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RULES FOR THE CALCULATION OF THE HEAT REQUIREMENTS OF BUILDINGS.

UDC: 697.12/.14 ; 536.68

Prepared by the Special Standards Committee for Heating and Ventilation (FNHL) at DIN, the German Institute for Standardization.

Previous Edition: Jan. 1959

Alterations March 1978: Calculations converted to the new legal units; Addition z_U for interrupted operation omitted. Values for the addition z_A to compensate for cold outside surfaces increased. High rise blocks are no longer considered "special cases". (see also the introductory remarks to the standard).

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DIN 4701: Draft March 1978

Rules for the Calculation of the Heat Requirements of Buildings.

Objections before 31st July 1978

This draft standard, the contents of which do not yet constitute the definitive version of the intended standard and which is, therefore, not intended for practical application, is submitted to the public for examination and comment so that it may be improved if required. It contains the intended version of the revision of DIN 4701, Jan. 1959.

If this draft standard is to be used in exceptional cases in economic transactions this has to be agreed between the participants, e.g. the supplier and the purchaser.

Objections and amendments to this draft standard are invited in duplicate to the Special Standards Committee on Heating and Ventilation at DIN, Burggrafenstrasse 4 - 10, 1000 Berlin 30.

The method for the calculation of the heat requirements contained in DIN 4701, Jan. 1959, is maintained in its essential physical bases. Due to technical development in building technology and also in heating and ventilating engineering a number of alterations and additions have become possible or even necessary.

The addition z_U for interrupted operation has not been maintained since modern control methods have made it redundent. This makes it possible to restart heating after interruptions automatically at any desired time.

The evenness of room temperatures in a building in continuous use is also improved by this method.

The addition z_A to compensate for cold outside surfaces has been considerably increased to raise the air temperature in rooms with low surface temperatures more than before in conformity with present day ideas of comfort evaluation. The omission of the addition z_U acts in the same direction.

The "D-Value" introduced by O. Krischer has been accepted internationally as an important characteristic. The intended revision of the standard is, therefore, to be used to introduce the term "Krischer-Value D" in recognition of the merits of Prof. O. Krischer, Dr. Ing., the former chairman of the Committee DIN 4701.

The calculation of the ventilation heat requirement applies now also to high rise buildings, buildings or rooms with mechanical ventilation as well as for inside sanitary rooms with free ventilation. The calculation method takes now into consideration the buoyancy effects in buildings higher than 10 m. Data for the joint leakage coefficients have been extended. In particular computation values for windows which can not be opened and for gaps in finished buildings have been included.

The significant alterations in the "special cases" include a limitation of the heating-up times for rarely heated buildings, a revision of the heat transmission resistance for high halls and an extension of the calculation methods to include green houses. The calculation of the heat requirement of surfaces in contact with the soil is no longer included in the special situation but is now considered a routine situation. The calculation of for heat-insulated surfaces in contact with the soil has been altered. High-rise buildings are no longer included in the special cases.
Further more, a number of partly important formal alterations were introduced: With regard to the great number of different modern multilayer building methods the tabulation of the heat transmission coefficients k has been omitted. In its place the thermal resistivities $R_\lambda = \frac{d}{\lambda}$ have been tabulated so that the heat transmission resistance $R = 1/k$ can be determined from the sum of the thermal resistivity and heat transfer resistance. The collection of tables has thus been kept within reasonable limits.
The standard has been converted to the legally prescribed SI-Units. Only conversion equations to the previously used units are given. The present time is particularly suited for this important step since the project engineer has to familiarize himself anyway with new empirical values because of the conversion to calculation with resistance values instead of heat transmission coefficient and the heat transfer coefficient.

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1. SCOPE.

This standard applies for completely and permanently heated buildings. Houses are considered as being completely heated in which all the rooms, with the exception of a few secondary rooms, are heated.

Heating installations designed to this standard may during periods of milder weather provide satisfactory heating conditions if they are operated with some restrictions or interruptions (e.g. during the nights).

A calculation methods for buildings heated only infrequently is given among the "special situations".

2. SYMBOLS.

The most important symbols used in this standard are given below in alphabetical order (Note by Translator: in alphabetical order according to their symbols) with explanations.

The units to be used in each case are also mentioned.

Symbol	Designation	Unit.
A	Area	m^2
a	Gap-leakage coefficient or permeability coefficient	$m^3/m\ h\ Pa^{2/3}$
b	Width	m
c	Specific Heat Capacity	J/kg K
D	Krischer-Factor D	$W/m^2\ K$

Symbol	Designation	Unit
d	Thickness	m
$H_{G\,10}$	Standard house characteristik	$W\,h\,Pa^{2/3}/m^3\,K$
h	Height	m
k	Thermal transmittance, heat transmission coefficient	$W/m^2\,K$
l	Length	m
p	Air pressure	Pa
Q	Heat flow	W
Q_L	Standard ventilation heat requirement	W
Q_N	Standard heat requirement	W
Q_T	Standard transmission heat requirement	W
Q_0	Transmission heat requirement without addition	W
R	Heat transmission resistance	$m^2\,K/W$
R_a	External heat transmission resistance	$m^2\,K/W$
R_i	Internal heat transmission resistance	m^2K/W
R_λ	Thermal resistance	m^2K/W
r	Room characteristic	-
t	Temperature	°C
t_a	Standard outside temperature	°C
t_i	Standard inside temperature	°C
$\dot{V}$	Volume flow	m^3/s
V_R	Room volume	m^3
z_A	Addition for outside wall	-
z_H	Addition for the point of compass	-
α_a	External heat transfer coefficient	$W/m^2\,K$
α_i	Internal heat transfer coefficient	$W/m^2\,K$
β	Air changes	1/s or 1/h
ε_H	Correction factor for height	-
λ	Heat conductivity coefficient	$W/m\,K$
ρ	Density	kg/m^3

3. CONVERSION OF IMPORTANT UNITS.

Below are given the conversion equations for the most important SI-units into those units which have till now been used in heat requirement calculations.

for heat flow: (Q, Q_N, Q_L, Q_T, Q_O): 1 W = 0,86 kcal/h

for thermal transmittance and heat transfer coefficient (k, α_i, α_a)

1 W/ m² K = 0,860 kcal/h m² degree

for the heat conductivity coefficient (λ)

1 W/m K = 0,860 kcal/h m degree

for pressure (p): 1 Pa = 0,102 kp/m² ≈ 0,102 mm WG

for the gap leakage coefficient (a):

$1\ m^3/m\ h\ Pa^{2/3} = 4,58\ m^3/\ m\ h(kp/m^2)^{2/3}$

for the standard house characteristic (H_{10}):

$1\ Wh\ Pa^{2/3}/m^3\ K = 0,188\ kcal(kp/m^2)^{2/3}\ /\ m^3$ degree

for the specific heat capacity (c) :

1 kJ/kg K = 0,239 kcal/kg degree

An important identy is given by: 1 J ≙ 1 Ws ≙ 1 Nm

4. SURVEY OF CALCULATION METHODS AND THEIR BASES.

A distinction is made between calculation methods for routine cases and those for special situations.

4.1 Routine Cases.

The method for routine cases is applicable to the overwhelming majority of all buildings occurring in practice. By way of examples we mention dwelling houses, office blocks, stores, hospitals, schools, sports halls, hotels, restaurants and workshops having an average heights.
Occasionally it has to be examined whether some parts of buildings (e.g. rarely used halls in hotels) should be treated according to the method for special situations.

4.2 Special Situations.

Calculation methods for the following special situations are given:

a) Rooms which are heated only rarely,
b) Rooms constructed in a exceptionally heavy manner,
c) Halls of exceptional room heights,
d) Green houses.

4.3 Fundamentals of the Calculation Methods for Routine Cases.

The amount of heat which has to be introduced into a room in order to obtain under standard weather conditions a defined standard thermal internal room condition is called the standard heat requirement of the room.
A stationary condition, i.e. a temporal constancy of all variables required for the calculation is assumed as the basis for the calculation.
It is further assumed that the surface temperatures of the surrounding surfaces between heated neighbouring rooms are equal to the air temperature and that the external walls are exchanging radiation only with internal boundary surfaces of the room.
In these circumstances the standard heat requirement is a property of the

building. It can be used with adequate accuracy for the design of the usual heating system, even if its heat transfer to the room is subject to certain deviations from the above mentioned preconditions. (See the explanations to section 6, table 3.)

The installation of heating surfaces with a significant radiant component (e.g. radiators or panels) in front of glass surfaces may, however, lead to so large deviations that the design of the heating system may no longer follow the standard heat requirement programme. With regard to the increased energy consumption such a lay-out should be avoided. If required data for the dimensioning should be taken from the literature[1].

The standard heat requirement of a room is composed of the standard transmission heat requirement (heat loss through the enveloping surfaces by heat conduction) and of the standard ventilation heat requirement (the heat requirement for warming the introduced outside air).

The standard transmission heat requirement has to be calculated separately for each component of the surfaces having a different thermal transmission coefficient or being subject to a different temperature difference. The "transmission heat requirement of a room without any additions", which is primarily calculated according to the equations for plane panels, has to be increased by additions which allow for the effects of the compass directions and for the comfort reducing effect of cold outside surfaces. These additions have the effect that the room air temperature is [illegible] be higher than the fundamental calculated value of the internal temperature (See the explanations to section 6, table 3.)

The calculation of the standard ventilation heat requirement is based on a simplified determination of the air volumes which can enter the room through gaps in joints under certain conditions. It has to be based on the effective pressure differences on the building for the wind conditons prevailing under the usual outside temperatures and also on the thermally produced pressures as well as the flow resistances in the gaps of the outside and inside components of the building. In rooms with mechanical ventilation a check calculation is required because of the excessive volume of expelled air and the additional amount of frech air being sucked in to compensate for it.

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1) Esdorn H., Kast W., Schauss H., and Zöllner G.; The effect of the temperature of the back-wall on the performance of panel heaters. wkt 24 (1972), Nr. 9, p.251-253.

4.3.1 Adequate Heating.

An adequate dimensioning of the heating installations is ensured the calculation of the standard heat requirement is based on adequately low outside temperatures and the appropriate wind velocities as well as on sufficiently reliable material constants for the heat conductivity of the building materials. In porous materials they are based on average humidity. An adequate air-tightness of the external building components is of particular importance for a satisfactory heating of a room. It must be ensured that the gap leakage on which the calculations have been based are not exceeded during the construction - this has to include the constructional joints between the windows and doors and the wall construction. The gap leakage coefficients of the windows have to be classified according to DIN 18055/2.

4.3.2 Even Heating.

It is the purpose of the heat requirement calculation to ensure in addition to an adequate heating also a sufficiently even heating of the rooms in a building equipped with a centrally controlled heating installation or-group to the temperatures which have formed the basis of the calculation. This is, however, possible only within certain limits.

An obvious precondition for the reaching of the desired temperatures is that all the rooms in the building are heated according to the calculated plan. The temperatures which establish themselves, when a steady state has been reeched, in the individual rooms follow from the equilibrium between the output from the heating surfaces and the heat losses from the rooms.

Theoretical investigations have shown 2) that, although all these conditions have been observed, a central control of a building or of a zone in a building leading to a sufficiently even temperature is possible only because of the thermal linkage of the rooms through the internal walls, ceilings and floors and the air exchange also contributes to it significantly. In rooms or parts of the building which are badly linked to the rest (e.g. annexes) a careful zoning of the heating installations is more than usually important.

If centrally controlled heating installations are to be extended over and above their original design to previous editions of DIN 4701 it is recomended - if no separate control zone is planned for the extension - to calculate the extension according to the same issue of the standard which was used for the main installation.

2) Esdorn H.: The effect of the type of construction and of the installation system on the temperature distribution in buildings with centrally controlled heating - and air-conditioning plants. VDI-Report Nr. 152; VDI-Verlag, Düsseldorf; 1971.

4.3.3. Heat Insulation of the Building.

The requirement for a low-heatloss construction is based on energy-saving structural physics and room-climatic reasons.

The minimum heat insulation of buildings is laid down in DIN 4108. This standard contains minimum values of heat insulation, graded according to areas, of individual building components. These values are derived from the requirement to prevent condensation on the interior wall surfaces at low outside temperatures and for defined room air humidities.

At present it is usual to consider in addition to DIN 4108 also thermal comfort criteria when minimum thermal resistances are laid down with regard to extreme winter and sommer conditions.

Compliance with these requirements alone does not ensure a comfortable room climate. This aim can be attained in a satisfactory manner only if the heating system has been so designed that it compensates for the downcurrent of cold air on cold surfaces and for the penetration of cold air through leakages in joints. It may also be necessary to compensate for radiation losses from the human body to cold surfaces by a radiation gain from suitably positioned heated surfaces.

