Fellow ASHRAE, Technical University of Denmark, Lyngby, Denmark

Recently ISO, CEN and ASHRAE have revised/or developed new standards for indoor environmental quality. For many years the recommended criteria for thermal comfort and air quality in international standards were independent of the exterior climate. Some years ago ASHRAE Standard 55 introduced the adaptive model, where the recommended criteria for the indoor temperature is dependent on the outside temperature. This keynote speech presents and discusses the new standards related to hot climates and the issues, such as the effect of humidity, benefits of increased air velocity, the influence on occupant's productivity, and transient exposure when moving between in- and outdoors.

Sunday, February 26, 10:30 AM - 12:30 PM

Conference Paper Session 1

Energy Efficiency in Architectural Design

Room: Hall 1

1. Roof Gardens Application in Hot, Humid Climate (Jubail Industrial City Case Study) (HC-17-01)

Rania Obead, Jubail University College, Jubail Industrial City, Saudi Arabia

Roof gardens (RG) are considered as one of the important sustainable practice in buildings. RGs have a significant role in environmental, economic and social factors. RGs reduce CO_2 amounts in the atmosphere and add oxygen, besides decreasing the pollution, as well as cooling the air and all these are environmental benefits. RGs economic role can be clear in reducing the energy used for heating and cooling buildings because of its thermal insulation properties. Moreover, it can reduce the maintenance required for the roof (it covers the roof and protects it from deteriorating). The social impact of the RGs is providing a space for family gathering and social activities. This research discusses the benefits of the RG in a certain town (Jubail Industrial City-Eastern Province – Saudi Arabia) and measures the trust of the citizens in this practice through a questionnaire. Then the paper suggests using portable gardens (in containers) instead of constructing one. The research will recommend a design for the planting container, size and dimension. The plant selection is an important factor in successful RGs, the paper recommends using native and desert plants and some types of vegetables and herbs for the RGs. Besides suggests a suitable soil for the plants growing. At last suggests a solution for the RGs irrigation by using an atmospheric water generator.

2. Understanding Building Compactness Metrology, Originating Compact Architectural Forms (HC-17-02)

Mohamed Almumar, P.E., Independent, Erbil, Iraq

This paper aims to establish a methodology to originate compact architectural forms that ensure efficient thermal performance and indoor environment by exploring appropriate compact morphologies during the early stage of design process. Compactness in the recent literature associates to the thermal efficiency of geometries regardless to their indoor environment, and yields particular constant proportions of the geometry dimensions independent from building type, volume, or site conditions. No consensus of opinions exist for identifying the efficient proportion of compact forms which revealed contradicted findings. This paper adopts the thermal and environmental performance requirements that interoperates with the building design functions, as generators to originate compact architectural forms. The standard rate of horizontal surfaces by volume was derived, which in conjunction with the standard rate of vertical surfaces and their sum, can evaluate the thermal and environmental performance of a morphology. This paper derives the mathematical equation that can calculate dimensions of a preliminary compact morphology that can be cast to match the functional design requirements, and comply to standard rates of vertical and horizontal surfaces by volume to originate compact architectural forms, during the early stage of the design process.

3. An Approach in Architectural Design of Energy-Efficient Classrooms with a Focus on the Optimal Glazing Size in the South-Oriented Façade for Hot and Dry Climate (HC-17-03)

Mohammadjavad Mahdavinejad, Ph.D.[1] and Hossein Fallah[1], (1)Department of Architecture, Tarbiat Modares University, Tehran, Iran (Islamic Republic of)

The current research presents an architectural design approach to determine an optimal proportion of the glazing areas needed to reach an energy efficiency improvement in classrooms in hot and dry areas, with a special focus on the south-oriented glazing envelopes. The method of this research is quantitative by comparing annual loads with different window-wall ratios. A classroom representing the conventional type of educational spaces in hot-arid climate, selected for simulation. Four variables of wall U-factor, window U-factor, SHGC and Tvis were the parameters considered in the calculation of annual loads of the case. The studied results provide useful information for future designs of educational buildings for more energy efficiency.

5. Energy Efficient Perspective to Typology of Summer Cooling Shading Structures (HC-17-05)

Tarlan Abazari, CEng, BEMP, Fellow ASHRAE[1] and Mohammadjavad Mahdavinejad, Ph.D.[2], (1)Tarbiat Modares University, Tehran, Iran (Islamic Republic of), (2)Department of Architecture, Tarbiat Modares University, Tehran, Iran (Islamic Republic of)

In Iran, residential and commercial buildings consume 9.39 % of total primary energy. (Iranian Energy Balance Sheet. 2014) Therefore to reduce the vast of energy, there is a large effort to construct building with inappropriate thermal comfort which is caused by using the unsuitable windows and shading or incorrect orientation of the building. Undesirable thermal comfort inappropriately affects human health and living. Enhancing the quality of the indoor environment in order to provide comfort and convenience is receiving more and more attention from the designers and the researchers in the architecture field. Nowadays, optimization of the energy consumption in buildings is a major priority of the energy policy in Iran. Windows characterize energy use and visual comfort patterns in buildings. This paper ascertains the interaction of shading structures and shading geometry in building (by indicating the function of shading device in receiving day light heat and gaining or losing heat during the day). Afterward, according to the obtained information the process of architectural designing and computation of thermal load is accomplished. The studies in this research are based on library studies and computer simulation by the *Design Builder* software. Finally, computer simulations have been conducted to investigate the obtained result. After that on the last part the result of the simulation was compared with other researches for validating the results.

