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"The effect of wind on the heat demand of dwellings"

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THE INFLUENCE OF WIND ON THE HEAT DEMAND OF DWELLINGS

A contribution to the more reliable sizing of heating installations

The following standards and guidelines are used in Austria for sizing heating installations and for calculating the heat demand over a heating season:

* ONORM M 7500. Heating installations. Calculating the heat demand. Vienna, July 1959. [1)]
* DIN 4701. Rules for calculating heat demand of buildings. Berlin, January 1959.
* VDI Guideline 2067. Standard values for the preliminary calculation of the economy of different fuels (coke, coal, heating oil, gas) for hot water central heating systems. Dusseldorf, January 1957
* HEA-Guideline. Electric space heating. Standard values for the preliminary calculation of the economy of electric heating installations. Guidelines of the Chief Electrical Applications Committee (HEA). Essen, March 1969.

It will be demonstrated in what follows that with a normal, relatively pervious building fabric the above sizing procedures can give unsatisfactory values and that for the satisfactory sizing of heating installations it is necessary to have precise meteorological information on the concurrence of air temperature and wind velocity

1. Analysis of the traditional sizing procedures:

1.1 ÖNORM M 7500

The required output of a heating installation to maintain a uniform room temperature in the winter is:

1) A revised edition of ÖNORM in 7 parts was issued in 1981.

$$Q = F_f \cdot k_f (t_i - t_a) + F_w \cdot k_w \cdot (t_i - t_a) + I \cdot k_i \cdot (t_i - t_a)$$

Q	Heat demand in kcal/h
k_f	Thermal transmittance for windows/doors in kcal/m^2.h.°C
k_w	Thermal transmittance for walls, ceilings and floors in kcal/m^2.h.°C
k_i	Heat loss factor taking account of ventilation heat demand caused by leakage (infiltration) in kcal/m^3.h.°C
F_f	Surface area of the external windows and doors in m^2
F_w	Surface area of the exposed walls, ceilings and floors in m^2
I	Room volume in m^3
t_i	Calculation room temperature in °C
t_a	Calculation outside temperature in °C

For the heat loss factor the following values apply according to Table 3 of the Standard for double-glazed and sealed windows and doors, in kcal/m^3.h°C:

* Rooms with windows or external doors on one side: k_i = 0.1
* Rooms with windows or external doors on two sides: 0.2
* Rooms with windows or external doors on three sides: 0.3
* Entrance halls: 0.3
* Sunny rooms with numerous windows on three sides: 0.4

The calculation outside temperature is taken as the average yearly minimum, which is approximately -18°C in most built-up areas. In very windy areas the yearly minimum is approximately -21°C

According to the calculation formula the required capacity is affected uniformly by the wind in proportion to the share of the walls, windows and ventilation, which does not correspond to the actual circumstances.

Since the ventilation heat loss is related to the room volume and not to the window area or the length of the window joints, differing proportions of window area do not figure in the results as much as they should to correspond with reality.

1.2 DIN 4701:

When DIN 4701 was revised in 1958 the exposure to wind of the room and the leakiness of the windows and doors were taken into account for the determination of the ventilation heat demand which can be written as follows:

$$Q = \sum F_i \cdot k_i \cdot (t_i - t_a) \cdot (1 + z_U + z_A + z_H) + \sum (a \cdot l)_A \cdot R \cdot H \cdot (t_i - t_a) \cdot Z_E$$

F_i Area of the room-surrounding surfaces in m^2

k_i Thermal transmittances assigned to these surfaces in $kcal/m^2 \cdot h \cdot °C$

t_i Design temperature indoors in °C

t_a Design temperature outdoors in °C, or in a neighbouring room in °C

z_U Addition for interruption to the heating

z_A Addition to compensate for cold external surfaces

z_H Addition for orientation

$\sum (a \cdot l)_A$ Perviousness of windows and doors exposed to wind

R Room characteristic value

H House characteristic value

Z_E Additional factor for corner windows

If the heating is interrupted for 9-12 hours the sum of the additions z_U and z_A can be assumed to be approximately 15%.

The addition for orientation is:		
	for N, NW, NE	+5%
	for E, W	0
	for S, SW, SE	-5%

The room characteristic value can be assumed to be 0.8 in the first approximation; the additional factor for corner windows Z_E is 1.2 if the windows and external doors are directly in the corner formed by two external walls, otherwise it is 1.0

The house characteristic value is decisively affected by the wind and is:

		Terraced House	Individual House
In a normal district,	sheltered	0.24	0.34
	open	0.41	0.58
	very open	0.60	0.84
In a windy district,	sheltered	0.41	0.58
	open	0.60	0.84
	very open	0.82	1.13

Exposure to wind and leakiness of windows are clearly associated here but the question of low temperatures with high wind speeds is not raised.

1.3 VDI-2067 (and therefore: HEA-Guideline)

(quoted according to F. Bruckmayer: Economic thermal insulation, part 3, FGW Vienna, 1972).

$$Q = \frac{1}{24} (6 \cdot 3 . f_A . k_A + 7 \cdot 7 . f_F . k_F + a_F . L_{FM} . H + 7 \cdot 5 . k_d + 3 \cdot 3 . k_K + 1 \cdot 4) . B . V . (t_i - t_a)$$

(for mid-terrace houses)

$$Q = \frac{1}{24} . (8 \cdot 5 . f_A . k_A + 8 \cdot 5 . f_F . k_F + a_F . L_{FE} . H + 7 \cdot 5 . k_D + 3 \cdot 9 . k_K + 1 \cdot 4) . B . V . (t_i - t_a)$$

(for corner houses)

f_A	Share of the external wall surface
f_F	Share of the external window surface
k_A	Thermal transmittance of the external wall kcal/m^2.h.°C
k_F	Thermal transmittance of the windows kcal/m^2.h.°C
a_F	Permeability of the windows m^3/mh. (mmWG)$^{2/3}$
k_D, k_K	Thermal transmittance of the roof or ceiling beneath the loft and the cellar ceiling kcal/m^2.h.°C
H	Factor taking account of the situation of the building
V	Dwelling volume m^3
L_{FE}	Factor taking account of heat loss through window and door joints for corner dwellings
L_{FM}	Factor taking account of heat loss through window and joints for mid-terrace dwellings
B	Factor taking account of the mode of heating
$(t_i - t_a)$	Difference between internal/external design temperatures.

This heat demand formula is based to a striking degree on the room volume although it also takes into account the size of the windows by the proportion of the window surface area, assuming normal room proportions.

The operating factor B only varies between 1.0 and 1.15. However the factor taking account of the window joints L_{FM} or L_{FE} shows a wide variation (as a function of the proportion of the window surface area f_F).

	Corner	Mid-terrace
f_F = 0.1	L_{FE} = 1.60	L_{FM} = 0,86
0.2	2.28	1.24
0.3	4.32	2.38
0.4	7.72	4.28

The house characteristic value H is graduated as in the DIN Standard, the values of the terraced houses and multi-family houses are 0.4-0.7-1.0-1.4,and therefore permit the wind to be taken into account to the same extent. Its concurrence with low temperatures is similarly not taken into account.

