PERFORMANCE OF HEATING SYSTEMS FROM THE POINT OF ENERGY CONSUMPTION AND THERMAL COMFORT IN DWELLINGS

D. Petrás[1]

[1] *Department of Building Services, Civil Engineering Faculty, Slovak University of Technology, 813 68 Bratislava, Slovakia*

ABSTRACT

The quality of indoor environment in dwellings is provided by physical properties of building constructions and by operation of HVAC-systems. From the point of view of comfort, energy and economy as well as HVAC-system are designed and operated to maintain an acceptable indoor climate, i.e. an acceptable air quality and thermal environment play the key role in dwellings.

KEYWORDS

thermal comfort - heating system - energy consumption - dwellings

INTRODUCTION

The indoor climate becomes one of the main determinants of a man's life. There might occur a question why to bring a man in a dwelling in the state of thermal comfort? The term of comfort sounds like luxury but it should be treated very carefully. In the middle of the 70-ties in the last posthumously presented publications of Nevis there he said:"....Environmental control has caused human progress, not resulted from it. It has become a necessity rather than a luxury.", Nevis (1975).

Most of these problems are caused by operation of heating system, because of the influence of so called thermal-hydraulic stability on thermal regime in heated interiors of dwellings. On the other hand in the past there was found that thermal effects in dwellings during the heating season result in a general increase of indoor/air temperature and that man accepts in winter more positively the warm discomfort rather than the cool one.

Therefore we hypothesis an impairment of thermal comfort either towards cool or warm sensations during the heating season to cause higher temperatures and higher energy consumption. People behave like assuring their thermal state ahead with respect to "worse times". There is an underlying assumption that the best indoor thermal environment never needs to be noticed and that once an objectively "comfortable" thermal environment has been provided all of our needs will have been met, Petrás (1988).

THERMAL COMFORT

The thermal comfort criteria in heated dwellings from the point of building construction must be provided by following thermo-technical properties:

a) thermal resistance of structures,
b) thermal capacity of structures,
c) thermal accumulation of floors,
d) thermal stability of rooms,
e) water condensation on structures,
f) air infiltration through structures.

The prior building constructions are designed under the assumption of quasi-stationary state, where indoor air temperature is being considered 20 °C. Then thermo-technical properties of engineering structures must guarantee the basic thermal state of heated interiors which in our climatic conditions is expressed by the following values (according to the mentioned properties):

a) indoor surface temperature is higher than 16 °C by vertical and 17.8 °C by horizontal outside structure,
b) temperature amplitude on indoor surface of envelope structures must be lower than 0.6 K during the heating season,
c) floor temperature is 17°C and more,
d) so called total temperature of rooms (sum of indoor air temperature and mean surface temperature) must be in heating season higher than 38°C, by intermittent heating can not drop lower than 32°C,
e) indoor surface temperature of outside structures must be always higher than dew-point temperature, i.e. under assumption of indoor air temperature 20°C and at relative air humidity 64% can not be lower than 12°C,
f) air infiltration through structures can not cause the drop of temperature in the crevice higher 0.2 K,

Here it was said values of thermo-technical properties of engineering structures must guarantee the basic thermal state of heating interiors and their exact calculation is made under the assumption that indoor temperature in interiors is 20°C.

The heating systems are designed secondary. The supposed thermal condition of heated interiors, which is characterized by a so-called globe temperature, is used in its design. The globe temperature values for dwellings are changing are changing in dependence on the kind of rooms. In this non-direct way the human activity and clothing are taken into consideration. For example, globe temperature for occupied spaces is 20°C, for bathrooms 24 °C and corridors 15°C, and for the heated staircases only 10 °C.

From the point of energy conservation by heating of dwellings the globe temperature must be controlled according to the following values during the day:

a) required mean globe temperature from 8 AM to 9 PM should be 18 °C,
b) globe temperature between 10 PM and 6 AM can drop about 3 °C but not lower than 16 °C in occupied rooms, of about 5 °C in other spaces,
c) temperature difference of the same two randomly chosen rooms situated among bottom and top floors must not be more than 3 K.

