Energy – saving potential of the HBIVCU system

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Energy – saving potential of the HBIVCU prototype: *The HBIVCU (Hospital Bed with Integrated Ventilation and Cleaning Unit) is an advanced air distribution system that protects the person lying in a hospital bed, from airborne contaminants, by supplying cleansed air, while capturing polluted (may be infected) air he/she exhales in order to protect visitors and medical staff in the room. The ventilation unit can contribute to significant decrease in the exposure of a doctor or other people in the room to contaminated air from a sick occupant in the bed compared to mixing ventilation alone. The use of the HBIVCU system with reduced background total volume ventilation can lead to better air quality with less use of ventilated air. The energy saving potential of the ventilation unit was studied by means of simulations with IDA-ICE software.*

Key words*: Energy – saving potential, IDA ICE simulations, Energy need, HBIVCU system*

INTRODUCTION

Creating healthy and comfortable environment in hospitals is vital for the fast recovery of the patients and the good performance of the medical personnel. Protection of patients, visitors and medical staff from airborne cross infection is of great importance. For this reason the ventilation rates in modern hospitals are kept elevated in order to decrease the risk of cross infection by diluting the contaminated air in the hospital rooms. The standards and guidelines recommend ventilation rate of up to 12 ACH in infectious wards and 6 ACH in recovery wards and normal patient rooms, [1], [4], [7]. However, the elevated ventilation rates may cause high energy consumption.

The HBIVCU is an advanced air distribution system that can provide better indoor air quality and decrease the risk of airborne cross infection at lowered background ventilation rates by employing more effective air distribution method. The HBIVCU system evacuates the exhaled air close to the breathing zone of the patient in the bed and thus reduces the spread of contaminated air in the room.

The HBIVCU system supplies clean and cool/warm air at low velocity directly to the breathing zone of the occupant. This allows the bed ventilation system to be classified as personalized ventilation (PV) unit. The main strategies for energy –savings with personalized ventilation are as follows:

- Reducing the background airflow rate due to the higher ventilation effectiveness of the PV.
- Expanding the room temperature comfort limits by using the ability of the PV system to create comfortable microenvironment
- Supply the personalized air only when the occupant is present (occupancy schedule), [8].

The use of the HBIVCU provides the opportunity to decrees the background ventilation in hospital rooms to 3 ACH and maintains the standardized air quality conditions at lower energy costs, [3], [9]. The energy saving strategies used in this study are reducing the background airflow rate due to the high effectiveness of the HBIVCU and supply personalized air only when the occupant is present. The reduction of ventilated air in the hospital wards and the occupancy schedule as a strategy for saving energy were investigated with simulations.

METHODS

The European standard EN15265 [5], recommends a format for reporting the input data of an energy simulation. The following presentation of simulation input data follow the guidelines provided by the standard.

1.1 Building location and weather data

In this study was simulated a standard single patient hospital room that was located in Copenhagen (Denmark). The ASHRAE IWEC weather file for Copenhagen was used as input data to the simulation model.

1.2 Description of the Hospital Room

The single patient hospital room had floor surface area of 3m x 6m (width x length) and height of 3 m. The walls of the room were constructed with 0.026 m of plaster (heat conductivity λ=0.6 W/m K), air gap with thickness of 0.032 m (thermal conductivity λ=0.17 W/m K), light insulation with thickness of 0.03m (thermal conductivity λ=0.036 W/m K), 0.200 m clay brick (thermal conductivity λ=0.57 W/m K) and another layer of plaster with thickness of 0.010 m. The overall U- value of the walls was 0.37 W/ m^2K. The simulated window was facing south. It had dimensions of 1.2 m x1.7 m (width x length) and surface area of approx. 2 m^2. The window was composed of external clear glass pane (thickness 4mm), air gap of 12 mm and internal clear glass pane of thickness 4 mm. The overall U-value of the simulated window was 2.9 W/m^2K. The solar transmittance was equal to 0.7 and the visible transmittance was 0.81. There were internal blinds on the window. There was no schedule to the window shading – the blinds were always up.

1.3 Internal Temperature, Ventilation and Infiltration Rate

The indoor operative temperature was kept within the range of 21^{o}C as lower room operative temperature limit and 23^{o}C as upper room operative temperature limit. The designed airflow rate was supplied during the occupancy hours. The supply airflow rate of the AHU system was calculated in order to correspond to the required simulated air change rate. The calculations were done based on the volume of the patient room. The minimum required clear floor area per bed is 10.8 m^2 for single patient room-, [2]. The infiltration rate used for the simulation was wind driven infiltration from the window facade.