10:30 AM - 12:30 PM

Conference Paper Session 2

Indoor Air Quality and Energy Efficiency

Room: Hall 2

1. ASHRAE Standard 62.1 and LEED: Using Enhanced Air Cleaning to Integrate IAQ and Energy Conservation (HC-17-07)

Christopher O. Muller, Member[1], Youssef Zouggari[1] and Hassan Chamas[2], (1)Purafil, Inc., Doraville, GA, (2)Innovations Technical Equipment Trading Co LLC., Dubai, United Arab Emirates

It is a fact nowadays that urban air pollution in many locations has reached and maintains unacceptable levels with regards to national and regional air quality standards. Because of this the use of enhanced air filtration in HVAC design specifications is no longer a luxury but a necessity. With the notable trend in the region, most notably in Qatar and the U.A.E., toward high-rise commercial and residential buildings, employing Standard 62.1's IAQP as a design basic for HVAC systems in high-rise buildings can easily achieve the dual benefits of achieving energy savings by reducing the amount of outdoor ventilation air that has to be brought into the building and achieving significantly improved indoor air quality by direct control of pollutants not guaranteed when using the VRP. The use of the IAQP can also be used in buildings seeking LEED or similar certifications by qualifying for credits under IAQ, energy conservation, design innovation, and other categories. This paper discusses the IAQP and current work being done to make this a more relevant design option when using ASHRAE Standard 62.1. Examples of the application of enhanced filtration as a replacement for ventilation air in locations with significant ambient air pollution and the resulting energy savings will be provided.

2. Using Air Cleaning with Reduced Ventilation Rates for Achieving Energy Savings and IAQ in Commercial Buildings Located in a Hot Climate (HC-17-08)

Marwa Zaatari, Ph.D., Member, enVerid Systems, Boston, MA

Different ventilation strategies can have an enormous impact on both exposures to contaminants of concern (COCs) and energy use in commercial buildings. To test various strategies, researchers implemented two pollutant exposure control strategies in two commercial buildings located in a hot climate. In order to compare energy usage and indoor air quality, researchers operated the building alternatively in conventional mode and air cleaning mode. For each, they measured electrical and/or thermal energy by installing an energy meter on the air handling units. Also, for each period, speciated VOCs, aldehydes, CO_2, and $PM_{2.5}$ were tested. The outcomes of these tests showed that using the air cleaning mode - employing a pollutant exposure strategy with air cleaning and minimum ventilation coupled with smart controls - realized double digit energy savings (20-40%) compared to conventional modes, while at the same time maintained or improved the air quality in the space. Formaldehyde is one of the key contaminants that was identified as a COC. Formaldehyde was successfully maintained below 33 ug/m^3. Field measurements in

this study, which compared conventional and air cleaning modes, demonstrate that efficient air cleaning is a superior option delivering both IAQ and energy savings.

3. Coupling Multi-Zone and CFD Models for Investigating Indoor Air Quality (HC-17-09)

Christos Argyropoulos, Ph.D.[1], Atif Ashraf[1], Luc Vechot, Ph.D.[1] and Konstantinos Kakosimos[1], (1)Department of Chemical Engineering and Mary Kay O'Connor Process Safety Center, Doha, Qatar

Buildings can be exposed to outdoor contaminants due to various reasons; accidents which involve toxic gas releases or severe weather conditions (e.g. dust storms). Such events can produce large amounts of outdoor contaminants and as a result can penetrate into the building environment through any opening and the ventilation system (HVAC). This process of air infiltration is known as ingress. Building ingress depends on wind pressures, ventilation system, leakage characteristics of the building envelope, among others. All these driving factors can lead to uncertainties when trying to quantify them. Therefore, it is necessary to select a suitable method for the investigation of the phenomenon. The building airflow and concentration transport modelling can be achieved by using two main classes of indoor air quality (IAQ) models, namely multi-zone and Computational Fluid Dynamics (CFD). The proposed methodology examines the building ingress, by using three different approaches for computing the external wind pressure of the building, for two different scenarios: particulate matter (PM) infiltration during a dust storm event and a release of a toxic gas affecting an administration building. The results obtained are compared with the different approaches for the computation of building pressure and with measurement data wherever is available.

4. Experimental Analysis of Ventilation Effectiveness and Tracer Gas Dispersion in a Boeing-737 Mockup Cabin (HC-17-10)

Mohammad Hosni, Ph.D., Fellow ASHRAE[1], Byron Jones, Ph.D., P.E., Fellow ASHRAE[2], James Bennett, Ph.D., Member[3] and Jignesh Patel[1], (1)Kansas State University, Manhattan, KS, (2)Mechanical and Nuclear Engineering Department at Kansas State University (KSU), Manhattan, KS, (3)National Institute for Occupational Safety and Health, Cincinnati, OH

High occupant density in an aircraft cabin raises passenger health concerns related to spread of diseases and/or contaminants. To ensure a safe and comfortable cabin environment, it is imperative to understand the various factors affecting the quality of air in an aircraft cabin. Ventilation effectiveness is one such factor which needs to be understood and studied well. Ventilation effectiveness is defined as "The ability of the air distribution system to remove internally generated pollutants or contaminants from a building, zone or space" (ASHRAE 2013). One of the purposes of this study is to evaluate the local effective ventilation rates ($\mathbf{e}_L$) and ventilation effectiveness (**E**) inside an aircraft cabin mockup. Experiments were also conducted to examine the dispersion of gaseous contaminants inside an airliner cabin mockup. All experimentation documented in this paper was carried out in a five-row, full-scale, Boeing 737 cabin section. For the purpose of this study, manikins wrapped with heater wires occupied all seats inside the cabin. Each manikin was connected to a 115V AC supply to generate 100 W (341 BTU/hr) of heat to account for the thermal load inside an aircraft cabin. To study the effectiveness of the ventilation system, carbon dioxide (CO2) was used as a tracer gas. The ventilation effectiveness was evaluated using the tracer gas decay technique. This study shows that the ventilation effectiveness is uniform throughout the cabin with no distinct relation to the seat locations or height.

