Seventh International
Cold Climate HVAC Conference

Monday, November 12

Monday, November 12, 8:00 AM-8:30 AM

CONFERENCE INTRODUCTIONS

Welcome from ASHRAE

Tom Watson, ASHRAE President, P.E., Fellow Life Member, *McQuay International, Staunton, VA*

Welcome from SCANVAC

Per Rasmussen, SCANVAC President*, Hvidovre, Denmark*

Welcome from REHVA

Bjarne W. Olesen, REHVA Vice President, *International Center for Indoor Environment and Energy, Technical University of Denmark, Lyngby, Denmark*

Norwegian Research Initiative

Maria Justo Alonso, *SINTEF Energy Research, Trondheim, Norway*

Broadening ASHRAE's Horizons

Tom Watson, ASHRAE President, P.E., Fellow Life Member, *McQuay International, Staunton, VA*

ASHRAE President Tom Watson emphasizes the role of the built environment community, including engineers, researchers, consultants and other building professionals as represented by ASHRAE members globally, as leaders in the application of sustainable design and practices in our communities. He will concentrate on how the three focal points of technology, applications and people can readily combine to develop stronger, more sustainable communities.

Monday, November 12, 9:00 AM-10:30 AM

CONFERENCE PAPER SESSION 1a

Building Envelope (1a)

Room: Imperial Ballroom 1

Chair: Carey Simonson, Ph.D., P.E., Member, University of Saskatchewan, Saskatoon, SK, Canada

To achieve very high levels of building energy efficiency, builders in cold climates utilize significant levels of thermal insulation in the building envelope, in both new and retrofit buildings. This reduces heat loss through the thermal envelope which reduces drying potential in the wall, thus moisture control in highly insulated thermal envelopes becomes more important. Papers in this session discuss the design and construction of energy efficient building envelopes that work including challenges related to retrofitting existing buildings.

Learning Objectives:

1. Define available technical solutions to cope with nZEB requirements while renovating multi-dwelling buildings in cold climate.
2. Define the metrics for monitoring moisture in-situ.
3. Describe concerns for using foam insulation in retrofits.
4. Distinguish retrofits that consider moisture performance versus that only reduce heat loss.

Is It Possible to Achieve Zero Energy Demand While Rebuilding Multi-Dwelling Buildings?

Åsa Wahlström, Ph.D.*, CIT Energy Management, Göteborg, Sweden*

The Swedish Energy Agency's national strategy and the National Board of Housing, Building and Planning's upcoming conversion rules are likely to lead to energy performance requirements at major renovation of apartment buildings. The proposed levels of maximum energy performance in the renovated housing strive towards nearly zero-energy buildings (nZEB). The purpose with the present study is to analyze which consequences the proposed nZEB requirements will lead to major renovations of apartment buildings. Which combinations of different heating systems and packages of energy efficiency measures will be necessary to meet the new nZEB requirements at major renovation in Sweden's three different cold climate zones? The present study investigates typical buildings for low-rise apartment buildings, tower blocks of flats, high-rise blocks of flats and a small apartment building located in Sweden's three different climate zones and constructed in three different time periods. The number of investigated buildings is thirty-six. Six different packages of energy efficiency measures have been examined with four different heating systems. Energy performance for each combination of heating package has been calculated and then the present value of costs during a time of 30 years was calculated and compared. The results show that the shape of the building has little impact on the package of measures in combination with a heating system that will cope with nZEB requirements for major renovation. The larger apartment buildings (low-rise apartment buildings, tower and high-rise blocks of flats) on the whole give the same results. Also age of the building is largely insensitive while the climate is of great importance. In the small apartment building it is much more difficult to cope with nZEB requirements. In several of the typical buildings for low-rise apartment buildings, tower and high-rise blocks of flats the four heating packages are competitive with each other. Depending on predicts on energy prices and inflation in the future it may be one or the other option that is the most advantageous. Profitability of the different heating packages is also dependent on the district heating price prevailing in the current city.

Moisture Conditions in Exterior Walls for Net Zero Energy Buildings in Cold Climate Considering Future Climate Scenario

Björn Berggren, Student Member *and Maria Wall, Lund University, Lund, Sweden*

Reduction of energy use constitutes as an important measure for climate change mitigation. Buildings today account for 40% of the world's primary energy use and 24% of the greenhouse gas emissions, according to International Energy Agency (IEA). Today, the concept of Net Zero Energy Buildings (NZEBs) is no longer perceived as a concept that only can be reached in a very distant future. A growing number of projects/buildings in the world, in different climates, show that it is possible to reach NZEB balance with technologies available today on the market. To reach the NZEB balance in cold climates, increased thermal resistance of the building envelope is a fundamental measure. Increasing the thermal resistance in combination with climate change will result in a different microclimate within the building envelope. Possible future micro climate in exterior walls is produced by hygrothermal simulations using the numerical software WUFI. The simulations are conducted for four different locations in Sweden, where the main difference is geographically in the respect of latitude, for the year period 1961-2100. Regional climate is based on data from the Swedish Meteorological and Hydrological Institute, using regional climate models developed at the Rossby Centre, RCA3. The RCA3 model covers Europe with a horizontal resolution of 50x50 kilometers. The boundary conditions are from the global climate model ECHAM5. The increased risk for performance failure due to high humidity levels is conducted by assessing the result from the simulations combining four different evaluation models, which mainly differ in respect of the consideration of fluctuating hygrothermal conditions. Preliminary results show that the risk of performance failure related to moisture conditions will increase in the future. Furthermore, the results show that simple measures could significantly decrease the risk of performance failure. Reviewing the different evaluation models shows that they all are relevant to use. The more simplified evaluation models may be used in early design stages and the more comprehensive ones may be used when construction documents are produced and different building techniques are more specified.

Exterior Insulation Envelope Retrofits in Sub-Arctic Environments

Colin M. Craven *and Robbin L. Garber-Slaght, Cold Climate Housing Research Center, Fairbanks, AK*

Retrofitting above-grade walls with foam insulation has become common practice to reduce residential heating demand. Because structures in sub-arctic environments typically have a vapor retarder on the interior framing surface, the addition of relatively water vapor impermeable exterior foam insulation on the exterior has the potential to significantly reduce the drying ability of wall systems. This reduction in drying ability is problematic if the retrofit does not adequately reduce the potential for condensation within the wall framing. Such retrofits may induce mold growth, thereby increasing the potential for indoor air quality problems and reducing the service life of retrofitted structures.

To investigate the potential for this retrofit strategy to cause moisture accumulation in wood-framed structures in sub-arctic environments, nine nominal four foot by eight foot test wall sections were constructed using varying ratios of stud fill fibrous insulation and foam insulation exterior to the wall sheathing. The use of a polyethylene vapor retarder varied with each wall section. Each test wall with a vapor retarder had unsealed penetrations typical of past construction practices. The wall sections were tested in Fairbanks, Alaska over two winters under varying interior relative humidity and pressure conditions and monitored for temperature, relative humidity and wood moisture content. The test walls were simulated using WUFI Pro 5.1 for a ten-year period for the test wall configurations and additional scenarios. Test walls with less than half of the total wall R-value on the exterior performed poorly in terms of wood framing moisture content and relative humidity at the sheathing interior surface. Wall systems without a polyethylene vapor retarder had widespread visible mold growth at the end of the two-year empirical test. Wall systems with a polyethylene vapor retarder tended to have lower humidity at the sheathing surface and visible mold growth only near penetrations in the vapor retarder, but tended to retain moisture well into the summer drying season. Problems with moisture accumulation were largely absent from test wall sections that had 65% or more of the total wall R-value on the exterior, regardless of whether an interior vapor retarder was present.

Super-energy Wrap-up Solution for Renovation of Standard Wooden Houses in Greenland

Søren Peter Bjarløv[1] *and Petra Vladykova*[2]*, (1)Technical University of Denmark, Lyngby, Denmark, (2)Swegon AB, Göteborg, Sweden*

Existing residential buildings, built from the 1950s until 2006 (more than half the building stock in Arctic Greenland), often have problems with draught and uncomfortably low temperatures in the interior due to lack of insufficient thermal insulation and airtight properties of the building envelope and the properties of commonly used technical systems. The standard wooden houses provide low thermal comfort and poor indoor air quality, high energy consumption and high CO_2emission. Work in this paper focuses on the developed theoretical practice of super-insulation solution for renovation of standard wooden houses in Greenland. Using extensive measurement data from the original and super-insulated houses, the new wrap-up system for retrofitting was developed as a package solution without the need for reallocating the inhabitants during the process. From various perspectives, the method is evaluated as a building method with focus on a robust membrane for air tightness, high level of insulation with very few thermal bridges and high attention on solving details in the building envelope. The task is to discuss the impact of energy usage of buildings in extreme Arctic climate. This interesting method using wrap-up and package solution can easily be modified and applied to many standard wooden houses in Greenland, but also across the Arctic regions. Linking all these aspects lead to interesting findings about high energy savings, reduction of oil usage and decrease of CO_2 emissions in retrofitting of Arctic buildings.

Monday, November 12, 9:00 AM-10:30 AM

CONFERENCE PAPER SESSION 1b

Ventilation Applications

Room: Imperial Ballroom 5-7-9

Chair: Bill Dean, National Research Council of Canada, Saskatoon, SK, Canada

Providing an acceptable indoor environment in cold climates can be very costly because of the amount of energy needed to condition and/or move ventilation air coupled with often expensive unit energy costs. Innovative ways and means of reducing the amount of ventilation air needed and/or reducing the energy utilized to deliver ventilation air are of interest. Papers in this session explore some of those ways and means, including displacement ventilation, direct cooling and dilution ventilation for industrial facilities.

Learning Objectives:

1. Describe the procedure to assess IAQ.
2. Provide an overview of performance of DV in schools.
3. Describe the Impact of diffuser locations, core and perimeter area on ACE.
4. Provide an example of the performance of one DV system in cold climate (heating season).

Performance of Displacement Ventilation in Canadian Schools: Field Studies

Boualem Ouazia, Ph.D., Member[1]*, Iain Macdonald, Ph.D.*[2]*, Michel Tardif, P.Eng., Member*[3]*, Alexandra Thompson*[2] *and Daniel Booth*[2]*, (1)The Institute for Research in Construction (IRC) / National Research Council Canada (NRC), Ottawa, ON,* *Canada, (2)National Research Council Canada, Montreal, QC, Canada, (3)CanmetENERGY Natural Resources Canada, Ottawa, ON, Canada*

Displacement ventilation systems take a fundamentally different approach than those found in the majority of non-residential buildings, which currently use a fully mixed and dilution approach to ventilation. Displacement ventilation (DV) is an alternate air distribution method for commercial spaces, in particular schools. Previous research has shown that this type of system works well for regions where buildings require year-round cooling, however there are a growing number of buildings using this approach in Canada, where buildings require heating during winter months. The NRC Institute for Research in Construction and Canmet-Energy Resources Canada have conducted field studies in existing Canadian schools with displacement ventilation systems. This paper presents results from three field studies conducted in schools designed for displacement ventilation combined with a perimeter radiant heating system. We measured several aspects of the performance of DV systems installed in schools located in different parts of the country. The results show that the measured contaminant removal efficiency was higher than that predicted in previous studies for heating conditions. In addition, key predictors of thermal comfort (the measured vertical air temperature difference and draft rating at ankle and head height) are also generally within limits set by ASHRAE standards. The results of theses field studies provide some evidence of thermal comfort and IAQ-related benefits of DV in cold climate. However, before general conclusions are drawn, the benefits need to be confirmed in other studies.

Air-Change Effectiveness with Displacement Ventilation System

***Boualem Ouazia, Ph.D., Member**[1], Iain Macdonald, Ph.D.[2], Alexandra Thompson[2], Daniel Booth[2] and Michel Tardif, P.Eng., Member[3], (1)The Institute for Research in Construction (IRC) / National Research Council Canada (NRC), Ottawa, ON, Canada, (2)National Research Council Canada, Montreal, QC, Canada, (3)CanmetENERGY Natural Resources Canada, Ottawa, ON, Canada*

Stratified air distribution systems such as Displacement Ventilation (DV) have been known to provide better indoor air quality. Previous research has shown that this type of system works well for regions where buildings require year-round cooling but ignored the specific characteristics of the Canadian climate: the need to operate in heating and cooling modes. There are a growing number of buildings using this approach in Canada, where buildings require heating during winter months. This investigation compared the air-change effectiveness of DV systems that use four different diffusers configurations (perforated wall diffusers and perforated corner diffusers) in an indoor environment research facility that can simulate open concept office space (6 cubicles). We measured air-change effectiveness of the performance of DV systems based on tracer gas step-up and decay methods. The DV systems had higher air-change effectiveness (0.8 – 1.4) than the mixing one under heating mode. The study found that the air-change effectiveness at breathing zone was higher than that predicted in previous studies for heating conditions. The experimental results studies provide some evidence of IAQ-related benefits of displacement ventilation in cold climate.