2. Critical commentary on the conventional sizing procedures

At the moment the required output of a heating installation is calculated by adding an additional value to transmission losses (through external walls, ceilings, doors and windows) to take account of ventilation heat losses (through leaky window joints, through opening windows and by continuous operation of ventilation installations).

The heat demand over a heating season is calculated either with the aid of a fictitious number of hours of full load operation (related to an extreme design temperature, normally the average yearly minimum outside temperature) [1)] or by a degree day value (the integral of the difference between the outdoor temperature and the 20°C indoor temperature over the entire heating season):

$$E = \frac{Q}{t_i - t} \cdot 24 \cdot G_t$$

G_t = degree day value (for external temperatures below t)

Both methods are very practical since they are simple to apply if the corresponding data are known (additional factors, temperature, hours of full load operation or degree day number) which is usually the case.

1) $E = Q \cdot b$, b = (equivalent) full load operation time (hours/year)

However three particular circumstances give rise to the need to revise both these methods and to suggest improved sizing procedures:

* The inadequate account taken of certain environmental conditions, in particular the probability of the simultaneous occurrence of low outdoor temperatures and high wind speeds (a temperature addition for wind on cold days is not sufficient; it will be demonstrated that this generally causes building space heating installations to be very under-sized).

* The inadequate account taken of particular window constructions which have greately differing effects on the overall heat losses by the permeability and length of their joints as well as their thermal insulation and the proportion of glazed area. It will be shown that they also have greatly differing effects on the value of the decisive design parameter.

* Insufficient evidence concerning the capacity of the heating installation to meet unfavourable climatic conditions. The new method makes it possible either to determine the suitability of an installation directly or to use it as an initial requirement for the dimensioning of the heating installation.

The dimensioning procedure is described in what follows and illustrated in the accompanying diagrams.

The requisite meteorological data can be obtained from the appropriate weather stations; they require some further processing for the present requirements.

3. **Calculation of the critical heat output**

3.1 Preliminary remarks concerning simplifying assumptions

Several simplifying assumptions are used when calculating the heat output necessary to cope with unfavourable climatic conditions, but these do not significantly alter the result:

* The climatically unfavourable conditions cannot be compensated for by the addional heat from insolation through the windows; (as will be demonstrated, climatic conditions with a high wind speed are normally decisive for the critical design conditions. In our latitudes these winds almost always occur in lowland areas with an overcast sky).

* During the critical phase - because of the high wind speeds which occur then - practically no additional ventilation is required since the air change through the window joints more than meets fresh air requirements. The only exception is in fully air-conditioned office buildings where there are few window joints.

* The critical phase for dimensioning the heating installation is so prolonged that, as a result of the non-steady behaviour of the building structure, there is usually no bridging help available. This means that the present study will not concern itself with the influence of heat storage of the room-surrounding surfaces on the heat demand with interrupted heating operation. As regards the remarkable energy savings obtainable with night-time set back we refer to Blodau (8) who has also shown how this effect can be increased by optimised heating control.

3.2 Critical heat output

The energy loss through the external wall of a building comprises:

* Transmission energy loss through the massive sections of the wall Q_W
* Transmission energy loss through the windows Q_F
* Ventilation energy loss, in particular through the joints of windows and outside doors Q_L

  $Q = Q_W + Q_F + Q_L$

Q_W Transmission energy loss through the massive sections of the entire area of the outside wall

$$Q_W = f_w \cdot k_w \cdot \Delta t \quad [W/m^2]$$

$$K_w = \frac{1}{\frac{1}{\alpha_i} + \sum_W \frac{d}{\lambda} + \frac{1}{\alpha_a}} \quad [W/m^2 \cdot K]$$

Thermal transmittance of the massive sections of the outside wall

$$\alpha_i = 8 \quad [W/m^2 \cdot K]$$

Heat transfer coefficient inside, approximately constant

$$\alpha_a = (8 + 4v) \quad [W/m^2 \cdot K]$$

Heat transfer coefficient outside, a function of wind speed v

$$f_w = \frac{Fw}{F}$$

The external heat transfer coefficient α_a is a function of the speed of the wind on the building fabric. The expression $(8 + 4_v)$ is a simplified assumption for this function, which a study of the literature has shown to be a workable compromise for the range of wind speeds up to 15 m/s (see Fig. 1).

Q_F Transmission energy loss through the windows

$$Q_F = f_F \cdot k_F \cdot \Delta t \quad [W/m^2]$$

$$K_F = \frac{1}{\frac{1}{\alpha_i} + \sum_F \frac{d}{\lambda} + \frac{1}{\alpha_a}} \quad [W/m^2.K]$$

Expression analogous to the above

Q_L Ventilation energy loss

As already determined under Section 3.1, when determining ventilation energy loss it was assumed with permissible simplification that in the critical days (simultaneously cold and windy) the fresh air supply was met exclusively through the leaky joints in the windows and outside doors. This simplification can be permitted for dwellings:

$$Q_L = V \cdot \Delta h$$

On the basis of investigations by Reiher, Fraass and Settele (1) on window joints, the volume of ventilation air V can be calculated as follows:

$$V = (\sum_F a.1) \cdot (\Delta p)^{2/3}$$

$\sum_F a.1$ Sum of the leakiness of all window joints

a Joint leakiness $[m^3/h.m.Pa^{2/3}]$

1 Joint length $[m/m^2]$

for the conversion of the old joint characteristic values we have:

$$a\,[m^3/h.m.Pa^{2/3}] = \frac{a_{ALT}}{0.218}\,[m^3/h.m.\ (mm.WG)^{2/3}]$$

This can be more easily expressed:

$\sum_{FA} a.l = A$	Joint leakiness on the side of the building exposed to wind
$\sum_{FB} a.l = B$	Joint leakiness on th side of the building away from the wind
$\frac{A}{B} = \varphi^{2/3}$	Ratio of the leakiness of the joints

Δp Air pressure difference outdoors/indoors [Pa]

The pressure conditions which prevail on the outside of the building are easily determined on the basis of aerodynamic investigations, or they are also in the appropriate Standards. They can be determined with the coefficients c_A or c_B (on the windward or sheltered side) from the dynamic pressures q. For sealed buildings we have $c_A - c_B = 1.2$, the windward component being approximately $c_A = 0.7$ and the sheltered component $c_B = -0.5$; pressure with a positive sign.

The air change rate with low wind speeds (v = 2 m/s), which is caused either by the temperature difference between indoor and outdoor air or by opening the windows is disregarded here in the first approximation but must be taken into account if a precise value is required.

