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SOME ASPECTS OF HEAT REQUIREMENTS IN RESIDENTIAL BUILDINGS

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Abstract. This paper discusses some aspects of establishing heat requirements, degree days in Tallinn and the effect of control units in heat energy conservation in typical Estonian apartment buildings.

Key words: heat losses, heat gain, free heat, space heating requirements, degree days, balance temperature, duration of daily external temperature, relative heat requirements.

1. INTRODUCTION

Determined by its geographical position, the climatic conditions in Tallinn are typically northern. The average external temperature of the eight coldest months is approximately 1 °C. This results in a long heating period. Due to great energy consumption for heating, it is essential to find some measures of energy conservation. To obtain reliable results, realistic data are crucial.

In a regular apartment building, the main sources of heat gain are:

– heat supplied by a heating appliance (Ql);

– internal and solar gains:

  – heat supplied by electric lighting, cookers, water heaters, and produced by other domestic appliances (Qd);

  – heat given off by occupants (Qi);

  – radiant heat gain (Qs).

The main sources of heat loss in a building are:

– transmission losses:

– through the roof (Qr);
– through the walls (Qw);
– through the floor (Qf);
– through the windows and doors (Qa);
– heat loss due to ventilation (Qv).

Figure 1 demonstrates heat losses and gains in a residential building.

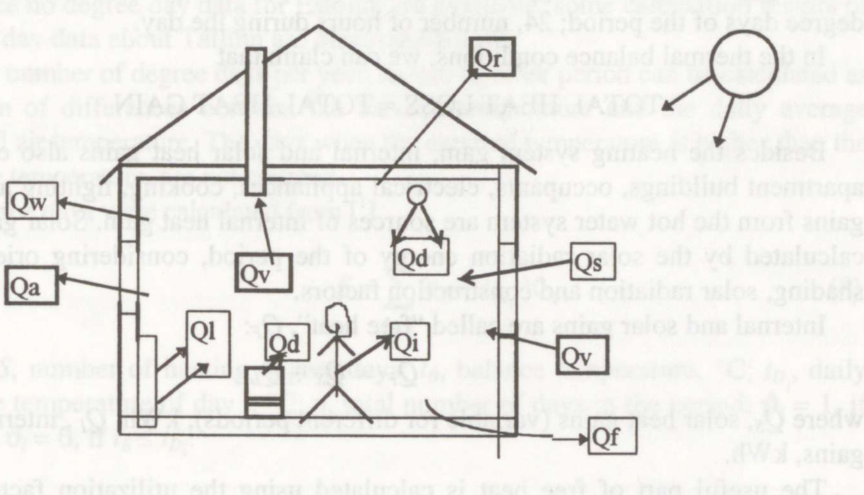

Fig. 1. Scheme of heat losses and gains in a residential building.

2. CALCULATION OF HEAT REQUIREMENTS FOR SPACE HEATING

We can calculate specific transmission losses (i.e. losses per 1 K temperature difference) by

$$H_T = \sum_{i=1}^{n} U_i A_i, \quad (1)$$

where H_T, specific transmission heat losses of the building envelope, W/K; A_i, the area of the element i of the building envelope, m^2; U_i, heat transfer coefficient of the building envelope element i, W/m^{2}K; n, the number of the building envelope elements.

Specific ventilation losses are calculated by

$$H_V = c\rho L_v, \quad (2)$$

where H_V, specific ventilation losses, W/K; c, specific heat capacity of air, J/kgK; ρ, density of indoor air, kg/m^3; L_v, average volume of air flow rate, m^3/s.

Space heating load (power) is calculated by

$$P = H_S \Delta t_c, \quad (3)$$

where P, space heating load (power), W; H_S, total specific heat losses of transmission and ventilation, W/K; Δt_C, difference between the indoor set-point temperature and the designed external temperature for heating, K.