Direct Cooling of Shopping Malls in Cold Climates: Potential and Limitations

***Sofia R.E. Stensson, Associate Member** and Per Fahlén, SP Technical Research Institute of Sweden, Borås, Sweden*

The objective of this paper is to illustrate how a number of parameters influence the heating and cooling demands and energy use in shopping malls situated in cold climates. The parameters of particular interest are: lighting power, building shape, infiltration through the building envelope and entrances and the use of direct cooling (also known as free cooling). The approach includes monitoring of an existing shopping mall situated in Sweden. An extensive foundation of input data concerning the building construction, HVAC systems, internal and external heat loads and measured energy use was collected. Based on the case study shopping mall, a simulation model was developed. The model facilitates studies of the effect of parameter changes, separately and in different combinations. The results are illustrated in duration diagrams, divided between day and night conditions. An interesting combination is, for instance, future energy efficient lighting in combination with direct cooling by means of low-temperature outdoor air supplied by ventilation systems very low Specific Fan Power (SFP). Studies have showed that lighting power dominates the cooling demands in shopping malls, and this implies that the size of current internal loads make the energy demand less sensitive to other parameters such as the shaping of the building envelope and the proportion of window facade area. However, emerging technologies for energy efficient lighting systems and the increasing awareness of the shop owners will most likely lead to drastic reduction of the cooling demands. The simulations presented in this paper illustrate the impact this will have for the overall HVAC system, especially for the possibility of utilizing direct cooling by allowing lower supply air temperatures. In the case study building, the supply air temperature is regulated depending on the heating demand between 16°C to 20°C. With modern supply air terminal devices the supply air temperature can be significantly lower. The paper not only shows the potential for future use of direct cooling in shopping malls in cold climates but also points out the requirements on ventilation system design to make direct cooling electrically as well as thermally efficient.

Cold Climate Dilution Ventilation Systems for Industrial Oil and Gas Facilities

*John M. Gallagher, P.Eng., Member, Mike L. Carriere, P.Eng., Associate Member and **Erich Binder, Member**, Worley Parsons, Calgary, AB, Canada*

Cold climate heat dilution ventilation in industrial applications when engineered and designed properly will provide economical ventilation systems. Industrial processes which generate large amounts of heat require an economical method of building temperature control. Heat rejection from pumps, gear boxes, electric motors, hot process piping etc. is considered a clean source of heat. Excessive heat rejected into the building needs to be exhausted outdoors to maintain desired indoor design temperatures. The basic principal of heat dilution ventilation is to remove large volumes of clean heat. Various methods of heat control have been utilized to some degree of success. This report will summarize the common heat dilution ventilation methods exposing their strengths and weaknesses. Concentrated heat sources such as heat exchangers used in radiators on air compressors and lube oil coolers can be ducted directly to the outdoors, however complications may arise if the ductwork is intrusive or beyond the appliance exhaust fans capacity. Ductwork may not be desirable for general heat rejection from large equipment, exposed piping and exposed fittings. Ductwork may hinder visual inspection of the equipment, may block maintenance requirements of the equipment, may be physically too large and often is not desirable in the core process line. Clean heat therefore is often radiated directly into the building. Heat dilution ventilation is ideally suited for these applications.

In cold climates the ventilation design must be cognizant of the supply air temperature especially when outdoor ambient temperature is below freezing. Specific humid process buildings provide unique situations which can be problematic if not correctly designed. In high humid buildings, especially in cold climate conditions, the humid air escaping the building will form ice. Ice will damage the building structure and will fall off during a warm up creating unsafe and hazardous conditions. During winter periods, maintaining the building under a negative air pressure will minimize the ice accumulation and protect the building and occupants. Heat dilution ventilation using fans and dampers is an economical ventilation method; however, in a cold climate atmosphere, this ventilation method has an unique challenge.

Monday, November 12, 11:00 AM-12:00 PM

CONFERENCE PAPER SESSION 2a

VIPs and PCMs

Room: Imperial Ballroom 5-7-9

Chair: Kwang Woo Kim, P.Eng., Seoul National University, Incheon, South Korea

While the idea of utilizing VIPs (vacuum insulated panels) and PCMs (phase change materials) in building construction to reduce heating and cooling energy costs is not new, these technologies are still futuristic/experimental. The papers in this session assess the practicality and energy benefits of incorporating these technologies into buildings.

Learning Objectives:

1. Define the thermal performance of the radiant heating combine-system.
2. Apply solar energy-phase change storage-floor radiant heating combine-system in a cold region for heating.
3. Explain the design considerations and construction specifications associated with high insulating wall systems.
4. Describe various construction methods and thermal and hygrothermal assessment methods for incorporating vacuum insulation panels in conventional wood-framed wall systems.

Incorporation of Vacuum Insulation Panels in a Wood Frame Net Zero Energy Home

Anil Parekh, P.Eng., Member[1] *and Chris Mattock*[2]*, (1)Natural Resources Canada, Ottawa, ON, Canada, (2)Habitat Design + Consulting Limited, Vancouver, BC, Canada*

One of the key elements of achieving net-zero energy efficiency in cold-climate houses is to radically increase thermal performance of building envelopes. For low-rise housing, built in Canada as per the current energy efficiency regulation requirements, the annual heat losses range from 80 to 130 GJ per year depending on the climate. These heat losses must be further reduced by 50% to 60% (about 40 to 70 GJ per house). With low heat losses, the size of renewable energy systems will be curtailed and also can be seamlessly integrated with the heating, ventilation and air-conditioning systems. Vacuum insulation panels (VIPs) are the newest emerging technological breakthrough for Canadian residential construction markets. The vacuum insulation panels are particularly useful in places where space is at a premium or where energy demand is high. The higher insulating values of VIPs can effectively reduce the thickness of building envelopes. The thermal resistance of vacuum insulation panel ranges RSI 0.2 per mm (R-30 per inch) to RSI 0.3 per mm (R-45/inch) thickness. The first known Canadian field demonstration of VIPs is in Burnaby, B.C. The project team of net-zero energy Harmony House, successful winner of CMHC's EQuilibrium™ Sustainable Housing Demonstration Initiative, has used exterior walls with vacuum insulation panels. With a number of mock-ups and field tests, the Harmony House team adopted to install 15 mm thick VIP in the stud cavity, covered by a 50 mm foil-faced isocyanurate foam board on the exterior and spray-foam on the interior providing an effective insulation value of more than RSI 7.0 (R-40). This paper will provide design, construction and measured performance of an exterior wood frame wall assembly that utilizes vacuum insulation panels (VIPs). The paper will provide the (1) 2-D heat transfer analysis of wall assembly details, (2) hygrothermal analysis, (3) construction specifications, and (4) elaborate lessons learned from the demonstrations. Preliminary monitoring data showed that the construction methods for the VIP are developing and the walls do exhibit superior thermal performance. Field demonstration of vacuum insulation panels showed that builders in cold-climate countries can build thin-profile low heat loss wall systems.

Experiment Research on Thermal Performance of Solar Energy-Phase Change Storage-Floor Radiant Heating Combine-System in Urumqi China

Zhang Ye, Ph.D.[1]*, Chen Chao, Dr.Ing., P.Eng.*[2]*, Liang Lu*[2]*, Deng Chao*[2] *and Qidian Wei*[3]*, (1)Xinjiang University Civil Engineering Department/ Beijing University of Technology, Urumqi/Beijing, China, (2)Beijing University of Technology, Beijing, China, (3)Xinjiang University, Urumqi, China*

Urumqi is located in Xinjiang province, which belongs to the cold climate zone in China; the local heating period during the winter lasts up to 6 months. The local solar energy is abundant, up to 5.4×10^9-$5.8\times10^9 J/M^2\cdot y$(130-140 $Kca/cm^2\cdot y$) which can provide advantageous conditions for utilization of solar energy. However, the heat supplied by the solar collector determines the useful solar energy proportion for the heating terminal. During the high solar radiation intensity period, the choice of the collector according to local climatic conditions and the utilization of phase change thermal storage facility directly impact the improvement of solar energy efficiency. This project research established a solar energy-phase change storage-floor radiant heating combine-system in an office in Urumqi. The influence on thermal efficiency of solar collector from outdoor weather conditions (solar radiation intensity, temperature, wind speed etc.), inlet and outlet water temperature, connect method during local heating period and thermal performance of this combine-system was developed experimentally. The research result provides a reference for optimization design for this kind of system.

Analysis of Indoor Thermal Characteristics for the Application of PCMs in Buildings

Soojin Lee[1]*, Jae-han Lim, Ph.D.*[1]*, Su-min Kim, Ph.D.*[2] *and Seung-Yeong Song, Ph.D.*[1]*, (1)Ewha Womans University, Seoul, South Korea, (2)Soongsil University, Seoul, South Korea*

A Phase Change Material (PCM) is a substance capable of storing or releasing energy as latent heat. The amount of latent heat, which is absorbed or released when material changes phase or state, is much bigger than sensible heat, so the application of PCMs have great potential to reduce energy consumption in buildings. In particular, it is important to use appropriate PCM composite blends for its purpose, because each PCMs have their own phase change temperature. Therefore, this study aims to analyze optimal phase change temperature of PCM composite wall panel through building energy performance simulation using EnergyPlus. A reference building is an eight-storeyed research building located in Seoul. The exterior wall of this building consists of galvanized steel sheet, air cavity, insulation and gypsum board from outside to inside. A PCM composite panel with microencapsulated paraffin was developed, and its heat capacity according to the temperature variation was measured by experimental work. Based on the experimental data, PCM composite exterior wall panels with phase change temperature between 22 °C to 30 °C were established. And the energy simulation using Energyplus was performed on the supposition that each PCM boards were applied instead of a gypsum board. Through the comparison of inside temperature, peak heating/cooling load, energy consumption, etc., optimal phase change temperature for reduction of annual energy consumption was analyzed.

Monday, November 12, 11:00 AM-12:00 PM

CONFERENCE PAPER SESSION 2b

Air Cleaning Technologies

Room: Imperial Ballroom 1

Chair: Bert G. Phillips, P.Eng., MBA, UNIES Ltd., Winnipeg, MB, Canada

Providing acceptable indoor air quality in cold climates can be very costly because of the amount of energy needed to condition ventilation air coupled with often expensive unit energy costs. Therefore, innovative ways and means of reducing the amount of ventilation air needed by cleaning air (such as UV-PCO (ultra violet - photocatalytic oxidation) air cleaning) or keeping the air in the building cleaner (e.g., by duct cleaning) are of interest. Papers in this session explore these technologies.

Learning Objectives:

1. Describe test procedure for gas-phase air cleaing system performance measurement
2. Describe new protocol for duct cleaning performance.
3. Provide a new decision making tool for safe building occupancy.
4. Provide overview of possible UV-PCO by-products in different classes of VOCs.

Application of a Protocol to Evaluate Impact of Duct Cleaning on IAQ of Office Buildings in Cold Climate

Zuraimi Sultan, Ph.D., Member[1]*, Gregory Nilsson*[1]*, Robert Magee*[1] *and* ***Boualem Ouazia, Ph.D., Member***[2]*, (1)National Research Council of Canada, Ottawa, ON, Canada, (2)The Institute for Research in Construction (IRC) / National Research Council Canada (NRC), Ottawa, ON, Canada*

Field investigations reporting increased airborne particles concentrations after ventilation duct cleaning (DC) and emissions of biocides following its use in DC highlight a need to protect building occupants from possible exposures to these harmful pollutants. A new test protocol was developed and applied on 2 buildings to include assessments of duct surface cleanliness and harmful airborne pollutant associated with DC. Using the protocol, duct surface cleanliness was found to be acceptable in a building but post-DC dust level in the other was higher than the recommended 0.75 $mg/100\ cm^2$. The protocol has found no airborne particle and fungi emissions attributed to the DC activities in the 2 test buildings. However, an increased emission in airborne organic alcohol compound was noted after DC in a building using biocides. The application of this test protocol on 2 buildings in Canada has demonstrated that harmful airborne pollutant concentration levels attributed to DC activities can be determined while still maintaining cleaning efficiency. The guidelines provided in the protocol can be useful to building operators for their maintenance program and assessment of building occupancy post DC.

Investigation of Ultraviolet Photocatalytic Oxidation by-Products

Donya Farhanian, Student Member[1], Fariborz Haghighat, Ph.D., P.E., Fellow ASHRAE[1], Chang-Seo Lee, Ph.D., Member[2], ***Lexuan Zhong, Student Member[1]*** *and Ness Lakdawala, Member[2], (1)Concordia University, Montreal, QC, Canada, (2)Dectron Internationale, Inc., Montreal, QC, Canada*

The quantity of the outdoor air brought into the building can have a direct negative effect on the energy cost of ventilation and the climate. There is a cost to heat, cool, humidify or dehumidify the outdoor air depending on the location and season. This leads to a balancing act between indoor air quality (IAQ) and energy cost. Nowadays, air cleaning technologies have become an essential element of designing an effective and energy efficient mechanical ventilation system. Ultraviolet photocatalytic oxidation (UV-PCO) has been acclaimed as one of these innovative technologies for purifying indoor air by decomposition of pollutants, especially volatile organic compounds (VOCs). Although, numerous researches have been carried in this field, limited numbers of them can be transferable to real life applications. Experimental conditions of most previous works focused on ppm level of VOCs in ideal bench-top-scale reactor with low flow-rate and high residence time conditions. On the other hand, limited research has been devoted to investigation of the UV-PCO toxic by-products generation while this issue is one of the main drawbacks and obstacles in its wide application and design of immune buildings. This paper summarizes the outcomes of an extensive literature review on the VOCs ultraviolet photocatalytic oxidation mechanism in order to identify potential intermediates and by-products formation, and factors affecting the removal efficiency and by-products generation. Also, an experimental study was performed to investigate the generation of the by-products under single pass in duct system. The experiments were carried out in an UV-PCO test rig consisted of four parallel test ducts 0.3m × 0.3m cross sectional area which facilitates carrying out four experiments simultaneously. By-products of Toluene and n-Hexane as a result of ozone producing UV254+185 radiation have been compared with UV254 radiation. Removal efficiency measurement and by-products identification have been accomplished with analytical ATD-GC/MS and HPLC analysis, and results are tabled and discussed.