HEATING SYSTEMS AND THEIR PERFORMANCE

Heating systems can essentially classified as falling into the following categories:

a) by type of heat sources:
- central heating (fossil fuel, liquid fuel, natural gas or electrical heat - only boiler plant),
- decentralized heating (direct heating equipment),

b) by type of heating medium:
- water (hot water, high temperature and low temperature water distribution networks),
- steam (medium-pressure, low-pressure steam distribution networks),
- hot air distribution network,

c) by type of heat transfer:
- convective heat transfer (heating convectors, hot air blowers, ventilation and air-conditioning units),
- radiant heat transfer (large-area, hung radiant panels, infra-radiators).

The choice of the heating system is determined by:

- heating source and fuel type selected,
- the distribution network selected,
- the type of heat transfer used in the heated buildings.

Most of all the heat supply control is remarkably influenced by the operation of the heating system under so called transient regime, e.g. at the changes of heat conductivity coefficient in dependence on water flow, on the pressure losses due to friction, on flow speed and water kinetic viscosity etc. It is therefore obvious that when performing control of heat supply to heated interiors with the aim to lower its energy consumption the most important factor becomes ratio of temperature and real outdoor air calculation temperature difference. It is obvious that the real heat need and therefore also energy consumption are in reverse proportion to the temperature gradient of heating medium.

Without presentation any detail mathematic formulations for warm water heating system 90/70 °C, i.e. with a temperature gradient 20K, under condition that the deviation of globe temperature of the heated interiors are not access ± 1K the following can be state:

a) outdoor air temperature -15 °C a mass flow in the heaters can vary within a range (0.809 - 1,295) x m,
b) at the outdoor air temperature +10 °C and corresponding temperature gradient 46/40 °C a mass flow of the heating water in the heaters can vary within the range (0.607-2,478)x m, where "m" is mass flow of the heating water in kg/h in the heaters which is necessary to reach the final water temperature, Petrás (1988).

To provide the proper thermal regime in heated dwellings under nonstationary run of outdoor climatic parameters using heating systems with a small temperature gradient, the continuous flow change of the heating medium is needed. This should secure that temperature difference of the same two randomly chosen rooms situated among bottom and top floors should be greater than 3 K. This indirectly confirms the thermal -hydraulic stability of the heating system.

ENERGY CONSUMPTION

An obvious step in the conservation strategy of energy is to lower the temperature level in buildings in winter and to raise it in summer. A decrease of 1 °C in winter would alone amount to a saving of 4-6% in heating costs (presuming an average outdoor temperature of 0-8 °C in the heating season). Man s preferred ambient temperature (air temperature = mean radiant temperature) is dependant on his clothing, activity, and furthermore, on air velocity and humidity.

An alternation in clothing can give quite considerable potential possibilities for conservation. Thus air temperature can be dropped 1 °C by increasing usual clothing (0.8-0.9 clo) by 15-20% (sedentary activity). In theory it is possible to avoid heating of building altogether and instead increase the clothing.

Cold, noninsulated walls and windows reduce the mean radiant temperature in a room so that people prefer a higher air temperature. The insulation of walls and windows reduces heat loss not only because the U value is decreased but also because the air temperature necessary for comfort is lower. Radiant heating systems are particularly energy conservation and advantageous in enclosed spaces with a higher air change because a lower air temperature can be maintained.

The air velocity influences the preferred ambient temperature. People can feel draft at mean air velocities of 0.2-0.3 m/s and large velocity fluctuations, while a condition of comfort can be created for them at a velocity as high as 0.8 m/s, as long as the velocity is reasonable uniform (small fluctuations).

Considerable amounts of energy are used today for the purpose of humidification and dehumidification of air. Is this justified from the point of view of human requirement? Humidity in the air has only a moderate thermal influence. At normal ambient temperatures an increment of the relative humidity from 30% to 70% provides the same change of thermal sensation as a 1 °C increment of the ambient temperature. In order to attain thermal comfort, therefore, it is much more important and more economical to control the air temperature rather than the air humidity.