Using the number of degree days of the period and total space heat losses, we can calculate

$$Q_L = H_S\, 24\, S\, 10^{-3}, \tag{4}$$

where Q_L, total heat energy losses of the period, kWh; S, number of heating degree days of the period; 24, number of hours during the day.

In the thermal balance conditions, we can claim that

TOTAL HEAT LOSS ≈ TOTAL HEAT GAIN

Besides the heating system gain, internal and solar heat gains also exist. In apartment buildings, occupants, electrical appliances, cooking, lighting and heat gains from the hot water system are sources of internal heat gain. Solar gains are calculated by the solar radiation energy of the period, considering orientation shading, solar radiation and construction factors.

Internal and solar gains are called "free heat", Q_F:

$$Q_F = Q_S + Q_I, \tag{5}$$

where Q_S, solar heat gains (variable for different periods), kWh; Q_I, internal heat gains, kWh.

The useful part of free heat is calculated using the utilization factor φ, a reduction factor for the heat gains. By multiplying the utilization factor by free heat, we can calculate the part of free heat that takes part in covering the heat losses. First, the utilization factor depends on the control efficiency of the heating system, although free heat and heat loss ratio and the internal thermal inertia of a building influences this factor.

The main sources of heat gain are heating appliances. The space heating requirements can be calculated as

$$Q_H = (Q_L - \varphi Q_F), \tag{6}$$

where Q_H, heat requirements for a heating system, kWh; Q_L, heat losses, kWh; φ, utilization factor.

We can calculate heat requirements for a space heating system connected to the district heating network with different control levels as

$$Q_{HC} = (Q_L - \varphi Q_F)/\eta, \tag{7}$$

where Q_{HC}, heat requirements for a heating system connected to the district heating network with different control levels, kWh; η, efficiency of a heating system as dependent on the control level.

Space heating requirements depend considerably on the control efficiency of the heating system (Figs. 2–4).

3. DEGREE DAYS CALCULATION FOR TALLINN

To calculate space heating energy losses, the degree day method is widely used because of its simplicity. The annual heating energy, estimated by the degree day method, is an approximation of that calculated using computer simulation when the balance point temperature has been determined by accurate heat transfer calculations [1].

Since no degree day data for Estonia are available, some calculation results of degree day data about Tallinn are discussed below.

The number of degree days per year, month or other period can be calculated as the sum of differences between the balance temperature and the daily average external air temperature. The days when the external temperature is higher than the balance temperature, are not counted.

Degree days were calculated from [1]

$$S = \sum_{i=1}^{n} (t_B - t_{D_i}) \vartheta_i , \quad (8)$$

where S, number of heating degree days; t_B, balance temperature, °C; t_{D_i}, daily average temperature of day i, °C; n, total number of days in the period; $\vartheta_i = 1$, if $t_B > t_{D_i}$; $\vartheta_i = 0$, if $t_B \leq t_{D_i}$.

Table 1

The average number of degree days in Tallinn in 1967–92 by months for different mean balance temperatures*

	t_B, °C				
Month	15	17	18	19	20
January	626.2	688.2	719.2	750.2	781.2
February	570.8	627.3	655.6	683.8	712.1
March	512.8	574.8	605.8	636.8	667.8
April	347.2	407.0	437.0	467.0	497.0
May	170.1	227.8	257.8	288.1	318.8
June	50.0	90.9	115.6	142.0	170.0
July	11.6	40.4	61.2	85.4	112.4
August	23.7	60.9	85.2	112.0	140.5
September	131.0	187.7	217.0	246.5	276.3
October	281.6	343.6	374.6	405.6	436.6
November	410.6	470.6	500.6	530.6	560.6
December	543.0	605.0	636.0	667.0	698.0
Total	3678.6	4324.2	4665.6	5015.0	5371.3

* The degree days data were calculated using daily external temperatures of the Climatic Centre at Harku.

The balance point t_B is the temperature above which the building heat loss is offset by the heat gain from solar energy and indoor heat sources.

