Influence of Climate Change on Modelling of HVAC Systems

LÁSZLÓ KAJTÁR - SZILÁRD VÖRÖS
Department of Building Service Engineering
Budapest University of Technology and Economics
H-1111 Budapest, Műegyetem rkp. 9
HUNGARY

Abstract: The selection and design of air conditioning systems in Hungary are based on a determined modelling state. In the last decade this was a safe enough basis for the management of systems. As a result of the changes in the macroclimate, however, there has been a major increase in summer temperatures. Taking into account this fact and the need to develop the earlier deterministic modelling techniques we chose to focus on risk-based modelling.

Key-Words: air-conditioning, risk-based modelling, risk level, enthalpy distribution function

1 Introduction

The selection and design of air conditioning systems in Hungary are based on a determined modelling state. Design parameters given in guidelines and technical regulations have been determined based on results from former longer periods. Although there were summer days, on that ambient temperature was higher than the design value. However these taken slight percent (only a few hours or days) in respect of total cooling period. Due to this, guidelines and prescriptions usually have not dealt with expected risk of design value [3]. In the last decade all around the world and in Hungary changes in the macroclimate could be detected. Hotter and longer summer periods came about than earlier. The same applies to the winter, too. The period between the more extreme winter and summer get shorter. This is why design values according Hungarian standards need to be revised.

2 Problem Formulations

In Hungary the following summer modelling for air conditioning is effective for the design of „h-x" flow charts: t_{out}= 30°C, φ_{out} =45%, h_{out} ≈61 kJ/kg. Air conditioning engineers face a difficult task concerning the macroclimate change. The cooling capacity must be modelled beyond the modelling basis – using their individual considerations and to an individual degree. The need to over-dimension for reasons of safety and the need to win tenders place engineers in a conflicting situation.

Tasks to be solved for the development of the basis of risk-based modelling:

- creating a proper outdoor condition (t, φ, h) database,
- distribution and density functions of outdoor air conditions must be determined,
- distribution and density functions of specific cooling capacity (enthalpy) must be determined,
- an automated air condition measuring system - physical and mathematical - for the above tasks, and the development and starting of the programme system.

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3 Problem Solution

From the perspective of air conditioning technology the key attributes of outdoor air are temperature, humidity and enthalpy. Their values randomly vary from minute to minute. The probability theory starts from the bulk of the elementary results of some experiment (e.g.: air temperature measurement). One single real number can be attributed to each elementary event (the measured temperature). The correlation interpreted with this attribution is called the probability variable. We can talk about discrete and continuous distribution probability variable. The air condition values can take any value within a range and may be regarded as a continuous probability variable.

3.1 Air Condition Parameters as Probability Variables

A probability variable may have an expected value, dispersion, distribution and density function. A probability variable with a continuous distribution is characterized by the distribution (F(x)) and density (f(x)) functions. The probability that the probability value is between „a" and „b":

$$P(a < x < b) = \int_a^b f(x)dx \qquad (1)$$

Total area above density function is given:

$$P(-\infty < x < +\infty) = \int_{-\infty}^{+\infty} f(x)dx = 1 \qquad (2)$$

In any density function the total area is equal to one. Set of elemental events give the total action. The distribution function shows the probability of „t" probability variable taking a value less than „x":

$$F(x) = P(t < x) \qquad (3)$$

The phenomena occurring in nature as continuous probability variable distribution characterise the normal distribution or Gauss distribution amongst various distribution types. Probability variable „t" is the function of the density of normal distribution (see Figure 1.) with parameters „m"(the expected value of the probability variable) and „σ" (the square of the probability variable dispersion):

$$f(x) = \frac{1}{\sigma \cdot \sqrt{2\pi}} \cdot e^{-\frac{(x-m)^2}{2\sigma^2}} \qquad (4)$$