Energy conservation efforts have resulted in tighter and better insulated buildings, reduced capacities of HVAC systems and control strategies that minimize air movement in occupied spaces. These efforts have frequently resulted in elevated levels of contaminants traditionally considered innocuous. Effluents from sources such as synthetic materials, cleaning fluids, environmental tobacco smoke, copy machines and biological organisms have intensified the concern to acceptable IAQ.

Also energy consumption profiles are now available, comparable values of the energy consumed in terms of the indoor environmental quality it maintains is not well documented. For example, are today s building achieving the optimal balance between decreased energy consumption as by reduced ventilation rates and acceptable indoor air quality? Are the more energy efficient variable rates air volume systems of the 1980s providing indoor air quality comparable to that provided by the constant volume/ reheat systems of 1960s? Research devoted to indoor air quality infiltration and ventilation performance in buildings is addressing theses and related questions. Therefore energy may be conserved by tight buildings to ventilate only where and when it is required. The application of air quality sensors to control the ventilation systems is an interesting possibility.

PERFORMANCE OF HEATING SYSTEMS - CASE STUDIES IN SLOVAKIA

During the last decades three separate case studies were carried out under the Slovak climatic, material and technical conditions. One comprehensive about the actual state of indoor climate in dwellings in the locality of interest and one specialized interested only in subjective evaluations and energy consumption in selected buildings in the same locality. The method was combined from objective and subjective evaluations.

Results 1

The most important results from the experiments are that neither requirements on building constructions nor on HVAC-systems alone could guarantee without an effective price policy expressive energy-savings in dwellings. By objective evaluations the mean indoor-air temperatures are higher than previously expected in both living rooms and bedrooms. Thermal sensations, in this case as a statement of thermal preference, indicate that in spite of higher indoor-air temperatures people declare to wish a further slight rising. On the other hand the actual energy consumption for heating of the specific flat was about 10% higher than the theoretically calculated value and the same 10% of the tenants felt themselves in positive thermal discomfort because of overheating.

The found mean indoor-air temperatures are in a good correlation with the measured energy consumption. The energy consumption is being calculated under the assumption of the indoor-air temperature being 20°C. The measured energy consumption was about 10% higher than the calculated one. Under the Slovak conditions represents an increase in indoor-air temperature of 1°C approximately 6% higher energy consumption. Thus the found increase of about 2,5°C theoretically represents an increase of approximately 15% of heat energy.

Results 2

The two buildings were compared based on the following 2 parameters:

a) An overall heating energy consumption for the whole building during the measurement between Febr.25 and March.25 1992:

Kamzík E = 45,5 MWh
Hrebienok E = 42,3 MWh

b) Heating energy consumption for the whole heating period, recalculated for a reference flat with a 200 m^3 volume:

Kamzík E = 9,242 + 2,0 MWh/flat and year
Hrebienok E = 8,411 + 1,64 MWh/flat and year

The heating energy saving is 9% when we take as a reference the heating energy consumption for the reference flat and year in the Kamzík building.

Based upon the results presented here we state that an annual thermal energy consumption in a reference flat within a building with the thermal control valves installed is 9% smaller when compared with an object without those control valves. Hereby we must state that the average indoor air temperatures measured are in both buildings n fact identical. The state of thermal comfort, verified by the subjective thermal feeling of the users, has not been disturbed in any case.

Results 3

In accordance to the answers in the questionary the discussion about the occupant's thermal habits in dwellings Hrebienok (with thermostatic valves) and Kamzík (without the thermostatic valves) is following:

- the total average values of the clothing ensembles are 2 and 1,75, they are almost the same and significantly slightly warm clothing with long sleeves during a heating season,
- the total average of the intensity of air exchange rate are twice a day (Hrebienok) and 2,8 times a day (Kamzík), it means the air exchange rate of dwelling with thermostatic valves is 1/3 lower than in unregulated dwelling,
- the length of ventilation is much lower in controlled building Hrebienok (only 15 minutes) than Kamzík (60 minutes or continually).

The results of our case study aimed at a compare of users of buildings with controlled and uncontrolled heating systems have showed:

1. only minimum differences by subjective thermal evaluation of users of both apartment houses,
2. moderate differences in ventilation frequency and its duration,
3. significant differences in ventilation frequency and its duration.