The requirement for rational energy use, which has become very important in recent times, has led to the publication of the "Additional Requirements to DIN 4108 - Heat Insulation in High-rise Buildings" which contain in particular regulations for the construction of windows as well as for the proportion of window surface in the overall outside surface of a building. They have been officially required by the authorities of the "Bundes Länder" (the constituent parts of the Federal Republic). Going even further an "Addendum to DIN 4108 - Heat Insulation in High-Rise Buildings" has been published in which questions of improved heat insulation are discussed. This addendum is at present only a recommendation . On the 22nd July 1976 the "Law about Saving Energy in Buildings" (Energy Savings Law =EnEG) came into force, since the 1st Nov. 1977 the additional order concerning heat insulation in buildings "Order about Energy Conserving Insulation of Buildings" has also been in force. This order distinguishes between "Buildings with Normal Interior Tempratures"; "Buildings with Low Interior Temperatures" and "Buildings for Sport- and Assembly Purposes", for each of which different conditions for minimum heat requirements apply. This order and its requirements for the first mentioned group of buildings is based , mainly, on the mentioned Addendum to DIN 4108 - Heat Insulation in Buildings. Exeptions apply for buildings mainly heated by waste heat and for rooms serving horticultural purposes, e.g. green houses.

All the requirements in the mentioned guidelines have a favourable effect on energy consumption as well as on the protection of buildings against moisture damage and also on the attainment of optimum room-climatic comfort conditions.

Progress in the design of windows do no longer justify the previous classification with regard to the leakage rates through gaps. Independent of the material of the windows any classification is based exclusively on stress groups according to DIN 18055/2.

4.3.4 Heat Consumption.

The standard heat consumption is the basis of the calculation of the heat input. Even under standard weather conditions this is not identical with the actual input required for practical heating purposes. This will, generally, be lower since the material constants include certain safety factors and the calculated standard ventilation heat requirement occurs simultaneously only in a part of the building. This has to be considered in the determination of the annual heat consumption as well as the effect of solar irradiation.

More detailed instructions are contained in the VDI-Guideline 2067 "Economic Calculations of Heat Consuming Plants".

5. CALCULATION OF THE STANDARD HEAT REQUIREMENT FOR ROUTINE CASES. -

5.1 Structure of the Calculation.

The standard heat requirement Q_N[3] is the sum of the standard transmission heat requirement Q_T and of the standard ventilation heat requirement Q_L:

$$Q_N = Q_T + Q_L \qquad (1)$$

For the standard transmission heat requirement applies Eq. (2):

$$Q_T = Q_o \cdot (1 + z_A + z_H) \qquad (2)$$

where: Q_o..... Transmission heat requirement without any addition

z_A..... Addition for outside wall

z_H..... Addition for the oint of compass (direction)

The standard ventilation heat requirement is the heat input required for heating the cold air which enters through gaps of windows, doors, walls etc from the outside temperature to the roomair temperature. (See sect. 5.4).

5.2 Temperatures.

5.2.1 Standard Outside Temperature.

The calculation of the standard heat requirement is based on the outside temperature of the place which is the lowest average over two days which, in a period of 20 years, is reached or exceeded 10 times. This agreed calculation basis is called the standard outside temperature (see the explanations to Table 2, section 6.)

3) See next page.

5.2.2 Standard Inside Temperature.

The inside temperature, as used in these calculations of the standard heat requirement, is a "perceived temperature" which includes the effect of the air temperature as well as the mean temperature of the surrounding surfaces. It is called the "standard inside temperature" (see explanations to tab.3, sect.6

5.3 Standard Transmission Heat Requirement.

5.3.1 Transmission Heat Requirement without Additions.

The standard heat requirement without additions of a room is the sum of the heat losses which a room suffers due to the passage of heat through walls, windows, doors, ceiling and floor. For building components bordering to the outside air or to neighbouring rooms Equ. (3) applies:

$$Q_o = \sum \frac{A . \Delta t}{R} \qquad (3)$$

where: A ... area of the building component

Δt .. temperature difference

for external building components: $\Delta t = (t_i - t_a)$

for internal buildin g components: $\Delta t = (t_i - t_i')$

R ... heat transmission resistance

t_i ... Standard inside temperature of the room to be heated

t_i' ... Standard inside temperature of neighbouring rooms

t_a ... Standard outside temperature

The heat transmission resistance is composed additively of the internal heat transmission resistances R_i and the external heat transmission resistances R_a and of the heat conduction resistances (thermal resistances) of each layer of the wall of the building component.

$$R = \frac{1}{k} = \frac{1}{\alpha_i} + \sum \frac{d}{\lambda} + \frac{1}{\alpha_a} = R_i + \sum R_\lambda + R_a \qquad (4)$$

where: α_i ... internal heat transfer coefficient

α_a ... external heat transfer coefficient

λ ... heat conductivity coefficient

d ... layer thickness

k ... heat transmission coefficient

In components in contact with the soil heat losses occur not only through the soil to the outside air but also to the ground water.

In the estimation of the first mentioned component the standard outside temperature is not to be used since this is based on short periods of cold weather which can not be applied because of the great heat storage capacity

3) Since the present standard is to be used widely in building practice it is important for the terminology to be suitable for typewriting. Differing from DIN 1301 heat output data are designated by the Q without a dot over it ($\dot{Q}$).

of the soil; it is necessary to use a mean outside temperature over a longer period of cold weather. The thermal resistance through the soil to outside air depends on the area of the soil surface and its geometry.

The heat losses to the ground water may be calculated in a simplified manner according to the usual set-up for plane-parallel plates. As the temperature difference one has to use the difference between the inside temperature and the mean ground water temperature. The heat transmission resistance from the room to the groundwater is the sum of the internal heat transmission reistance and the thermal resistances of the building component and the soil.

The transmission heat requirement without additions of surfaces in contact with the soil can be calculated as follows:

$$Q_o = A_{tot.} \left[\frac{t_i - t_{AL}}{R_{AL}} + \frac{t_i - t_{GW}}{R_{GW}} \right] \qquad (5)$$

where:

$$A_{tot} = l.b + 2\,(l + b).h \qquad (6)$$

$$R_{AL} = R_i + R_{\lambda B} + R_{\lambda A} + R_a \qquad (7)$$

$$R_{GW} = R_i + R_{\lambda B} + R_{\lambda E} \qquad (8)$$

$$R_{\lambda E} = \frac{T}{\lambda_E} \qquad (9)$$

and where:

A_{tot} .. is the sum of all surfaces in contact with the soil,

t_{AL} .. the mean outside temperature over a prolonged cold spell,

t_{GW} ... the mean temperature of the ground water,

R_{AL} ... the equivalent heat transmission resistance from the room to the outside air.

R_{GW} ... the equivalent heat transmission resistance from the room to the ground water.

$R_{\lambda B}$ ... the thermal resistance of the building component.

$R_{\lambda A}$ ... the equivalent thermal resistance of the soil to the outside air to fig. 1.

$R_{\lambda E}$.... the thermal resistance of the soil to the groundwater,

R_i .... the internal heat transmission resistance(to table 18)

R_a ... the external heat transmission resistance (to table 18).

λ_E ... the heat conductivity coefficient of the soil.

Dimensional designation see fig. 1.

As a rule the following numerical values can be assumed:

t_{AL} = - 5° to 0°C

t_{GW} = + 10 °C

λ_E = 1,2 W/mK

Where the thermal resistances of various building components in contact with the soil are only insignificantly different (e.g. where the concrete thicknesses are different) one should use uniformly the thermal resistance of the larger surface for R_{AL} and R_{GW}. Where the thermal resistances have larger differences (e.g. where some components are insulated and others are not insulated) the heat requirements for the corresponding surfaces have to be calculated separately according to equ.(5). For the determination of the thermal resistance $R_{\lambda A}$ to fig. 1 the entire floor area has to be used; as the depth of the ground water level T one has to take the measure with regard to the soil surface to fig.1 - this applies also for vertical surfaces reaching to a higher level.
If the floor surface is heat-insulated but the vertical surfaces are not insulated only 50 % of the value of $R_{\lambda A}$ to fig. 1 is to be used (parameters as above)for the vertical surfaces in contact with the soil.
In the case of individual heated cellar rooms the determination of $R_{\lambda A}$ is to be based on the appropriate dimensions of the floor of the cellar room instead of the building dimensions l and b in fig. 1. In the case of contiguous cellar rooms which have no rectangular ground plan one has to use a rectangel of the same area one side of which is to be equal to the greatest single dimenion of the actual ground plan.

5.3.2 Additions.

5.3.2.1 Addition for outside walls.

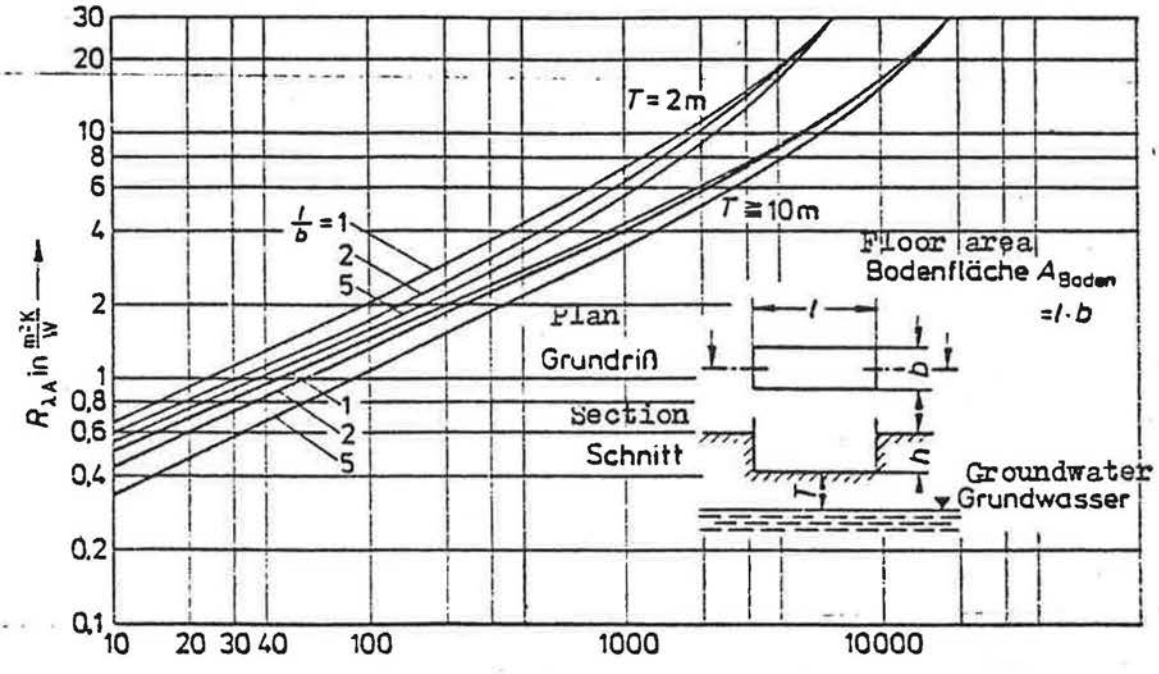
Since the internal surface temperatures of outside surfaces (outside walls or windows) are, depending on the heat insulation of these surfaces, more or less lower than the surface temperatures of inner surfaces (partition walls, floors or ceilings etc.) the user of the room is losing more heat, mainly by radiation, to these colder surfaces on outside walls. To improve the comfort in these rooms - in particular those with large, poorly insulated outside faces - the heat supply to these rooms has to be increased. The heat loss to the cold outside surfaces can be described by the use of the Krischer-Factor D,which is directly connected with the mean surface temperature, and by the radiation exchange between the inhabitants of the room and the outside surfaces.
The Krischer-Factor D is defined as follows:

$$D = \frac{Q_o}{\sum A(t_i - t_a)} \qquad (10)$$

where $\sum A$ is the sum of <u>all</u> surfaces enclosing the room.
If average assumptions for the radiation conditions in the room are acceptable <u>the addition z_A becomes a function</u> of the Krischer-Factor D only[4] (see fig.2).

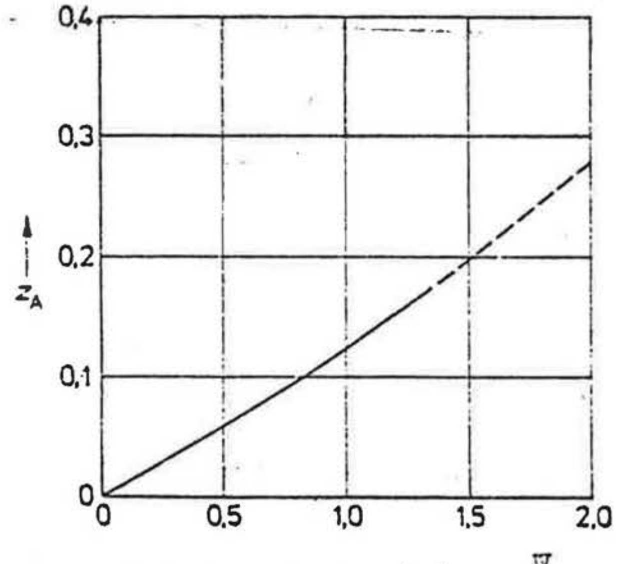
4) Kast W. : Considerations concerning the additions for interrupted operation and cold outside surfaces to DIN 4701. Ges. Ing.91 (1970),Nr.9,p.252-257. (Ges.Ing. = Gesundheits Ingenieur = Health Engineer).

