Simplified Evaluation Method for the Necessity of Air Conditioning Systems under Summer Conditions

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Introduction

Up to now, there have not been any simple evaluation methods for the assessment of the room climate that is expected in summer. Therefore a procedure is needed, which can show criterions for the construction to avoid overheating in summer and can show the necessity of air conditioning. A method will be presented that will allow for statements to be made about the thermal performance of rooms in summer with just one characteristic: the standardized not useful heat gains, Q_{NN}. To ascertain this characteristic, a simple quasi-stationary calculation method, the European Standard (CEN TC 89 - WG4), is applied and extended. Therefore it is possible to give a description of the dynamic behaviour of rooms in summer, that means the frequency of certain internal temperatures, with a characteristic which is determined quasi-stationary. The method is also practicable, when an air conditioning system is assigned for a room. An analytic statement will be given, that allows a computer simulation, based on the European Standard CEN TC 89. Furthermore, tabulated surveys will be presented, from which structural and user specific standards can be followed to keep up to thermal comfortable conditions.

Background and Use in Practice

The warming up of buildings during summer, especially in office and administration buildings, is caused by changing trends of design in architecture and the use of buildings. The increased share of glazing at facades, the lighter and compacter construction method have to be mentioned here (Figure 1). Furthermore, the internal heat loads are still increasing. Because of these tendencies it is often indispensable to cool office buildings even in Central European latitudes. However, the subjective opinions of the necessity of air conditioning have to be objectivized.

It would be quite helpful to know the structural conditions for the necessity of air conditioning during the conception phase. These structural conditions depend on the internal and external heat gains, the insulation of a building, the effective thermal capacity, the standard and the size of the windows, the time of utilization, the alignment of the building, the lighting and the shading factor. Furthermore, the planner should get information about the cooling power that is required if comfortable conditions can't be guaranteed without air conditioning or he should be enabled to foresee the frequency of certain internal temperatures when the cooling power is fixed. The latter is important when redevelopment has to be made and it is possible to influence the internal temperatures with structural measures.

The complex computer-aided calculation methods (like TRNSYS, DOE, SUNCODE), which can describe the thermal performance of a building in summer (especially the frequency of certain internal temperatures), require detailled user knowledge and a considerable time is involved. Besides, a lot of required data is not known during the conception phase. Generally the results of these computer programmes aren't comprehensible to an architect, therefore countermeasures to avoid overheating can't be deduced.

It would be a great progress to have a simplified evaluation method for the summer period during the construction phase, as it is quite normal for the calculation of the heat requirement of buildings. Up to now, such simplified methods for the evaluation of the thermal performance of buildings in summer just exist in approaches, like the German Standard DIN 4108 or the VDI 2078, Cooling Load Regulations. This loophole should be closed with this method that is based on the European Standard CEN TC 89.

Quasi-Stationary Description of the Thermal Performance of Buildings

The energy requirement of a building is associated with the transmission heat loss through the fabric, the ventilation heat loss and the internal and solar heat gains. Furthermore, the heat storage in construction materials is relevant for the energy balance (Figure 2). A monthly balance sheet of the heat gains and losses is the result of the calculation methods of norm CEN TC 89. A utilization factor for heat gains takes into consideration the ratio of heat gains and heat losses, the effective thermal capacity and the maximally allowed set-point temperature of a building. This factor allows to show the not useful heat gains, which lead to overheating. Figure 3 shows the formalized connection of the standard CEN TC 89.

Procedure of the New Method

The starting point of the method is the consideration to ascertain one quite simple characteristic that is a measure for the frequency of certain internal temperatures, especially too high internal temperatures. To ascertain the structural demands for the avoidance of air conditioning, it is necessary to define a criterion of comfort, that has to be fullfilled. Following the German Standard 1946, the overstepping of 25°C internal temperature on 10 % of the duration of stay is the limiting comfort criterion. However, with this method it is also possible to define any other temperature limits. Figure 4 shows the frequency of appearing internal temperatures in an examplary room. Three areas have to be distinguished: up to 22°C, up to 25°C and more than 25°C. When the normally fixed set-point temperature is 20°C, here a deviation of 2 Kelvin is allowed. Therefore, all temperatures over 22°C are defined as a result of not useful heat gains.