If the effect of inner walls is disregarded - assuming mainly open or poorly closing inner doors - we can draw up the following balance for the air flowing in and out of a dwelling or room:

$$V_A = V_B$$

$$\sum_A a.l.(p_A)^{2/3} = \sum_B a.l.(\Delta p_B)^{2/3}$$

$$A.(c_A \cdot q - p_i)^{2/3} = B.(p_i - c_B \cdot q)^{2/3}$$

This balance permits the easy determination of the magnitude of the unknown internal pressure p_i:

$$\frac{A}{B}^{3/2} = \frac{\Delta p_B}{\Delta p_A} = \frac{p_i - c_B \cdot q}{c_A - p_i} = \varphi$$

$$p_i - c_B \cdot q = c_A \cdot q \cdot \varphi - p_i \cdot \varphi$$

$$p_i = \frac{\varphi \cdot c_A + c_B \cdot}{1 +} = \frac{\left(A/_B\right)^{3/2} \cdot c \cdot_A + c_B}{1 + \left(A/_B\right)^{3/2}} \cdot q$$

For the particular case where the leakinesses on the windward and sheltered sides are the same ($A = B, \varphi = 1$) as can happen with terraced houses and blocks of flats arranged in a square we have

$$p_i^* = \frac{c_A + c_B}{2} \cdot q$$

The quantities of air flowing into the inner room through leaky joints can therefore be calculated as:

$$V_A = A \cdot (\Delta p_A)^{2/3} = A \cdot (c_A \cdot q - p_i)^{2/3} = A \cdot \left(q \cdot \frac{c_A - c_B}{1 + (A/_B)^{3/2}}\right)^{2/3} =$$

$$= \sum_A a \cdot l \cdot q^{2/3} \cdot \left(\frac{c_A - c_B}{1 + \varphi}\right)^{2/3} ; \quad \text{with } \varphi = \left(\frac{\sum_A a \cdot l}{\sum_B a \cdot l}\right)^{3/2}$$

The dynamic pressure q can also be calculated from the wind speed at the front of the building, for which the meteorological wind speed is used as an approximation (this value is measured at a height of approximately 10m, which corresponds to the values for the high sections of buildings; for lower sections a slight subtraction is required).

$$q = \frac{\rho . v^2}{2} = 0\cdot64.v^2 \left[P_a\right]$$ Dynamic pressure

$\rho \left[\frac{k_g}{M^3}\right]$ Air density

The following expression

$$\left(\frac{c_A - c_B}{1 + \varphi}\right)^{2/3}$$

takes account of the wind pressure and flow ratios in and outside the building; it can be resolved into two components:

The numerator $(c_A - c_B)^{2/3}$ takes account of the wind flow outside the building and can be designated as the characteristic value of the house H' as in DIN 4701. The denominator $(1 + \varphi)^{2/3}$ takes account of the wind flow inside the building and can be designated as the characteristic value of the room R' as in DIN 4701.

Both values can be defined with sufficient accuracy: they are both larger than 1: $(c_A - c_B) = 1.2$ to 1.5; $(1 + \varphi) = 2$ under the further assumption that the different leakage on the windward and sheltered sides is usually compensated by varying wind directions.

For average conditions we therefore have, for the volume of wind entering a building

$$V = \sum_A a.l.(0{\cdot}64.v^2)^{2/3}.\left(\frac{1{\cdot}2}{2}\right)^{2/3} = \sum_A a.l.(0{\cdot}64.0{\cdot}6)^{2/3}.v^{4/3} =$$

$$= 0{\cdot}53.\sum_A a.l.v^{4/3}$$

This value is nevertheless approximately 30% lower than the figure obtained when the full dynamic pressure is used (see Ref. (3)).

An approximation calculation is also necessary for the difference between the enthalpy of the room air and of the inflowing air. There are two reasons for this:

* In winter the moisture content of the outdoor air is largely constant; the enthalpy of the outdoor air therefore can be determined very accurately as a function of the outdoor air temperature. Howeverthe moisture content and therefore also the energy content of the indoor air is very variable. In the author's opinion there is no justification to relate the enthalpy of the indoor air only to the air temperature and to calculate it as the amount of energy required to warm the outdoor air. In order to maintain an air humidity which satisfies physiological requirements it is necessary to humidify the air for outdoor temperatures below approximately 8°C, thereby adding additional energy.

* As can be seen from Fig. 2 no linear relationship can be derived. It is necessary to supplement the energy required to warm the dry air with an addition set at 75% to warm the added moisture.

  [illegible] 2 [illegible] indoor climate of t_i = 22°C and φ_i = 60% with 85% outdoor air humidity for outside air temperatures from +5 to −15°C. When the energy required to humidify the outside air in addition to that required to warm it up is calculated, values of 78 to 62% are obtained; for the commonest outdoor conditions in winter, around 75%.

$$\Delta h = (1+\text{z}).c.\Delta t \quad [W.h/m^3] \qquad \text{Enthalpy difference}$$

$$\text{z} = 0{,}75 \qquad \text{75\% addition for humidification}$$

$$c = 0{,}36 \quad [W.h/m^3.K] \qquad \text{Specific heat of the air}$$

$$\Delta h = 1{,}75.0{,}36.\Delta t = 0{,}63.\Delta t \quad [W.h/m^3]$$

The energy demand created by ventilation is therefore:

$$Q_L = V.\Delta h = 0{,}53.\sum_A a.l.v^{4/3}.0{,}63.\Delta t = 0{,}33.\sum_A a.l.\Delta t.v^{4/3} \quad [W/m^2]$$

or for "old" characteristic values for joints:

$$Q_L = 0{\cdot}072.\sum_A a_A.l.\Delta t.v^{4/3} \quad [W/m^2]$$

The overall energy loss through the outside wall is

$$Q = Q_W + Q_F + Q_L = \Delta t.\left(q_W + q_F + q_L\right) =$$

$$= \Delta t.\left(f_F.\frac{1}{R_w + \frac{1}{8+4v}} + f_F.\frac{1}{R_w + \frac{1}{8+4v}} + 0{,}072.\sum_A a_A.l.v^{4/3} \right)$$

the share attributable to the thermal resistivity $\left(\frac{1}{\alpha_i} + \sum \frac{d}{\lambda}\right)$ is designated R_W or R_F.

We can now calculate as a function of the parameters f_W, f_F, R_W, R_F, a and l, the energy loss related to the unit temperature difference and plot it as a function of the wind speed (see Fig, 3). It can be seen from this that with the commonest type of wall construction (25% glazed with double glazing, joints with a permeability of a = [illegible] and a massive wall with a k-value of around 1 $kcal/m^2.h.°C$) with the average wind speeds of 2 or 3 m/s the heat loss through the joints, window areas and the massive walls is approximately the same, at around 1 $W/m^2.K$ (this time related to the total wall area).

With higher wind speeds energy loss through the window joints gradually increases, while energy losses through the window areas and through the massive wall areas remain practically constant.

We can now take into account the effect of the outside/inside temperature difference (the inside temperature being assumed to be a constant +22°C) on the heat consumption according to the above equation. The values obtained can be plotted as a series of curves in the coordinates air temperature/wind speed. There is thus obtained for each state of the outside air (expressed by the parameters air temperature and wind speed) the heat loss per m_2 of outside wall (see Fig. 4)

Meteorological records demonstrate that this pair of values (outdoor air temperature t /wind speed v) occurs at a given location with a given frequency. The cumulative frequency of the simultaneous occurrence of this pair of values for a given location in the heating season can be plotted on the same axes as the energy loss for the outside wall (Fig. 4) which gives an important criterion for determining the critical heat installation output for a given geographical location (see Fig.5).