To calculate energy consumption, it is essential to know the assumed mean balance temperature. We can calculate the mean balance temperature of the period approximately as

$$t_B = t_S - [Q_F \varphi (t_S - t_V)]/Q_L , \quad (9)$$

where t_B, mean balance temperature, °C; t_S, indoor set-point temperature, °C; t_V, average external temperature of the period, °C; φ, utilization factor (can be obtained from computer simulation).

As the heat requirements for heating depends on the level of control efficiency of the heating system, degree days were calculated for different mean balance temperatures.

The number of degree days was calculated on daily temperature data of 26 years (1967–92) in Tallinn. Table 1 shows the average monthly data and the sum of degree days.

Table 2 shows the average duration of daily external temperature (below fixed temperature) in Tallinn in 1967–92.

Table 2

The average duration of daily external temperature (below fixed temperature) in Tallinn in 1967–92

Temperature, °C	Number of days	%
24	365	100
22	364	99.7
20	359	98.2
18	346	94.6
16	323	88.3
14	291	79.7
12	263	72.1
10	239	65.4
8	216	59.1
6	193	52.8
4	169	46.3
2	139	38.0
0	95	26.1
−2	70	19.1
−4	51	13.9
−6	36	9.9
−8	24	6.6
−10	16	4.5
−12	10	2.6
−14	7	1.8
−16	4	1.1
−18	3	0.7
−20	1(1.4)	0.4
−22	1(0.8)	0.2
−24	0(0.3)	0.1

4. RELATIVE HEAT REQUIREMENTS

Diagrams with duration curves and balance temperatures characterize relative heat requirements. The actual balance temperature depends greatly on free heat and heat losses ratio, on thermal inertia of a building and on the level of control efficiency. For Estonia's typical apartment buildings with balanced heating system and control units in the heat distribution centre of the building, the average balance temperature of the heating period is about 19 °C if set-point indoor temperature is 20 °C. Figure 2 shows the mean external temperature duration curve for Tallinn, calculated by 26 years and the balance temperature curve *1* (control units in the heat distribution centre).

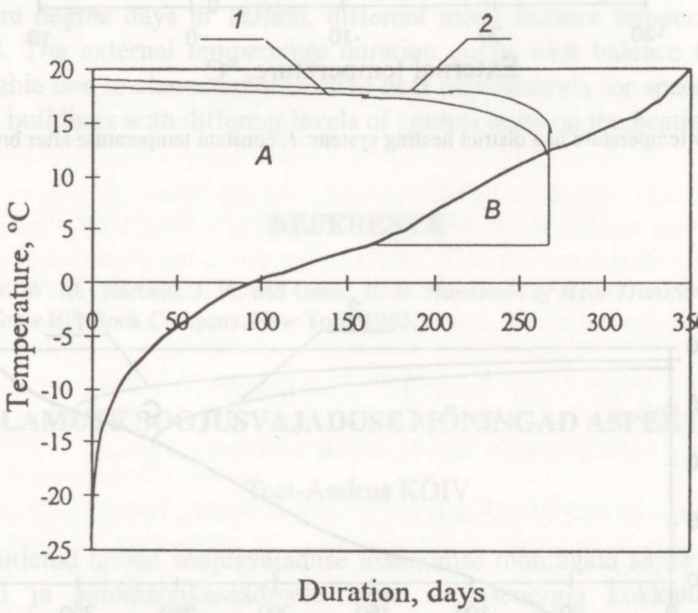

Fig. 2. Duration curve (for heating) in Tallinn with approximate balance temperatures: *A*, relative heat requirements for space heating (with control units in the heat distribution centre); *B*, theoretical overheating caused by constant flow temperature after break-point (Fig. 3) and lack of control units in the heat distribution centre; *1*, balance temperature with control units in the heat distribution centre; *2*, balance temperature without control units on the heating system.