CONCLUSION

The performance of heating systems in dwellings is the result of the three activities:
a) design,
b) implementation,
c) operation.

Therefore it is very important to keep correct input data for the phase of design, to apply good components of heating systems by implementation and to be sure by adequate measuring and control techniques in operation. If all three points are fulfilled, it should be significant base for either thermal comfort conditions as well as for optimal energy consumption by heating of dwellings.

References

Fanger, P.O. (1972). Thermal Comfort. McGraw -Hill Book Company, New York, 242

Jokl, M (1987). A New COMMECON Standard for Thermal Comfort within Residential and Civic Buildings. In: Indoor Air Quality And Climate-Indoor Air 87, Berlin, **3**, 457-460

Nevis, R.G.. (1975). Energy Conservation Strategies and Human Comfort. *ASHRAE Journal,* **4**, 33-37

Petrás, D. (1988). Quality of Indoor Environment of Thermal Comfort and its Relation to Energy Consumption for Heating in Dwellings. In: Indoor Air Quality and Climate. INDOOR AIR 87, West Berlin, **3**, 487-490

Petrás, D. (1990).Heating System Design and Thermal Comfort Criteria in Dwellings. In: CLIMA 2000, **4**, 83-87

Petrás, D.: Quality of Indoor Environment in Dwellings According to Performance of Heating System. In: Present and Future of IAQ. Elsevier Science Publisher, Brussels, 143 - 246.

PDF | In the light of energy reduction, transitional spaces are recognised as ways to receive natural light and fresh air. This paper analyses the | Find, read and cite all the research you need on ResearchGate.Â demand and thermal comfort of a Dutch low-rise dwelling, at current and future climate in 2050. The inclusion of a. courtyard within a reference Dutch terraced dwelling showed an increase in annual heating energy demand and a. decrease in the number of discomfort hours. In contrast, covering the courtyard and making an atrium led to.Â From the summer thermal comfort point of view, the. indoor operative temperatures of the model needs to be. analysed and compared together. In Figure 3, the indoor. operative temperatures of the reference and the. Energy efficiency of heating systems. In many buildings, HVAC is the first or second item in terms of energy costs. This technical article deals with optimisation tips and energy efficiency savings in heating systems of a building.Â Heating systems have always been used when the outside temperature drops below a certain comfort threshold (a highly relative concept in terms of time and space). The majority of countries in Africa, South Asia and Latin America do not use heating.Â When heat is purchased from a supplier, the energy is delivered via hot water pipes and thermal metering is used for billing purposes. In other cases, thermal energy is generated in a boiler located in the building. Most of the predictions of energy consumption in buildings are based on fixed values related to the internal thermal ambient and pre-established operation hypotheses, which do not reflect the dynamic use of buildings and usersâ€™ requirements. Spain is a clear example of such a situation.Â Adaptive Comfort Control Implemented Model (ACCIM) for Energy Consumption Predictions in Dwellings under Current and Future Climate Conditions: A Case Study Located in Spain. by Daniel SÃ¡nchez-GarcÃa 1 , David Bienvenido-Huertas 2 , MÃ³nica Tristancho-Carvajal 1 and Carlos Rubio-Bellido 1,* 1. heating systems and ventilation systems work together in terms of energy. consumption and thermal comfort. Calculations were done based on a multi-. family residential building.Â for operating characteristic. The crossing point of two curves gives monthly average values of air. infiltration to the building and accounting number degree-days in dynamic. assume. Danish energy consumption by sector 2012. industry transport buildings agriculture and forestry fishing other.Â All heating systems are designed for the critical conditions of a specific climate; however, in reality those conditions rarely occur. Moreover, there will be a different demand on the system due to change in outdoor temperature and internal gains.Â The energy performance and the thermal comfort of the case study are not handled as individual parameters, but as interconnected parts, which combined, will provide the best outcome in terms of comfort and energy consumption. The thermal comfort and energy usage in the case study is evaluated through both measurements and simulations.