Both these sets of curves (Fig. 4, external wall heat losses of a given type of construction, and Fig. 5, cumulative frequency of the simultaneous occurrence of air temperature and wind speed at a given location) can be superimposed (as pointed out by Valko (5)).

(1) The combination of v and t which is decisive for the dimensioning of a heating installation is found where the maximum energy losses are plotted for an assumed probability of incidence f, which is where the set of curves appear to touch (see Fig. 6).

(2) For differing requirements of the reliability of the heating installation (measured on the curves for cumulative frequency) a curve for the unfavourable dimensioning conditions can be drawn by connecting the fictitious touching points (see Fig. 6 dashed line).

(3) If this procedure is carried out for a number of different wall constructions in the identical climatic location we obtain regions of critical sizing conditions for windowless walls on the one hand and for walls with windows of normal size and construction on the other hand (see Fig. 7).

(4) It is clear that the main influence on the location of the critical sizing condition in the v,t-diagram depends on whether there are joints in the wall and their tightness (see Fig. 7 dashed lines).

(5) If we reverse the procedure and plot in this diagram the climate data (v,t) actually used for sizing a heating installation and proceed along a curve Q = constant until we reach the maximum curve of the cumulative frequency we can then read off each frequency for which the installation is unsatisfactorily dimensioned or the extent as a percentage of the capacity of the installation to meet critical operating conditions (see Fig. 6 dotted and dashed line, f = 16%).

(6) At each critical point both the capacity of the installation and the maximum heat output to be installed can be read off simultaneously (see Fig. 6).

(7) It can be seen that for normal types of external wall constructions in dwellings average outdoor temperatures at high wind speeds are the decisive factor (eg. 0°C, 9 m/s according to Fig. 6 for f = 5%).

(8) When dimensioning according to conventional methods a two-fold under-dimensioning of installation is possible (with respect to dimensioning for 99% reliability) or a reduced reliability of approximately 80%, so that in each heating season the heating installation is inadequate on approximately 20 days.

(9) By integrating the heat output over the field of probability $\int Q, dp$ it is possible to determine the average heat demand for a heating season. The numerical evaluation takes place for defined fields $\Delta t \cdot \Delta p$ = constant with the formula

$$Qges = \sum Q_i \cdot \Delta p_i = \sum Q_i \cdot (p_{lo}+p_{ru})-(p_{ro}+p_{lu})$$

p = probabilities in the corner of a field

lo, upper left corner

ro, upper right corner

lu, lower left corner

ru, lower right corner

Fig. 1 Outdoor thermal transmittance α_A as a function of wind speed v according to various authors.

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$_A = 10,3 + 4,0\ v\ (v \quad 5\ m/s)$ according to Jurges

$_A = 4.5 + 7.1\ v^{0.78}\ (v \quad 5)$

Ref.: Recknagel-Sprenger
Heating and Air Conditioning Handbook
Munich-Vienna, 1972 p. 120

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$_A = 8,7 + 3,2\ v$ (Wall//Wind) according to Gerhart

$_A = 8.7 + 2.6\ v$ (Wall/Wind)

Ref.: Gerhart, K.
Model Investigations of the Distribution of Convective Heat Transfers Over Building Faces
Kaltetechnik (1967) 5, p. 122 - 128

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$\alpha_A = 6.2 + 4.2\ v\ (v \leqslant 5\ m/s)$

$\alpha_A = 7.5 \cdot v^{0.8}\ (v > 5\ m/s)$

Ref.: Hütte. The Engineer's Handbook, Volume 1, Theoretical Fundamentals.
Berlin, 28/1955, p. 499.

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$\alpha_A = 8 + 4\ v$

Simplifying assumption, whose validity is accepted to 15 m/s

Fig. 2 Additional heat demand for humidification

a Additional energy consumption for humidification of the fresh air

b Humidification of the fresh air

c Warming the fresh air

Fig. 3 Heat losses q of an outside wall as a function of wind speed

Fig. 4 Heat losses Q of an outside wall 1 m_2 as a function of the outdoor temperature t and the wind speed v

Fig. 5 The cumulative frequency of the simultaneous occurrence of wind speed v and air temperature t (mild location)

Fig. 6 The critical combination of the values outdoor air temperature-/wind speed for the dimensioning of the heating installation.

a Critical states for the dimensioning of the heating installation

b v...Wind speed $\frac{(m)}{s}$

t...Outdoor air temperature (K)

f...cumulative frequency of the occurrence of the combination v-t (%)

Q...Heat losses of the wall (kW/m^2)

Fig. 7 The critical combination of outdoor temperature t and wind speed v as a function of f for dimensioning heating installations

External wall with windows

a Leaky joints ($a \approx 3$)

b Average joints ($a \approx 1.5$)

c Tight joints ($a \approx 0.5$)

d Very tight joints

e Few tight joints

f Single glazing
Double glazing

External wall without windows

g Minimum insulation ($k \approx 1$) (corresponds to former Austrian standard)

i Medium insulation ($k \approx 0.6$)

j Good insulation ($k \approx 0.3$)

L I T E R A T U R E

(1) Reiher, H./Fraass, K./Settele, E.
Concerning air and heat permeability of windows.
Wärmewirtschaftliche Nachrichten 1932/33

(2) Rögelein, W.
Determining the heat demand of high buildings due to wind.
HLH 18 (1967) 12, p. 454 - 461

(3) Stöcher, H.
Taking account of the effects of wind when dimensioning heating installations.
Contribution B 3 in Book 5 of the Research Report "Optimising Wall Constructions", Vienna, 1974

(4) Kionka, U./Sitzler, R.
The effect of the outdoor climate on heat demand.
PEK 16 (1968) 1/2 p. 8 - 12

(5) Valko, P.
Meteorological map tables for economic air conditioning.
Unpublished manuscript of the Swiss Meteorological Central Institute, Zurich, 1973.