Development of a Parallel Test System for the Evaluation of UV-PCO Systems

Chang-Seo Lee, Ph.D., Member[1], ***Lexuan Zhong, Student Member[2]*** *and Fariborz Haghighat, Ph.D., P.E., Fellow ASHRAE[2], (1)Dectron Internationale, Inc., Montreal, QC, Canada, (2)Concordia University, Montreal, QC, Canada*

Ultraviolet photocatalytic oxidation (UV-PCO) is considered as a promising technology but the complicated PCO reaction mechanisms and unexpected intermediates still need to be further explored in order that PCO technology can be successfully applied. Standard test methods for air cleaning systems are limited to measuring particulate removal, limiting ozone generation. ASHRAE has been developing test methods for gaseous pollutant removal; however, these are mainly applicable for sorbent media like activated carbons. Numerous papers on UV-PCO technology present the potential of UV-PCO, but the majority of these works were done in bench-top scale reactors under ideal reaction conditions. The main objective of this research is to evaluate UV-PCO systems equitably and thoroughly under the conditions relevant to the actual applications. For this purpose a test rig composed of four parallel test ducts, with 0.3m x 0.3m of cross-sectional area each, was designed and constructed. UV-PCO section was designed to be versatile so that different UV-PCO systems with various geometries can be installed. Each duct has a fan with a variable speed control so that the test air flow can be controlled regardless of the flow resistances of different UV-PCO systems. We carried out prequalification tests of the test rig including an air leakage test, a velocity uniformity test, a concentration uniformity test and a sink effect test of the test rig. At present different UV-PCO systems are being evaluated for the removal of different volatile organic compounds (VOCs) under identical test conditions. The concentrations of challenge gases and intermediates are analyzed by Gas Chromatograph/Mass Spectrometer (GC-MS) and High Performance Liquid Chromatography (HPLC). The paper presents the details of the design and the prequalification tests of the test rig, the developed test method, and the performance of the UV-PCO systems for different VOCs.

Monday, November 12, 12:30 PM-1:00 PM

KEYNOTE

International Standards Related to the Influence of the Indoor Environment on People's Health, Comfort and Productivity

Room: Imperial Ballroom 5-7-9

Chair: Bjarne W. Olesen, International Center for Indoor Environment and Energy, Technical University of Denmark, Lyngby, Denmark

People spend in industrialized countries more than 90 % of their lives in an artificial indoor environment (home, transportation, work). This makes the indoor environment much more important for people health and comfort than the outdoor environment. In typical office buildings the cost of people is a factor 100 higher than energy costs, which make the performance of people at their work significantly more important than energy costs. The task is to optimize indoor environmental conditions for health, comfort and performance while conserving energy, since more than one third of current global energy consumption is used to maintain indoor environments. . The paper presents an update on today's requirement for a healthy and comfortable environment. The paper will mainly be dealing with the indoor thermal environment and air quality. Several international standards and guidelines from ISO (International Organization for Standardization), CEN (European Committee for Standardization) and ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) are specifying requirements related to comfort and health. Several of these standards have been developed mainly by experts from Europe, North America and Japan, thus guaranteeing a worldwide basis. Are there, however, special considerations related to other parts of the world (lifestyle, outdoor climate, and economy), which are not dealt with in these standards and which will require revision? Critical issues such as adaptation, effect of increased air velocity, humidity, type of indoor pollutant sources etc. are still being discussed, but in general these standards can be used worldwide. The productivity of people is however not taken into account in these documents. Recent studies are showing that comfortable room temperatures, increased ventilation above normal recommendation, reduction of indoor pollution sources and more effective ventilation increases the performance of people.

Monday, November 12, 1:30 PM-3:00 PM

CONFERENCE PAPER SESSION 3a

Building Envelope (3a)

Room: Imperial Ballroom 5-7-9

Chair: Colin M. Craven, Cold Climate Housing Research Center, Fairbanks, AK

To achieve very high levels of building energy efficiency in cold climates, significant levels of thermal insulation are utilized in building envelopes and measures to reduce air leakage/uncontrolled ventilation are implemented. Thermal bridging and moisture control in the occupied space and in the thermal envelope require special consideration, as do the cost/benefit of energy upgrades. Papers in this session explore these issues.

Learning Objectives:

1. Gain knowledge on user behavior-related parameters.
2. Learn how to find mold behind bathroom walls in buildings.
3. Explain linear thermal transmittance of thermal bridges.
4. Provide regression equations applied to calculating linear thermal transmittance.

Measured Indoor Hygrothermal Conditions and Occupancy Levels in Arctic Swedish Multi-Family Buildings

Hans Bagge, Ph.D.[1]*, Dennis Johansson, Ph.D.*[2] *and Lotti Lindstrii, M.D.*[3]*, (1)Building Physics, Lund University, Lund, Sweden, (2)Building Services, Lund University, Lund, Sweden, (3)Karlstad University, Karlstad, Sweden*

As requirements regarding energy efficiency are getting tougher, buildings in the arctic, as well as the rest of the world, need to be more energy efficient without compromising a good indoor climate. To be able to really end up with the designed-for building performance, there is an increased demand for high quality predictions of energy performance during the design phase and verifications of performance during operation. In energy efficient buildings, the occupants' behavior generally has a high impact on the building performance, which means that the characteristics of behavior related parameters are important to know. Whether these parameters are 'normal' should be described not only by average values but also by different characteristics, for example daily, weekly and yearly patterns and statistical descriptive data. This is not only true for new buildings but also in the case of renovation of existing buildings. Performance after improvements must be compared with the original performance and to do that verification, several parameters must be taken into account, and not only the main parameter. If, for example, water taps are to be replaced by energy-saving taps, not only the use of domestic hot water should be measured before and after replacement but also the occupancy level since a subsequent reduced use of hot water might, in fact, be due to a lower occupancy level. There is a lack of data on occupant behaviour parameters relevant for energy, moisture and indoor environment calculation. This paper presents measured indoor temperature, indoor relative humidity, moisture supply and occupancy level in Swedish Arctic multi-family buildings. Measurements were done during one year with readings every 30 minutes in five buildings consisting of 51 apartments located in Kiruna at latitude 67.9°. Averages and typical variations on different timescales, year, week and day are presented for the different parameters as well as correlations between the parameters, for example moisture supply as a function of occupancy level. The results can be used when input data for simulations of energy use, moisture conditions and indoor climate are chosen as well as a reference to compare measurements to during verifications.

Building Performance Investigation in the Arctic by Help of Destructive Testing in Buildings – A Pilot Study

Dennis Johansson, Ph.D.[1]*, Hans Bagge, Ph.D.*[2]*, Johan Stein, M.D.*[2]*, Jesper Arfvidsson, Ph.D.*[2]*, Petter Wallenten, Ph.D.*[2] *and Lars-Erik Harderup, Ph.D.*[2]*, (1)Building Services, Lund University, Lund, Sweden, (2)Building Physics, Lund University, Lund, Sweden*

It is important to investigate building performance and relate it to health and satisfaction of the occupants in order to enable sustainable and healthy buildings. This applies to both new buildings and renovation projects. Cross sectional studies and case control studies have been made on relationships between indoor environment and occupants´ health and satisfaction. However, to be able to connect the building performance and construction conditions, such as moisture conditions or material degeneration, with the indoor environment and air quality, it is necessary to look into the construction behind the surface layers, which means that the building must be taken apart. This is usually not possible because it is not allowed or economically reasonable in inhabited dwellings. This paper presents a pilot study of a project that introduces the unique possibility of investigating building performance where the buildings will be taken apart to reach behind the surface layers with the aim to develop methods for destructive testing in the main project. In the pilot study, the aim was to provide an image of the normal state of normal buildings after normal aging to assist in the design of energy-saving measures, methods for studying the performance of buildings including several leakage tests, and state of the external walls and connecting parts of the building and building services and HVAC systems for expanded research in the main project. Non-destructive and destructive tests were carried out in a few of houses in Malmberget in the Arctic, northern Sweden, and wall elements were taken out and tested in lab. Examples of results are damages found in attics and in wet rooms, leakage through different weaknesses in the envelope and measured U-values. The pilot study also resulted in a number of useful methods for destructive testing behind the surface layers to enable efficient destructive testing in the main project.

Feasibility on Upgrading Moscow Apartment Buildings for Energy-Efficiency

Satu H. Paiho*, Mari A. Sepponen, Rinat Abdurafikov, Åsa E. Nystedt, Ilpo E.O. Kouhia, Malin C. Meinander and Ha M. Hoang, VTT Technical Research Centre of Finland, Espoo, Finland*

This paper describes a feasibility study for the energy-efficient and sustainable renovation and modernization of a selected Moscow building stock. The developed sustainability criteria include criteria for planning structure/functional planning, surrounding terrain, buildings, transport solutions, waste disposal and energy supply. Most of the apartment buildings in the Soviet Union were constructed between 1960 and 1985, and as a result the urban housing stock today consists mainly of a few standard building types. Energy efficiency of buildings is typically poor. The energy consumption of typical buildings was estimated, including both space heating, heating of domestic hot water and electricity consumptions. Energy consumption of the selected building stock was calculated based on the consumptions of these type buildings. The state of the art of the district level was studied firstly, including energy chain analyses. The typical energy production and distribution chain was analysed. The efficiencies of the production and distribution are interesting, as well as the data about primary energy sources. The important question is which part of the energy production and delivery chain can have the biggest influence on the energy efficiency of buildings and entire building stock. After the analysis of the state-of-art energy performance of buildings, available technical possibilities for building renovation and modernization were analysed. These included energy renovation solutions for buildings, energy chain solutions, modernization solutions for other regional systems, solutions for operation and usage, and solutions supporting decision-making and renovation process. Special interest was given to prefabricated modular solutions suitable for cold climates. With the identified technical solutions, the actual retrofit concepts could be formulated. The last part of the project will include technical, financial and business implementation plans for the renovations. Then different renovation concepts will be analysed from technical and economic aspects. This will form an understanding which renovation solutions will really be possible in Moscow apartment districts.

Statistical Analysis on the Prediction of Linear Thermal Transmittances for Thermal Bridges in Residential Buildings in South Korea

Bo-Kyoung Koo, Ph.D. *and Seung-Yeong Song, Ph.D., Ewha Womans University, Seoul, South Korea*

An internal insulation system has been applied to the outside walls of most Korean apartment buildings since the first modern apartment building was built in the early 1960s. Consequently, there are many cases in which the layer of insulation is disconnected due to structural components at the wall-slab and wall-wall joints in the envelope. These joints become thermal bridges which appears repeatedly and in which heat transfer increases. In particular, the amount of heat loss is large at the wall-slab joints adjacent to hot water heating pipes. In Europe, EPBD (Energy Performance of Building Directive) came into effect, and national building energy performance evaluation tool is needed for issuing EPC (Energy Performance Certificate). Though thermal bridges are not explicitly mentioned in EPBD, they are included in the calculation of building energy performance. To calculate heat gain or loss through thermal bridges, "linear thermal transmittance" is required in most European countries. Linear thermal transmittance can be calculated by an expert with an experience of 2-D heat transfer simulation. But it may be easier and faster to use tabulated values or atlases of thermal bridge details when dealing with standard details.(Most European countries are providing reference values of linear thermal transmittance of standard thermal bridge details.) With regression models of linear thermal transmittance, it can be much easier and flexible to predict the value of linear thermal transmittance of different element thickness, especially in typical type of thermal bridges of Korean apartment buildings. In this study, the regression models which predict linear thermal transmittances for three types of wall-slab joints (internal insulation, internal insulation with subsidiary insulation under slab, and external insulation) are suggested. 2-D heat transfer simulations were performed to calculate linear thermal transmittances for several variables, and then regression equations were derived, which showed a good match with 2-D heat transfer simulation results with p values <0.0001. These regression models can be used for the building energy performance calculation including the effects of thermal bridges.

Monday, November 12, 1:30 PM-3:00 PM

CONFERENCE PAPER SESSION 3b

Ventilation and IAQ

Room: Imperial Ballroom 1

Chair: Lexuan Zhong, Student Member, Concordia University, Montreal, QC, Canada

Building indoor air quality is linked to occupant productivity and well being in built environments, regardless of whether that environment is an office building, a swimming pool, a residence or a pig barn. Papers in this session address ventilation system performance and indoor air quality issues in three building occupancy types.

Learning Objectives:

1. Describe ventilation requirements specified in ASHRAE Standard 62.1 for indoor swimming pools.
2. Describe how the improper design of ventilation units affects the IAQ and energy consumption.
3. Apply meteorological data for energy calculations (air conditioning).
4. Learn to design while taking into account working regimes of HVAC systems in piggeries.

Effects of Ventilation and Air Cleaning on Indoor Air Quality of An Indoor Swimming Pool - Mass Balance Analysis Approach

Chang-Seo Lee, Ph.D., Member *and Ness Lakdawala, Member, Dectron Internationale, Inc., Montreal, QC, Canada*

Achieving healthy environment in indoor swimming pools requires good thermal comfort, moisture management and indoor air pollution control. HVAC industries have more focused on achieving the first two areas, and less attention was given to indoor air pollution control. Indoor air contaminants are either originated from outdoor air or generated from indoor sources. The major air contaminants of concern in indoor swimming pools are generated from water disinfection byproducts (DBPs) formed in the swimming pool water. A recent study (Richardson et al., 2010) identified more than 100 DBPs in swimming pool water including trihalomethanes (THMs), chloramines, haloacetic acids, haloacetonitriles, haloketones and halophenols. THMs such as chloroform and trichloramine are volatile, hence easily becoming airborne. Some THMs can be carcinogenic, and trichloramine can cause respiratory irritation and trigger asthma. Conventionally we rely on ventilation to control indoor air contaminant levels. ASHRAE Standard 62.1 Ventilation for Acceptable Indoor Air Quality (2010) specifies the required minimum outdoor air ventilation rate for indoor swimming pools. However, swimming pools operating above the required ventilation rate can result in unacceptable airborne DBP levels. In order to improve the indoor air quality (IAQ) in swimming pools, US Center for Disease Control (CDC)'s Model Aquatic Health Code (MAHC) proposed Ventilation Module, which requires much higher outdoor air ventilation rate than ASHRAE Standard 62.1. Under the presence of strong sources of specific air contaminants like swimming pools, air cleaning can be a promising technique to improve IAQ. This study carries out mass balance analysis to investigate the effects of ventilation and air cleaning on the indoor air pollution levels in a typical public swimming pool. Ventilation rates by both ASHRAE Standard 62.1 and MAHC will be considered and compared. Air cleaning combined with different ventilation rates will be studied. The energy implication of the considered cases for cold climate will be examined.