If the not useful heat gains are ascertained on basis of the European Standard CEN TC 89, the formalized connection is given as shown in figure 5. $Q_{VÜ}$ and q_V are the heat losses respectively specific heat losses which are necessary to draw off overheating. By rearrangement it is possible to get the standardized not useful heat gains Q_{NN}.

The sticking point of the examination is the transition from the monthly, quasi-stationary viewing with average monthly external temperatures to the dynamic viewing and the exact frequency of certain internal temperatures. The integral in figure 5 is the number of hours on which overheating exists. The evidence of this correlation is made by a large number of simulation calculations with a dynamic building simulation programm (GEBSIMU of Prof. Rouvel, Technical University of Munich) that ascertains the frequency of certain internal temperatures, corresponding to the integral mentioned above. The not useful heat gains Q_{NN} are ascertained with a programmed version of the European Standard CEN TC 89.

To prove the correlation for different structural conditions, the following parameters are varied:

- the total solar energy transmittance of the window, g, and the shading,z:
  $g_F = g \cdot z = 0.0 \cdots 0.8$

- the ratio area of window / area of outer wall (0 • • • 100 %)
- the thermal transmittance coefficent of the window (k_F = 1.0 • • • 5.0 W/(m² K)) and of the outer wall (k_W = 0.2 • • • 1.0 W/(m² K))
- the air change rate (n = 0 • • • 20 per hour)
- the period of air change (24 h, during the day, during the night)
- sources of internal heat gains (0 • • • 60 W/m² during the working hours)
- the thermal capacity of a room (300 • • • 1200 kJ/($m^2_{\text{outer wall}}$ K))
- the direction (north, south, east, west)
- the size of a room.

On basis of these variations of parameters the correlation between the standardized not useful heat gains and the frequency of overheating temperatures is verifiable. Figure 6 shows the frequency of more than 25°C internal temperatures in dependence on the standardized not useful heat gains in an examplary room (climate dates of Würzburg, Germany). Each point in the graph shows one calculated variation of parameters. The presentation also can be done for any other limit temperature. On account of different radiation conditions a distinction between the directions has to be made. The spreading of the different points also can be described as a function for the frequency of certain internal temperatures. Within the scope of the examination, these functions are ascertained as fourth-degree polynoms, e.g.

$$H_{25} = 0.124 \cdot 10^{-16} \cdot Q_{NN}^4 - 1.314 \cdot 10^{-12} \cdot Q_{NN}^3 + 2.956 \cdot 10^{-8} \cdot Q_{NN}^2 + 10.734 \cdot 10^{-4} \cdot Q_{NN}$$

for a west room. To keep the criterion for comfort (e.g. more than 25°C on less than 10 % of the duration of stay) therefore the standardized not useful heat gains have to be less than 8100 Kh for a west room.

So a user is enabled to calculate the standardized not useful heat gains (CEN TC 89) for any room and evaluate the gains with regard to thermal comfort with the ascertained limits (8100 Kh for a west room as mentioned above). With the functions for different directions the frequency of certain internal temperatures can be established. Furthermore, in the examination a method is described, how the whole spreading of the frequency of certain internal temperatures can be reconstructed.

In several tabulated surveys the limit for comfortable conditions can be followed depending on two simple characteristics: the level of internal heat sources and a characteristic for solar heat gains as an evaluation index of the structural standard (figure 7).

characteristic for solar heat gains as an evaluation index of the structural standard (figure 7).