(6) Rietschel/Raiss
Heating and air conditioning.
Berlin, Heidelberg, New York, 15/1970

(7) Spaethe, A.
Commentaries on DIN 4701/59
Dusseldorf, 5/1973

(8) Blodau, A.
Optimisation system for reducing operating costs of heating and air conditioning installations in non-residential buildings.
HLH 21 (1970) 9, p. 306 - 308

(9) Esdorn, H.
Revision of DIN 4701. The current position.
Ges.-Ing. 94 (1973) 1, p. 18 - 23

(10) Kollmar, A.
DIN 4701 - Principals and corresponding fields of application.
Ges.-Ing. 93 (1972) 1, p. 1 - 10

(11) Gerber, E.
Heat demand calculation for entire buildings?
HLH 17 (1966) 4, p. 121 - 122

(12) Zöld, A.
Investigating the addition for orientation.
HLH 22 (1971) 8, p. 265 - 268

(13) Kollmar, A.
DIN 4701: Addition z_A - equalising the cold external surfaces.
Ges.-Ing. 91 (1970) 2, p. 33 - 41

(14) Kast, W.
Consideration on the additions for interrupted operation and cold external surfaces in DIN 4701.
Ges.-Ing 91 (1970) 9, p. 252 - 257

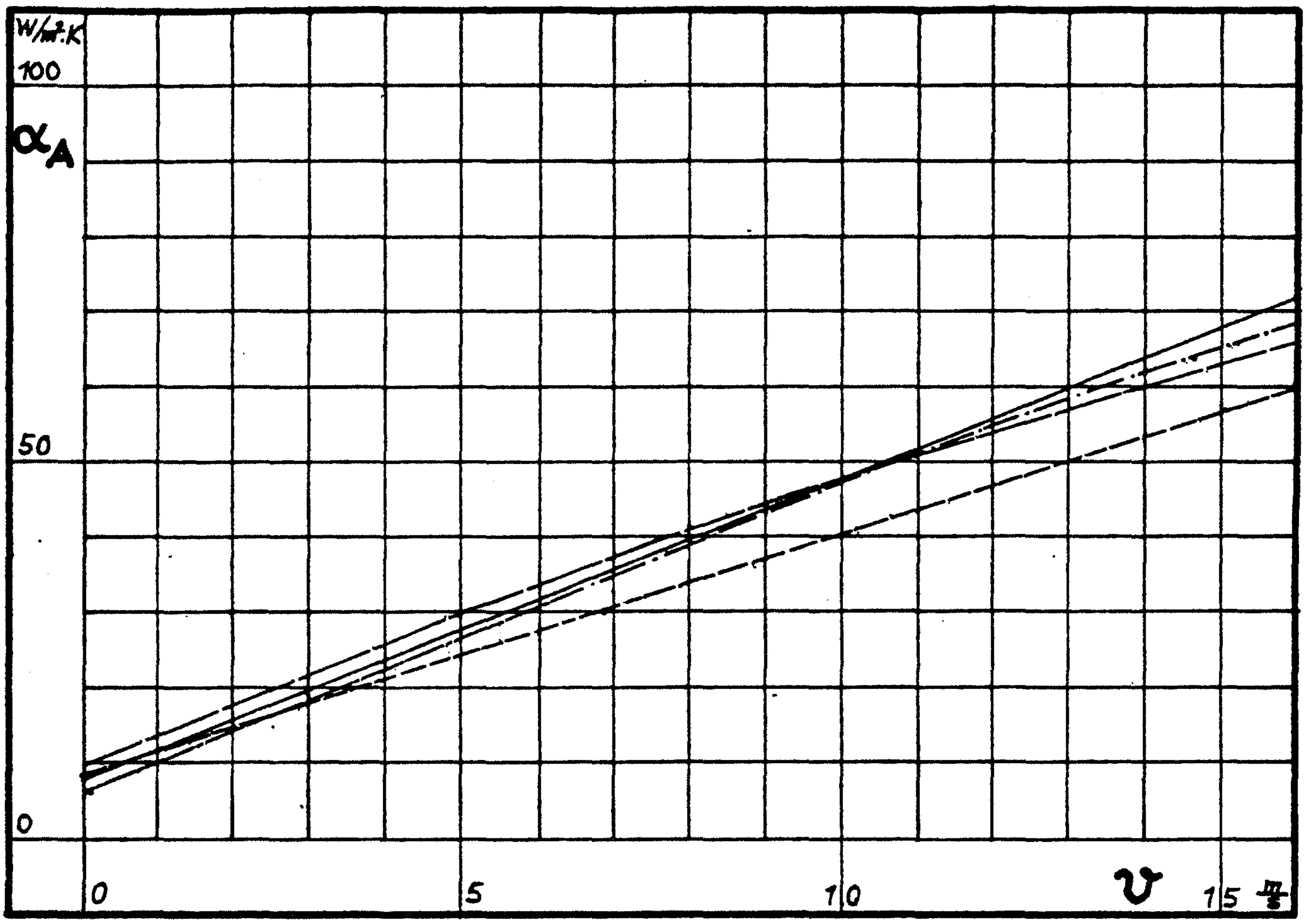
(15) Preussker, H.
Determining the ventilation heat demand
HLH 22 (1971) 8, p. 269 - 270

(16) Gerber, E.
New heat demand calculation?
HLH 21 (1970) 9, p. 326 - 332

(17) Knabe, G.
Calculating the heat demand of rooms with radiant space heating.
Stadt- und Gebäudetechnik (1974) 3, p. 64 - 70

(18) Franke, H.
Temperature distribution and heat flux in composite walls with non-steady ambient air temperatures and solar radiation.
Die Bautechnik (1970) 7, p. 244 - 248; 8, p. 273 - 279

Abb. 1 Die äußere Wärmeübergangszahl α_A in Abhängigkeit von der Windgeschwindigkeit v, nach Angabe diverser Fachautoren.



——— ——— ——— $\alpha_A = 10{,}3 + 4{,}0\ v$ (v≤5 m/s) nach Jürges

$\alpha_A = 4{,}5 + 7{,}1\ v^{0{,}78}$ (v>5)

Lit.: Recknagel-Sprenger :
Taschenbuch für Heizung und Klimatechnik.
München-Wien, 1972. p.120.

– – – – – – – – $\alpha_A = 8{,}7 + 3{,}2\ v$ (Wand // Wind) nach Gerhart

$\alpha_A = 8{,}7 + 2{,}6\ v$ (Wand ⊥ Wind)

Lit.: Gerhart, K.:
Modellversuche über die Verteilung des konvektiven Wärmeübergangs an Gebäudefassaden.
Kältetechnik (1967)5,p. 122-128.

—·—·—·— $\alpha_A = 6{,}2 + 4{,}2\ v$ (v≤5 m/s)

$\alpha_A = 7{,}5\ .\ v^{0{,}8}$ (v>5 m/s)

Lit.: Hütte. Des Ingenieurs Taschenbuch.
Band I. Theoretische Grundlagen.
Berlin 28/1955, p.499.

———————— $\alpha_A = 8 + 4\ v$

Vereinfachende Annahme, deren Gültigkeit bis etwa 15 m/s gegeben ist.