Energy Performance and IAQ in Modern Buildings in Greenland – Case Study Apisseq

Martin Kotol *and Carsten Rode, Ph.D., Member, Technical University of Denmark, Kgs.Lyngby, Denmark*

Dwellings in Greenland consume large amounts of energy for heating (in average 373 kWh/m^2per year). In order to decrease the energy consumption, new buildings have better insulated envelopes and are tighter than the existing ones. In such tight buildings, proper air change has to be solved by other means than just by infiltration in order to provide the inhabitants with health and comfortable indoor environment. The fresh, heated outdoor air will be delivered to the living space whereas the polluted air is removed from the kitchen and bathroom. Heat recovery from the extracted air needs to be considered in such a cold region. However this solution might experience some specific problems such as freezing of the heat exchanger or too low humidity in the rooms due to replacing the humid air by outdoor air (which contains almost no moisture during extremely cold periods). In the autumn 2010 brand new engineering dormitory Apisseq was built in Sisimiut, Greenland. The building is not only high end construction with an ambition to meet the low energy demands; it is also equipped with mechanical ventilation system to secure healthy and comfortable indoor environment. The building was equipped with a complex monitoring system which allows us to study its energy performance and the indoor air quality. During the first 12 months of the operation the building consumed 203 kWh/$m^2$of energy from district heating grid. This paper brings an evaluation of the results obtained from the monitoring system and from several surveys performed during the year 2011. The tests included blower door, tracer gas, and biological examination for mould growth or thermo graphic survey. It explains the causes of the problems and brings the suggestions for remedy where possible. Also suggestions for future buildings are brought.

Impact of Indoor Climate on Energy Efficiency and Productivity in Office Buildings

Galina Stankevica *and Andris Kreslins, Dr.Ing., Riga Technical University, Riga, Latvia*

Most of energy in buildings is used for creation of healthy and comfortable indoor environment, and therefore lately an increased attention has been directed towards optimization of operation of heating, ventilation and air conditioning (HVAC) systems. This paper presents graphic-analytical approach to investigate the impact of indoor climate on energy efficiency and productivity in office buildings. Thermodynamic analysis of air conditioning processes is performed using statistical data for outdoor air conditions in Baltic States and recommended values of indoor air parameters for office buildings, prescribed by European standards in the field of indoor climate. The economic evaluation is based on introduction of coefficients describing the price of heat carrier with higher or lower temperatures. The proposed equations enable estimation of additional energy expenses that are required to maintain the optimal temperature and humidity levels for maximal productivity. The study shows that it is not viable to maintain optimal indoor air condition throughout the entire year, thus the allowance for deviation of temperature and humidity should be considered during certain periods, especially in cold and humid climate. Results of this study could be further used for improvement of building norms and regulations regarding design and operation of HVAC systems.

Ventilation of Piggeries in Cold and Humid Climate

__Anna Ramata, Dr.Ing.__, Riga Technical University, Riga, Latvia

Optimization of the operation schemes of the ventilation devices and their consumption of energy is an important measure from the viewpoints of animal welfare, the cost reduction, and the environment conservation. Intense scientific research is going on in the world how to ensure microclimate in the animal houses, how to reduce energy consumption, and how to apply various heat retrieval devices in the ventilation systems. Methodology has elaborated the calculation of energy consumption for various sets of ventilation systems in the air treatment processes using systems optimization. The operation of various air treatment devices is analyzed by the variations in the enthalpy of the outdoor air, the supply air and the exhaust air treatment processes. Using the climatological data for Rezekne (Latvia) in a five-year period, the values of the intervals of the mean temperatures and relative humidity were calculated for a one-year heating season. With the help of the calculations about the outdoor air temperatures, how often and how long the combinations of temperatures and relative moisture continue in Latvia, we determined the average repetition frequency of the enthalpies of the outdoor air parameters. In this way the possible energy consumption of the air treatment devices was estimated in the animal house for a heating season. On the basis of an assumption about climate as a limited system in the h-x diagram in which every point of the outdoor air parameters has a non-uniform repetition frequency we determine the change in the enthalpies of each interval vs. the enthalpy of the working area. In the further course of investigation, using various ventilation systems and heat exchange apparatus, the most economical way of ventilation systems was searched for in order to make it possible to use the obtained data in a far distant future in planning capital investments and their payback. Energy economy results in financial saving, conservation and safety of the environment, which ensures the animal welfare.

Tuesday, November 13

Tuesday, November 13, 8:45 AM-10:15 AM

CONFERENCE PAPER SESSION 4a

Codes and Standards

Room: Imperial Ballroom 5-7-9

Chair: Asa Wahlstrom, Ph.D., CIT Energy Management, Goteburg, Sweden

The intent of codes and standards is to ensure that buildings, systems and equipment meet or exceed minimum performance standards with respect to occupant health and life safety, energy efficiency, durability, function, etc. Codes and standards need to keep up with new materials and practices, ensuring that new concepts with merit are allowed while bad practices and materials are disallowed. Designers and builders need to keep up with codes and standards as well to ensure that their projects are code compliant. Papers in this session address this range of code and standard related issues.

Learning Objectives:

1. Understand the basis of opaque assembly & fenestration criteria in ASHRAE/IES Std 90.1.
2. Describe simplified energy calculation.
3. Derive the correlation between the specific heat loss coefficient and net energy need for space heating.
4. Describe importance of interrelations between innovative technology stakeholders.

Building Code Regulations 101 - Are Regulatory Procedures Reactive or Proactive?

__Dennis C. Terhove, Member__, City of Calgary, Calgary, AB, Canada

Constructing the built environment in sustainable and energy efficient ways, regulators, through Building Code development, ensure compliance. But does it, or should it, stop there? The roles of Building Codes have long been meant to ensure public safety in the occupied structure. But Building Codes are changing. These changes occur via the development of energy efficient regulatory procedures. No longer to simply consider public safety, Codes now are taking on a role in controlling the use of energy within our living and work environments. No where can this be more evident, or more necessary, than in colder climates. Development of “Energy Codes” is a result of the reaction by governments to the understandable need to reduce and ultimately eliminate inefficient energy use. Designing and constructing tighter building envelopes while improving indoor environments is now essential and mandatory. Reducing heating (and cooling) loads through tighter and better insulated envelopes, shading, natural ventilation and lighting is returning to building design. Moving to energy efficient HVAC systems through the use of bio-fuel, geoexchange, cogeneration, solar and other systems can provide alternatives to conventional fuels. But how do Building or Energy Codes, and regulators in general, consider these systems? The City of Calgary views these as challenges to be faced proactively. Energy efficiency in HVAC design is critical, now more than ever, and we won't be going back to the days of standardized over sizing of systems. Today, energy efficient system regulations, forged and led by jurisdictions such as Calgary, are being developed to ensure a smooth integration into "regular" design and construction practices. Establishing regulatory procedures (i.e., compliance standards, permit applications, plans approval and site inspections), which ensure compliance in manufacture, integration and installation, are critical components of assisting architects and consultants to confidently use these technologies. In short, governmental reaction to energy wastefulness and economics of the past has led to Energy Codes. But the transition should not end there. It is up to regulators at every level to continue this action to ensure evolving systems and components receive equal and balanced attention to better integrate them into current and future projects.

Early Stage CAD-Compliant Correlation Based Energy Performance Assessment Method for Residential Buildings

Jarek Kurnitski, Dr.Ing.[1]*, Targo Kalamees, Ph.D.*[2] *and Teet Tark*[3]*, (1)Finnish Innovation Fund Sitra, Helsinki, Finland, (2)Tallinn University of Technology, Tallinn, Estonia, (3)Hevac Ltd., Tallin, Estonia*

Energy performance of buildings EPBD directive aims to nearly zero energy buildings in 2021. In the design process, implementation of improved energy performance means that quick energy performance assessments are needed in very early stages in order to ensure that the architectural concept and technical solutions enable achieving required performance. For that purpose new simple calculators are needed. In this article, a simple correlation based method is developed and its calculation accuracy is analyzed against well validated dynamic simulation tool. The method is targeted for architects with the intention to enable an instant delivered/primary energy use calculation when sketching the building. As a correlation based method, it is limited to residential buildings, which are less sensitive to dynamic behavior caused by intermittent use. The principle of the method is similar to ISO 13790 monthly calculation method with correlation based gain utilization factor. In this method the correlation approach is expanded so that the correlation of the net energy need on the specific heat loss coefficient of the building is determined by simulations. The specific heat loss coefficient includes transmission and infiltration losses through the building envelope. In the method, the heat recovery efficiency, internal heat gains and windows orientation and solar protection are fixed, i.e. if some of these parameters are changed, a new correlation has to be determined. All other parameters, i.e. thermal and infiltration properties of the building envelope as well as heating and cooling systems can be changed without any limitations. Calculation procedure includes the calculation of specific heat loss coefficient, which can be done by a worksheet calculation or implemented into CAD-programs. From the specific heat loss the net energy need can be calculated with the correlation equation determined. Delivered energy use can be calculated with tabulated system efficiency values. In the article, the developed method is applied for typical residential houses and apartment buildings. Sensitivity of accuracy on main parameters like window sizes and orientation, massing and solar shading options is analyzed. Based on these analyses, it is concluded, how reliable early stage energy performance assessments are possible for residential buildings in a cold climate.

What HVAC Designers Need to Know about Upcoming Changes

John Hogan, P.E., Member*, Seattle Department of Planning and Development, Seattle, WA*

ASHRAE/IES Standard 90.1 is cited in the U.S. Energy Policy Act as the national energy standard for buildings, except for low-rise residential buildings. This presentation will provide a detailed review of the upcoming changes in the building envelope requirements for cold climates in ASHRAE/IES Standard 90.1, and compare them with the previous requirements for cold climates in the 2010 version of ASHRAE/IES Standard 90.1. This session will inform attendees about upcoming changes in energy standards, thereby providing HVAC designers with information to update their design practices to incorporate improvements in the energy efficiency of the building envelope. Heat loss and heat gain through the building envelope is a significant factor in HVAC design. Changing standards for the building envelope are resulting in new options for HVAC designers. For example, the switch to double-glazing several decades ago in commercial buildings in mild and moderate climates allowed designers to eliminate the use of separate perimeter baseboard heating systems. Heating and cooling could be provided from a single overhead system in those climates. Now, windows with multiple low-emissivity coatings and triple glazing and better frames, and opaque walls with better insulation and reduced thermal bridging, allow for the consideration of new options for HVAC design of buildings in cold climates. Energy efficiency is a key component of ASHRAE's goals to minimize the environmental impact of building construction and operation. With information on updates to the national energy efficiency standards for building construction, the HVAC designer will depart with information allowing them to keep their designs up with changes in construction practices.

Non-Traditional Envelope Assemblies – Theory, Regulation, and Testing

Justin Pockar*, City of Calgary, Calgary, AB, Canada*

Concerns over climate change, increasing energy costs, and improved environmental performance have brought energy conservation in buildings to the forefront of design considerations for building owners, operators and designers. Conventional wisdom has identified envelope improvement with respect to thermal resistance and reduced air leakage as the most economical means to reduce a building's overall energy use. This has, in turn, spurred manufacturers and constructors to adopt many new and innovative techniques and materials in building envelope assemblies, including Insulated Concrete Forms (ICF), spray foam insulations, and multiple-cavity wall assemblies to name a few. However, with this innovation, have come many questions relating to the durability, regulations, constructability, and vapour and thermal performance of these sometimes unproven, untested systems; limited laboratory test data or field installation history is available to mitigate either performance or liability concerns for owners, consultants, or regulatory bodies. Using an analysis of conventional construction techniques and materials as point of reference, non-traditional envelope assembly alternatives are presented and explained with respect to constructability, thermal performance, and vapour control mechanism(s). Starting from the fundamentals of building physics, non-traditional envelope assemblies are described, highlighting benefits, concerns and specific innovations germane to specific systems. To further the discussion, assembly and materials vapour permeance and thermal properties are highlighted and compared. Correspondingly, envelope failure modes and field fabrication concerns are highlighted for the non-traditional envelope systems. The specific conditions of cold climate performance are illustrated in this analysis, identifying relevant examples as required. In addition, regulatory concerns associated with non-traditional envelope assemblies are addressed. Using the Alberta Building Code as the foundation document, conflicts are identified by the Authority Having Jurisdiction, and examples highlighted for discussion. Agreed upon solutions and approved alternatives are identified and explained where available. Finally, testing procedures for quantifying air infiltration and thermal performance of assemblies (for example, CAN/ULC-S742-11) are presented, explained, and critiqued as a potential solution to the lack of field data.

Tuesday, November 13, 8:45 AM-10:15 AM

CONFERENCE PAPER SESSION 4b

HVAC Systems and Equipment (4b)

Room: Imperial Ballroom 1

Chair: Bjarne W. Olesen, International Center for Indoor Environment and Energy, Technical University of Denmark, Lyngby, Denmark

The four papers in this session examine a range of ideas and issues specific to HVAC systems and equipment operating in cold climates.