Prospect

The presented method for natural ventilation can also be extended for air conditioning. Therefore it is possible to forecast the required cooling power during the building conception phase to fullfill the comfort demands. So the planner and the architect can measure which kind of air conditioning system will be necessary. The exact procedure for the inclusion of air conditioning is described in the thesis of Mr. Kolmetz ("Thermal Evaluation of Buildings under Summer Conditions"), a former employee of our institute. The evaluation method also will be presented in an essay of the German specialist journal "Gesundheitsingenieur" in number 2/97.

At present, we are working on the inclusion and realisation of the method as part of the new energy saving decree for Germany, respectively the German Standard DIN 4108 as the national conversion of the European Standard CEN TC 89. In this commissioned work for the German Ministry of Buildings it's also supposed to extend the method from cooling load to the end energy requirement of an air conditioning system. This depends on the ascertained cooling load respectively possible air conditioning system that arises from the calculations of the method mentioned above.

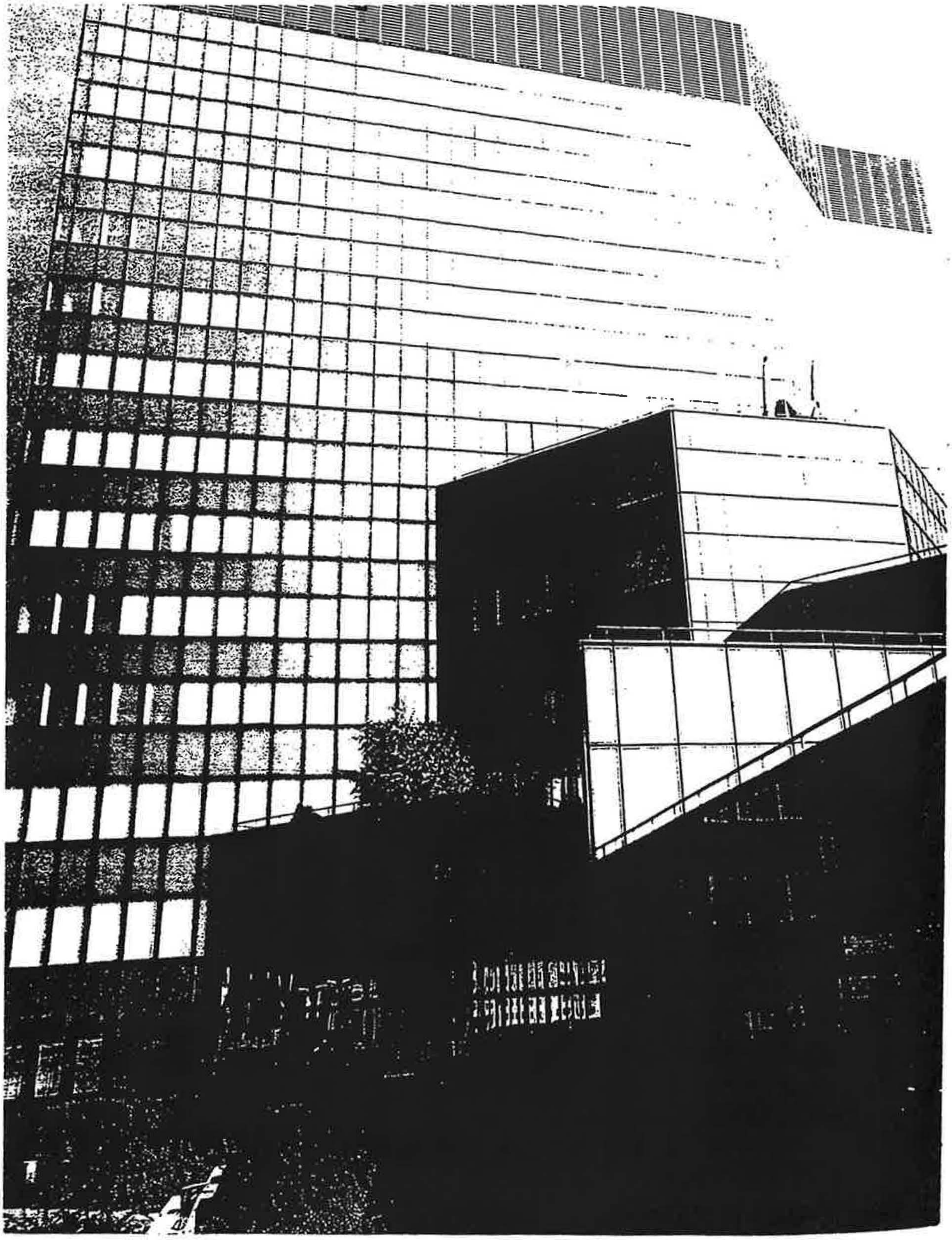

Figure 1

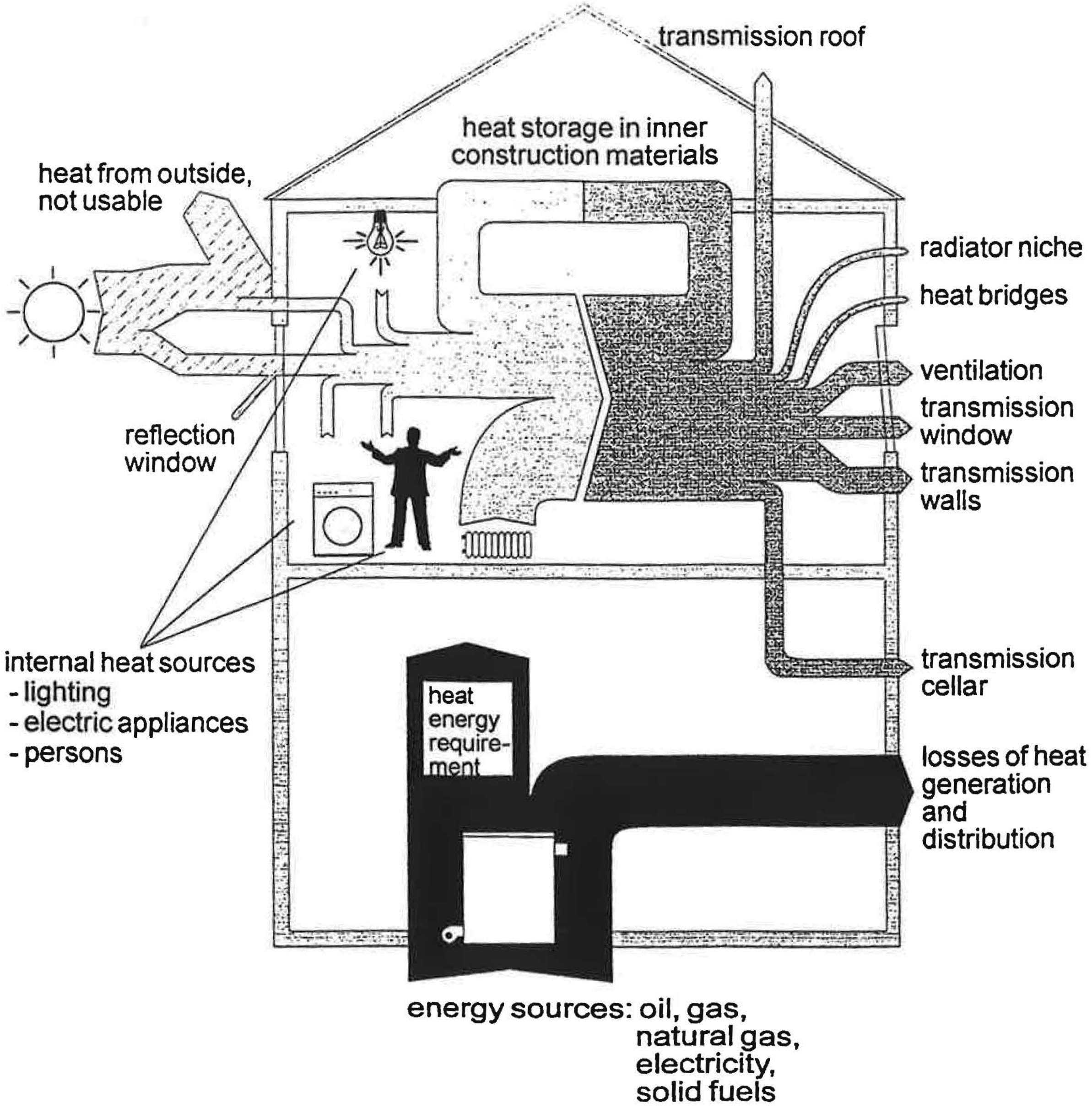

Figure 2: Heat Balance of a Building.