Abb. 2 Für die Befeuchtung zusätzlich erforderlicher Wärmebedarf

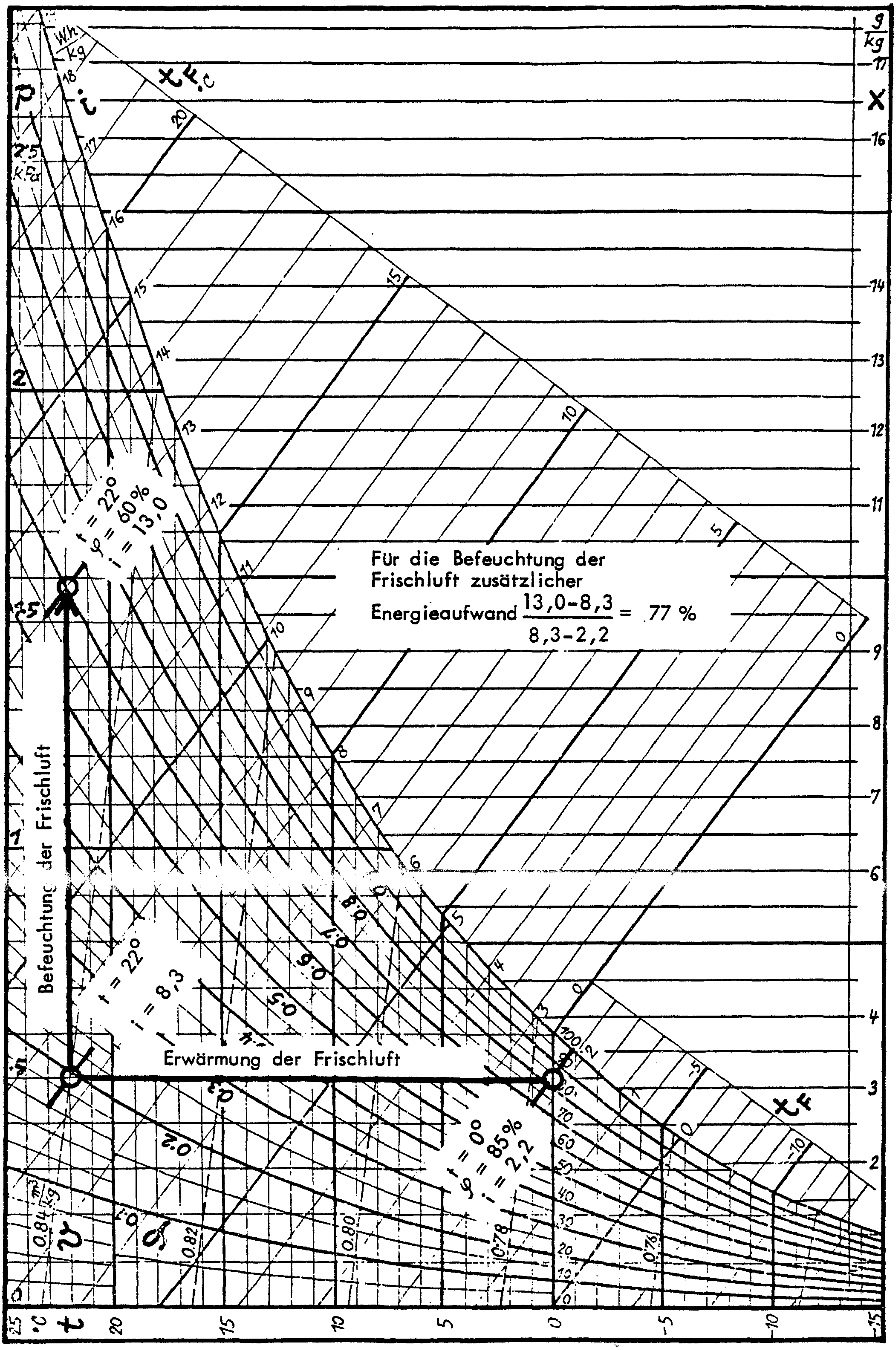


Abb. 3 Wärmeverluste q einer Außenwand in Abhängigkeit von der Windgeschwindigkeit

FALL n	$f_W = 0{,}75$	$R_W = 0{,}75 \frac{m^2 K}{W}$	$f_F = 0{,}25$	$R_F = 0{,}25 \frac{m^2 K}{W}$	$l_F = 1{,}0 \frac{m}{m^2}$	$\alpha = 3 \frac{m^3}{h \cdot m \cdot (\frac{kp}{m^2})^{2/3}}$

$$q = \frac{Q}{\Delta t} = q_W + q_F + q_L = 0{,}75 \cdot \frac{1}{0{,}75 + \frac{1}{8+4v}} + 0{,}25 \cdot \frac{1}{0{,}25 + \frac{1}{8+4v}} + 0{,}072 \cdot 1 \cdot 3 \cdot v^{4/3}$$

Σq	1,52	1,86	2,27	2,70	3,18	3,67	4,21	4,76	5,33	5,94	6,57	7,20	7,85	8,52	9,19	9,91
q_L	0,00	0,21	0,55	0,93	1,37	1,85	2,36	2,90	3,45	4,05	4,66	5,29	5,93	6,60	7,27	7,99
q_F	0,67	0,75	0,80	0,83	0,86	0,87	0,89	0,90	0,91	0,92	0,93	0,93	0,94	0,94	0,94	0,94
q_W	0,86	0,90	0,92	0,94	0,95	0,95	0,96	0,96	0,97	0,97	0,98	0,98	0,98	0,98	0,98	0,98