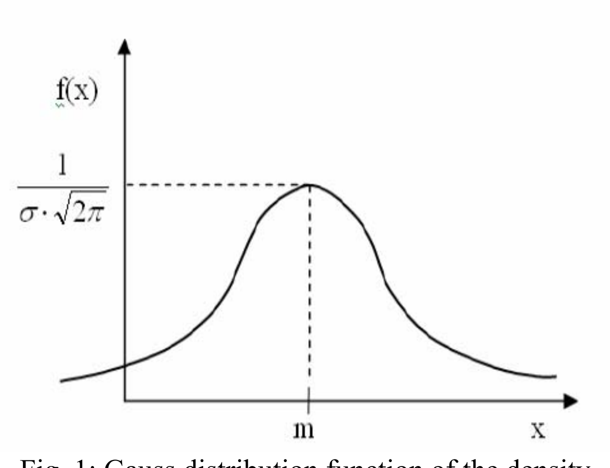

Fig. 1: Gauss distribution function of the density [4]

and the function of the distribution (see Figure 2):

$$F(x) = P(t < x) = \int_{-\infty}^{x} \frac{1}{\sigma \cdot \sqrt{2\pi}} \cdot e^{-\frac{(t-m)^2}{2\sigma^2}} dt \qquad (5)$$

Distribution functions of different outdoor climatic parameters (air temperature, enthalpy) are the base to determinate design values according selected risk level. To risk – based calculation of cooling capacity, mathematical model of cooling process in central unit is necessary with respect of optional outdoor conditions.

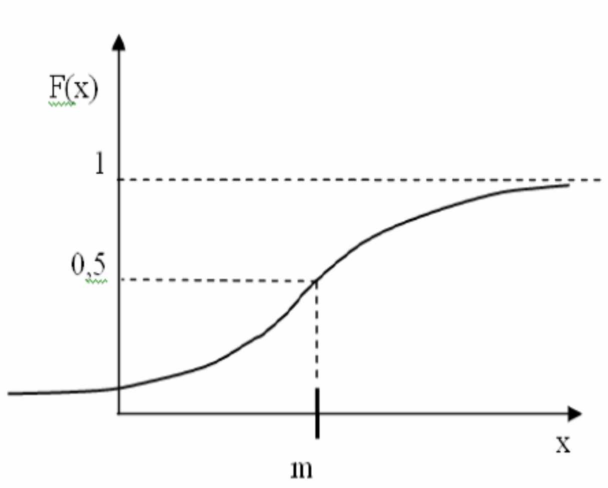

Fig. 2: Gauss distribution function of the distribution [4]

Hereby published model has been developed in case of outdoor air system by given supply air temperature.

3.2 Measurement of Outdoor Air Condition

To develop risk-based modelling there was a need of new database. It has been created by continuous measurements. Because of this, a new measuring and data sampler system has been made since 2003. Outdoor air temperature and relative humidity are constantly measured by a TESTO 175-2 data logger through samples taken every 5 minutes.

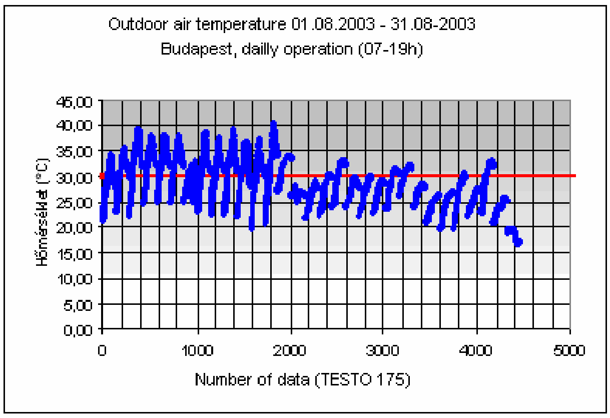

Fig. 3. Outdoor air temperature in August 2003, Budapest (07:00h – 19:00) [6]

It was extremely hot in August 2003 in Hungary. The thin red line represents the design outdoor temperature. In same cases (see Figure 3.) measured temperature dates are much higher than the value of design outdoor temperature. The highest

measured outdoor air temperature value was 40,14°C.
Outdoor enthalpy can be calculated from outdoor air temperature and humidity (see Figure 4.)
With the help of the developed software system the distribution functions of air temperature and enthalpy can be prepared for each month and the whole cooling season.