The calculation is to be based on values from Table 7.



Floor area - A_{floor} in m^2

Fig.1. Equivalent Thermal Resistance $R_{\lambda A}$ fo the Soil to the Outside Air.



Krischer Factor D in $\frac{W}{m^2 K}$

Fig. 2 Addition for Outside Walls z_A

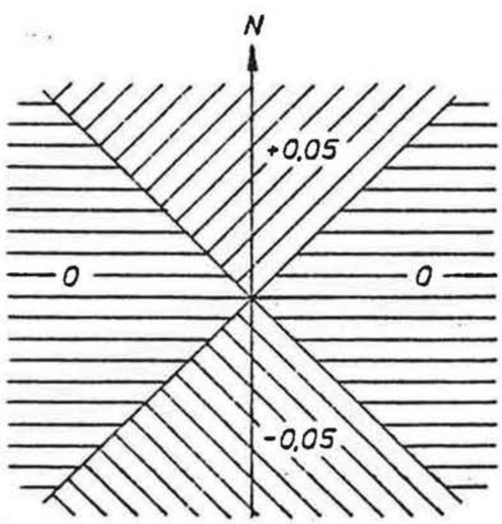


Fig. 3 Addition for the Points of the Compass z_H.

5.3.2.2 Addition for the Points of the Compass.

The addition z_H (see fig. 3) is based on the solar irradiation which depends on the direction with regard to the points of the compass. The values from Table 8 are to be used for the calculation.

Regarding the direction of a room with regard to the points of the compass the position of the outside wall is the controlling factor in rooms with one outside wall; in corner rooms the direction of the corner is controlling.

In rooms with 3 or 4 outside walls the highest addition is to be used. In centrally situated parts of buildings (e.g. light wells) without direct solar irradiation the addition z_H is to be omitted.

5.4 Standard Ventilation Heat Requirement[5)]

5.4.1 Buildings with Natural Ventilation

5.4.1.1 Fundamentals.

Buildings of the usual construction are up to a point permeable for air. The inflowing ambient air has to be heated to room temperature (approximately the standard interior temperature).

For this heat requirement eq. (11) applies generally:

$$Q_L = \dot{V}\, c\, \rho\, (t_i - t_a) \qquad (11)$$

Where: $\dot{V}$ ..the air volume flow

c .. spec. heat capacity

ρ .. density

For the air flow through gaps in joints eq. (12) is to be used:

$$\dot{V} = \sum (a.l) .(p_a - p_i)^n \qquad (12)$$

Where: a ... gap leakage coefficient

l ... length of gap

p_a ... external pressure

p_i ... internal pressure

For gaps in building component it is sufficiently accurate to use 2/3 as the exponent n for the pressure difference.

The pressure difference $(p_a - p_i)$ can be caused by buoyancy or wind forces. For low buildings (height < 10 m)the buoyancy forces can be neglected.

a) Wind Pressure.

The effect of wind movement produces on the side exposed to the wind in general a positive pressure and on the other faces a negative pressure which depends on the speed of the wind , on the shape of the building and on the flow conditions. Neglecting the buoyancy effect air enters the building only on the sides exposed to the wind and produces a ventilation air requirement while on the other faces warmed interior air is expelled. With increasing height above the surrounding land the wind velocities increase and with it the external wind pressures.

b) Buoyancy Pressure.

Due to the difference in density between the cold outside air and the warm inside air thermal differential pressures are produced against the outside air in continuous vertical ducts (e.g. lift shafts, stair cases) which are proportional to the height of the duct and the pressure difference - according to the temperature difference. Neglecting the wind effect and assuming an even distribution of leakages over the building height this has the effect,that

5) see p.18

in winter there exists a negative pressure in the lower parts of the building against the outside and a positive pressure in the upper part. Therefore, cold air enters through all faces in the lower parts and in the upper parts it is again expelled as warm inside air. A ventilation heat requirement exists, therefore, only in the lower parts of the building, but on all sides.

c) Combined Effect of Wind and Buoyancy.

Regarding the combined effect of wind and buoyancy the ventilation flow of a building can be calculated only with the help of expensive computer programmes because the internal pressures depend in a complicated manner on the distribution of all the external and internal flow resistances of the building. For a justifiable expense it is possible to calculate the ventilation heat requirement only for a few limiting cases of which always the most unfavourable shall form the basis for the standard ventilation heat requirement.

For instance, it depends on the size of the wind velocity whether on the wind exposed side of a high building in the upper sections air enters due to the external wind pressure or whether air is there expelled by the internal thermal positive pressure. Equally, it is not possible to say in general, whether in the lower parts of a high building on the lee-side air is expelled due to the external negative wind pressure or whether the internal negative thermal pressure predominates and thus air is sucked in also on this side and not only on the side exposed directly to the wind.

It is useful to differentiate (see fig. 8) between buildings of shaft type (without internal sub divisions) and buildings of multi-storey type (with airtight storey divisions).

Shaft type buildings are subject simultaneously to wind and buoyancy effects. The parameter, however, which governs the penetration is the ratio of the permeabilities of the faces directly exposed to the wind $A = \sum(al)_A$ and those not directly exposed to the wind $N = \sum(al)_N$ which can be mapped comparatively simply to certain plan types (see fig. 9) which correspond in turn to the house types used up til now (DIN 4701, Jan.1959) "individual house" "terrace house":

Plan type I (individual house) $\frac{A_H}{N_H} = \frac{1}{3}$

Plan Type II (terrace house) $\frac{A_H}{N_H} = 1$

Shaft type buildings represent in their lower sections always the most unfavourable limiting case.

Multi-storey type buildings are subject to wind effects only. In their upper sections they have always a greater ventilation heat requirement than shaft type buildings and they represent here the most unfavourable case.

5) Krischer O. & Beck H: The ventilation of rooms due to wind effects and the heat requirement for the ventilation. VDI-Reports; vol.18,1957

5.4.1.2 Calculation Set-ups.

It follows from equ. (11) and (12) that:

$$c \cdot \rho \cdot (p_a - p_i)^n = H_h = \varepsilon_h \cdot H_{G10} \qquad (13)$$

where: H_h ... house characteristic at the height h

H_{G10}.. Standard house characteristic for wind effect; (G = storey type house) referring to a height of 10 m.

ε_h... Height correction factor for wind and buoyancy effects at the height of h m.

One obtains thus for the ventilation heat requirement of the described limiting cases [6]:

for a shaft type building (range of applicability $\varepsilon_{SN} \geq 0$)

$$Q_{LS} = [\varepsilon_{SA} \cdot \sum (a\,l)_A + \varepsilon_{SN} \cdot \sum (a.l)_N] \cdot H_{G10} \cdot r \cdot (t_i - t_a) \qquad (14)$$

for a storey-type building:

$$Q_{LG} = \varepsilon_{GA} \cdot \sum (a\,l)_A \cdot H_{G10} \cdot r \cdot (t_i - t_a) \qquad (15)$$

Where: H_{G10} ... Standard house characteristic to Table 12,

ε_h Height correction factor (to tables 13 & 14

a .... Gap leakage coefficient to table 11

l ... length of gap

t_i .... standard inside temperature [7]

t_a .... standard outside temperature [7]

r ... room characteristic (to table 15 or eq. 18)

Indices:

S .... Shaft type

G ... Multistorey type

A .... Side exposed to wind

N .... Side not exposed to wind

The larger of the two limit values to eq. (14) or (15) is taken as the standard ventilation heat requirement Q_L.

For rooms inhabited for long periods (living rooms, bed rooms, offices etc.) a minimum value of air changes has to be laid down for hygienic reasons. It is useful to start from a defined multiple of the room volume for the air volume flow requirement (minimum number of air changes).

The eq. (16) applies for the standard ventilation heat requirements at minimum rates:

$$Q_{Lmin} = \beta_{min} \cdot V_R \cdot c\,\rho\,(t_i - t_a) \qquad (16)$$

where β_{min}.... Minimum air changes c ... Spec. heat capacity of the air

V_R .... Room volume, ρ ... Density of the air

6) Esdorn H. & Brinkmann W.: The ventilation heat requirement of buildings under the effect of wind and buoyancy. Ges. Ing. 99 (1978), Nr. 3

7) With regard to the limited accuracy of the standard ventil. heat requirement the standard temperature is used instead of air temperature as a simplification.

Assuming 0,5 room air changes per hour the minimum value of the standard room ventilation heat requirement becomes, in rounded off figures

$$Q_{L\ min} = 0,17 \cdot V_R(t_i - t_a) \text{ in W.} \qquad (17)$$

where V_R is given in m^3

$t_i - t_a$ in K.

5.4.1.3. Permeability of the Building work for air.

The significant contributions to the air permeability are in the gaps of closed windows and doors, which can be opened, as well as in the gaps between the window frames and the wall or between the individual outside wall elements, in particular between prefabricated units.

The most unfavourable value of wind exposure is to be used in the value of $\sum (a.l)_A$ that is:

in the case of corner rooms : For the two outside surfaces in contact with each other the larger permeability,

for rooms with two opposing outside walls: For the wall with the larger permeability.

Table 11 contains gap leakage coefficients for doors, windows and other building components.

5.4.1.4 Standard house-characteristic.

The standard house characteristic depends on wind velocity. This in turn depends on the geographic position of the building and on its position with regard to its environment.

Regarding the strength of the wind one has to distinguish between regions of slight wind exposure and of strong wind exposure. The region of strong wind exposure includes the area between the coast and the edge of the sub-alpine hills. The area to the south of it is in its lower altitudes considered as being a region of slight wind exposure. From a certain hight onwards - a level which increases as one gets nearer to the Alps - one has to consider these regions also as being exposed to strong winds (see also the map of isotherms, fig. 7).

Assessing the situation of a house one has also to consider that near the ground or immediately above roof level of a closely built-up area the wind velocity is lower than higher up. Only at a certain hight above ground level or the surrounding roof level does the wind obtain its full force.

One has to distinguish between:

Normal situation for houses in densly occupied areas (town centres) or with prevailing continuous loose occupation.

Exposed situation for isolated houses immediately at the coast, at the edge of large lakes, on hill tops or exposed ridges, or on islands.

The effect of the type of house on the permeability and, therefore, on the standard house characteristic is derived from the wind pressure distribution around the building (positive pressure on the side exposed to the wind and negative pressure an the side turned away from the wind) and from the distribution of the individual permeabilities $\sum(a.l)$ with regard to the exposed and the not directly exposed surfaces. The greater the permeability $\sum(a.l)_N$ of the not exposed surfaces is compared to that of the exposed surfaces $\sum(a.L)_A$ the lower is the internal pressure p_i in a house without internal resistances, i.e. the greater will be, accordigg to eq.(12), the volume of air blown into the building on the side exposed to the wind.

The behaviour of individual houses and of terrace houses is basically different. In a terrace house (see fig.9) there exists only one face from which air can escape for the same wind exposure conditions. The internal pressure adjusts itself to these conditions and the air volume passing through is reduced.

Those houses are considered to belong to the plan type I (individual houses) in which the air can escape from two or more outside surfaces.

Example for plan-type I: Houses detached on every side (see fig.9a) For exemptions see plan-type II.

Houses detached on three sides to figs. 9b and 9c, (corner houses of terraces) or parts of houses.

Houses are considered to belong to the plan type II (terrace houses) if they are divided by partition walls in such a manner that air can, essentially, escape through one outside surface only.

Example for plan-type II: Terrace houses to fig. 9d.

Inside flats in large units to fig. 9e,

Completely detached houses with a side ratio greater than 5 to fig. 9f;

Completely detached houses or those detached on 3 sides with 2 outside surfaces without any significant permeability to figs. 9g & 9h.

5.4.1.5 Correction factor for height.

The correction factor for height ε corrects for the increase in wind velocity with height and for the thermal pressure effects. They depend on the height of the room under consideration above the ground, on the type of the building to fig. 8 (shaft type building, multi-storey type building) as well as on the plan type (individual house, type I; terrace house, type II).

It is, generally, possible to estimate without calculation from the values of ε_{SA}, ε_{SN} and ε_{GA} and considering the permeabilities $\sum(a.l)_A$ and $\sum(a.L)_N$ whether eq.(14 or (15) will give the higher ventilation heat requirement. If not, both equations have to be evaluated and the maximum value selected accordingly.