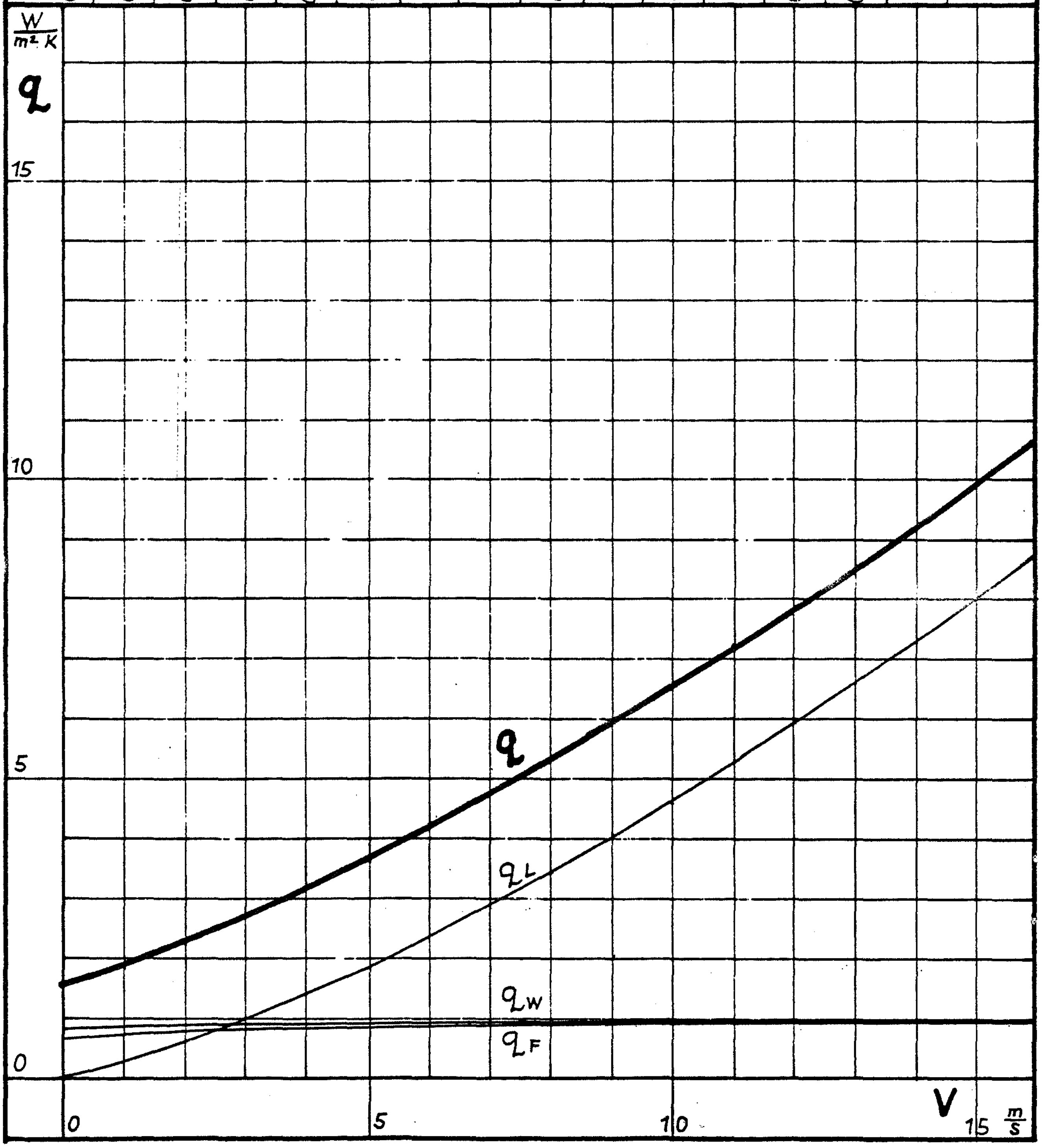


Abb. 4 Wärmeverluste Q einer Außenwand von 1 m2 in Abhängigkeit von der Außentemperatur t und der Windgeschwindigkeit v

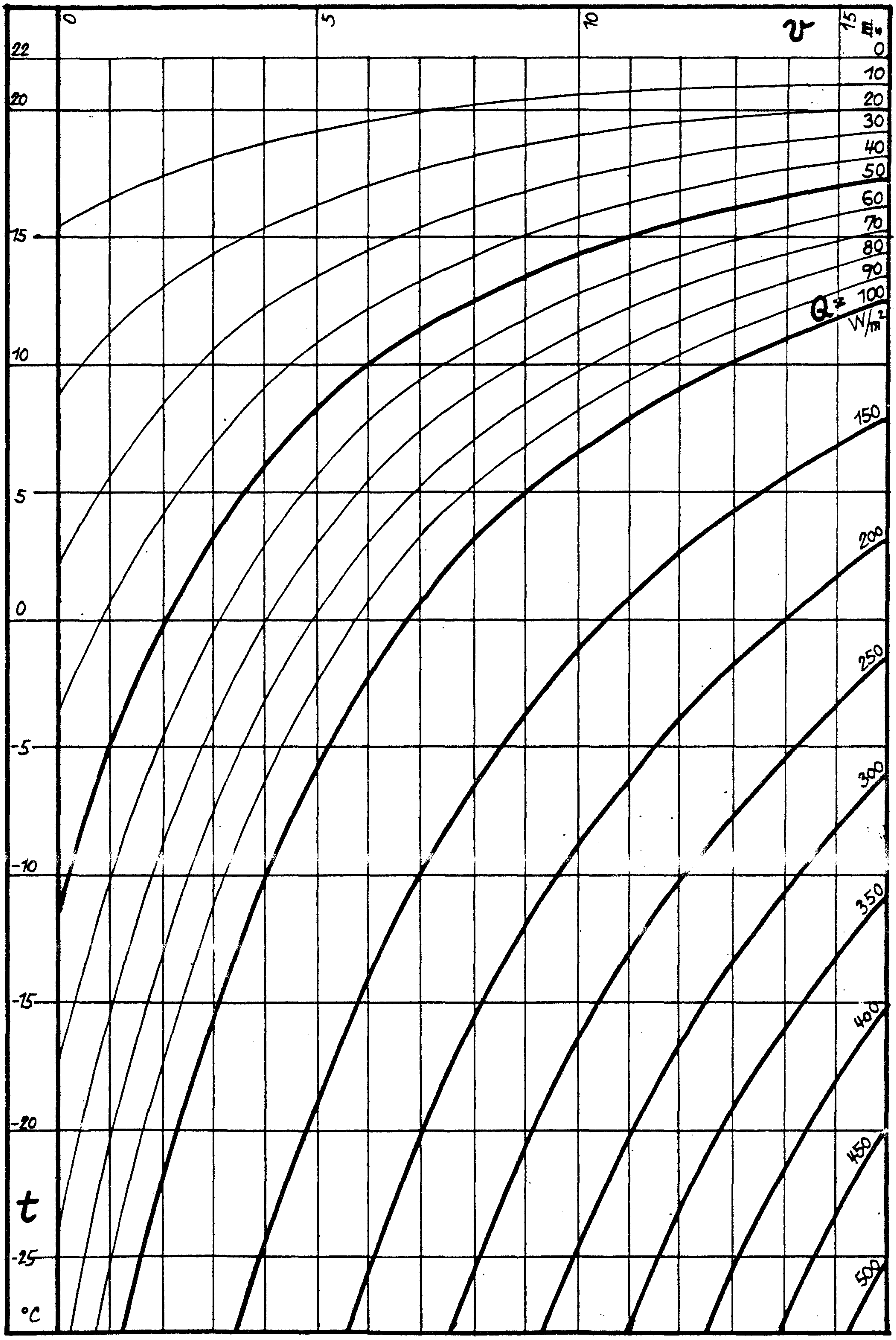


Abb. 5 Die Summenhäufigkeit des gemeinsamen Auftretens von Windgeschwindigkeit v und Lufttemperatur t (milde Lage)