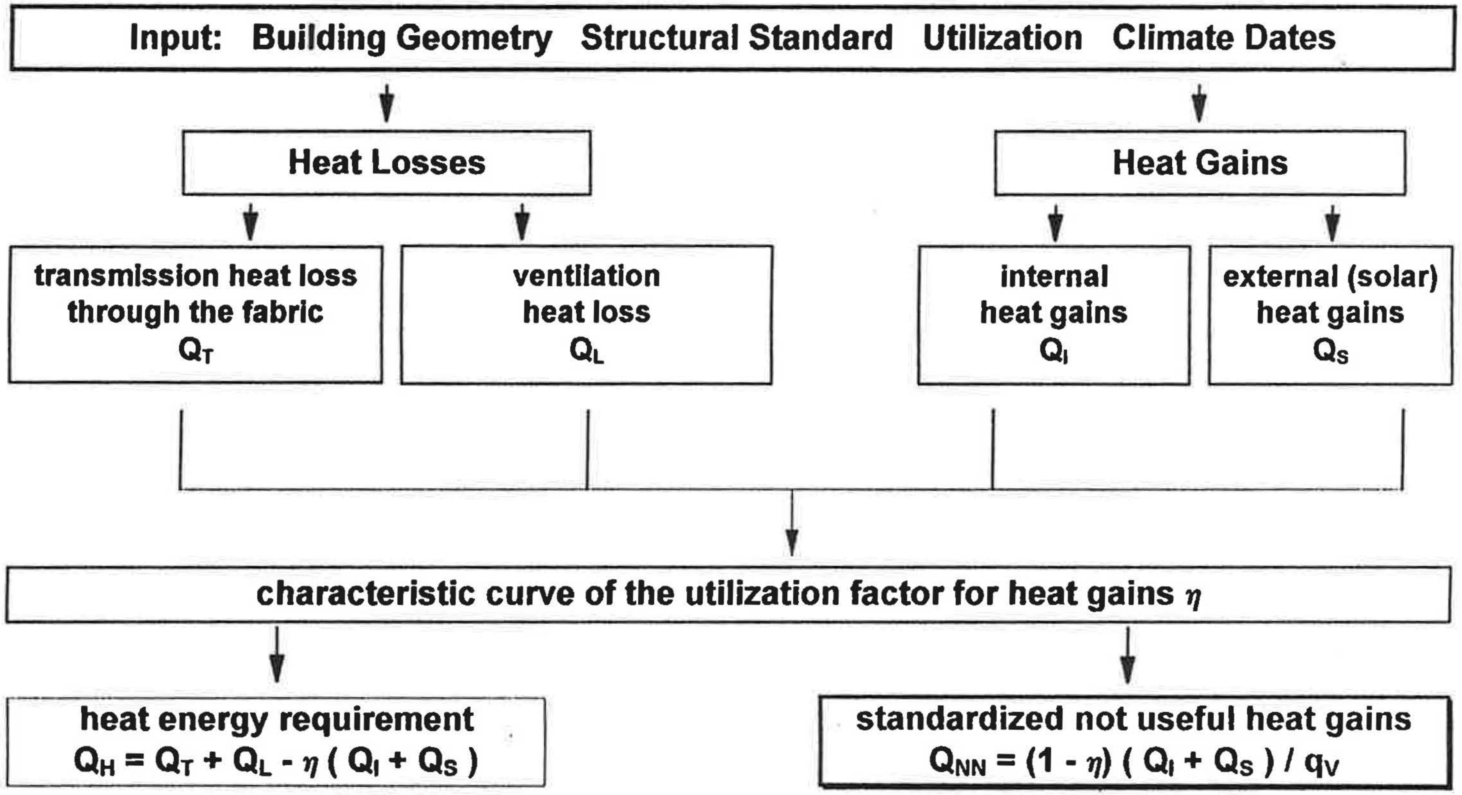

Figure 3: Calculation Method of the European Standard CEN TC 89 (Thermal Performance of Buildings = DIN EN 832) and Extension for Evaluation of the Summer Performance.