For building heights not exceeding 10 m buoyancy effects need not be considered. In this height range a constant wind velocity for a height of 10 m is presupposed. For buildings up to 10 m height it applies that $\varepsilon_{GA} = \varepsilon_{SA} = 1$ and $\varepsilon_{SN} = 0$. Tables 13 and 14 contain the height correction factors for the mentioned situations.

5.4.1.6 Room characteristic.

The room characteristic r is a reducing factor which takes into consideration the reduction of the overall permeability of the building caused by internal resistances (partition walls with doors). Analogous to the house characteristi in relation to the entire building, it depends on the ratio of the permeabilities of the wind-exposed outside surface $\sum(a.l)_A$ of the room under consideration to those of the internal doors and, ultimately, of the windows on the not wind-exposed surface $\sum(a.l)_N$. through which the air may escape. The smaller the permeability of the flow-off paths is in relation to the one of the flow-in paths the lower becomes the room characteristic.

The following equation applies approximately:

$$r = \frac{1}{\frac{\sum(a.l)_A}{\sum(a.l)_N} + 1} \qquad (18)$$

Due to the limited accuracy of this relationship and also to the great width of the fluctuations of permeabilities it is sufficient to classify the room characteristics only roughly.

For the most frequent situation, that the air flows off through partition-wall-doors only a room characteristic r is given in table 15 depending on the number and quality of these internal doors and on the values of $\sum(a.l)_A$, which is also required for the remainder of the calculation, (eq. 14) in steps (r=0,7 or r = 0,9). For rooms without internal doors between the exposed side and the lee side (e.g. large halls, open plan offices) r can be taken as equal to zero. The approximate equation (18) is not applicable in this case.

5.4.1.7 Temperature difference.

For rooms, where it must be assumed that air penetrates directly from the outside the same temperature difference is to be applied as for the calculation of the transmission heat requirement of outside surfaces; for internal sanitary rooms according to the conditions of the incoming air (see section 5.4.1.8).

5.4.1.8 Kitchens and internal sanitary rooms.

Kitchen in dwelling houses to DIN 18022 and internal bath rooms and toilets to DIN 18017 shall always be equipped with installations for natural or mechanical ventilation.

If installations for free ventilation are provided for these rooms four air changes per hour[7] are to be taken as basis for the calculation of the heat requirement. The actual number of air changes, in particular during cooking, may be greater. The heat requirement in this case is, at least, partly covered by the cooking process.

Thus it follows for the standard ventilation heat requirement that

$$Q'_L = 1,36 \cdot V_R \, (t_i - t_Z) \quad \text{in W} \qquad (19)$$

where: V_R room volume in m^3

$t_i - t_Z$ temperature difference in K

The temperature t_Z of the incoming air is laid down according to the conditions of the air supply:

For rooms with a special fresh air duct[8] $t_a = +10$ °C;

for rooms without fresh air duct[9] according to the conditions in the rooms from which the air comes.

for mechanical ventilation section 5.4.2 applies.

5.4.2 Buildings with mechanical (forced) ventilation.

In the case of mechanical ventilation the pressure conditions in the building and, therefore, the amount of outside air penetrating through leaks is affected by the ventilation plant. In this case one has to distinguish the position according to section 5.4.2.1 and to section 5.4.2.2.

5.4.2.1 Installations without excess of discharge air (spent air)

The positive pressures which can be achieved if there is an excess of fresh air are small compared with pressures caused by wind or buoyancy. For this reason the ventilation heat requirement for such plants is determined as for buildings with natural ventilation (section 5.4.1).

5.4.2.2 Installations with excess of discharge air (spent air).

In addition to the calculation to section 5.4.1 it is necessary to carry out a check calculation in which the mean temperature t_Z of the incoming air volumina, penetrating through leaks, is estimated according to the flow resistances and the ambient temperatures. The required ventilation heat requirement follows then from:

$$Q'_L = (\dot{V}_A - \dot{V}_Z) \cdot c \quad (t_i - t_Z) \qquad (20)$$

where $\dot{V}_A$ is the volume of spent air

$\dot{V}_Z$ is the volume of fresh air

The higher calculated value according to eq. (16) or (20) is taken as the standard ventilation heat requirement.

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7) By analogy with DIN 18017/3

8) See DIN 18017/1, fig.5.

9) See DIN 18017/1, fig. 1.

5.5.2 Details of the calculation.

The standard heat requirement of a room is given, according to eq. (1) by:

$$Q_N = Q_T + Q_L$$

The transmission heat requirement Q_T is according to eq, (2)

$$Q_T = Q_0 \cdot (1 + z_A + z_H) \text{ and } \quad Q_0 = \sum \frac{A \cdot \Delta T}{R}$$

according to eq. (3); the standard ventilation requirement for a shaft type building is given according to eq. (14) by:

$$Q_{LS} = \left[\varepsilon_{SA} \cdot \sum (a.1)_A + \varepsilon_{SN} \sum (a.1)_N \right] \cdot H_{G\,10} \cdot r \cdot (t_i - t_a)$$

or for a storey type building to eq. (15):

$$Q_{LS} = \varepsilon_{GA} \cdot \sum (a.1)_A \cdot H_{G\,10} \cdot r \cdot (t_i - t_a)$$

or according to the equations (17), (19) or (20).

The pro-forma given in Appendix A is used for the calculation of the standard heat requirement. If electronic data processing plants are used the terms have to be analog and the operation has to be such that it can be followed step by step.

5.5.2.1 Calculation of the standard transmission heat requirement.

To calculate the transmission heat requirement without additions one line in the pro-forma is filled up for each building component; the building components are to be identified by the following abbreviations:

AF	Outside window	FB	Floor
AT	Outside door	IF	Internal window
AW	Outside wall	IT	Internal door
DE	Ceiling	IW	Internal wall (partition).

The clear carcassing dimensions are to be used for lengths and widths, the floor heights (from the top of the floor to the top of the floor of the next storey) for the height of the walls. The dimensions of the wall openings are used as the dimensions of the windows and doors.

For the calculation of the heat requirement with the help of the obligatory pro-forma (appendix A) the following details of the data are required:

Lengths:	2 digits after the decimal point
areas	1 " " " "
Heat transmission resistance	3 " " " "
Temperatures & quantities of heat	no " " " "

Intermediate results are to be rounded off in manual calculations; in computer calculations they are to be rounded off or cut off, according to the facilities of the machine. The calculation is to proceed using the full accuracy of the calculator. Internediate calculation results may not be in complete agreement.

5.5 Calculation Methods.

5.5.1 Bases for the calculation.

The planning engineer has to supply the following data for the calculation of the standard heat requirement.

Situation plan;

This shall indicate the direction to north and access possibilities of wind. Additionally data are required about the height of neighbouring buildings and of other effects on the house characteristic (see sect. 5.4.1.4)

Plans and views: (at least to a scale 1:100)

These must contain the building dimensions including window and door dimensions (maximum rough structural dimensions).

Sections:

These must show the clear room heights, the floor heights (from the top surface of the floor to the top surface of the next floor, and the heights to the window sills and of windows and doors.

Description of the building:

It is required that data be provided for all building components regarding their thermal resistance, failing these about their construction (building materials and layer thickness) as well as about those properties which affect significantly their thermal resistance (e.g. density).

The description of the windows shall include details about the type of glazing, the material of the window frames, the lengths and permeability factors of the gaps in the windows or the quality class of the windows to DIN 18055/2. The gap around the window frame is to be used for the calculation for windows which can not be opened. If prefabricated components are to be used the constructional gaps shall be considered. It is, therefore, necessary to have data concerning the length of these gaps and their tightness (with or without tightness guarantee).

Data are also required for the material of the door leaf and the proportion of the glazing as well as for the air permeability. For outside doors they are the same as for windows. For inside doors it suffices to give information about thresholds and similar sealing materials.

Use of the rooms:

The intended use of each room has to be given as far as this is not immediately obvious from the plan drawings.

Selection of temperatures:

Table 2 controls the requirements for standard outside temperatures according to the geographic position of the building.

The selection of the inside temperatures is done to table 3 unless the customer has given special instructions. Temperatures noted in the drawings are obligatory for heated rooms only.

The final result only for each room is to be rounded off to the next higher 10 W, to give the standard heat requirement Q_N.
In the calculation concerning areas; those which have to be deducted in column 5 (Note by translator: This seems to be a printing error; areas appear in column 6) are to be characterized by a minus sign placed after the figure.
In the case, that the minimum ventilation heat requirement Q_{Lmin} is to be inserted as the standard ventilation heat requirement this ventilation heat requirement is to be marked by an asterisk placed before it in column 20 (Note by translator: This too seems to be a printing error, it should be column 26). This is, then, not included in the addition but the minimum ventilation heat requirement is added at the top of the pro-forma.
The heat transmission resistances of the building components are to be calculated to eq.(4) using the heat transfer resistances to table 19 and the thermal resistances of the individual layers to table 16 - for windows and doors to tables 9 or 10.
The thermal resistances for several ceiling constructions are given in table 17 for the complete assembly.(see section 7).
The addition for outside walls z_A can be determined only in the course of the calculation as a function of the Krischer factor to table 7.

5.5.2.2 Calculation of the standard ventilation heat requirement.
In the calculation of the standard ventilation heat requirement for buildings less than 10 m high only those components are to be considered which may, in the most unfavourable situation, be exposed to the wind simultaneously. For higher buildings it may be necessary to compare several variants according to eq. (14) and (15).
The standard house characteristic is determined to table 12 depending on the location, position and plan type of the building. The height correction factor, which has to be considered for each storey, follows from the standard house characteristic, the plan type, and the height of the storey above ground level to tables 13 or 14. The room characteristic is taken from table 15.

5.5.3 Example of a heat requirement calculation.
For the corner house of a (staggered) terrace, shown in the drawings 5 and 6, the heat requirement for the following rooms is to be determined: 02 (hobby-room, in basement), 5 (living room, ground floor), 103 (children's room, 1st floor). The dimensions, the construction and data concerning the position of the building as well as for the materials used are to be taken from the plans and the associated building specification.
The climatic data, standard outside temperature and position with regard to the wind, which apply to the whole house are put in front of the calculation

for the individual rooms as shown below.