Sunday, February 26, 1:30 PM - 3:00 PM

Conference Paper Session 3

Refrigerants and System Performance

Room: Hall 1

1. Environmental Performance of Air Conditioner Remanufacturing (HC-17-11)

Aiman Ziout, Ph.D.[1], Bashir Salah[1], Ahmed Azab[1], Mohammed Alkahtani[1] and N Biswas[1], (1)United Arab Emirates University, Al Ain, United Arab Emirates

Air conditioning industry is continuously improving the energy efficiency of their manufactured air conditioners (AC). Energy efficiency of used AC can be improved by adopting remanufacturing. Remanufacturing is considered the most preferable recovery option, it brings end of life products to like-new state. Remanufacturing saves resources, reduces environmental impacts and incorporates new improvements into recovered products. This paper analyzes the environmental performance of remanufacturing initiatives in the air conditioning industry. Window-type AC is selected as case study to verify the environmental benefits of remanufacturing; the product is characterized by high energy consumption during the use phase in its lifecycle. Lifecycle approach has been followed. Lifecycle phases of remanufactured AC are identified. The assessment is conducted with the guidance of ISO 14044 -2006 Life Cycle Assessment (LCA). GaBi's LCIA approach is adopted to evaluate five selected environmental impact categories. The developed lifecycle models can be utilized to help AC manufacturers make decisions about AC remanufacturing as well as the overall environmental performance of their products.

2. Efficiency Improvement Opportunities for Next Generation HVAC Refrigerants in High Ambient Climates (HC-17-12)

Mike Thompson, Member, Trane, College Station, TX

In the 1990's, the HVAC industry underwent a major transition away from ozone depleting CFCs. As the industry moved away from ozone depleting CFCs, the industry began to embrace the importance of energy efficiency, and was able to use this transition to usher in a new generation of highly efficient products. Today, the HFCs are dramatically lower in global warming contribution than the CFCs, but the increase in their use in the coming years could contribute significantly to climate change. There are a number of challenges that manufacturers will face when transitioning to next generation solutions in order to minimize contributions to climate change from both the refrigerant and energy consumption. This paper outlines all of the major segments of the HVAC market, and explains how next generation, low GWP solutions can offer both improved environmental performance, and reduced energy consumption. From small residential mini-splits to large tonnage centrifugal chillers, offerings are becoming available on the market with next generation refrigerants. As new solutions are being developed, special considerations are being given to high ambient locations to ensure reliable and environmentally beneficial solutions.

3. Alternative Lower Global Warming Potential Refrigerants for Air Conditioning in Hot Climates (HC-17-13)

Omar Abdelaziz, Ph.D., Member[1], Som Shrestha, Ph.D., BEMP, Member[1] and Bo Shen, Ph.D., Member[1], (1)Oak Ridge National Laboratory, Oak Ridge, TN

The earth continues to see record increase in temperatures and extreme weather conditions that is largely driven by anthropogenic emissions of warming gases such as carbon dioxide and other more potent gases such as refrigerants. The cooperation of 188 countries in the Conference of the Parties Paris 2015 (COP21) in resulted in an agreement aimed to achieve a legally binding and universal agreement on climate, with the aim of keeping global warming below 2°C. A global phasedown of hydrofluorocarbons (HFCs) can prevent 0.5°C of warming by 2100. However, most of the countries in hot climates are considered as developed countries and as such are still using R-22 and considering the phase-out of R-22 (a Hydrochlorofluorocarbon (HCFC)) which is controlled by current Montreal Protocol to R-410A and other HFC based refrigerants. These HFCs have significantly high Global Warming Potential (GWP) and might not perform as well as R-22 at high ambient temperature conditions. This paper presents recent results on evaluating the performance of alternative lower GWP refrigerants for R-22 and R-410A for small residential mini-split applications and large commercial packaged units. Evaluations were performed according to ASHRAE Standard 37 test method and relevant ANSI/AHRI standards. While it is difficult to compare this study with other studies completed through the AHRI AREP program and PRAHA, this study suggests that there is a strong potential for using lower GWP refrigerants to design and operate more efficient air conditioning systems in hot climates.