1.4 Internal Heat Gains, Occupancy and Description of the HVAC System

In the simulated cases 1 occupant was contributing to the sensible and latent heat load in the room. The activity level of the occupant was 1 met which corresponds to 58.15 W/m^2 of its body surface area. For the room occupancy schedule were simulated two cases: the occupant was either always present in the room or absent for 4 hours from Monday till Friday. The heat load due to equipment in the room was 11 W/m^2. When the occupant was absent for 4 hours the equipment was turned off. The lightning load was 4 W/m^2. The lightning was following a schedule where it was switched off from 22 pm to 7 am and from 9 am to 4 pm. The balance between the sensible and latent heat loads in the room was calculated by the software.

The ventilation system was used to condition the outdoor air supplied to the room without recirculation. The ventilation was operated as constant air volume system which adapts the supply air temperature in order to heat or cool the room. The relative humidity in the room was set to be in the limit from 30% to 50%

1.5 Simulation Software

IDA Indoor Climate and Energy (IDA ICE) is a whole year detailed and dynamic multi-zone simulation application for the study of indoor climate of individual zones as well as energy consumption of an entire building. IDA ICE is a tool for simulation of thermal comfort, indoor air quality and energy consumption. It covers a large range of advanced phenomena such as integrated airflows and thermal models, CO_2 modelling and vertical temperature gradients. The mathematical models are described in terms of equations in formal language named Neutral Model Format (NMF), [10].

RESULTS AND DISCUSSION

The energy saving potential of the bed ventilation system was evaluated by comparing the energy consumption of the system to the energy consumed by the conventional mixing ventilation system. According to the EN 15651 standard, [6], the "energy need" is the sum of the energy for heating (AHU heating) and cooling (AHU Cooling) of the supplied air in order to obtain the desired θ_{sup} and for heating (Room Heating) and cooling (Room Cooling) of the conditioned space in order to maintain the indoor operative temperature within the required range during the period of occupancy.

The energy consumption of the HBIVCU system was investigated for three different modes of operation: isothermal, heating and cooling. When the bed ventilation was operating at isothermal mode the horizontal air jet, which supplies clean air close to the breathing zone of the patient, had the same temperature as the surroundings (23^{o}C). When the system was operating in heating and cooling modes the temperatures of the horizontal air jet were 26^{o}C and 20^{o}C correspondingly. Two supply flow rates of the personalized air were tested 3 L/s and 5 L/s, which corresponded to 25% and 100% fan power.

Figure 1 shows the results from the simulated cases of operation of the HBIVCU system at 25 % fan power compared to the reference cases when the total volume mixing ventilation was working alone at different air change rates. Compared to the reference cases of 12 ACH and 6 ACH, which are the recommended ventilation rates by the standards, the use of the HBIVCU with reduced background ventilation rate can lead to energy savings of approximately 73% compared to the case with background ventilation of 12 ACH and with 61.1% compared to the case with background ventilation of 6 ACH. Compared to the reference case of total volume ventilation at 3 ACH only the HBIVCU system will consume approx. 9.1% more energy.

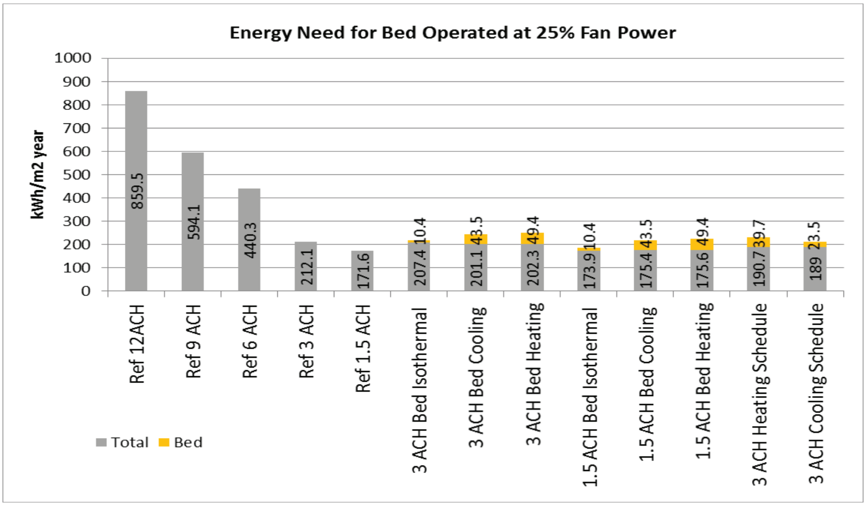

Figure 1 Annual energy need for single patient room with installed HBIVCU system operating at 25% fan power

The results from the simulated different modes of operation of the HBIVCU system at 100% fan power are presented on Figure. 2 The energy needs of the reference cases are shown for comparison. When the system operates at 100% fan power with reduced total volume mixing ventilation the energy need will decrease with approximately 70.6 %

compared to the reference case of 12 ACH mixing ventilation alone and with 57.5 % compared to 6 ACH mixing ventilation alone. The operation of the bed ventilation at 100% fan power will increase the energy need on average with 20.7% compared to the reference case when the total volume ventilation was working alone at 3 ACH.