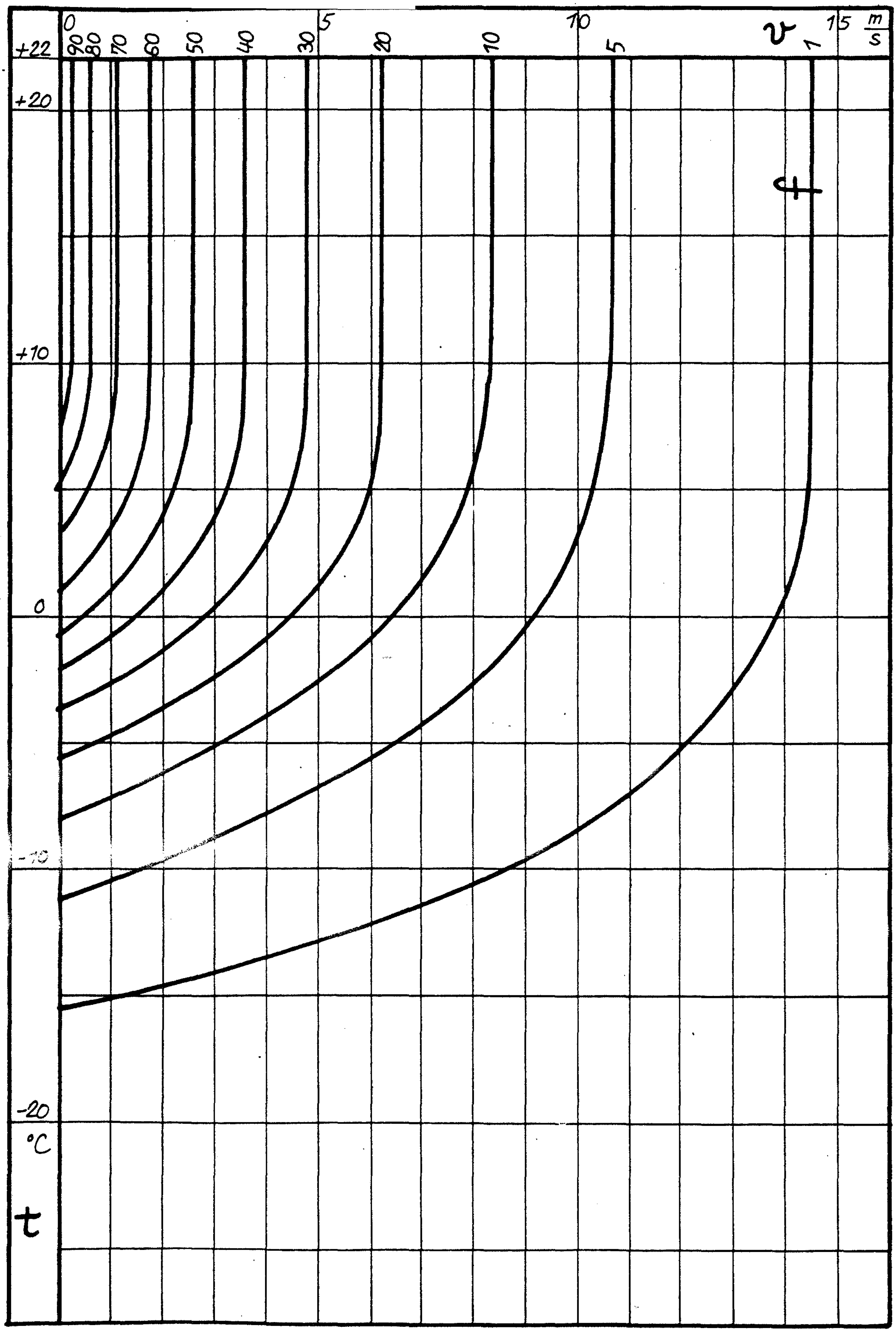


Abb. 6 Die für die Bemessung der Heizanlage kritischen Kombinationen der Werte Außenlufttemperatur/Windgeschwindigkeit

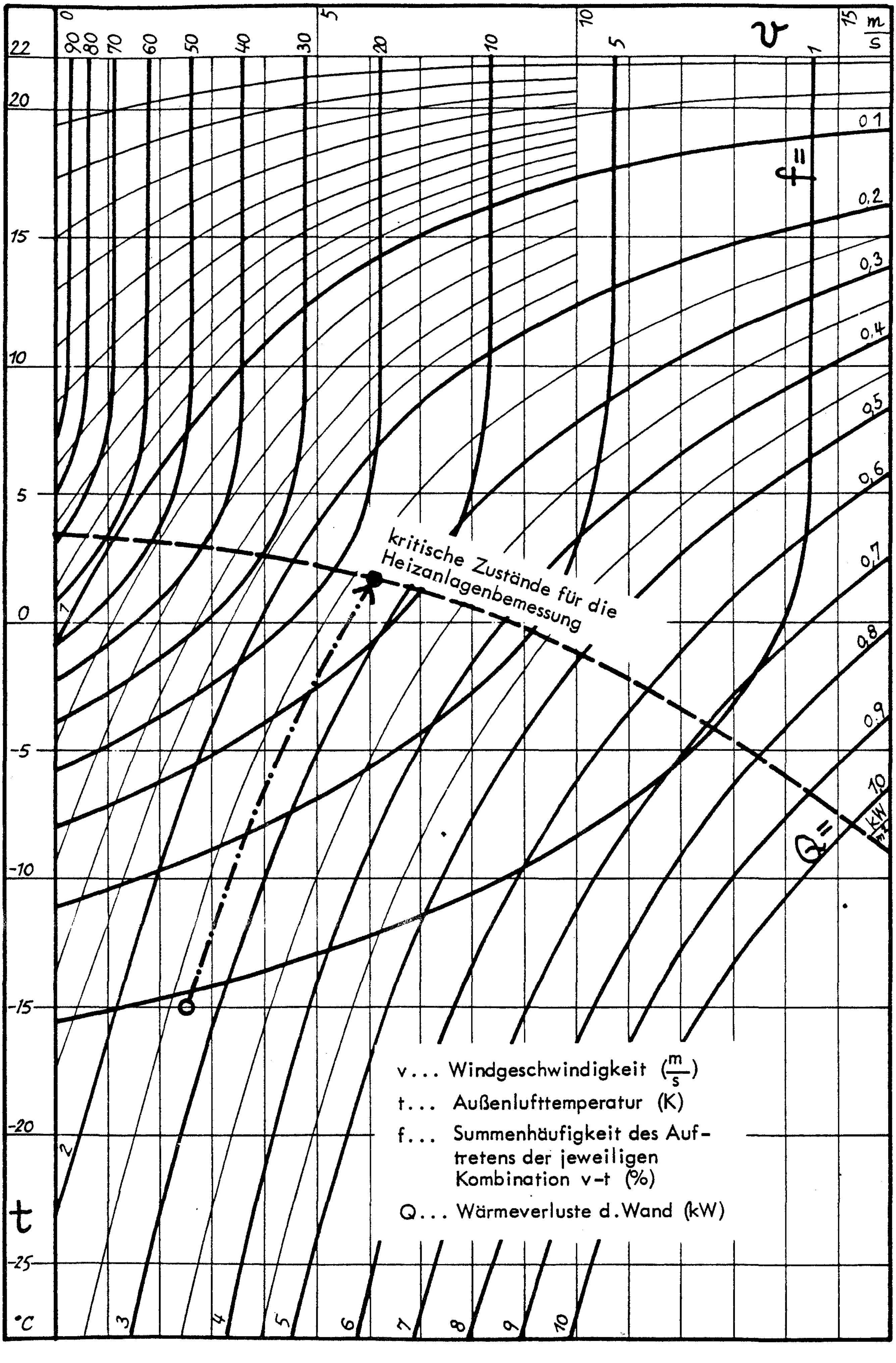


Abb. 7 Für die Bemessung von Heizanlagen kritische Kombination von Außentemp. t und Windgeschw. v in Abh. der Zuverl. f