4. Air Conditioning in High Ambient Temperatures. Steps Toward a Method to Compare Alternatives to R-22 and R-410A (HC-17-14)

Paul de Larminat, Ph.D., P.E., Member[1] and Anthony Wang, Member[1], (1)Johnson Controls Industries, Nantes, France

In Direct Expansion systems for Air Conditioning, R-22 is still almost exclusively used in Hot Climates, while R-410A is predominant in more temperate climates. In the quest for environment friendly solutions with high energy efficiency, several testing programs were undertaken, including "AREP", "ORNL", PRAHA" and "EGYPRA", evaluating alternatives to R-22 and R-410A. Lots of data is available, but it remains difficult to compare them. Some programs are focusing separately on alternatives to either R-22 or 410A, without cross comparisons. Others cover the whole range of fluids, but the detailed test data cannot be made available. Some tests are "drop-in", others "soft-optimized". Test conditions are not unified. Although highly desired, no satisfactory cross-comparison between the various programs is available yet. This paper provides a contribution to this goal, based on cycle calculations. To bridge the gap between various studies, a single base line system is chosen: the R-410A

split unit used in the ORNL tests. The study simulates “similar” units at various operating conditions, using fluids that are potential alternatives to R-22 and R-410A. “Similar” units are defined as providing the same capacity as the base line. The results are curves of COP versus volumetric capacity for various fluids, where each blend is represented by a segment between these two extremes. This analysis is used to comment on some aspects of results from the aforementioned test programs. It especially illustrates the challenges of replacing R-22 in HAT.

1:30 PM - 3:00 PM

Conference Paper Session 4

Thermal Comfort

Room: Hall 2

1. Evaluation of Thermal and Visual Comfort in University Classrooms: The Cases of Two LEED Silver Certified Buildings on the Campus of Texas A&M University (HC-17-15)

Mehdi Azizkhani, Ph.D.[1], Zahra S. Zomorodian, Ph.D.[2] and Liliana Beltran, Ph.D.[1], (1)Texas A&M University, College Station, TX, (2)Shahid Beheshti University, Tehran, Iran (Islamic Republic of)

Indoor environmental quality in educational buildings is of high importance due to its direct relationship with students’ health and productivity. Occupants often mention thermal and visual comfort as the most important requirements for indoor environmental quality (IEQ) and overall comfort. Leadership in Energy and Environmental Design (LEED)--an internationally recognized rating system for design, construction, and operation of high-performance sustainable buildings--defines credit scores for IEQ including thermal and visual comfort credits. Evaluating the actual performance of these buildings can determine the success/failure of LEED buildings in providing occupants’ satisfaction. This evaluation can highlight the gap between the designed and actual levels of building performance. The current study assesses the visual and thermal comforts of four classrooms with different window size, location, and orientation in two LEED-silver certified buildings on the campus of Texas A&M University. The study draws on questionnaire surveys, onsite measurements, and HDR images for glare analysis during February, March, and April 2016. The findings were used to compare students’ actual perceptions against comfort metrics.

2. Windows Dimensioning to Improve Thermal Comfort in Naturally Ventilated Buildings (HC-17-16)

Talita Andrioli Medinilha-Carvalho, M.D.[1] and Lucila Chebel Labaki, Ph.D.[1], (1)Unicamp, Campinas, Brazil

It is a known fact that architecture can directly affect natural resources consumption. Thus, there is a clear need to consider in the project passive strategies, taking into account the climate where the building is located, ventilation is a valuable one. This strategy has three functions: air renovation for sanitation purposes, air movement to improve thermal sensation, and reduce superficial temperature of the walls and objects. However, ventilation standards require further development since they only regulate minimal air change rate or window area, without considering other parameters that are important to natural ventilation. In this regard, we investigated open dimensioning for thermal comfort purposes in naturally ventilated buildings, evaluating: opening area, orientation towards prevailing wind, location, height in relation to the ground and building surroundings obstruction. The base model for this study was a residential building located at Piracicaba-Brazil, that was further modified to simulate diverse window situations using the software, Energy Plus with support of CFD (CFX) to obtain Pressure Coefficient values.

3. Thermal Comforts Models for Net Zero Energy Buildings in Hot Climates (HC-17-17)

Hamza Belkhouane[1], Shady Attia, Dr.Ing., Member[1] and Jan Hensen, Ph.D., Fellow ASHRAE[2], (1)University of Liege, Liege, Belgium, (2)Building Physics and Systems, Eindhoven, Netherlands

Several energy efficiency concepts and comfort models emerged in the last 15 years seeking high performance buildings and optimal occupant comfort conditions. The aim of high performance buildings is to reduce the carbon footprint and energy consumption of buildings while maintaining a fit to purpose comfort. In this context, this work raises the question of fit to purpose comfort models that can from one side reduce the energy consumption of typical office buildings in hot climates (cooling dominated) while on the other side ensuring indoor thermal comfort. The objective of this paper is to (1) combine several comfort models for a net zero energy building in hot climates, (2) select the comfort model that shows the optimal comfort quality of indoor environment and (3) compare the building's annual energy consumption for each used comfort model. A methodology has been established, which goes through several phases. First identifying the different comfort models comfortable to use in hot climates (ISO 7730 / EN 15251 / adaptive ASHRAE / Givoni), secondly selecting a typical validated office building model as a reference building and finally selecting representative cities in the Mediterranean arid and hot climate (Algiers / Sicily / Cairo / Dubai). The study used building performance simulation to generate the different results on the energy consumption and the operative temperatures of the different models of comfort in each city.