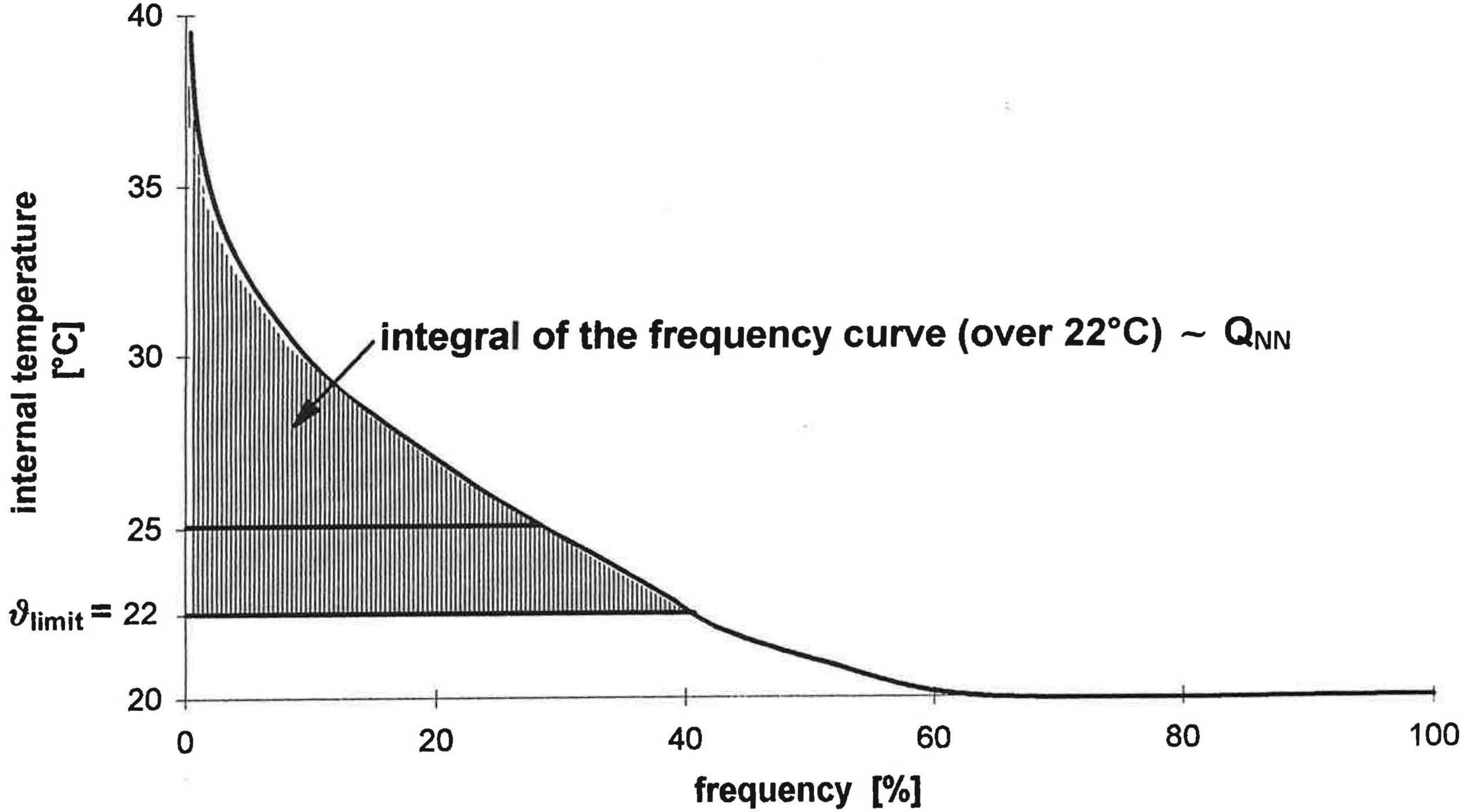

Figure 4: Example for the Frequency of Internal Temperatures (Light Construction, Share of Window 50% of the Façade, Air Change Rate 0.7 1/h, without Shading and Internal Heat Sources, Climate data TRY Würzburg, Germany, South Direction).

$$\sum_{i=1}^{12}(1-\eta)\ (Q_{I_i}+Q_{S_i}) = Q_{Lossses_O} = \sum_{i=1}^{12}\left\{q_{\,Losses_{Oi}}(\vartheta_{\,Internal_i}-\vartheta_{\,Limit})\Big|_{\vartheta_{\,Internal_i}\geq\vartheta_{\,Limit}}\Delta t\right\} \qquad (1)$$

with:

$$q_{Losses_i} = \sum\left\{k\,A + c\rho n_i V\right\}$$

$$Q_{NN} = \sum_{i=1}^{12}(1-\eta_i)\,\frac{Q_{Gains_i}}{q_{Losses_i}} = \sum_{i=1}^{12}(\vartheta_{\,Internal_i}-\vartheta_{\,Limit})\Big|_{\vartheta_{\,Internal_i}\geq\vartheta_{\,Limit}}\Delta t \qquad (2)$$

$$\sim \int_{t=0}^{8760h}(\vartheta_{\,Internal_i}-\vartheta_{\,Limit})\Big|_{\vartheta_{\,Internal_i}\geq\vartheta_{\,Limit}}dt$$

Figure 5: Mathematical Correlation for Derivation of the standardized ot useful Heat Gains.

characteristic for solar heat gains: (1-r) * z_{kor} * g_{kor} * f [-]

internal heat sources [W/m²]	0.000	0.025	0.050	0.075	0.100	0.125	0.150	0.175	0.200	0.225	0.250
0	0	0	2	4	6	10	14	18	22	26	30
5	1	3	6	9	13	17	21	26	30	33	37
10	5	8	12	17	21	25	30	33	37	40	42
15	12	16	21	25	30	34	37	40	43	45	46
20	21	25	30	34	37	41	43	45	47	49	
25	30	34	38	41	44	46	48	50			

[%]

(1-r)	share of glass
z_{kor}	average shading during the day
g_{kor}	average total solar energy transmittance of the glass
f	share of window (related to the area of facade)

Figure 7: Frequency of more than 25 C Internal Temperature during the Working Hours (Exemplary Room, South Direction, Air Change Rate 1.4 1/h, Light Construction < 750 kJ/(m²$_{\text{outer wall}}$ K)).