Learning Objectives:

1. Define the basic thermodynamics of an energy recovery system,
2. Determine the frost-threshold and frost-growth conditions for a typical energy wheel operating speed and a typical warm humid exhaust air flow.
3. Describe why stratification is problematic for airside economizer operation
4. Understand the sources of improvements brought about by vapor injection and oil flooding relative to the standard vapor compression system.

Multi-Functional, High-Performance Run Around Energy Recovery Systems in Cold Climate Zones

***Rudolf Zaengerle, Dr.Ing., Associate Member**, Konvekta USA, Princeton, NJ*

HVAC systems are among the greatest energy consumers of large buildings - in particular lab buildings and hospitals with 100% outside air. European high-performance 'run around energy recovery systems' (RAERS) with advanced control software are operating at efficiencies of net 70-90% (based on annual energy consumption for heating and cooling), taking into account the additional electricity needed for glycol pumps and added fan power to compensate for air pressure drop in the coils. While the thermodynamics of an energy recovery system are relatively simple, it is critical that high-performance systems operate at optimum performance under varying operating parameters. With several variable input parameters (outside air / supply air / return air temperatures; air volumes; glycol volumes & temperatures), controlling and optimizing a system requires a numerical simulation based controller that allows variable amounts of heat transfer fluid to be circulated throughout the system. In multi-functional systems, additional heat and/or cold is introduced into the glycol circuit, either to boost the heating/cooling capability of the energy recovery system from waste heat/cold sources, or to control the supply air temperature to the building to eliminate the need of separate heating/cooling coils in the supply air handlers. These features add yet another level of complexity to the controller function.

Frosting Conditions for An Enthalpy Wheel in Laboratory Simulated Extreme Cold Weather

*Gazi I. Mahmood, Ph.D. and **Carey Simonson, Ph.D., P.E., Member**, University of Saskatchewan, Saskatoon, SK, Canada*

Laboratory experiments are performed to determine the frosting conditions for an enthalpy wheel in simulated extreme cold weather. Frosting of enthalpy wheels in energy recovery units is common when operating at very cold outdoor conditions. Energy transfer effectiveness decreases and pressure-drop across the wheel increases significantly as the frost layer grows in the wheel channels. Determining the frosting conditions of the enthalpy wheel thus helps the designers and manufacturers to implement defrosting or frost prevention measures in the wheel during operation. The laboratory test conditions for the wheel provide supply-inlet (outdoor) air temperature between -20 ^oC and -38 ^oC and relative humidity between 45% and 100%. The exhaust-inlet (indoor) air is delivered to the wheel at about 22 ^oC and either 30% or 40% relative humidity. The supply and exhaust airstreams flow in a counter-flow configuration. An air flow rate between 80 cfm and 98 cfm is maintained during the tests to provide almost equal mass flow rates (0.05 and 0.06 kg/s) on the supply and exhaust sides. Measurements during the tests include instantaneous air temperature, dew point temperature, relative humidity, flow rate, and pressure-drop across the wheel. Test results of air temperature and relative humidity on all sides of the wheel, sensible effectiveness, and pressure-drop between the supply-inlet and supply-outlet are then presented. The frosting initiation and frost growth in the wheel pores are determined based on the instantaneous rise of pressure-drop values between the supply-inlet and supply-outlet side airflow. The results indicate the limit of supply-inlet (outdoor) temperature and relative humidity for the no-frost operating condition of the wheel. To avoid frosting during an operation at an extreme cold outdoor condition, the supply-inlet air flow to the wheel then may be pre-heated above the frosting temperature, or the wheel itself may be heated electrically, or both the supply-inlet air and wheel may be pre-heated.

Extending Airside Economizer Operation in Hydronic Coil Ahus: An Overlooked Opportunity for Substantial Energy Savings

__Jody Templeton, Associate Member__ and Steve Hill, Blender Products, Inc., Denver, CO

When designing for cold weather climates one area that has been largely disregarded is air stratification in the mixing box of an Air Handling Unit (AHU). The presence of air stratification is a threat to freeze and rupture hydronic coils and thus is the reason low-limit freeze stats are used to stop the unit from operating when freezing conditions are present. However repeated "nuisance trips" are also undesirable and the most commonly used technique to avoid this problem is having the control system abandon the airside economizer and switch the unit to heating mode. It is often assumed this fix is not highly impactful to energy use because it only happens on the coldest of days. However, in most cases the air stratification within the AHU mixing box is so prevalent the airside economizer ends up being abandoned when the outside air temperature drops below 40°F. Therefore in an effort to be energy conscious, system designers should strongly consider the benefits of an air mixing device to eliminate the air stratification. A well-mixed airstream would allow most airside economizer systems to operate until an outside air temperature of -5°F, which increases the functionality of the system design a significant amount of hours in cold climate locations. Thus the use of an air mixer to extend economizer operation provides even greater system benefits that just eliminating "nuisance trips" and protecting the coil. This paper serves to detail the significant opportunity for energy savings by installing an air mixer in AHUs using airside economizers coupled with hydronic coils.

Vapor Compression Cycle Enhancements Through Liquid Flooded Compression with Regeneration and Dual-Port Refrigerant Injection

Sugirdhalakshmi Ramaraj, Student Member[1], Yuanpei Song[1], __Eckhard Groll, Ph.D., Fellow ASHRAE__[1], James Braun, Ph.D., Fellow ASHRAE[1], Travis Horton, Ph.D., Member[1] and Kirill Ignatiev, Ph.D., Member[2], (1)Purdue University, West Lafayette, IN, (2)Emerson Climate Technologies, Sidney, OH

In very low outdoor ambient temperature regions, both heating capacity and coefficient of performance (COP) of traditional air-source vapor compression heat pumps drop significantly with the decrease in the outdoor air temperature. Many alternative technologies have been investigated for improving the efficiency of vapor compression refrigeration cycles and two methods have been proposed in this paper. The first method is liquid flooded compression with regeneration in which a significant amount of non-volatile liquid is mixed into the stream of refrigerant vapor entering the compressor in order to achieve isothermal compression. The flooding also improves volumetric efficiency by the improved sealing of compressor leakage gaps and can significantly reduce thermodynamic losses associated with the desuperheating of refrigerant in the condenser. The addition of regeneration to the flooded compression improves the system efficiency by reducing the losses due to throttling of a two-phase refrigerant in the expansion device. The second method is multi-port refrigerant injection during compression and economizing which is similar to multi-stage compression in providing cooling and higher-density refrigerant between compressor stages, but multi-port refrigerant injection within a single compressor eliminates the need for multiple compressors and thereby lowers the cost significantly. While multi-stage compression has been implemented for large-scale devices, the development of compressors with vapor injection ports within a scroll compressor enables smaller-scale application. The testing of prototype R410a oil-flooded compressor and prototype dual port R410a scroll compressor has been accommodated by modifying the hot gas bypass load stand. In addition, simulation models for both the cycles have been developed in EES. The predictions of the model indicate that the COP of a R410A flooded compression with regeneration cycle is 10% higher while that of the vapor injection cycle is 16% higher than the standard vapor compression cycle for climatic conditions such as experienced in Minnesota.

Tuesday, November 13, 10:30 AM-12:00 PM

CONFERENCE PAPER SESSION 5a ()

Ideas

Room: Imperial Ballroom 5-7-9

Chair: Michel Tardif, P.Eng., Member, CanmetENERGY Natural Resources Canada, Ottawa, ON, Canada

The four papers in this session examine a range of ideas and issues specific to climate construction and buildings operating in cold climates.

Learning Objectives:

1. Explain pile foundations in permafrost.
2. Define what is greywater and main difference against wastewater.
3. Describe in general terms typical mechanical systems used in buildings located in small remote communities of the Canadian

Arctic.
4. Distinguish the differences between earth-tube and thermal labyrinth ventilation system (TLVS).

Challenges Associated with Arctic Construction

Raymond W. LaTona, Ph.D., *Simpson Gumpertz & Heger Inc., San Francisco, CA*

Construction of the Operations Center facilities at Prudhoe Bay on Alaska's North Slope required improved technologies and methodologies to deal with the challenges of construction in remote, cold climate areas. The objective was to provide housing and work facilities for the personnel operating the oil fields. The design deals primarily with temperature, wind, and snow. In addition, considerations for maintaining the thermal regime of the permafrost and isolating heat transfer between the buildings and the permafrost were major considerations. Economics of construction and time required for construction were driving factors in the approach to the project. At the time of construction, the cost of labor and materials on the North Slope was many times the cost in the lower 48 states. The North Slope construction season was limited to about four months per year. These factors dictated constructing the facilities in the lower 48 states and shipping the completed buildings (weighing 700-1200 tons) to the North Slope by barge.
This presented a unique combination of the following conditions:

i. designing buildings for the environment at the construction site,
ii. moving the constructed buildings to the barge,
iii. subjecting the buildings to the environment on the barge at sea, and
iv. transporting them across the permafrost to their final resting place.

The design envelope had to encompass all of the above conditions. The design temperature range (-40°F to +80°F) required advances in building envelope design and construction, and supporting the buildings on permafrost required innovations in pile construction. Steel piles frozen into the permafrost support the buildings. The soffits of the buildings are approximately 7 feet above the tundra to allow blowing snow to pass under the buildings without forming snow drifts. The pile caps are reinforced concrete to reduce thermal conductance by breaking the continuity of steel piles from the permafrost through the ambient arctic air to top of the pile inside the heated building envelope (70°F±). The result is a group of functional buildings with pleasant interior accommodations in a hostile, cold weather environment. After 30+ years, these buildings continue to serve their intended purpose.

Piqqusilirvvik Inuit Cultural Learning Facility - A Case Study of Typical Canadian High Arctic Construction

Ross D. Abdurahman, P.Eng., Member[1] *and Rene Artacho, P.Eng., Member*[1]*, (1)Stantec Consulting Ltd., Edmonton, AB, Canada*

This study describes the development of the mechanical building systems and the criteria that resulted in their selection for the new Piqqusilirivvik Inuit Cultural Learning Facility, located on the northeast coast of Baffin Island in the arctic community of Clyde River. The Learning Facility uses systems common to buildings throughout the NWT and Nunavut Territories, making it an excellent representation of typical Canadian high arctic building technologies. High arctic buildings are unique in many ways. Energy costs are exceptionally high, environmental conditions are very severe, accessibility to qualified maintenance personnel is limited or non-existent, there is typically only one energy source in the communities, CP-43 ULSD, and construction logistics are hampered by a single seasonal sealift for material shipment. These limitations often constrain system development but over the years the GNWT and GN territorial governments working with northern construction professionals have developed reliable and efficient systems that meet the requirements of building in these demanding locations. Systems in the Learning Facility are typical for the location. Primary secondary variable flow hydronic heating with high efficiency modulating fuel oil boilers and a combination of perimeter convectors and steel radiators was used for building heating. Ventilation is through central heat recovery systems with displacement ventilation. Potable and fire water is through large horizontal pipe tanks located in an elevated crawlspace, as the community does not have a dedicated municipal water or sanitary infrastructure and uses trucked services. Along with a high performance building envelope, optimization of day lighting and electrical lighting controls the systems design are expected to achieve 45% energy savings referenced to the MNECB.

Energy Derived from the Wastewater

Adam Bartonik[1]*, Marek Holba, Ph.D.*[1]*, Karel Ploteny*[1] *and Petr Horak, Ph.D.*[2]*, (1)ASIO Ltd., Brno, Czech Republic, (2)Brno University of Technology, Faculty of Civil Engineering, Brno, Czech Republic*

The manuscript deals with possibility of the sewer heat exchanger placement in the sewerage systems for heat energy recovery. The manuscript also describes the wastewater utilization for heat energy recovery in the buildings. The combination of sewer heat exchanger and heat pump can utilize wastewater low-temperature potential. We developed and constructed sewer heat exchanger prototype based on numerical modeling in STAR-CCM+. Software simulated thermal performance of the system and we compared those data with pilot-plant installation at the wastewater treatment plant. Energy conservation measures are being discussed in the wastewater application context. We focused to decrease costs of hot supply water or heating by utilization of greywater heating potential. Greywater is the leftover water from baths, showers, hand basins and washing machines only (this implies that it is free of feces and urine). Different types of heat exchangers have been modeled on their thermal performance. Those data will be confronted with real data from the greywater system application in the building. Furthermore, basic economical evaluation, return of investment analyses and technical recommendation will be presented.

Annual Energy Performance Evaluation of Thermal Labyrinth Ventilation System Using Measured Data

Jin-Hee Song[1] *and Seung-Yeong Song, Ph.D.*[1]*, (1)Ewha Womans University, Seoul, South Korea*

With the ever-important issue of global warming and greenhouse gas emission, it becomes more important to reduce building energy consumption. Ventilation is essential to maintain a healthy indoor environment. However, in summer and winter, thermal conditions of outdoor air are so poor that ventilation cannot help but increase energy consumption. Thus, energy-efficient ventilation system is very important. Thermal labyrinth system is a ventilation system which intakes outdoor air through an underground concrete structure shaped like a labyrinth. By heat exchanges from air to ground, this system can pre-cool and pre-heat the outdoor air in summer and winter, respectively. It is similar to earth tube or cool tube which intakes outdoor air through buried pipes made of metal. Thermal labyrinth can use concrete structures to outdoor air pass way, so the air flow rate through thermal labyrinth is bigger than through earth tube. Thus, thermal labyrinth system can be applied to commercial or office buildings rather than dwellings. Recently, thermal labyrinth system has been applied to some environment-friendly architecture. However, the annual energy efficiency of the system is not exactly known. Therefore, this study aims to analyze the energy efficiency of the thermal labyrinth system applied Ewha Campus Center in Seoul, South Korea by field measurement from August 1 2010 to July 31 2011. Dry temperature(°C) and relative humidity(%) of outside and inside thermal labyrinth system as well as the air flow rate(CMH) through thermal labyrinth system were measured and analyzed. Based on the measured data of the system, the energy efficiency of the thermal labyrinth system was evaluated by comparing the pre-heating/pre-cooling and dehumidifying/humidifying rate between Case 1 (with thermal labyrinth, real) and Case 2 (without thermal labyrinth, assumed). Also, the increasing fan power due to applying thermal labyrinth system was analyzed. The energy efficient ventilation system is essential to maintain healthy indoor air quality and reduce building energy consumption. The annual energy efficiency analysis was shown that outdoor air pre-cooling and pre-heating effect of thermal labyrinth is 3.7~5.3°C and 7.5~13.3°C, respectively. Therefore, the system application can be helpful to reduce building energy consumption.