4. Learning from the Vernacular: The Impact of Screen Shades Typologies on Building Energy Savings and Thermal Comfort in Three Different Climate Zones (HC-17-18)

Ihab Elzeyadi, Ph.D., HBDP, Member[1] and Ayesha Batool[1], (1)University of Oregon, Eugene, OR

Screen shading systems applied to building facades present an opportunity to manage solar heat gains, daylight penetration, and glare impacts in multi-story commercial buildings. This paper aims to assess dynamic energy performance and indoor thermal comfort of three screen shading geometries in three different climate zones; Lahore, Pakistan a hot-humid climate, Doha, Qatar, a hot-arid climate, and Los Angeles, California, USA a hot-moderate climate. The paper reports on a multi-method approach research design combining a field assessment of three screen-shading systems with different geometries and perforation percentages, as well as comparing their performance to a typical optimized brise-soleil fixed horizontal shade. Experimental simulation of the different systems were simulated using a dynamic environmental modelling software that provides a graphical interface for a radiance engine. The simulation was performed for the winter and summer solstices and equinox solar angles for the three representative city locations. Independent variables including screen geometry, depth, and perforation percentages were manipulated for a south-facing glazed façade of an existing office building. The dependent variables of energy performance, solar heat gain coefficient, and indoor thermal comfort were analyzed for the different shading typologies and attributes.

Sunday, February 26, 3:00 PM - 4:00 PM

Keynote

Keynote 2

Room: Main Hall

The Impact of Temperature, Ventilation Rates and Indoor Air Quality on Student Health and Performance

Dejan Mumovic, University College London, London, United Kingdom

This keynote address primarily focuses on the potential associations between thermal conditions and ventilation rates/CO_2 in educational settings with health responses and cognitive performance of students. Lessons learned from two relevant projects are presented. The first study SINPHONIE (Schools Indoor Pollution and Health: Observatory Network in Europe), a complex research project which involved 25 European countries, aimed to prevent and reduce respiratory disease due to outdoor and indoor air pollution. The second study examined the effects of exposure to various temperature and ventilation rates settings on cognitive performance in the context of hot and dry climate. This address calls for integrated design of educational buildings and energy benchmarking conducive to learning.

Monday, February 27

Monday, February 27, 8:30 AM - 9:30 AM

Keynote

Keynote 3

Energy performance improvements in buildings are one key element in European energy and climate policy. Nearly zero energy buildings are technologically the most fascinating target being applied to new buildings in Europe: beginning in 2019 all new public buildings and beginning in 2021 all new buildings must be nearly zero energy buildings to meet the requirement set in EPBD directive in 2010. Performance levels of nZEB have been set by most of the EU Member States as well as energy calculation system boundaries and methodologies have been developed in the EU and at the national level. The presentation gives an overview of the progress, demonstrates the diversity of national approaches and highlights general principles and recent official recommendations and conclusions by the European Commission. Because of systemic development during last 10 years, Europe has achieved a leading role, and there is a lot of valuable experience which can be utilized in other countries.

Nearly Zero Energy (nZEB) Regulation Progress in Europe

Jarek Kurnitski, Tallinn University of Technology, Tallinn, Estonia

Energy performance improvements in buildings are one key element in European energy and climate policy. Nearly zero energy buildings are technologically the most fascinating target being applied to new buildings in Europe: beginning in 2019 all new public buildings and beginning in 2021 all new buildings must be nearly zero energy buildings to meet the requirement set in EPBD directive in 2010. Performance levels of nZEB have been set by most of the EU Member States as well as energy calculation system boundaries and methodologies have been developed in the EU and at the national level. The presentation gives an overview of the progress, demonstrates the diversity of national approaches and highlights general principles and recent official recommendations and conclusions by the European Commission. Because of systemic development during last 10 years, Europe has achieved a leading role, and there is a lot of valuable experience which can be utilized in other countries.

Monday, February 27, 9:30 AM - 11:30 AM

Conference Paper Session 5

Energy Efficiency in Buildings

Room: Hall 1

1. A Metamodel for Parametric Studies of Energy Consumption for Cooling (HC-17-19)

Issa Jaffal, Ph.D.[1] and Christian Inard, Ph.D.[2], (1)Cnam, Paris, France, (2)University of La Rochelle, La Rochelle, France

This paper presents a method for the parametric studies of building energy consumption for cooling based on metamodeling. Individual energy consumptions of building elements are studied. The energy consumption of the building is a polynomial function of these individual energy consumptions. The developed metamodel includes time variable parameters such as the solar heat gain coefficient and HVAC system efficiency. A model derived from the general model was tested on an office located in cold, moderate and hot climates. The model coefficients were identified from dynamic simulation by multiple regression. The accuracy of the model was verified by comparing its results with the dynamic simulations. The model allows to perform parametric studies with the speed of simplified models and the accuracy of dynamic simulations. It can be used as a base to perform parametric studies and in future building energy standards.

2. Daylight Responsive Lighting and Daylight Saving Time: A Perspective on Lighting Energy Consumption in Office Buildings (HC-17-20)

Samuel Mason, P.E., BEMP, Member, Encompass Energy LLC, Denver, CO

This paper investigates the effect of daylight saving time on lighting energy consumption, and in particular, lighting in commercial buildings with daylight responsive lighting controls. Utilizing the Commercial Reference Building Models created by the US Department of Energy, energy consumption for small, medium, and large office buildings in all sixteen US climate zones are estimated for the Uniform Time Act 1966 (UTA 1966) daylight saving time (1966 to 1986), the Uniform Time Act 1986 (UTA 1986) daylight saving time (1986 to 2006), the current daylight saving time (2007 to current day), and for no daylight saving time. Each building is simulated with timeclock only controls for lighting, two step daylight responsive lighting control, and continuous-off daylight dimming lighting control. The results of the simulations show first that daylight dimming in these typical building models estimate 16-19% lighting energy savings for a typical office building depending on the type of dimming.