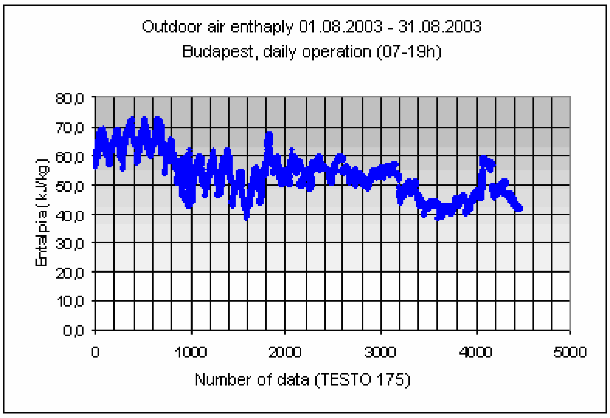

Fig. 4. Calculated outdoor enthalpy in August 2003, Budapest (07:00h – 19:00) [6]

The distribution functions may significantly vary if developed for 24 hours, or only for a half day (07:00h -19:00h), or the night (19:00h-07:00h). The risk levels of air conditioning systems operating continuously or just during the day or during the night certainly differ.

3.3 The mathematical model of air conditioning system

The mathematical model was developed for air conditioning system working with fresh air. Air conditioning process is presented in Mollier chart (Figure 5.). It can be comparable the design and an optional condition. The medium surface temperature of the cooler was set to 13,5°C and the temperature of the supply air was set to 21°C. Based on the theoretical fundamentals and using the developed mathematical model and computer software enthalpy „Δh" cooling enthalpy can be determined for a measurement result:

$$\Delta h = h_{outdorr\ air} - h_{\sup ply\ air} = 12{,}5\, kJ / kg \qquad (6.)$$

With the help of the developed mathematical model and computer software the distribution and density function of „Δh" as probability variable were also prepared.

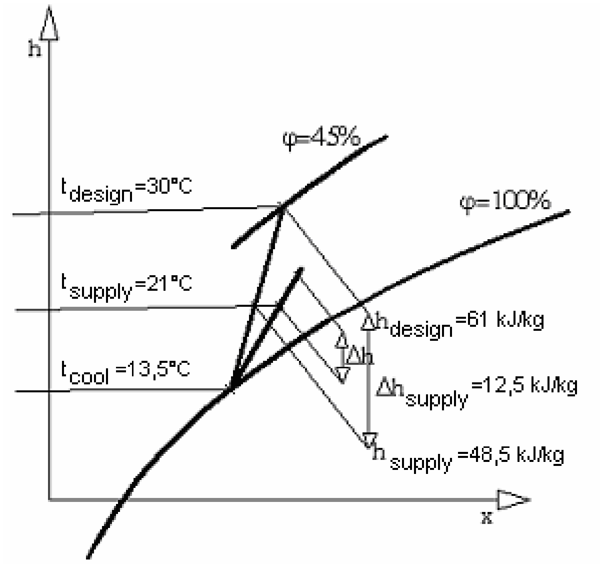

Fig. 5: Estimation of specific cooling capacity

Enthalpy difference can be plotted in a diagram by shifting left the outdoor air enthalpy curve with the value of supply air enthalpy difference. This can be seen on Figure 6. Due to the shift one section of the curve falls to the negative side of the x axis, i.e. the value of enthalpy becomes negative. As this doesn't mean cooling this part of the diagram further on is neglected. On the x axis of the diagram the design enthalpy difference (Δh=12,5 kJ/kg) should be marked. The point where the vertical line meets the function, can be read on the percentage axis. The value below the intersection is the safety, while above the point is the percentage of risk ((see Figure 7. and 8.).