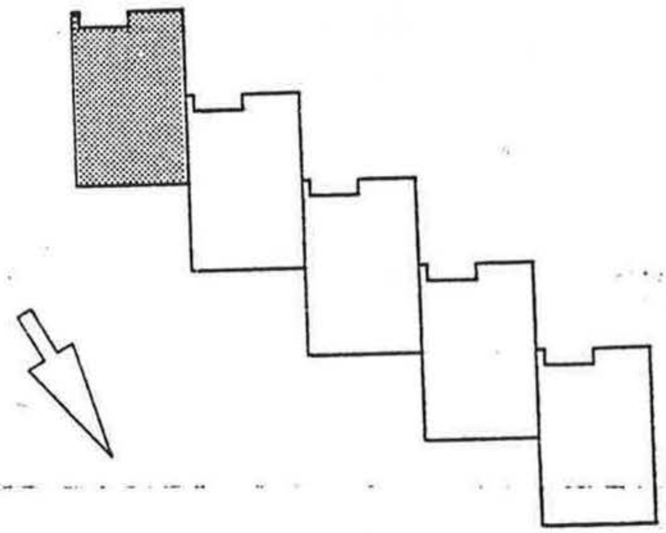


Fig. 4. Situation.plan

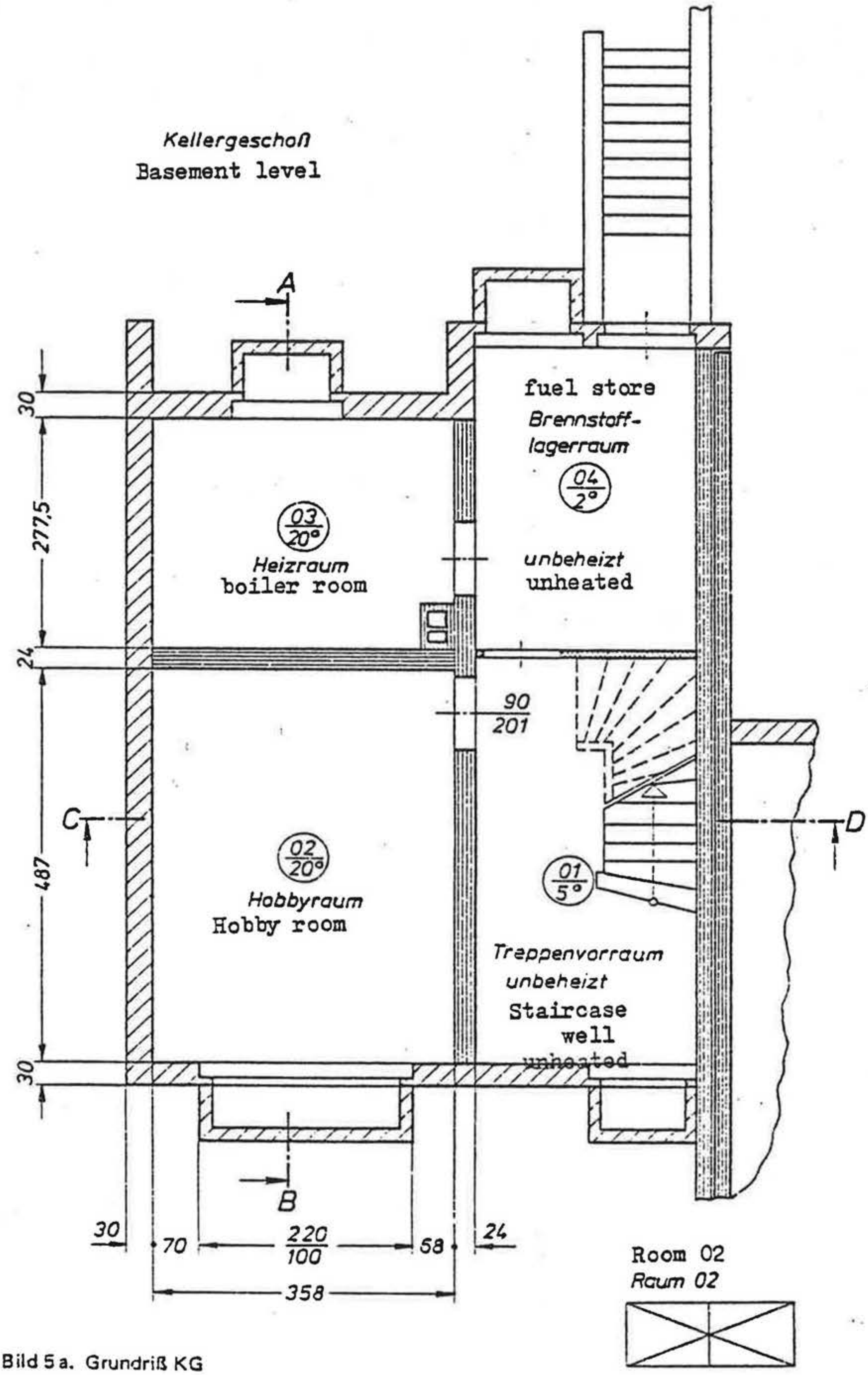


Bild 5 a. Grundriß KG

Fig. 5a; Plan, basement

Lengths of gaps, room 5
Fugenlänge Raum 5

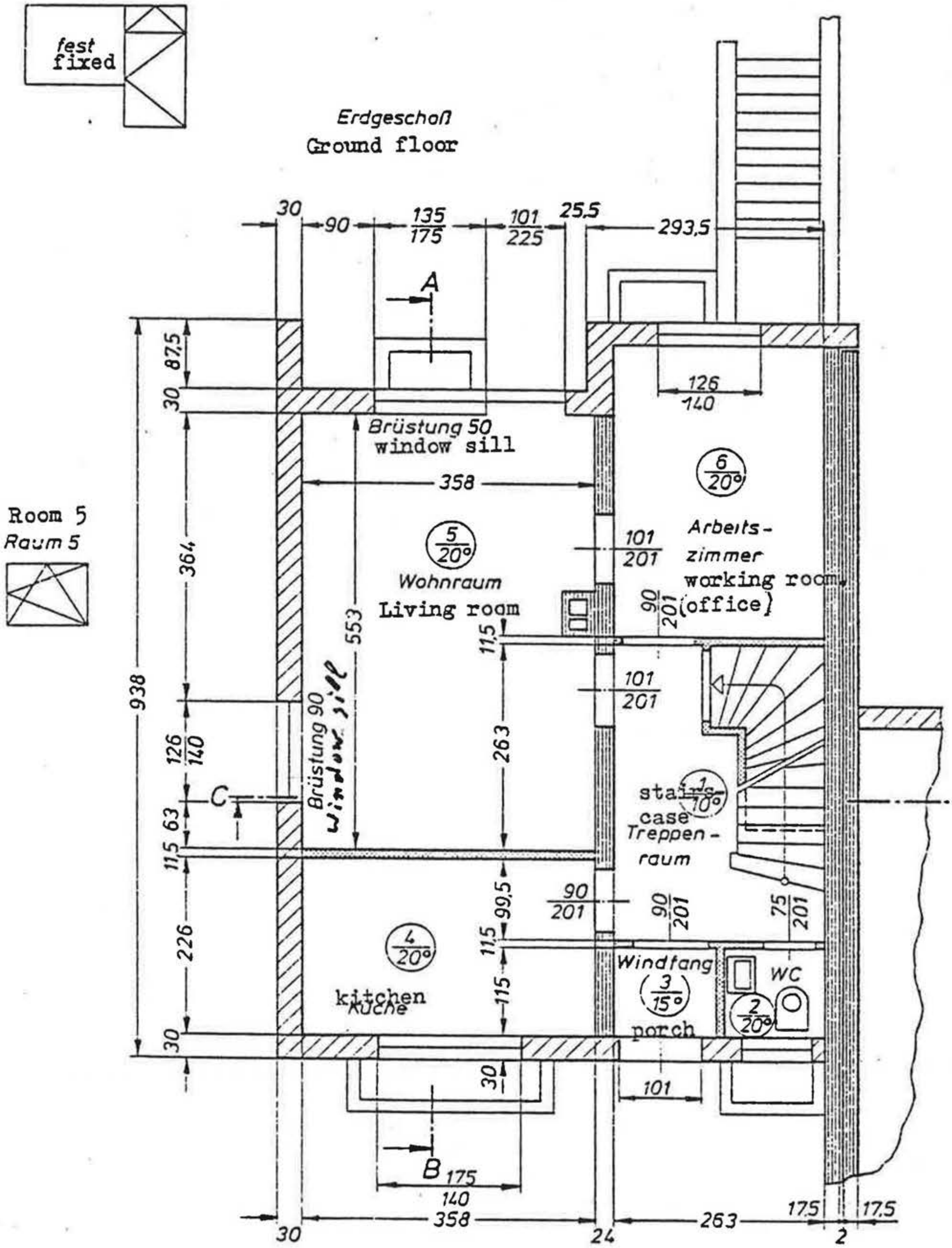


Fig. 5b, Ground floor.
Bild 5 b: Grundriß EG

1st floor

1. Obergeschoß

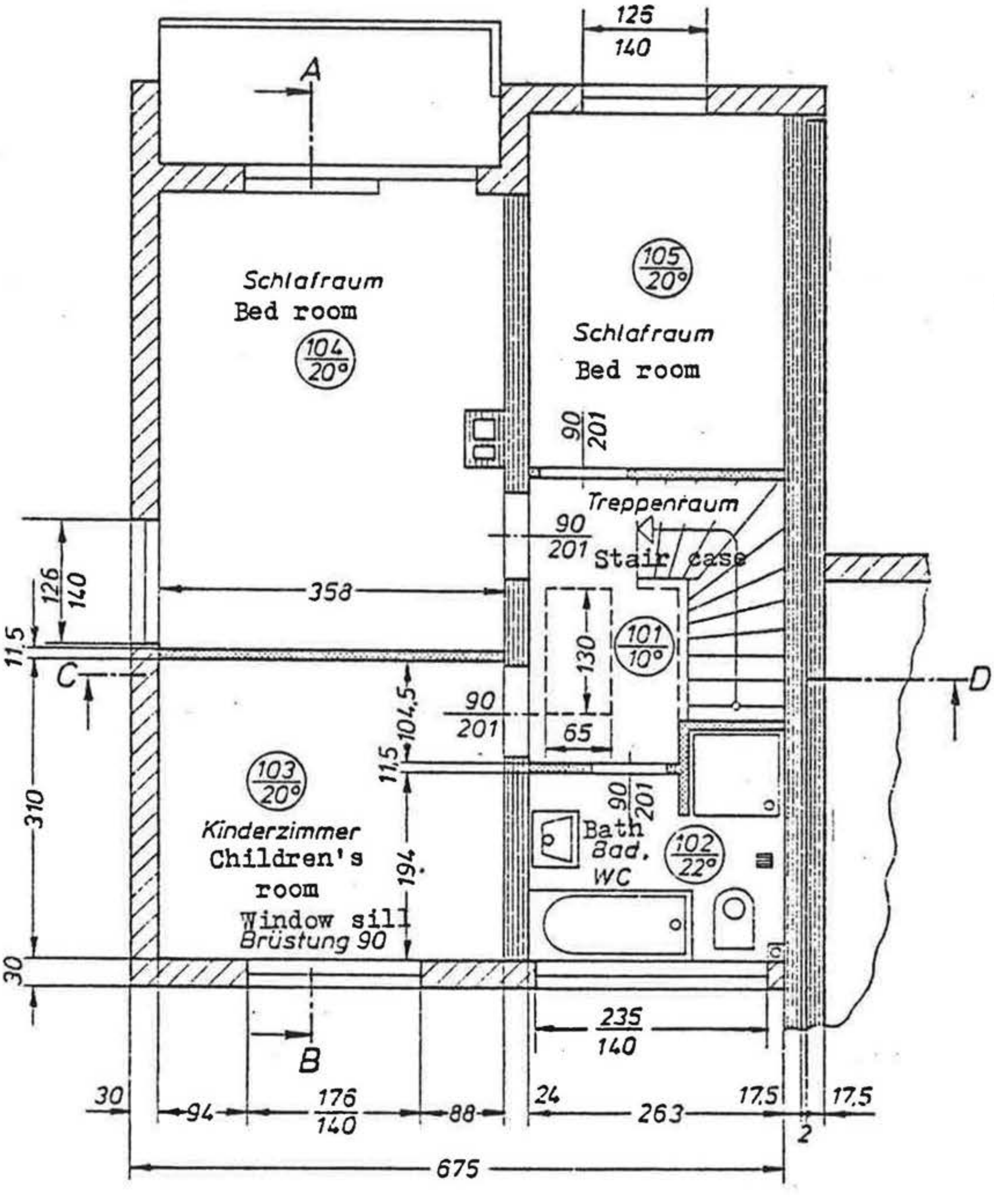
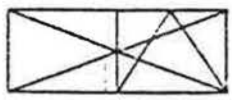