Second, typical office buildings with daylight dimming consume less electricity for lighting annually under a scenario with daylight saving time (0.6%-0.9% per building) as compared to no daylight saving time.

3. Optimized Energy Retrofit of Residential Buildings in Qatar (HC-17-21)

Fedaa Ali[1], Moncef Krarti, Ph.D., P.E., Member[1], Mahdi Houchati[1] and Byung Chang Kwag[2], (1)University of Colorado, Boulder, CO, (2)LG Electronics USA, INC., Alpharetta, GA

This paper outlines an optimization based approach to retrofit existing Qatari residential buildings in order to reduce their energy consumption. The analysis is based on energy audit and long term monitored data to develop calibrated energy models for villas in Qatar. In addition, a wide range of energy efficiency features and operating strategies are considered including orientation, window location and size, glazing type, wall and roof insulation levels, lighting fixtures, appliances, temperature settings and efficiencies of air-conditioning systems. Based on the results of the optimized retrofit analysis, the cost-effectiveness of deep retrofit energy efficiency program for the existing residential building stock in Qatar is evaluated. The results indicate that the implementation of optimized retrofits is highly cost-effective for the residential buildings in Qatar. In fact, the total retrofit costs would be recovered from the avoided investments needed to build new power plants that would be needed to serve the electrical energy needs of residential buildings. The benefits of a national energy retrofit program for the residential building in stock in Qatar include: 6660 GWh/year in energy use savings, 1553 MW reduction in peak demand, and 3290 10^3tons/year in carbon emissions. It is therefore, highly recommended that a retrofit program be developed and initiated by the Qatari government to improve the energy efficiency of the existing building stock. This paper is part of an on-going QNRF supported project, NPRP-6-1654-2-672.

5. Application of ASHRAE's Building EQ in Kuwait (HC-17-23)

Amer Najjar[1], Nawaf Juwayhel, Ph.D.[1], Osama Ibrahim[1] and Walid M. Chakroun, Ph.D., Fellow ASHRAE[1], (1)Kuwait University, Kuwait City, Kuwait

The aim of this study is to assess the application of ASHRAE’s Building Energy Quotient (Building EQ) labeling program for a school building in the State of Kuwait. The As-Designed analysis is used where a model has been established to perform and analyze in detail, the energy performance and the annual loading of the HVAC, lighting and other systems of a school building in a hot environment such as Kuwait. The building in focus is an educational facility (school), which is also used for extracurricular activities during holidays in climate zone 0A as defined in ANSI/ASHRAE/IES Standard 90.1-2016[1] and ANSI/ASHRAE Standard 169-2013 [2]. The model produced an annual EUI (energy use intensity), which was compared to median EUI of similar building application in climate zone 1A using ASHRAE’s Building Energy Labeling Program (Building EQ) As-Designed workbook. The model evaluates the annual power consumption of different components and shows the contribution of each component to the total power consumption. The comparison concludes that the energy consumption of buildings in climate zones 0A is two and a half times higher than a similar building in climate zones 1A. The high energy consumption is mainly due to the high capacities of HVAC systems and extended periods of operation.

9:30 AM - 11:30 AM

Conference Paper Session 6

Improvement of Cooling Systems (Part 1)

Room: Hall 2

1. PHASE Change Material Based Passive Cooling Systems Design Principal and Global Application Examples (HC-17-24)

Zafer Ure, CEng, Member, PCM Products Ltd., Yaxley, United Kingdom

A Thermal Energy Storage (TES) may be considered as a useful tool to reduce the cooling load requirement by means of spreading day time loads over 24 hour period utilizing the naturally occurring ambient temperature difference. The night-time cooler ambient or surplus energy during normal operation can be used to charge the latent heat capacity of various “Positive Temperature Eutectic” solutions between +4°C and +117°C without using any refrigeration machinery by simply allowing the surrounding air to freeze these solutions. Later the stored energy by the Positive Eutectic Thermal Energy Storage “PETES” can be released back to the occupied space during daytime to handle the heat gains. This technique is generally called Passive Cooling. PCM based passive cooling systems have no moving parts and it offers unmatched reliability and maintenance free operation. Furthermore, PETES opens new opportunities to explore heat balance for the existing and new systems, which could offer significant overall system efficiency improvements. This paper provides examples of the current Globally applied PCM based passive cooling applications as well as the possible alternative / new options to help practicing engineers or consultants developing a simple energy saving PCM based passive cooling systems for both new and retrofit applications.

2. PHASE Change Material (PCM) Based Thermal Energy Storage Materials and Global Application Examples (HC-17-25)

Zafer Ure, CEng, Member, PCM Products Ltd., Yaxley, United Kingdom

Thermal Energy Storage (TES) is the temporary storage of high or low temperature energy for later use. It bridges the time gap between energy requirement and energy use. For HVAC and refrigeration application purposes, water and the water ice constitute the principal storage media. Water has the advantage of universal availability, low cost and transport ability through other system components. However, water ice as latent heat energy storage can only be produced using inefficient low temperature chillers for cooling applications and if it is applied for heating using purely sensible heat storage capacity designers’ have to use large storage tanks. However, Phase Change Materials (PCM) between +4 °C and +90°C range offer us new horizons and practical application options. This paper aims to cover the commercially available PCM solutions and associated products together with their practical application examples around the World. Practical application guide together with the real application examples around the World are presented in a format that will aid practicing engineers or consultants to develop an effective and low energy design based on PCM based thermal energy storage cooling / heating and heat recovery systems.