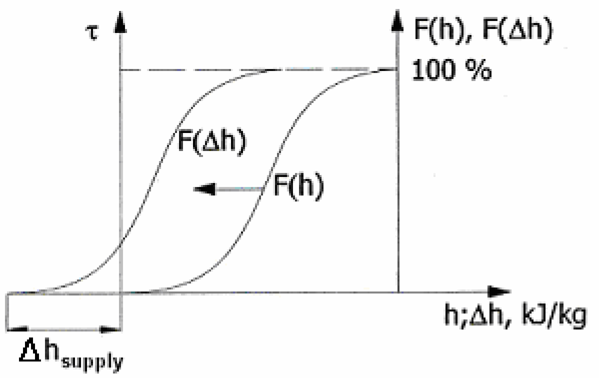

Fig. 6: Distribution function of enthalpy difference [7]

Accordingly this could be done for the entire cooling season, months, and daytime or night half-days or a whole day. The „Δh" distribution function for a half day (07:00h – 19:00h) in July 2005 is illustrated in Figure 7. In this period the risk level is 15,05%. In the similar way Figure 8. shows the results in August 2005. In this time the risk level is 10,75%.
Risk levels have been calculated for the whole cooling period. In Hungary period from beginning of July until end of August are the most critical with respect of cooling capacity. Risk level for this period from 2003 to 2005 can be seen in Table 1.

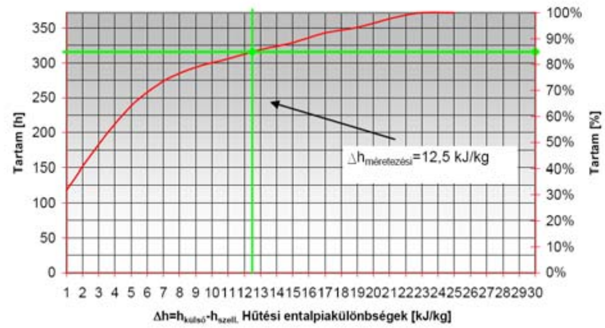

Fig 7: Risk level at night half day July 2005, Budapest [7]

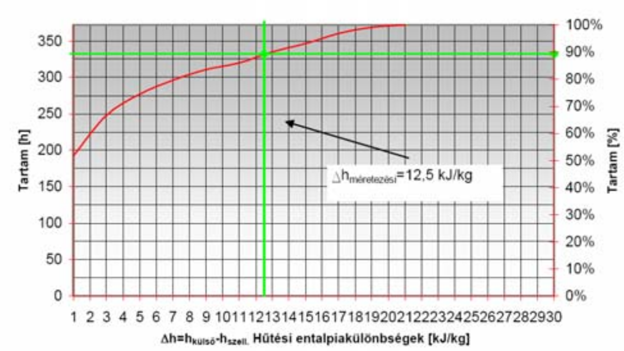

Fig. 8: Risk level at night half day August 2005, Budapest [7]

4 Conclusions

We proved that based on the measurements conducted in 2003-2005 the outdoor dimensioning values specified in standards are adequate nowadays. Owing to the macroclimate change the risk levels are higher.
The developed measuring and modelling method ensures that the outdoor air database can be extended in the coming years in the framework of a research.
The risk-based modelling can be executed already on the basis of the present results. Its application serves the interest of investors, engineers and constructors. Design outdoor parameters can be determined knowing the risk level.

Table 1: The risk levels at half-day operation in July and August 2005, Budapest

Half day operation (07:00h-19:00h)		
$t_{supply\ air}$=21°C		
2003.	July	13,17 %
	August	22,58 %
2004.	July	5,38 %
	August	1,88 %
2005.	July	15,05 %
	August	0 %

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