Tuesday, November 13, 10:30 AM-12:00 PM

CONFERENCE PAPER SESSION 5b (INTERMEDIATE)

HVAC Systems and Equipment

Track:

Room: Imperial Ballroom 1

Chair: Robert Bean, Healthy Heating, Calgary, AB, Canada

The four papers in this session examine a range of ideas and issues specific to HVAC systems and equipment operating in cold climates.

Learning Objectives:

1. Explain how the humidity is transferred through a permeable membrane
2. Understand principles of good mechanical insulation design and installation.
3. Describe the method used to determine the optimal operating range of VAV diffusers.
4. Describe common energy efficiency issues found in Northern Communities.

Heat and Mass Transfer in Membrane-Based Total Heat Exchanger, Membrane Study

Maria Justo Alonso[1]*, Hans Martin Mathisen, Dr.Ing., P.Eng.*[2]*, Vojislav Novakovic, Dr.Ing., P.Eng., Fellow ASHRAE*[2] *and Carey Simonson, Ph.D., P.E., Member*[3]*, (1)SINTEF Energy Research, Trondheim, Norway, (2)NTNU, Trondheim, Norway, (3)University of Saskatchewan, Saskatoon, SK, Canada*

Realisation of Net Zero Energy Buildings (NZEB) for residential use depends on, among many other things, minimizing air leakages. However, very airtight houses will have an increased risk for problems regarding indoor humidity, thermal comfort and indoor air quality. Focusing on ventilation systems becomes a requirement in this situation. For cold climates, mechanical ventilation systems are the state of the art solution and in order to achieve a further reduction in energy use, the focus must be on efficient energy recovery. This paper focuses on a quasi-counter flow membrane-based heat and moisture recovery system for cold climates such as the Norwegian climate. The membrane separates the two air streams and allows both heat and moisture transfer. Its effectiveness is crucially depending on the heat and mass transfer resistance of the membrane that separates the two air streams and therefore the characteristics of membranes have to be deeply analysed. To analyse the membrane, this study starts with a detailed theoretical study of the forces governing transfer through membranes. A literature review of available measurements for membrane resistance is performed. Following this, heat and mass transfer in selected types of membranes will be measured in order to validate the results of the theoretical analyse. The conclusion to be taken from this study is the selection of the characteristics of the most suitable membrane for a residential heat and moisture exchanger in cold climates.

Mechanical Insulation—A New Approach to an Overlooked Problem

Bud Fraser, P.Eng.[1]*, Micah Lang*[1] *and* ***Jeff Besant, P.Eng.***[2]*, (1)Golder Associates, Vancouver, BC, Canada, (2)Besant and Associates Engineers, Vancouver, BC, Canada*

Mechanical insulation is a critical element of the design, operation, maintenance and safety characteristics of mechanical systems. Because of the importance of these systems, there are established standards and guidelines in place. Yet, we have found through research and interviews that mechanical insulation is often poorly managed on job sites and throughout of the life of mechanical systems. Through these efforts, we identified some of the reasons why mechanical insulation systems are often not installed properly and we have recommended solutions for these problems. Further, we have provided empirical evidence that buttresses the justification for the proper application and maintenance of insulation systems in terms of energy, service life and maintenance savings. Our purpose is to provide information that will lead to an ultimate goal of having every section of pipe, duct and mechanical equipment insulated correctly. We have structured our documents in a top down definition system that can work in conjunction with existing standards and specification systems. We define assemblies through performance starting at a concept level then progressively refine the information, ultimately describing specific products and application methods. We developed a tool which owners, property managers, engineers, designers and capital planners can use to help make timely and effective decisions about their insulation needs, and what upgrades may be required to optimize the application of their mechanical insulation systems. At a meta level, we found methods for engineers to communicate complex technical information to lay people with enough content and detail so that they can make informed decisions. We incorporated these methods into our tools. Developing effective communication strategies is a challenge that all engineers encounter at various times in their career.

The Optimal Operating Range of VAV Supply Units

*Aleksejs Prozuments and **Anatolijs Borodinecs, Dr.Ing.**, Riga Technical University, Riga, Latvia*

Good IAQ requires sufficient amount of air to be supplied and well distributed within a space. Air diffusers equipped with VAV function control the air flow rate to meet the rising and falling heat gains or losses within the thermal zone served. The VAV unit is a calibrated air damper with an automatic actuator. When the air is supplied parallel to the ceiling surface negative pressure occurs between the air jet and the ceiling, causing the jet to "stick" to the ceiling (Coanda effect). This effect is of great importance, particularly when supplying cooling air. The velocity of the supplied air should be kept at a level which ensures that the mixing is effective, but at the same time ensures that the air velocity has fallen to the required level by the time it reaches the occupied zone. Several types of diffusers were tested to determine the influence of the shape and constructional features of diffusers on the air distribution pattern. The tests were performed in a specially designed test chamber which represented a single office room. 24 probes were installed at 3 levels: feet, waist and head area of a standing occupant in accordance with ASHRAE:55-2004. The point of reference (for the disposition of the probes) was the vertical axis of the diffuser installation plane. The probes were attached to support bars so that horizontal distance between two probes was 0.2m. At each of 24 points air temperature and velocity were measured. The test chamber was isolated so that isothermic conditions were maintained and all measurements were carried out at 4^oK (7.2^oF) and 8^oK (14.4^oF) temperature difference between supply and indoor temperatures. Two air flow values are of great importance to establish the operating range: the lowest point at which Coanda effect appears and the highest point at which noise level is exceeded (noise level data were gained from technical specifications). Thus we traced the path of air distribution pattern within the operating range, made the calculations on turbulence intensity, and draft rate, and eventually built the graphs to demonstrate the results on each type and size of diffuser.

Energy Conservation and Integration of Heat Pump Technologies in Arctic Communities

Martin Kegel[1], Antoine Langlois, Associate Member[1], Gisele Amow[2], Larry Wilkens[3], John P. Scott, Member[1] and Roberto Sunye[1], (1)CanmetEnergy, Varennes, QC, Canada, (2)DRDC Atlantic, Ottawa, ON, Canada, (3)CanmetEnergy, Ottawa, ON, Canada

Northern communities and military installations are challenged by harsh environments, remoteness and lack of indigenous energy sources. In many cases, nearly all energy used is generated from diesel generators and diesel fired heating devices. It is the case for an arctic military installation located in the Canadian far north, a community of 50 heated buildings sheltering between 50 and 200 people year-round. With increasing fuel costs, it is essential to find alternative sustainable options for power and energy in such communities, which includes energy conservation and novel technologies. The objective of this paper is to present an analysis to identify the best options to reduce the dependency on fuel use by remote arctic communities. Through several site visits, a building energy model of the community was developed in TRNSYS and validated to fuel consumption records of the building and monitored electrical usage. Using the energy model, the impact of numerous energy efficiency measures were assessed and quantified in terms of potential fuel savings. The most promising energy efficiency measures assessed include improvements to the amount of waste heat captured from the generators, building envelope upgrades to reduce heat loss and minimize infiltration as well as upgrading and controlling the lighting fixtures. A 70% fuel consumption reduction was predicted in some buildings using the energy model. This paper also investigates the possibility of integrating heat pumps for space heating after implementing the identified energy saving measures to the energy model. A novel approach, considering the climatic issue, aiming at using the sea water as a heat source for the heat pumps was developed and evaluated.

Tuesday, November 13, 12:30 PM-1:00 PM

KEYNOTE

The Design of Halley VI Antarctic Research Station

Room: Imperial Ballroom 5-7-9

The Design of Halley VI Antarctic Research Station
Peter Ayres, *AECOM, London, United Kingdom*

AECOM has just delivered Halley VI, British Antarctic Survey's Scientific Research Station, the first re-locatable and modular facility in Antarctica. Due to its remote nature and extreme climate it has been designed and constructed as off-grid energy solution. Back in 2005 AECOM won the competition and were commissioned to design Halley VI, the British Antarctic Survey's Scientific Research Station. The facility is now been built and the sun has just returned to the site allowing for final commissioning before being handed over to the British Antarctic Survey. Due to its remote nature and extreme climate it was designed and being constructed as an off-grid building. The new station will withstand prevailing winds of up to 90 mph and an average external temperature of negative 22°F with extreme lows of around -70°F. For the 105 days when the sun does not rise above the horizon. The life-critical design of the station was developed reliant on tried and tested technologies, although by necessity often applied in innovative ways such as technology transfer including insulated flexible links between modules developed from the rail industry, vacuum drainage systems used on ships, internal linings commonly used in aircraft and glazing insulation developed from the space industry. The project has provided tremendous opportunity to the AECOM design team pushing them up a steep learning curve for design in extremes. This challenge and lessons learnt can now be shared through an exciting interactive session where participants are introduced to the site and site conditions and guided through an off-grid design process in a fascinating yet demanding environment, in order to come up with a delivered design concept for an off-grid Antarctic research station.

Tuesday, November 13, 1:30 PM-3:00 PM

CONFERENCE PAPER SESSION 6a

Big Building Applications

Room: Imperial Ballroom 5-7-9

Chair: Jarek Kurnitski, Dr.Ing., Finnish Innovation Fund Sitra, Helsinki, Finland

Papers in this session, review design features and energy performance of four energy efficient facilities constructed in cold climates. These are a hospital, a laboratory, an office building and an office campus.

Learning Objectives:

1. Understand design challenges relating to designing a modern community hospital in a cold climate.
2. Discuss how building envelope effect facilities design in cold climates.
3. Design condenser water loops with higher temperatures for direct heating.
4. Consider DOAS/ERV with active recovery on exhaust as first stage of heating.

Dawson City Hospital
Paul Marmion, P.Eng., Member[1], *Ian Carter*[1] *and Jack Kobayashi*[2], *(1)Stantec, Vancouver, BC, Canada, (2)Kobayashi + Zedda Architects Ltd., Whitehorse, BC, Canada*

The sealed, artificially conditioned public building types developed over the last fifty years will be challenged in the light of climate change predictions, increasing cost of energy, and anxiety about global carbon emissions. This is especially true for northern locations with extreme winter's climate conditions. Hospitals in the North with their high ventilation rates and predominantly 24/7/365 occupancy consume more energy than almost any other building type. Our presentation will report on a LEED registered full service community hospital project in Dawson City located at -139° longitude and 64° latitude with summer temperatures in excess of 26°C and winter temperatures going below -51°C. The Dawson City hospital's design considerers the local climate conditions, melting permafrost, historical setting, and its local First Nations cultural context in providing the local community with a "state of the art" healthcare facility. The design strategies, derived in part from high performance building design, work in harmony with pre air-conditioning construction solutions including openable windows and the use of hybrid natural/ mechanical ventilation integrated with a heat pump energy recovery/ transfer distribution system. The project required careful integration of interdependent and synergistic building components/ systems to significantly reduce the operating energy and, at the same time, provide a high level of indoor environmental quality required for a hospital. Design stage energy modeling has been undertaken analyzing numerous energy conserving options. The designed hospital is estimated to consume 260 kWhr/m2/yr. as compared to a conventional code compliant design which would consume 340 kWhr/m2/yr., generating an operating cost saving of approximately $23,000/yr. and a CO² saving of over 100 tonnes CO²e/yr. These results are based on the first stage energy optimization analysis as part of the LEED compliance energy model process and will be updated in the presentation. Dawson City has a limited number of service technicians/ replacement parts and it is relatively difficult to get to, requiring resilient/ robust/ redundant system components. Taking this fact into consideration the mechanical and electrical systems have been designed so that they can be remotely monitored and controlled from Whitehorse (450 km south of Dawson City) using web based "BACnet" communications protocols.

High Performance Laboratory Design for the Sub-Arctic

Danny Rauchenstein, P.E., Member*, PDC Inc. Engineers, Anchorage, AK*

The University of Alaska Fairbanks Life Sciences Facility is a state-of-the-art research and teaching laboratory built in Alaska's sub-arctic interior region. Challenges included developing an efficient building for arctic conditions and optimizing building loads by use of a radiant floor system that handles concurrent heating and cooling as required for the facility. The building envelope employs an R-40 curtain wall system with an R-60 roof assembly. The radiant system effectively uses a 4-pipe common load configuration which has been mischaracterized by the ASHRAE Handbook. Providing an efficient chilled glycol source posed another challenge. A 1,800-ton central steam absorption chiller system for campus distribution was designed consisting of (2) 900-ton steam absorption chillers installed in the basement of the facility, coupled with (2) cross-flow cooling towers located on the site. The chiller plant is designed to run in the summer where it will use steam from the campus power plant. The facility is connected to this campus network for its chilled glycol source. In the winter, the campus chilled glycol system is shut-down due to low cooling load and the fact that the steam is used primarily for heating on campus. There are still cooling loads in the facility so a wintertime free-cooling system was designed to piggyback on the building chilled glycol system, using outside ambient air to chill the glycol for cooling. Other challenges included matching specific heat recovery to systems based on application and life-cycle analysis. Due to the corrosive and toxic nature of the fume-hood exhaust system, a run-around style loop was used to transfer heat out of the exhaust stream to preheat incoming outside air. A higher efficiency heat pipe system was used to recover heat from the laboratory general exhaust stream. Rather than waste the heat from the chilled glycol system in the wintertime, outside air serving the ventilation units is initially drawn through a parallel duct with a coil that functions as a dry cooler for the chilled glycol system. The outside air is preheated and then routed back to the ventilation units for use in the building. Bypasses were installed to prevent overheating.