3. Adiabatic Air Inlet Cooling Retrofit KIT for Any Dry HEAT Rejection Equipment Using Mains Water (HC-17-26)

Zafer Ure, CEng, Member, EcoMESH Adiabatic Systems Ltd., Yaxley, United Kingdom

Air cooled heat rejection systems such as condensers, chillers and dry coolers rely on ambient dry bulb which is generally between 5 and 15 °C, higher than wet bulb temperatures. Traditionally, large heat rejection systems use a cooling tower or evaporative coolers in order to reduce the equipment size and overall energy consumption. However, the water based corrosion, maintenance and legionella risks have moved the industry towards less efficient dry heat rejection systems. A new adiabatic air inlet cooling concept has been developed fitting a mesh in front of the dry air heat rejection coil and intermittently spraying tap water over the mesh surface. Using this adiabatic cooling addition introduces water into the incoming air stream while keeping the coil dry. Air flow rapidly evaporates the water on the surface of the mesh and the hidden energy of water evaporation provides a cooler downstream air temperature between 10 ~ 25 °C lower than the incoming air. This lower air temperature results in a lower condensing temperature and therefore saves as much as 30~40% of the peak power consumption simply by using water directly from the tap. This paper covers application examples around the world and design as well as selection guide to help practicing engineers or consultants developing a simple energy saving adiabatic air inlet cooling system for both new and retrofit applications.

4. Potential of Energy and Water Sustainability from HVAC Unit Condensate Water in Hot-Humid Climate of Jazan, Saudi Arabia (HC-17-27)

Salem Algarni, Ph.D., Associate Member[1], C. Saleel, Ph.D.[1] and Mostafa Abdelmohimen[1], (1)King Khalid University, Abha, Saudi Arabia

Building energy consumption and water scarcity have become a major concern in Saudi Arabia. One-half of the total energy use is consumed by the residential building sector due to the inefficient constructed buildings and the hot-dry and hot-humid climates. Heating, ventilating, and air-conditioning (HVAC) systems consume a big energy portion due to cooling, filtering, and dehumidifying the air especially in a hot-humid climate. This air treatment process is associated with a considerable water condensate removal that typically ended to be in a sanitary drain. This paper presents the potential of energy and water sustainability by collecting condensate water from a residential outdoor air handling unit in hot-humid climate of Jazan, Saudi Arabia. The collected water is re-used to periodically wash dusty roof and effectively reduce building energy consumption.

Monthly condensate water for the case study is collected for months of May, June and July, respectively. In addition, hourly dust fallout is predicted to calculate monthly dust accumulation. The building case study is modeled using eQuest 3.65, a building energy simulation program, to estimate energy consumption under the local dusty conditions.

5. Revealing the World's First Super-Efficient "All in One" Smart Cooling System (HC-17-28)

Esam Elsarrag, Ph.D., Member[1] and Yousef Alhorr, Ph.D., Member[1], (1)Gulf Organisation for Research & Development, Doha, Qatar

The design and construction of buildings in hot humid climates requires high energy consumption typically for air conditioning due to higher thermal loads. Regionally, there is a rising concern on the current rate of energy consumption due to air conditioning. Considering the wider impacts of carbon emissions on our climate, and the need to reduce these emissions, effective energy efficiency solutions are necessary in order to achieve the overall goal of reducing carbon emissions. This paper presents the simulated and measured efficiencies of the "All in One" 15 TR (52 kW) fully integrated HVAC systems driven by waste heat and renewables. The tested system is locally manufactured and installed in a testing facility at Qatar Science and Technology Park (QSTP). The system has shown 75% reduction in energy consumption compared to conventional systems.

Monday, February 27, 11:45 AM - 12:30 PM

Conference Paper Session 7

Outdoor Cooling

Room: Hall 1

1. Improving Comfort and Productivity of Workers at Moderate Activity and Hot Environment By Means of a PCM Cooling Vest (HC-17-29)

Mariam Itani[1], Nesreen Ghaddar, Ph.D., Member[2], Kamel Ghali, Ph.D.[2], Djamel Ouahrani, Ph.D.[3] and Walid M. Chakroun, Ph.D., Fellow ASHRAE[4], (1)American University of Beirut, Beirut, Lebanon, (2)American University of Beirut, Beruit, Lebanon, (3)Department of Architecture and Urban Planning, College of Engineering, Qatar University, Doha, Qatar, (4)Kuwait University, Kuwait City, Kuwait

The effect of using a phase change material (PCM) cooling vest by a worker performing moderate activity in a hot environment is studied through the use of a validated integrated fabric-PCM and bio-heat model. The integrated model takes into consideration both the effect of hot environment on the metabolic rate and heart rate and the effect of the carried PCM weight on the metabolism. Since condensation could happen in the cooling vest if the PCM surface temperature reaches values less than the dew point temperature of the microclimate air, the effect of the added heat due to condensation if it happens is also considered in the integrated model. The integrated fabric-PCM and bio-heat model is used to predict thermal sensation and comfort based on human physiology of worker at moderate activity wearing a PCM cooling vest in an environment at 40 °C and 40 % relative humidity for a period of 45 minutes. The cooling vest has 20 PCM packets, where ten packets are distributed on the back torso segment, six on the abdomen and four on the chest. Core and mean skin temperatures, sweat rate and overall thermal comfort and sensation are compared when wearing and not wearing the vest.