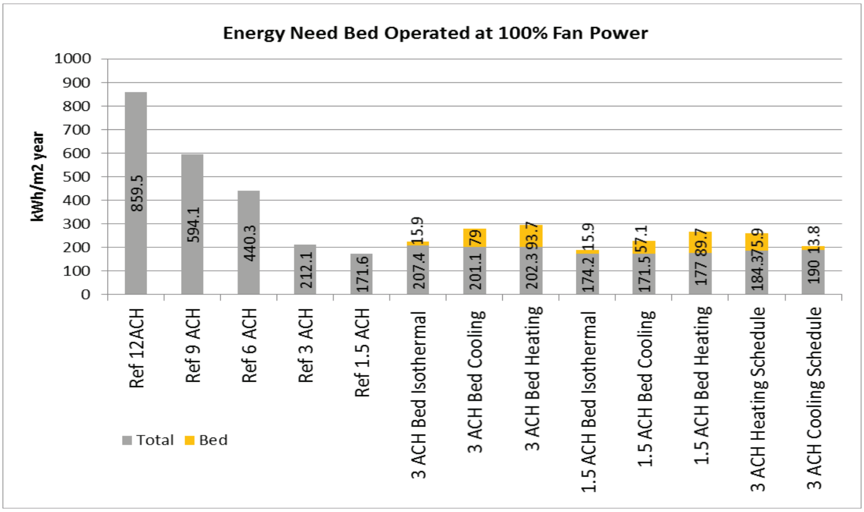

Figure 2 Annual energy need for single patient room with installed HBIVCU system operating at 100% fan power

The best performance of the system in terms of percentage saved energy was when the unit was operated in isothermal mode. From Figure 1 and Figure 2 it can be observed that operating the HBIVCU system at 25% fan power saved approx. 10% more energy compared to the case when it was operated at 100% fan power.

CONCLUSION

The use of the HBIVCU system with reduced background mixing ventilation is an effective energy saving strategy for a single patient hospital room. Compared to the mixing ventilation alone at 6, 9 and 12 ACH the use of the bed ventilation unit in a single patient hospital room can decrease the energy need with approximately 32.8% to 75.3% depending on the operation mode of the prototype. The HBIVCU system may gain advantage over conventional mixing ventilation systems not only by having a significant energy saving potential, but also by creating more healthy and comfortable indoor environment for the occupants.

References

[1]. ASHRAE/ASHE Standard, 170-2008, “Ventilation of Health Care Facilities, American Society of Heating, Refrigerating and Air-conditioning Engineers”, Inc. 1791 Tullie Circle NE, Atlanta, GA 30329

[2]. AIA (2001). “Guidelines for design and construction of hospital and health care facilities.” Washington, D.C., American Institute of Architects, Academy of Architecture for Health., Facilities Guidelines Institute, United States

[3]. Bolashikov, Z.D., (2010). “Advanced methods for air distribution in occupied spaces for reduced risk from airborne diseases and improved air quality.” PhD Theses,

Department of Civil Engineering, Technical University of Denmark, p. 61

[4]. [4] CDC (2003). “Guidelines for environmental infection control in health-care facilities.” Atlanta, GA 30333, U.S. Department of Health and Human Services Centres for Disease Control and Prevention (CDC).

[5]. CEN (European Committee for Standardization), EN 15265-2006, Thermal Performance of Buildings – Calculation of Energy Use for Space Heating and Cooling –General Criteria and Validatio

[6]. CEN (European Committee for Standardization), EN 15615-2007, Explanation of the General Relationship between Various European Standards and the Energy Performance of Buildings Directive (‘‘Umbrella Document’’), European Committee for Standardization, Brussels, Belgium, 2007.

[7]. DS 2451-9, Styring af infektionshygiejne i sundhedssektoren – Del 9: Krav til indkob og vedligehold af teknisk og medicinsk-teknisk udstyr, Dansk Standard – Danish Standards Association, 2003-04-30

[8]. Schiavon S., Melikov A. (2008), “Energy saving strategies with personalized ventilation in cold climates”, Energy and Buildings 41 (543 - 550)

[9]. Melikov, A., Bolashikov, Z., Georgiev, E. (2011). “Novel ventilation strategy for reducing the risk of airborne cross infection in hospital room.” In: Proceedings of Indoor Air 2011, University of Austin, paper 103.

[10]. Vuolle M., Sahlin P., “IDA indoor climate and energy application”, in: Proceedings of Healthy Buildings 2000, vol. 2, 2000, pp. 523–528

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This paper has been reviewed.