Energy Efficiency in a Cold Climate: Epcor Tower

Jillian D. Pederson, P.Eng., Associate Member*, AECOM, Calgary, AB, Canada*

Epcor Tower is a 29-storey office tower located in Edmonton, Alberta, Canada. It is located at 53.3° latitude. The design temperature is -34°C in winter and 28°C DB/19°C WB in summer (62°C delta). This paper outlines the measures used to achieve an energy efficient building in this varied and cold climate. A high performance envelope was used to minimize the effects of large temperature swings. A triple glazed product with an overall U-value of 1.23W/m^2K was chosen. Secondly, energy efficiency was achieved by providing an outdoor air system with geothermal pre-heating and pre-cooling via earth tubes. Other energy saving measures employed include exhaust air heat recovery, winter free cooling, and boiler stack condenser heat recovery. As a result of the high performance glazing, the requirement for perimeter heating was eliminated. Thermal modeling was performed to ensure adequate space temperatures would be maintained at the winter design point in the absence of perimeter heating. The earth tubes provide significant savings on the ventilation heating and cooling loads. Exhaust air heat recovery is also used to preheat ventilation air when available. Winter free cooling can be used 39% of the year. The stack condensing system increases the overall boiler plant efficiency from 85% to 95.5%. The estimated energy consumption for Epcor Tower is 121kWh/m^2/year. The annual projected building energy cost is CDN$767,177/year. This building demonstrates the potential to achieve energy efficiency in extreme climates. Using the energy saving measures presented, the building is expected to achieve a 41.4% energy use reduction as compared to ASHRAE Standard 90.1. The project is targeting a LEED® Gold rating.

Bell Campus, Montreal, QC

Daniel Bourque, P.Eng., Associate Member*, Kolostat, Laval, QC, Canada*

Our firm, a design-build mechanical contractor, was chosen for a major construction project which consolidated a leading telecommunication company's activities in a new campus located on Ile-des-Soeurs. Phase I, started in February 2007, consists of 600,000 sq. ft. of office space and was ready for occupancy by September 2008. The second phase adds another 240,000 sqft and was ready for occupancy by February 2009. Both phases will welcome approximately 4,000 employees and have a total of 766,000 sqft of underground parking which preserves the green space for which the area is renowned. Simulation to MNECB reference shows a 37% cost savings to a comparable compliant building. This is despite the fact that the constructed buildings had a 77% window-to-wall ratio, which was a major hurdle to overcome when trying to optimize energy efficiency. Nonetheless, real-life building trends show that no additional external heat (from the boilers) is required until outdoor temperatures fall below 14F. We hope to demonstrate how an innovative amalgamation of technologies allows the building to achieve these efficiencies in real life and to operate with high comfort and efficiency despite the apparent disadvantage of the glazing in a cold climate like Montreal. While many innovative technologies were incorporated into the design, the core of the system was designed around the hydronic loop, which connects all systems. The hybrid heat pumps used to have a flooded condenser (which allows for efficient heat exchange with hydronic loop temperatures up to 120F): however, for this project the heating requirements were designed with a loop temperature of 104F maximum. This low-grade heat is sufficiently warm to allow for direct heating, without the use of compressors. Although airside economizers have their place in the gamut of energy efficiency strategies available to designers, we believe that in Northern climates, where heating loads dominate the building's energy use profile, free-heating strategies are more appropriate than free-cooling ones. Hence, technologies incorporated in the design include active heat recovery on the dedicated outdoor air ventilation systems.

Tuesday, November 13, 1:30 PM-3:00 PM

CONFERENCE PAPER SESSION 6b (INTERMEDIATE)

HVAC Systems and Equipment (6b)

Room: Imperial Ballroom 1

Chair: Boualem Ouazia, Ph.D., Member, The Institute for Research in Construction (IRC) / National Research Council Canada (NRC), Ottawa, ON, Canada

Cold climates pose design challenges for both air source and ground coupled heat pumps. Papers in this session examine ways of meeting these challenges.

Learning Objectives:

1. Design and modeling of a two-stage heat pump for cold climates.
2. Describe why it is important to perform field measurements.
3. Propose a solar assisted heat pump system and introduce its operation modes and control strategy.
4. Follow a methodology to access hybrid heat sources to balance the loads on a borehole thermal energy storage system.

Simulation of Novel Air-Source Heat Pump with Two-Stage Compression and Economizing for Cold Climate Field Tests

*Stephen Caskey, Student Member[1], Derek Kultgen, Student Member[2], **Eckhard Groll, Ph.D., Fellow ASHRAE**[3] and William Hutzel, P.E., Fellow ASHRAE[2], (1)Purdue University - Ray W. Herrick Laboratories, West Lafayette, IN, (2)Purdue University - Mechanical Engineering Technology, West Lafayette, IN, (3)Purdue University, West Lafayette, IN*

This paper presents a new air-source heat pump that is optimized for colder climates. The heat pump is to provide 65,000 Btu/hr (19 kW) of heat at an ambient temperature of -5^{0}F (-21^{0}C) while achieving heating COPs that are approximately 45% of the maximum theoretical Carnot heating COP. The testing site requires the heat pump to operate on single-phase power but larger system capacities become feasible when utilizing three-phase power. A major modification from conventional air-source heat pumps is the use of two-stage compression with economizing; the high-stage compressor is a variable speed scroll compressor and the low-stage compressor is a large displacement fixed speed, tandem scroll compressor. All components were selected based on commercially available products. This will aid the commercialization potential of the system. The sizing of components was determined by simulating the system at different conditions and compressor configurations. Two heat pumps of identical design are installed in two barracks buildings at Camp Atterbury in Southern Indiana for field testing over the course of a year. Each building has two HVAC systems and one in each is replaced by a heat pump to provide accurate comparisons to conventional HVAC systems. Six performance objectives will be used to outline the comparisons; primary energy consumption, cost, emissions, installation and operation difficulty, and comfort. Each objective has defined conditions to quantify a successful demonstration and motivate the feasibility of commercialization.

Field Measurements to Demonstrate the Potential for Heat Pump Systems

***Pia Margareta Tiljander, Ph.D.**, SP Technical Research Institute of Sweden, Borås, Sweden*

Measurements of five heat pump facilities used for space heating and tap water in single-family houses were performed. The duration of measurements was one year. The purpose was to show the potential of heat pump technology in order to raise the acceptance of the technology, and to show that heat pumps are energy efficient in cold climate. Another goal was to achieve further knowledge of how SPF is influenced by different system solutions. Parts of this study are the Swedish contribution to IEA HPP Annex 37 "Demonstration of field measurements of heat pump systems in buildings" Included in the study are two buildings with geothermal heating, one with geothermal heating combined with solar panels, one brine/water heat pump connected to a ground storage combined with solar panels, and one building with an air/water heat pump combined with solar panels. The data collected in the project are temperature and volume flow on heat carriers and tap water, as well as electrical energy which the heat pumps and circulation pumps uses. Seasonal performance factor (SPF) energy coverage ratio, energy savings and CO_2reduction were calculated. There is a potential of energy savings and CO_2 reduction by using heat pump technology. Energy savings are up to 75% of the supplied heat. CO_2 reductions are influenced of which type of heating system the heat pump system is compared to, and how the electric energy is produced. When reporting results from field measurements, it is important to state which electrical components are included in the analyses. In this study, the system boundaries defined in the European project SEPEMO-build were used. SPF was determined to 4.0 - 2.8 for the different sites when all electrical equipment were included in the calculations. SPF decreases with decreased needs of space heating, which implies that heat pumps are energy efficient in cold climates. When evaluating heat pump systems it is important that, together with the SPF value, considers other performance indicators, such as energy demand, energy coverage ratio, CO_2 emissions, availability etc. This is most important for heating systems where a heat pump is combined with other heat sources.

A Solar Assisted Heat Pump System for Space Heating in Extremely Cold Areas

Yin Ping Yu, Yiqiang Jiang, Ph.D., P.E., Member and Yang Yao, Ph.D., P.E., Institute of Heat Pump and Air Conditioning Technology, Harbin Institute of Technology, Harbin, China

Considering the problem of energy shortage and rising price, solar energy as a kind of persistent energy source is becoming highly valued. Especially in extremely cold areas, the amount of energy consumed on space heating is huge, and the air pollution is very serious. Solar heating has great benefits in both economy and environment. In this study, a solar assisted heat pump(SAHP) system has been proposed, which consists of solar collectors, a thermal storage tank, a water source heat pump, auxiliary gas-fired boiler and heating terminal. The hot water storage tank is a solution of the discontinuance of solar energy that can provide low temperature water to heat pump. The system has many operating modes in different weather that shows good ability of energy conservation. Cooperated with effective control strategy, collected solar energy is used at the maximum extent. A system had been built in Daqing, China. It was responsible of space heating for 4000 square meter. The operating data from 2009.11 to 2010.4 shows that the gas-fired boiler only ran 360 hours during the 180 days. The heating expense is about 15 RMB each square meter while the district heating expense is 45 RMB each square meter. The investment payback period is 5 years. Such results will provide helpful reference for the potential application of SAHP system and future research work.

Balancing Act: Avoiding Ground-Source Permafrost and Optimizing Energy Storage in Heat Pump Systems for Cold-Climate Hospitals

***Trond Thorgeir Harsem, P.Eng.*[1]*, Robert Martinez, P.Eng.*[1]*, Vidar Havellen, P.Eng., Member*[1] *and Vladyslav Shchuchenko, P.Eng.*[2]*, (1)Norconsult AS, Sandvika, Norway, (2)Telemark University College, Porsgrunn, Norway*

Hospitals generally have large internal heat gains in core areas from diagnostic imaging and other medical equipment. Hospitals in Scandinavia also have a building envelope with large facades and glass for daylight and outside views. These factors, combined with high ventilation airflow rates and long occupancy schedules, make hospitals the most energy intensive of all building types. Ground source heat pumps can deliver both heating and cooling to such buildings, but their cold-climate performance will be much reduced without a well-designed energy collection and storage strategy. Poor collector design or improper dimensioning can lead to much reduced ground source effectiveness or permafrost formation. The timing of heating and cooling demands can also lead to reduced effectiveness due to higher return temperatures or increased compressor work. The authors show how these challenges can be converted into a cold climate advantage through the use of a seasonal energy balancing technique and storage elements to absorb variation. The authors also define a new metric for quantifying the overall energy performance from investing in increased storage capacity at different timescales. This metric is then used in case studies of actual buildings in Norway to compare several cold-climate thermal storage and free-cooling strategies. The energy balance method allows the HVAC designer to quickly evaluate different strategies to leverage both "free-heating" from the internal heat gains and free-cooling from the target climate without the need for a detailed thermal model. This approach will help to determine the cost-effective amount of extra thermal building mass and ideal number of ground-source boreholes. The method is also used to assess the performance of newer collectors which increase energy transfer in the ground source for the heat pump. The approach described in this paper may have cold-climate applications to other building types with large internal heat gains from process loads.

Wednesday, November 14

Wednesday, November 14, 8:00 AM-8:30 AM

KEYNOTE

Natural Ventilation in Cold Climates

Room: Imperial Ballroom 5-7-9

Chair: Frank A. Mills, P.E., Member, McGrath Mills Consulting Engineers, Leyland, United Kingdom

Natural ventilation is an attractive approach to zero carbon/ energy ventilation and cooling as it often reduces investment in expensive plant and equipment by using openings in the building fabric to allow air flow into, through and out of the building and can also operate without using any fossil fuels by using 'natural' driving forces - thermal and wind. Of these thermal is the preferred method as it is more effective and reliable than wind energy and can be modelled and visualised through a simulation programme to study performance through a range of climatic conditions. Wind could be used but is dependent on weather conditions which are notoriously variable. In practice wind speeds are often low when high air flows are needed.In cold climates the thermal buoyancy effect is particularly high due to the temperature difference between outside and inside and the forces of cold air trying to enter and hot air trying to exhaust. This is a very useful driving force but must be controlled to ensure warmth and comfort is achieved alongside air quality, acoustics and fire safety. This presentation considers the scope for and design approaches to achieve successful natural ventilation in cold climates.

Wednesday, November 14, 8:45 AM-10:15 AM

CONFERENCE PAPER SESSION 7a

Wind, Stack and Envelope Airtightness

Room: Imperial Ballroom 5-7-9

Chair: Anil Parekh, P.Eng., Member, Natural Resources Canada, Ottawa, ON, Canada

Wind and stack pressures are natural forces which drive air leakage across building envelopes. This air leakage results in uncontrolled ventilation which increases energy costs and may reduce occupant comfort, contribute to IAQ problems and cause moisture related problems in exterior walls. In addition, designing HVAC systems for unknown levels of "natural ventilation" may result in significant oversizing of HVAC system. While it may not be practical to try to reduce wind and stack pressures across building envelopes, reducing air leakage areas (i.e., improving building envelope airtightness) is practical. Papers in this session explore specific problems created by the natural forces of stack and wind pressures in buildings and challenges of and methods for reducing uncontrolled air leakage in buildings.

Learning Objectives:

1. Understand cold air infiltration through main entryways in tall buildings.,
2. Explain the role of wind lobby in food supermarkets.
3. Describe the effect of uncontrolled ventilation on vertical temperature distribution.
4. Understand how energy consumption can depend on air tightness.