Bild 5 c: Grundriß 1.OG

Fig. 5c Plan, 1st floor

Room 103

Raum 103



Section A - B
Schnitt A–B

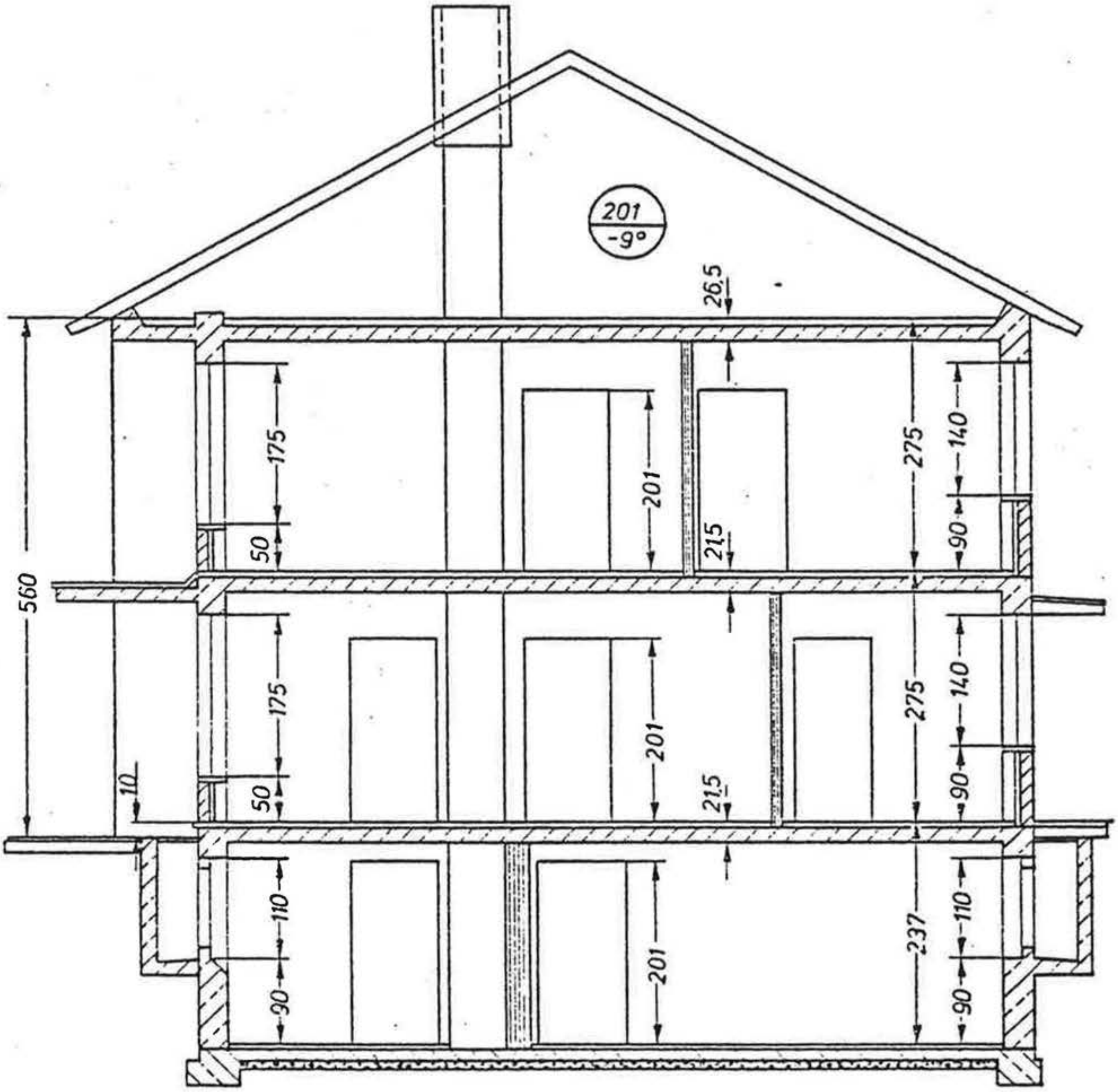
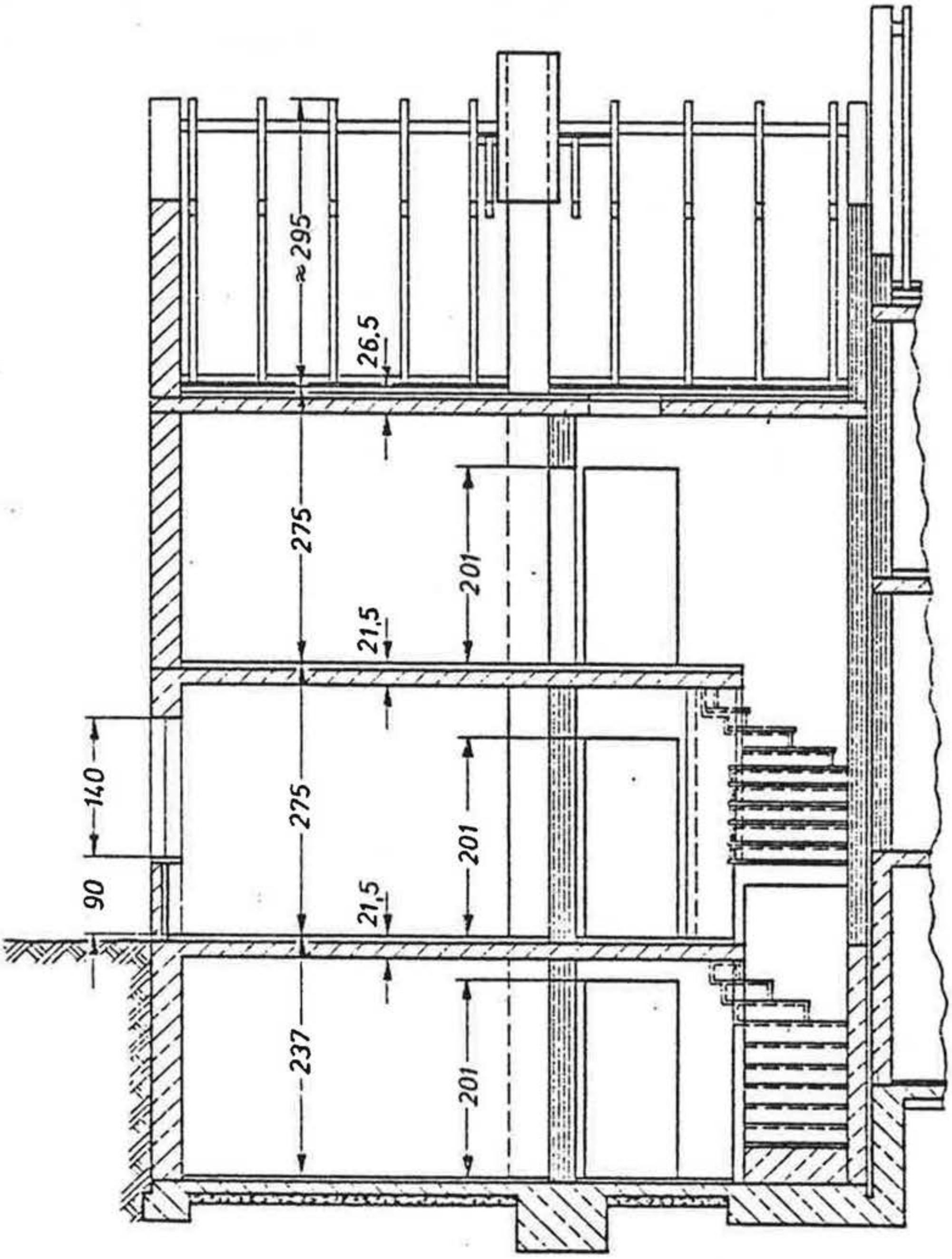


Bild 6 a: Schnitt A – B

Fig. 6a; Section A - B

Section C - D

Schnitt C-D



Beton: Bn 250 — Concrete Bn 250

Beton: Bn 100 — Concrete Bn 100

Mauerwerk: HLz 1.4/150 Mörtelgruppe II
Brick wall HLz 1,4/150 Mortar group II

Mauerwerk: KSHbl 1.2/150 Mörtelgruppe II

Mauerwerk: Vollsteine aus Leichtbeton
Walling solid blocks of light weight concrete

Bild 6 b: Schnitt C – D

Fig. 6b Section C - D.

5.5.3.1 Zusammenstellung der Rechenwerte Tabulation of Calculation Data.

Norm-Außentemperatur Standard outside temperature

Ort Locality	nach Tabelle to table	Norm-Außentemperatur standard outside temperature t_a °C
Hannover	2	– 14

Norm-Innentemperatur und Temperaturen unbeheizter Räume Standard inside temperature and temperatures of the unheated rooms.

lfd. Nr serial Nr.	Raum Nr Room Nr.	Raum Designation of the room	Bemerkungen notes	nach Tabelle to Table	Norm-Innentemperatur Standard inside Temperature t_i °C
1	01	Treppenraum Staircase		4	5
2	02	Hobbyraum Hobby room		3	20
3	03	Heizraum Boiler room		4	20
4	1	Treppenraum Staircase		3	10
5	4	Küche Kitchen		3	20
6	5	Wohnraum living room		3	20
7	6	Arbeitszimmer Working room		3	20
8	101	Treppenraum staircase		3	10
9	102	Bad bathroom		3	24
10	103	Kinderzimmer Childrens room		3	20
11	104	Schlafraum Bed room		3	20
12	201	Dachraum Roof space	dicht R_A = 0,4 m²K/W R_B = 1,6 m²K/W	6	– 9

Standard-Hauskenngröße Standard House Characteristic

Ort Locality	Gegend Wind exposure	Lage exposure	Haustyp plan type	nach Tabelle to table	Standard-Hauskenngröße Standard House Characteristic H_{G10} W · h · Pa$^{2/3}$/m³ · K
Hannover	windschwach low	normal	I	12	0,71

Höhenkorrekturfaktoren Correction factor for height

Gebäudehöhe in m Height of Building	5,60				
Geschoß Floor	Mean height of the storey above ground m	nach Tabelle to table	Höhenkorrekturfaktoren Correction factor for height ε_{GA}	ε_{SA}	ε_{SN}
Kellergeschoß Basement	– 1.08	13	1.0	1.0	0.0
Erdgeschoß Ground floor	1.48	13	1.0	1.0	0.0
Obergeschoß 1st floor	4.23	13	1.0	1.0	0.0

Thermal Resistances & Heat Transmission Resistances.
Wärmedurchgangs- und Wärmeleitwiderstände

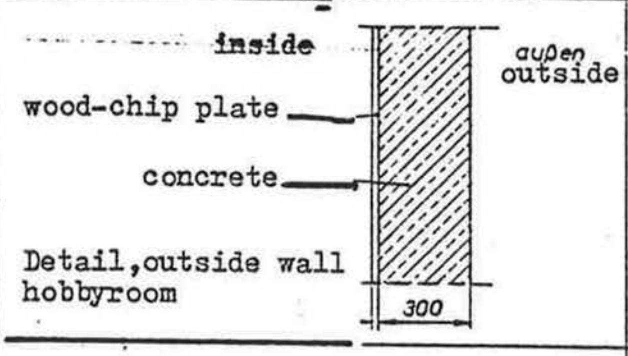
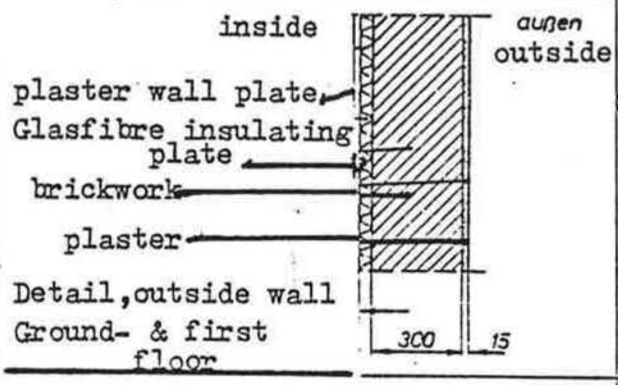
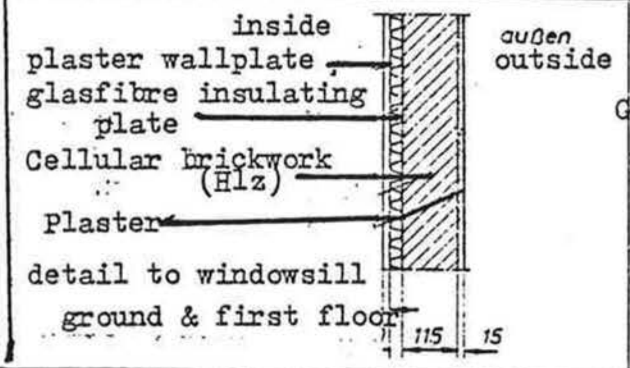
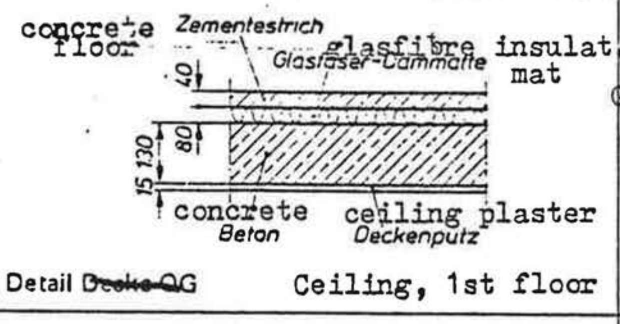
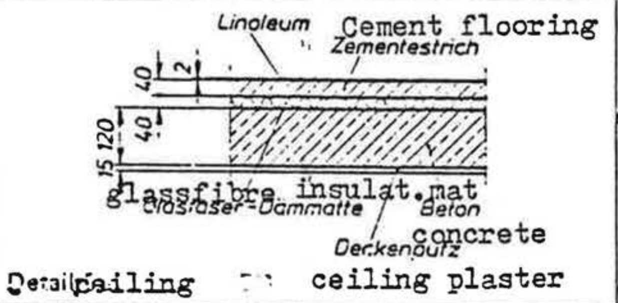
Serial Nr. lfd. Nr	Component Bauteil	Notes Bemerkungen	to table · nach Tabelle	Thermal Resistance R_λ	Heat Transmission Resistance R	Gap Permeability coefficient a
				$m^2 \cdot K/W$	$m^2 \cdot K/W$	$m^3/m \cdot h \cdot Pa^{2/3}$
1	AW	Hobbyraum Hobby room	1	0,491	0,671	–
2	AW	EG und OG Ground floor & first floor	1	–	1,310	–
3	AW	Fensterbrüstung Window sills	1	–	1,007	–
4	IW	KS-Hohlblocksteine hollow blocks	16	0,430	0,690	–
5	DE	OG first floor	1	–	2,315	–
6	DE	KG und EG Basement & ground floor	1	–	1,426	–
7	FB	KG Basement	1	0,950	–	–
8	AF	Wooden frame, double glaz. 6 mm, duty-group A, openable	9	–	0,310	0,6
9	AF	as Nr.8, not openable	9	–	0,310	0,1
10	AT	wooden frame, normal with threshold	10	–	0,300	2,0
11	IT	normal, without threshold	10	–	0,430	–