2. Energy Efficiency and Design Guidelines for Air Conditioned Stadiums in Hot Humid Climate (HC-17-30)

Esam Elsarrag, Ph.D., Member[1] and Yousef Alhorr, Ph.D., Member[1], (1)Gulf Organisation for Research & Development, Doha, Qatar

Energy efficiency awareness and regulations continue to rise in the Gulf Cooperation Council (GCC) countries. Extreme climatic conditions impose a heavy reliance on cooling, mostly electricity-based, and thus a strong and structural dependency of a high energy resource. The design and construction of low energy consumption open air conditioning stadiums in hot humid climate has raised several challenges. This paper explores the dynamic simulation modelling (DSM) methodology and results of a typical 40,000 spectators in Doha, Qatar. The DSM is used to estimate the energy performance of outdoor air conditioned stadiums without compromising the comfort levels for both seating and pitch areas. A comparative analysis of a set (parametric) designs is used to determine a reasonable reference value.

11:45 AM - 1:15 PM

Conference Paper Session 8

Workshop Session: The New ASHRAE Hot Climate Design Guide *Room: Hall 2*

1. ASHRAE's Hot Climate Design Guide (HC-17-31)

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

This paper provides an insight into the new ASHRAE Hot Climate Design Guide which is currently in progress and due for publication in 2018. The guide compliments the existing 'Hot and Humid' design guide by focusing onto other climate regions – arid, temperate and short term hot. The guide also addresses the challenges facing building service engineers who have to develop design solutions which are affordable to construct, affordable to operate, reduce energy consumption and meet carbon emission targets which are now being set by governments around the world in order to address climate change issues. The paper includes sections which describe how the guide deals with passive solar design as well as 'active' refrigerant based systems and also hybrid solutions which combine the benefits of each approach. Exemplar projects are shown which have design and operational feedback.

2. Workshop Session - The New ASHRAE Hot Climate Design Guide

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

This workshop is proposed as an interactive technical session to allow delegates to discuss and contribute to the new ASHRAE design guide which is currently being proposed with a publication date in mid 2018. By holding this workshop at the end of the conference, delegates will have had the benefit of new ideas and initiatives which they can then propose as possible content material. Ideas on content and format, as well as example projects and lessons learnt can be raised and identified. Some ASHRAE guides already have worked examples which show in a step by step approach, how to design a system and this helps understand the issues involved. Delegates can discuss whether they see this as helpful and/or whether they want other information included. The workshop is led by a facilitator who will have some presentation material and a structured approach which will seek to encourage delegates to come forth with ideas. The workshop will have a conclusion which will be used to assist development of this new guide.

12:30 PM - 1:15 PM

Conference Paper Session 9

Improvement of Cooling Systems (Part 2)

Room: Hall 1

1. Derivation and Validation of Dimensionless Models for the Heat and Mass Transfer Coefficients of a Structured Packed Bed Dehumidifier (HC-17-32)

Richard Jayson Varela[1], Seiichi Yamaguchi[1], Kiyoshi Saito[1], Niccolo Giannetti[1], Masatoshi Harada[1] and Hikoo Miyauchi[1], (1)Japan Society of Refrigerating and Air Conditioning Engineers, Tokyo, Japan

This work presents the derivation of dimensionless models for the heat and mass transfer coefficients using relevant dimensionless numbers in an adiabatic packed bed dehumidifier. In this study, a cross flow dehumidifier was constructed in a liquid desiccant system where the air flows horizontally and the liquid desiccant solution flows vertically through the contactor. Lithium chloride (LiCl) solution is used as liquid desiccant solution and structured packed bed is used as gas-liquid contactor. Dimensionless models for the heat and mass transfer coefficients were derived and validated using the available experimental data. Within the ranges mentioned, deviations between the predicted and experimental values of the heat and mass transfer coefficients were both within ±10%.

Keynote 4

Room: Main Hall

Monday, February 27, 2:30 PM - 3:30 PM

Keynote

Alternative Refrigerants for Air Conditioning in Hot Climates

Omar Abdelaziz, Ph.D., Member, Oak Ridge National Laboratory, Oak Ridge, TN

A global phasedown of hydrofluorocarbons (HFCs) can prevent 0.5°C of warming by 2100. Furthermore, most of the countries in hot climates are considered as developing countries and as such are still using the hydrochlorofluorocarbon (HCFC) R-22 as the baseline refrigerant. R-22 has superior performance to most HFC refrigerants when operating at hot climates; hence it is crucial to evaluate alternative refrigerants for R-22 and typical HFC refrigerants such as R-410A. This Keynote summarizes previous research efforts on evaluating alternative refrigerants for R-22 and R-410 Air Conditioning Equipment operating at high ambient temperature conditions showing promising candidates for a sustainable future.

Tuesday, February 28 – Thursday, March 2

Immediately following the conference, the ASHRAE Learning Institute will offer the HVAC Design: Level I – Essentials course, February 28 – March 2, 2017 at the Intercontinental Doha City Hotel. The course provides intensive, practical training for HVAC designers and others involved in the delivery of HVAC services. In three days, gain practical skills and knowledge in designing and maintaining HVAC systems that can be put to immediate use.