Tall Building Infiltration At Main Entryway

Derek A. Whitehead, P.Eng., Associate Member[1] *and Andrea Frisque, P.Eng., Associate Member*[2]*, (1)Ty Bob Consulting Ltd., Salmon Arm, BC, Canada, (2)Krieger SRM, Vancouver, BC, Canada*

In cold climates, infiltration plays a particularly important role in building conditioning, comfort, and energy efficiency. Designers need reliable tools to estimate the level of infiltration. The purpose of the research described in this paper is to evaluate the range of applicability of the RP-763 Method to estimate tall building infiltration at main entryway doors; recommendations are made to improve on the estimate. The RP-763 Method is published in the most recent ASHRAE Fundamentals and therefore quite widely used. In this paper, an estimate calculated using this method is compared to results from a multi-node airflow analysis for a range of scenarios. The example shown in ASHRAE Fundamentals is reproduced using a model with differing air path areas representing small, medium and large footprint buildings, three different construction tightness levels, and two different wind pressure coefficients at the main entryway. All simulations produced infiltration estimates ranging from 8.5% to 44% of the estimate shown in ASHRAE Fundamentals, meaning that the RP-763 Method over predicts infiltration by 127% to 1076% in the studied cases. As these are all over predictions of the airflow, the estimate is always conservative; however, an error in the orders of magnitude might not always be acceptable. It is important for designers to know what the limitations of the estimation method are so they can make informed choices about when to use more advanced analyses based on actual air pathways and construction tightness levels. The comparison of the estimation method and a more detailed analysis provided in the present paper provides valuable information to support designers.

Practical Stack Effect Study to Minimize the Problems Related to Pressure Difference in Severe Cold Climate

Jae Hun Jo, Ph.D.[1]*, Hoi Soo Seo, M.D.*[2]*, Myoung Souk Yeo, Ph.D., Member*[3] *and* ***Kwang Woo Kim, P.Eng., Member***[2]*, (1)Inha University, Incheon, South Korea, (2)POSCO E&C, Incheon, South Korea, (3)Seoul National University, Seoul, South Korea*

Stack effect is a natural phenomenon which occurs in all buildings. In tall buildings, especially during the winter season, it is considered to be the most serious issue than any others which are commonly raised such as wind effect. This paper presents a practical study to minimize the impact of stack effect in a 42-stories office building in extreme winter conditions, -13°C. Both architectural and mechanical drawings were reviewed in order to understand the airflow dynamics and field measurements were carried out to generate the pressure distribution caused by stack effect. Two recommendations were suggested which can reduce the stack effect problems most effectively: increasing the airtightness of building envelope and adding compartmentalization or separation to provide air barrier to the airflow path inside the building. In terms of mechanical approaches, it is suggested that stack effect pressure at higher part of the building can be managed by pressurizing the building using HVAC systems. In order to investigate the pressure and the airflow rates within the building, a detailed network model of the building was developed based on as-built drawings. Various scenarios of airflow simulations were carried out to evaluate the impact of stack effect, wind and the operation of HVAC systems. It was found that stack effect problems can be solved by increasing the airtightness of building envelope, by adding architectural compartmentalization, and by using HVAC systems.

Wind Lobby Analysis: Effects of Uncontrolled Ventilation in Food Supermarkets

Sahm Sawaf[1], *Janet Barlow*[1], *Emmanuel Adu Essah*[1], *Jeremy Broadbent*[2] *and Bob Gregson*[2], *(1)University of Reading, Reading, United Kingdom, (2)Johnson Construction Ltd., Delph, United Kingdom*

Mechanical ventilation systems account for a substantial proportion of the total energy consumption of retail buildings within the UK. Air infiltration through openings in the fabric of the building can increase the energy demands, as well as reducing the level of comfort on the shop floor for staff and customers. Entrances in supermarkets are an aspect of uncontrolled ventilation, where airflow is determined by door sizes, positions and opening frequency. Draught is caused by wind-induced pressure forces and buoyancy forces and these often act together. In order to reduce their impact, building designers often specify wind lobbies, which are often costly and may not always be effective. However, limited information is available in current literature regarding the success of such wind lobbies in buildings. The aim of this study is to assess the effectiveness of a wind lobby in reducing uncontrolled ventilation in a food supermarket. To improve upon current knowledge, data logging sensors are being installed to monitor the temperature and the relative humidity in a centrally air-conditioned store. The selected store is in Yorkshire, where the recorded average winter temperatures in 2010 were 4.1°C, -1.0°C, and 1.5°C for maximum, minimum and mean values respectively. The store has an approximate sales area of 5000m^2; however, because of concerns relation to the wind lobby, the research focuses on the front of the store, where an air curtain and a wind lobby are installed. The wind lobby dimensions are for the length, width and height respectively. Tinytag data loggers recording every two minutes are installed inside and outside the lobby at and heights. These heights were identified based on CFD simulations. Monitoring will take place over different seasons from January 2012 for one year to assess the variability in uncontrolled ventilation and how it is related to external weather conditions. Results will be presented concerning the temperature distribution around the wind lobby, and thus how effective it is in reducing cold air infiltration. If time permits, the results will be compared with energy use within the store, and the performance of the HVAC system.

Air Tightness and Energy Efficiency

Timo Kauppinen, Member[1], *Markku Hienonen*[2] *and Sami Siikanen*[1], *(1)VTT Technical Research Centre of Finland, Oulu, Finland, (2)Building Supervision Office of City of Oulu, Oulu, Finland*

After Energy Performance of Buildings-directive (EPBD) came into operation inside the European Union, Finland began the work to adjust building codes matching the new directive. There was no regulation dealing with air tightness before, but when the building codes were changing, the air tightness was taken into the codes. The changes in building codes caused an emergent interest to measure and to improve air tightness of buildings. Also measuring of air tightness was certified as building thermographer before that. In the new building code was also mentioned that the air tightness of a building can be measured also using the own ventilation system of the building. In this paper results and experiences of air tightness measurements of different buildings has presented using own ventilation system of the building. The results have also been compared with the results of coincident blower-door measurements. Some suggestive calculations of the effect of air leaks for energy efficiency have also been made dealing with various levels of air tightness. Also the use of two-stage thermography in locating air leak patterns has been introduced. The use of building's own ventilation system can be used in evaluation the level of air-tightness, but the results differs from achieved using blower-door method.

Wednesday, November 14, 10:30 AM-12:00 PM

CONFERENCE PAPER SESSION 8a

Alternate Energy Sources and Generation

Room: Imperial Ballroom 1

Chair: Andris Kreslins, Dr.Ing., Riga Technical University, Riga, Latvia

Buildings in cold climates face high space heating demands which are often coupled with relatively expensive unit energy costs. Therefore, innovative ways and means of maximizing utilization of available energy resources are of interest. Papers in this session explore some of those ways and means, including cogeneration, combined heat and power (CHP), heat and power generated in a biomass-waste boiler and district heating coupled with thermal power generation and heat pumps.

Learning Objectives:

1. Learn the energy loads to and from a ground heat exchanger.
2. Explain the greenhouse gas reduction from operation of mCHP systems.
3. Describe the selection of the heat pump/chiller for the boiler plant.
4. Understand the barriers faced by mCHP by national gas and building codes.

Cogeneration Unit with Absorption Heat Pump for DH System

Egils Dzelzitis, Dr.Ing., Member[1] *and* ***Agnese Lickrastina, Dr.Ing.***[2], *(1)Latvian Enterprise of Advanced Heat, Riga, Latvia, (2)Riga Technical University, Riga, Latvia*

Energy systems in the cold climate regions requires large amount of the energy resources to ensure certain quality of the indoor climate. District heating systems proved to be among the most efficient energy supply systems for the cold climate regions as they are comparatively easy to optimize and ensure high efficiency for the entire energy production chain. However still one of the key issues for the energy suppliers is further increase of the efficiency for the energy production. One of the boiler plants of the Riga District Heating system has undergone several reconstructions in order to become a high efficiency boiler plant. Firstly the ordinary boiler plant with steam and hot water boilers has been reconstructed to be the cogeneration plant supported with the hot water boilers. Further increase of the energy production efficiency required the decrease of the heat losses from the cogeneration unit through the cooling towers. Due to that one of the cooling towers has been replaced by the absorption heat pump thus installing the closed cooling water circulation system and recovering 2 MW low grade heat otherwise lost in the atmosphere and producing atmospheric pollution. The driving force for the absorption heat pump is steam produced by the steam boiler already located in the boiler plant. The efficiency of the absorption heat pump recovering low grade heat from the cogeneration units and increasing the heat supply to the DH system is closely related with the supply and return water temperature regimes that are regulated according the actual outside temperature. The more efficient energy production system allows decreasing the fuel consumption for the same amount of the produced energy with the following decrease of the expenses for the energy production and reduced amount of the polluting emissions into atmosphere.

Demonstration of a Micro Combined Heat and Power Plant in a Commercial Facility in Regina, SK

Shawn M. Wedewer, P.Eng., Member[1], ***Chris M. James, P.Eng., Associate Member***[1] *and Ray Sieber*[2], *(1)Saskatchewan Research Council, Regina, SK, Canada, (2)City of Regina, Regina, SK, Canada*

Combined heat and power (CHP) or cogeneration technologies that utilize natural gas are emerging as an economic and efficient method of heat and electricity production. There are many examples worldwide of large CHP (>150kW) systems that are part of district heating systems or incorporated into refineries to offset their electrical use and provide required process heating. There are very few small (50–150kW) or micro (<50kW) CHP systems installed in Canada, however, some regions have an abundant supply of natural gas, greenhouse gas-intensive electrical production and cold climate which makes CHP a good potential choice for space heating and distributed electrical production. The paper will detail the demonstration of a micro CHP (mCHP) system with a field-measured performance of 69.6% combined cycle efficiency; the system was integrated into a manufacturing plant located in Regina, Saskatchewan, to provide the building with base load space heating and electrical energy production. The prototype mCHP system was developed by Advance Engine Technologies (AET), and it is the first mCHP system with a 5.6 $kW_{electric}$, 13 $kW_{thermal}$ output with black start technology to operate as a back-up generator during grid power outages. The mCHP system was incorporated into the existing heating system through the use of heating coils installed on existing natural gas furnaces and a heat recovery ventilator. The system was commissioned in March 2010 and the paper will cover monitored results and observations until March 2011. The monitoring results show that nearly 185 GJ of useable heating energy and nearly 19,000 kWh of electrical energy were produced by the CHP system over its 3,800 hours of operation. The heat and power production on site showed a 34% reduction in greenhouse gas emissions when compared to using existing natural gas heating systems and purchased electricity from the grid. Examination of the effect of parasitic electrical loads on the output will be included. Electrical demand reduction and increased natural gas consumption will also be discussed.

600 Kw Clean Bio-Mass Power Plant

Raj Bhargava, P.E., Member, RBA Engineers, Inc., Anchorage, AK

This paper will address the design and layout of the 600 kW Clean Bio-Mass Power Plant, under construction in North Pole, Alaska, USA. The plant uses waste paper and cardboard to generate heat in a boiler, after forming dense pellets for proper burning. The owner has a perpetual contract with the solid waste recycler to obtain up to 14,000 tons of paper waste per day. The boiler uses a high-temperature, low pressure heat transfer fluid, Therminol-66, (boiling point = 650°F) heated to 500°F; the Therminol-66 passes through two heat exchangers, returning at 300°F. On the heat exchanger cold side, refrigerant R245FA is heated from 240°F up to 410°F and the pressure is increased from 30 psi, up to 250 psi. This high pressure refrigerant drives (5) 125 kW turbines which rotate at 28,000 RPM, with magnetic bearings, to generate AC power. A rectifier-inverter polishes this into utility-grade AC power, at 60 Hertz, which is back fed into the power grid, as a basis for “green” recycled power. Eventually, the carbon dioxide from the combustion process will be connected to a greenhouse for absorption by plants, to form the first commercial power plant without a smokestack, notable because it is located in an arctic climate zone.

District Geothermal Energy and Waste Heat Recovery

Ed Lohrenz, Member, *Geo-Xergy Systems, Inc., Winnipeg, MB, Canada*

Remote northern communities often must import energy to sustain life. Diesel generators are often employed to provide electricity in small communities. Even if wind or solar energy can provide a portion of the electricity needs, diesel generators are used for back-up power. There are often other energy sources in northern communities, such as refrigeration plants in ice arenas, manufacturing process heat, etc. Detailed energy modeling, site planning to take advantage of such synergies, and energy storage can reduce energy consumption in many of these remote communities. A ground heat exchanger (GHX) will operate as a storage medium on both a short term as well as on a seasonal basis. Waste energy can be stored in the ground and extracted as needed. By working with the building owner(s) and/or design teams for new buildings, and with the community, it is possible to take advantage of diverse building loads, reduce the cost of constructing a GHX and ensuring the system is sustainable over the long term.

Wednesday, November 14, 1:30 PM-3:00 PM

Cold Climate Design Guide Workshop

Room: Imperial Ballroom 5-7-9

Chair: Frank A. Mills, P.E., Member, McGrath Mills Consulting Engineers, Leyland, United Kingdom

This session is the launch meeting for a new design guide which focuses on the technical challenges, sustainability issues and opportunities in Cold Climates. It will establish the scope of the guide – from concepts of warmth, comfort, health and wellbeing in cold climate regions, the types of systems and equipment to provide heating, ventilation, humidification and even cooling where that is required to the energy sources including the challenge of Net Zero energy/ Carbons as fossil fuels are depleted. Anyone involved in the design, construction, operation, commissioning, testing of buildings, or the manufacture of plant and equipment for Cold Climates, should attend to help define the Scope and Content of this important ASHRAE publication.