Fugenlänge Gap lengths

Serial Nr. lfd. Nr	Room Nr. Raum-Nr	Room Raum	Gap Length openable	Gap Length not openable
			m	m
1	02	Hobby room	7,40	–
2	5	living room	5,32	6,20
3	103	childrens room	9,10	–

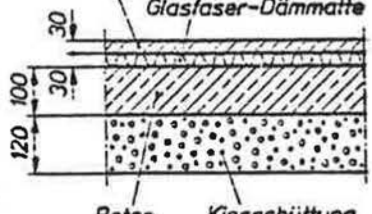
Table 1; Examples of Calculations of Heat Transmission Resistances

Tabelle 1. Berechnungsbeispiele von Wärmedurchgangswiderständen

Serial Nr. lfd. Nr	Sketch Skizze	Building Material Baustoff	Thickness d (m)	λ (W/m·K)	R_λ (m²·K/W)
1	 inside; außen outside; wood-chip plate; concrete; 300; Detail, outside wall hobbyroom	Wood-chip plates *Holzspanplatte*	0.020	0.058	0.344
		Beton (Bn 100) Concrete (Bn100)	0.300	2.040	0.147
				$R_{\lambda B}$ =	0.491
				R_i =	0.130
				R_a =	0.050
				R =	0.671
2	 inside; außen outside; plaster wall plate; Glasfibre insulating plate; brickwork; plaster; 300; 15; Detail, outside wall Ground- & first floor	Plaster wall plate	0.010	0.580	0.017
		Glasfibre insulat. Pl	0.025	0.041	0.610
		Brickwork	0.300	0.610	0.492
		plaster	0.015	1.400	0.011
				R_λ =	1.130
				R_i =	0.130
				R_a =	0.050
				R =	1.310
3	 inside; außen outside; plaster wallplate; glasfibre insulating plate; Cellular brickwork (Hlz); Plaster; 115; 15; detail to windowsill ground & first floor	Plaster wall plate	0.010	0.580	0.017
		Glassfibre insul. pl.	0.025	0.041	0.610
		Brick work (Hlz)	0.115	0.610	0.189
		Plaster	0.015	1.400	0.011
				R_λ =	0.827
				R_i =	0.130
				R_a =	0.050
				R =	1.007
4	 concrete floor *Zementestrich*; glasfibre insulat. mat *Glasfaser-Dämmatte*; 40; 80; 15 130; concrete *Beton*; ceiling plaster *Deckenputz*; Detail ~~Decke OG~~ Ceiling, 1st floor	Concrete floor	0.040	1.400	0.029
		Glasfibre insul. pl.	0.080	0.041	1.951
		Concrete	0.130	2.040	0.064
		Ceiling plaster	0.015	1.400	0.011
				R_λ =	2.055
				R_i =	0.130
				R_a =	0.130
				R =	2.315
5	 *Linoleum*; Cement flooring *Zementestrich*; 40; 2; 40; 15 120; glassfibre insulat. mat *Glasfaser-Dämmatte*; *Beton* concrete; *Deckenputz* ceiling plaster; Detail ceiling Basement & ground floor	Lino	0.002	0.190	0.011
		cement flooring	0.040	1.400	0.029
		glasfibre insul. mat	0.040	0.041	0.976
		concrete	0.120	2.040	0.059
		plaster	0.015	1.400	0.011
				R_λ =	1.086
				R_i =	0.170
				R_a =	0.170
				R =	1.426

Note by translator: I could not find room to enter the various thicknesse in the sketches; they are repeated in the tables on the right hand side.

Table 1; continued.
Tabelle 1. (Fortsetzung)

Serial Nr. / lfd. Nr	Sketch / Skizze	Building Material / Baustoff	Thickness	λ	R_{λ}
			m	W / m · K	m² · K / W
6	Flooring / Estrich; Glassfibre insulating mat / Glasfaser-Dämmatte; concrete / Beton; loose gravel / Kiesschüttung  Detail FB Hobby room	flooring Glassfibre insul.mat concrete loose gravel	0.030 0.030 0.100 0.120	1.400 0.041 2.040 0.810 $R_{\lambda B}$ =	0.021 0.732 0.049 0.148 0.950

Heatloss to the ground.
Wärmeabgabe an das Erdreich

Floor Area	Depth of Ground Water	Side ratio of floor Area.	Equivalent Thermal Resist. Room-Outs. air (Fig. 1)	Room-Ground-water (λ_E = 1,2 W/mK)	mean outside Temperature	Groundwat temperat.
A_{Boden}	T	l/b	$R_{\lambda A}$	$R_{\lambda E}$	t_{AL}	t_{GW}
m²	m	–	m² K/W	m² K/W	°C	°C
17,4	10,0	1,36	0,610	8,333	–5	10

Bauteil	Internal Heat Transmission Resistance	Thermal Resistance	Equivalent Thermal Resistance. Room-outside air	Room-Ground water	Equivalent Heat Transmission Resistance Room-outside air	Room-ground water
	R_i	R_{λ}	$R_{\lambda A}$	$R_{\lambda E}$	R_{AL}	R_{GW}
	m² K/W	m² K/W	m² K/W	m² K/W	m² K/W	m² K/W
Floor	0,170	0,950	0,610	8,333	1,780	9,453
Side wall	0,130	0,491	0,305	8,333	0,976	8,954

5.5.3.2 Berechnung des Norm-Wärmebedarfs — Calculation of the Standard Heat Requirement.

Beispiel siehe Seiten 22 bis 24 — Example: See pages 37 - 39.

Calculation of the Standard Heat Requirement

Undertaking: Example of Calculation DIN 4701 *)

Projekt/Auftrag/Kommission

Seite 1 page 1:

Room number: 02 Designation: Hobbyroom; outside temp. in °C −14 ~~Norm-Innen~~ Inside temp. in °C 20 Roomvolume V_R in m³ 41

Minimum Ventilation Heat Requirement Q_{Lmin} in W: 239

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Calculation of the Transmission Heat Requirement											Calculation of the Ventilation Heat Requ.							
Symbol	Point of Compass	Length	Height or width	Area	Number	Area used in Calculation	Heat Transmission Resistance	Temperature difference	Heat Transmission requirement without addition	Krischer factor	Outsidewall-point-of-compass-& other additions	Gap length	Gap permeability factor	Permeability of Facades	Room Characteristic	Standard House Characteristic	Hight Correction Factor	Temperature Difference	Standard Heat Requirement
—	—	b	h	A	n	A'	R	Δt	Q_0	D	z_A z_H / $1+z_A+z_H$	l	a	$(n \cdot a \cdot l)_A$ $(n \cdot a \cdot l)_N$	r	H_{G10}	$\varepsilon_{SA}, \varepsilon_{SN}$ ε_{GA}	Δt	Q_N
—	—	m	m	m²	—	m²	m² K/W	K	W	W/m² K	—	m	m³/mh Pa^2/3	m³/mh Pa^2/3	—	W·h Pa^2/3/m³K	—	K	W
AF	NO	2.20	1,00	2,2–	1	2,2	0,310	34	241			7,40	0,6	4,4					
AW	NO	2,20	1,50	3,3–	1	1,1	0,671	34	56										
AW	–	8,45	2,37	20,0	1	16,7	0,976	25	428										
						16,7	8,954	10	19										
IT	–	0,90	2,01	1,8–	1	1,8	0,430	15	63										
IW	–	4,87	2,37	11,5	1	9,7	0,690	15	212										
FB	–	3,58	4,87	17,4	1	17,4	1,780	25	245										
						17,4	9,453	10	18										
										0,50	0,06				0,9	0,71	1,0	34	* 96
						74,9		34	1282		0,00			4,4					
																			239
											1,06								1359
																			1600

*) ausführliches Formular siehe Anhang A, Seite 62.

more detailed pro-forma see Appendix A.

Calculation of Standard Heat Requirement to DIN 4701

Undertaking: Example of Calculation to DIN 4701

Room Nr. : 5, Designation: Living Room.

Minimum Ventilation Heat Requirement: Q_{Lmin} in W: 315

Standard Outside Temp. −14 °C

Standard Norm-Innentemp. in °C 20 | Raumvolumen V_R in m³ 54

Projekt/Auftrag/Kommission

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		Calculation of the Transmission Heat Requirement									Calculation of the Ventilation Heat Requirem.								
Symbol	Point of Compass	Length	Height or width	Area	Number	Area used in calculation	Heat transmission resist.	Temperature difference	Heat transmis. requirement without addit.	Krischer factor	Additions for outside walls, point-of-compass, etc. z_H	Gap length	Gap permeability factor	Permeability of facades	Room characteristic	Standard house characterist.	Height correction factor	Temperature difference	Standard heat requirement
—	—	b	h	A	n	A'	R	Δt	Q_0	D	$1+z_A+z_H$	l	a	$(n \cdot a \cdot l)_A$ $(n \cdot a \cdot l)_N$	r	$H_{G\,10}$	$\varepsilon_{SA} \cdot \varepsilon_{SN}$ ε_{GA}	Δt	Q_N
—	—	m	m	m²	—	m²	m² K/W	K	W	W/m² K	—	m	m³/mh Pa^2/3	m³/mh Pa^2/3	—	W h Pa^2/3/m³ K	—	K	W
AF	SO	1,26	1,40	1,8–	1	1,8	0,310	34	193			5,32	0,6	3,2					
AW	SO	1,26	0,90	1,1–	1	1,1	1,007	34	38										
AW	SO	5,53	2,75	15,2	1	12,3	1,310	34	319										
AF	SW	1,35	1,75	2,4–	1	2,4	0,310	34	259			6,20	0,1	0,6					
AW	SW	1,35	0,50	0,7–	1	0,7	1,007	34	23										
AT	SW	1,01	2,25	2,3–	1	2,3	0,300	34	258			6,52	2,0	13,0					
AW	SW	3,58	2,75	9,8	1	4,4	1,310	34	115										
IT	–	1,01	2,01	2,0–	1	2,0	0,430	10	47										
IW	–	2,62	2,75	7,2	1	5,2	0,690	10	75										
										0,44	0,06				0,9	0,71	1,0	34	365
						89,7		34	1327		−0,05			16,8					
																			1340
											1,01								
																			1710

Calculation of Standard Heat Requirement to DIN 4701

Undertaking: Example of Calculation to DIN 4701.

Room 103; Designation: Childrens' Room.
Minimum Ventilation Heat Requirement: Q_{Lmin} in W: 176

Stand. Outsid. Temp: −14 °C Projekt/Auftrag/Kommission

~~Norm-Innentemp. in °C 20~~ Roomvolumen V_R in m³ 31

Stand. inside temp. in °C: 30

page ~~Seite~~ 3

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		Calculation of the Transmission Heat Requirement									Calculation of the Ventilation Heat								
Symbol	Point of Compass	Length	Height or width	Area	Number	Area used in calculation	Heat transmission resistance	Temperature difference	Heat transmiss. requirement without addit.	Krischer factor	Additions for outside walls, point-of-compass etc.	Gap length	Gap permeability factor	Permeability of facades	Room characteristic	Standard House characterist.	Height correction factor	Temperature difference	Standard Heat requirement
–	–	b	h	A	n	A'	R	Δt	Q_0	D	$\frac{z_H}{1+z_A+z_H}$	l	a	$(n\cdot a\cdot l)_A$ $(n\cdot a\cdot l)_N$	r	$H_{G\,10}$	$\varepsilon_{SA}\cdot\varepsilon_{SN}$ ε_{GA}	Δt	Q_N
–	–	m	m	m²	–	m²	m² K/W	K	W	W/m² K	–	m	m³/mh Pa²/³	m³/mh Pa²/³	–	Wh Pa²/³/m³K	–	K	W
DE	–	3,58	3,10	11,1	1	11,1	2,315	29	139										
AF	NO	1,75	1,40	2,5–	1	2,5	0,310	34	268			9,10	0,6	5,5					
AW	NO	1,75	0,90	1,6–	1	1,6	1,007	34	53										
AW	NO	3,58	2,75	9,8	1	5,7	1,310	34	149										
AW	SO	3,10	2,75	8,5	1	8,5	1,310	34	221										
IT	–	0,90	2,01	1,8–	1	1,8	0,430	10	42										
IW	–	1,05	2,75	2,9	1	1,1	0,690	10	16										
IW	–	1,94	2,75	5,3	1	5,3	0,690	−4	−31										
										0,43	0,04				0,9	0,71	1,0	34	* 119
						58,9		34	858		0,05			5,5					176
																			935
											1,09								
																			1110