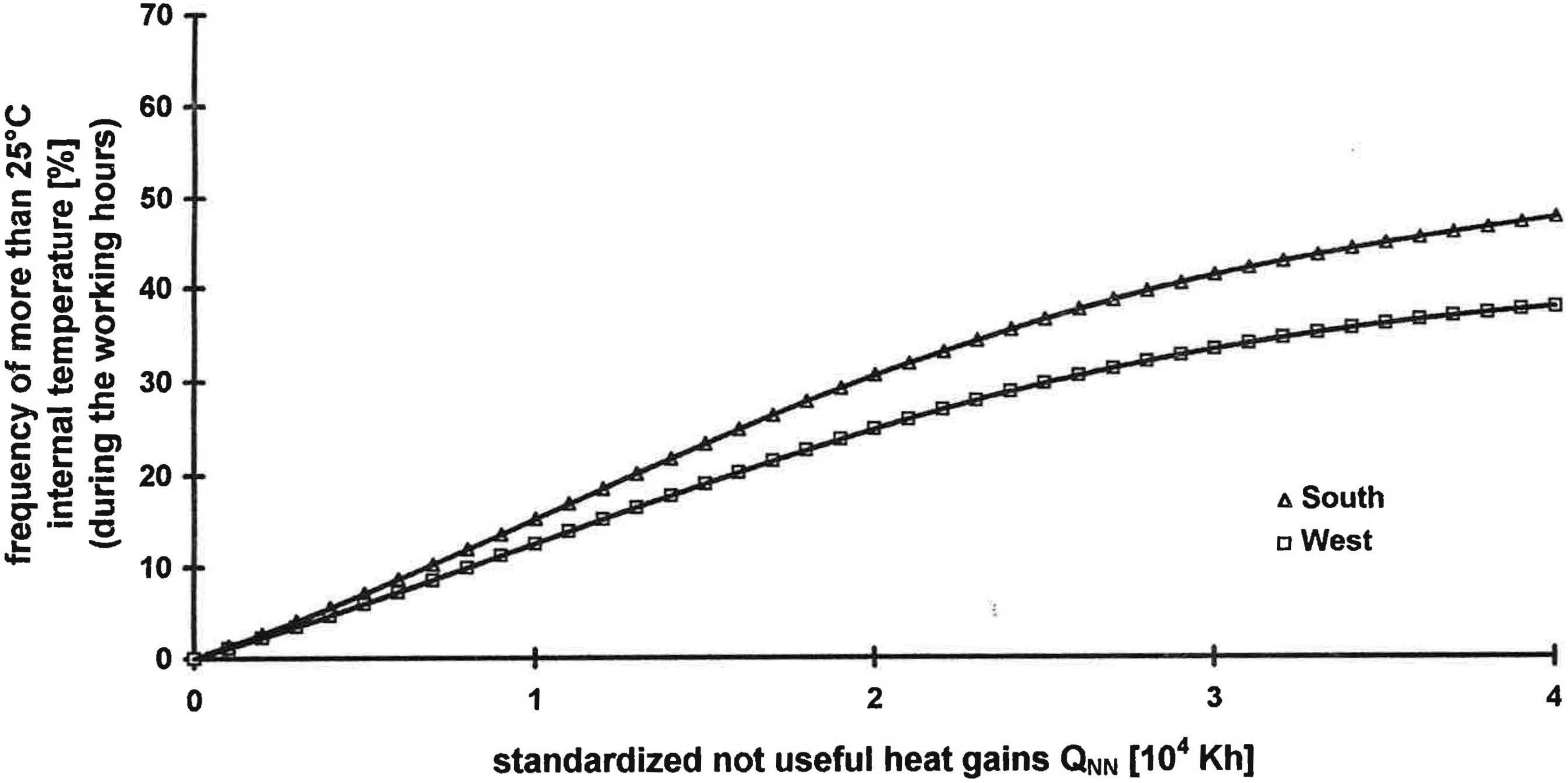

Figure 6: Example for the Frequency of Internal Temperatures over 25 C in a Room dependent on the standardized not useful Heat Gains Q_{NN}.