In this figure, theoretical overheating area *B* and balance temperature curve *2* were added for a building connected to the district heating network without heating control units.

This overheating area *B* is caused by the constant flow temperature after break-point (line *1* in Fig. 3), necessary for hot tap water heating in two pipe network system if indoor temperature is controlled by opening of windows. Figure 3 shows a network flow temperature curve (with a maximum value of 130 °C) if constant temperature is 70 °C higher than the break-point (2.8 °C).

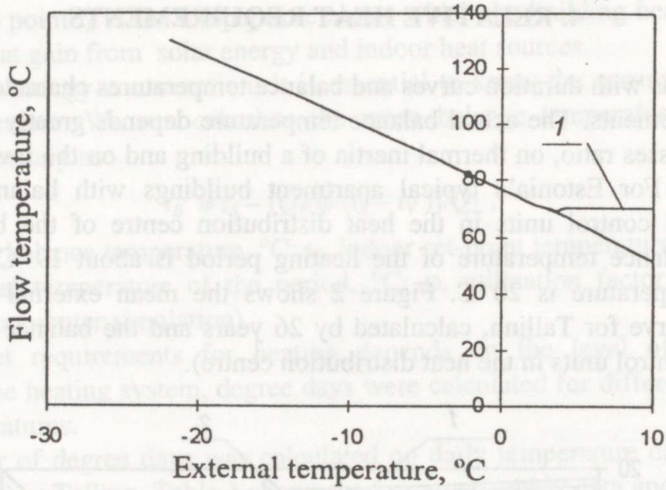

Fig. 3. Flow temperature in a district heating system: *1*, constant temperature after break-point.

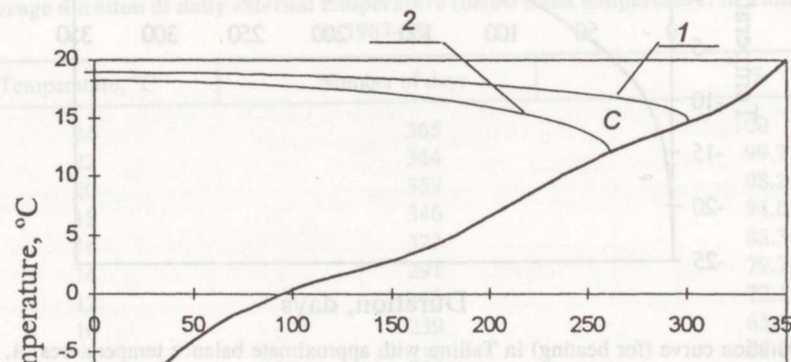

Fig. 4. Duration curve (for heating) in Tallinn with approximate balance temperatures: *C*, heat energy conservation with control units on heating appliances; *1*, balance temperature with control units in the heat distribution centre; 2, balance temperature with control units on heating appliances.

In typical apartment buildings, control units on heating appliances reduce the mean balance temperature of the heating period close to 18 °C on the same set-point temperature. Figure 4 demonstrates the external temperature duration curve for Tallinn, balance temperature curve *1* (with control units in the heat distribution centre) and curve *2* (in addition, control units on heating appliances).

5. CONCLUSIONS

This study discussed the calculation of heat requirements for space heating, based on specific heat losses and degree days. In addition, the balance temperature was defined. On the basis of the data of 26-year external temperature degree days in Tallinn, different mean balance temperatures were calculated. The external temperature duration curve with balance temperature curves enable one to characterize relative heat requirements for space heating in apartment buildings with different levels of control units on the heating systems.

REFERENCE

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ELAMUTE SOOJUSVAJADUSE MÕNINGAD ASPEKTID

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On käsitletud hoone soojusvajaduse määramise mõningaid aspekte, Tallinna kraadpäevi ja automaatikaseadmete mõju soojusenergia kokkuhoiule Eesti tüüpiliste korterelamute kütmisel.