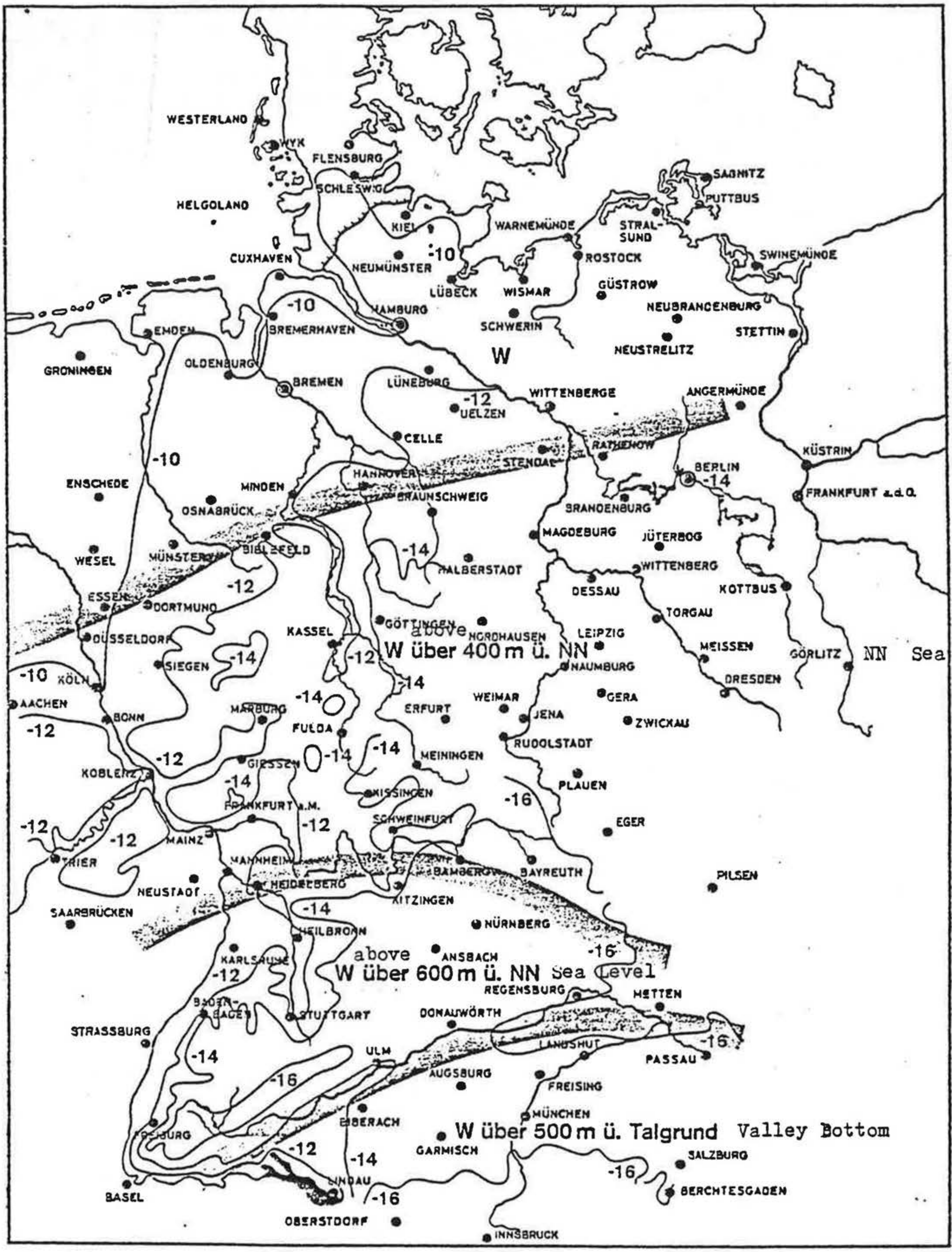


Bild 7. Isothermenkarte

Fig. 7. Map of Isotherms.

Tiefstes Zweitagesmittel der Lufttemperatur in °C (10mal in 20 Jahren), Zeitraum: 1951 bis 1970
Aufgestellt vom Deutschen Wetterdienst, Zentralamt Offenbach/Main

Lowest two-day average of air temperature in °C (10 times in 20 years) 1951 to 1970; published by the German Meteorological Service, Head office in Offenbach /Main

6. NUMERICAL VALUES FOR THE CALCULATION OF THE HEAT REQUIREMENT FOR ROUTINE CASES.

Table 2 contains data for the standard outside temperature t_a [10] and for areas exposed to strong winds [12]. For localities not mentioned in the table 2 the standard outside temperature of the nearest place mentioned in the table and having similar climatic conditions is to be used. The map of isotherms in fig. 7 (see explanations) is useful; it contains also information about places exposed to strong winds.

Table 2. Standard Outside Temperatures for places with more than 20 000 inhabitants [11]

(Lowest two-day average of the air temperature which is reached or exceeded 10 times in 20 years).

10) In the centre of large towns the outside temperatures are somewhat higher than in the peripheral districts to which the standard temperatures mentioned in table 2 refer. A general consideration of these conditions is not possible due to the various uncertain factors (river courses, squares, ill defined boundary lines against outside districts). It is, however, possible to come to some agreement in towns with more than 100 000 inhabitants and with dense occupation according to which for areas with a plot ratio $\geq$ 1,8 the outside temperature may be taken as being up to 2K higher than according to this standard provided the building is not significantly higher than its surroundings.

11) Smaller towns with meteorological stations, the data of which have been considered are included.

12) Places with strong wind exposure are designated "W"; places not exposed to strong winds are not specially designated.

Table 2. Introduction see page 41.

Post-code	Town Stadt	Standard outside temperature °C
7701	Aach, Hegau	− 14
5100	Aachen	− 12
7080	Aalen, Württ.	− 16 W
4730	Ahlen, Westf.	− 12 W
2070	Ahrensburg	− 12 W
5110	Alsdorf, Rheinl.	− 12 W
5990	Altena, Westf.	− 12 W
6508	Alzey	− 12
8450	Amberg, Oberpf.	− 16
5470	Andernach	− 12
8800	Ansbach, Mittelfr.	− 16
5760	Arnsberg	− 12 W
8750	Aschaffenburg	− 12
8900	Augsburg	− 14
7960	Aulendorf, Württ.	− 16 W
7150	Backnang	− 12
7570	Baden-Baden	− 12
7847	Badenweiler	− 14
8600	Bamberg	− 16
8580	Bayreuth	− 16
4720	Beckum, Westf.	− 12 W
6124	Beerfelden, Odenw.	− 14 W
5060	Bensberg	− 12
6140	Bensheim (Bensheim-Auerbach)	− 10
8240	Berchtesgaden	− 16
5070	Bergisch-Gladbach	− 12
6748	Bergzabern, Bad	− 12
1000	Berlin	− 14 W
5550	Bernkastel-Kues	− 10
6631	Berus	− 12 W
7950	Biberach, Riß	− 16
3560	Biedenkopf	− 12
4800	Bielefeld	− 12
6530	Bingen, Rhein	− 12
6588	Birkenfeld, Nahe	− 14 W
5581	Blankenrath	− 14 W
4290	Bocholt	− 10 W
4630	Bochum	− 10

Post-code	Town Stadt	Standard outside temperature °C
4713	Bockum-Hövel	− 12 W
7030	Böblingen	− 14
5300	Bonn	− 10
5300	Bonn-Bad Godesberg	− 10
5300	Bonn-Beuel	− 10
2972	Borkum	− 10 W
8801	Bottenweiler, Post Zumhaus (Wörnitz)	− 16
4250	Bottrop	− 10 W
4800	Brackwede	− 12
3300	Braunschweig	− 14 W
2800	Bremen	− 12 W
2850	Bremerhaven	− 10 W
2140	Bremervörde	− 12 W
5790	Brilon	− 14 W
7520	Bruchsal	− 12
5040	Brühl, Rheinl.	− 10
6967	Buchen, Odenw.	− 14 W
8602	Burghaslach	− 16
4620	Castrop-Rauxel	− 10
3100	Celle	− 12 W
3392	Clausthal-Zellerfeld	− 14 W
8630	Coburg	− 14
4420	Coesfeld	− 10 W
7180	Crailsheim	− 16
2190	Cuxhaven	− 10 W
8060	Dachau	− 16
6100	Darmstadt	− 12
4354	Datteln	− 12 W
2870	Delmenhorst	− 12 W
4930	Detmold	− 12
5509	Deuselbach	− 12 W
6340	Dillenburg	− 12
8880	Dillingen, Donau	− 16
4220	Dinslaken	− 10 W
4270	Dorsten	− 10 W
4600	Dortmund	− 12
6602	Dudweiler, Saar	− 12

Foot notes 10), 11) & 12) see page 41.

Tabelle 2. (Fortsetzung) Table 2, continued.

Postcode	Town Stadt	Standard outside temperature °C
4060	Dülken	– 10 W
4408	Dülmen	– 12 W
5160	Düren	– 12
4000	Düsseldorf	– 10 W
4100	Duisburg	– 10 W
7470	Ebingen (Albstadt)	– 18 W
2330	Eckernförde	– 10 W
2903	Edewechterdamm (Friesoythe)	– 12 W
3352	Einbeck	– 16
7090	Ellwangen, Jagst	– 16
2200	Elmshorn	– 12 W
5153	Elsdorf, Rheinl.	– 12
2970	Emden	– 10 W
5427	Ems, Bad	– 12
4407	Emsdetten	– 12 W
5250	Engelskirchen	– 10
5828	Ennepetal	– 12
8520	Erlangen	– 16
3440	Eschwege	– 14
5180	Eschweiler, Rheinl.	– 12
4300	Essen	– 10
7300	Esslingen am Neckar	– 14
7505	Ettlingen	– 12
5350	Euskirchen	– 12
2420	Eutin	– 10 W
8411	Falkenstein, Oberpf. (Großer Falkenstein)	– 18 W
7821	Feldberg, Schwarzwald	– 18 W
6384	Feldberg (kleiner), Taunus	– 16 W
7012	Fellbach, Württ.	– 12
8591	Fichtelberg, Oberfr.	– 16 W
2390	Flensburg	– 10 W
7831	Forchheim, Breisgau	– 12
8550	Forchheim, Oberfr.	– 16
6710	Frankenthal, Pfalz	– 12
6000	Frankfurt/Main	– 12
5020	Frechen	– 10
7800	Freiburg i. Br.	– 12
8050	Freising	– 16
7290	Freudenstadt	– 16 W
7990	Friedrichshafen	– 12
5300	Friesdorf (Post Bad Godesberg)	– 10
8080	Fürstenfeldbruck	– 16
8510	Fürth, Bay.	– 16
6400	Fulda	– 14
8100	Garmisch-Partenkirchen	– 18
2054	Geesthacht	– 12 W
7340	Geislingen, Steige	– 16
6460	Gelnhausen	– 12
4650	Gelsenkirchen	– 10
6970	Gerlachsheim (Lauda-Königshofen, Baden)	– 14
5820	Gevelsberg	– 12
6300	Gießen	– 12
3170	Gifhorn	– 14 W

Postcode	Town Stadt	Standard outside temperature °C
3579	Gilserberg	– 14
4390	Gladbeck, Westf.	– 10 W
2208	Glückstadt	– 10 W
7320	Göppingen	– 14
8551	Gössweinstein	– 16
3400	Göttingen	– 16
3380	Goslar	– 14
4402	Greven, Westf.	– 12 W
4048	Grevenbroich	– 10 W
4432	Gronau, Westf.	– 10 W
7162	Gschwend b. Gaildorf	– 16
4830	Gütersloh	– 12 W
5270	Gummersbach	– 12
5800	Hagen	– 12
2000	Hamburg	– 12 W
3250	Hameln	– 12
4700	Hamm, Westf.	– 12 W
3000	Hannover	– 14 W
6450	Hanau	– 12
3388	Harzburg, Bad-	– 14
3579	Hauptschwenda (Neukirchen, Knüllgeb.)	– 14 W
4320	Hattingen, Ruhr	– 12
2240	Heide, Holst.	– 10 W
6900	Heidelberg	– 10
7920	Heidenheim, Brenz	– 16
7100	Heilbronn, Neckar	– 12
5628	Heiligenhaus b. Velbert	– 12
3330	Helmstedt	– 14 W
5870	Hemer	– 12
6424	Herchenhain	– 14 W
4900	Herford	– 12
3443	Herleshausen	– 14
4690	Herne	– 10
7506	Herrenalb, Bad	– 14
6430	Hersfeld, Bad	– 14
	Herstein	– 12
4352	Herten, Westf.	– 10 W
5231	Hilgenroth, Westerw.	– 12
3200	Hildesheim	– 14 W
4010	Hilden	– 10
7821	Höchenschwand	– 16 W
8204	Höllenstein (Post Degerndorf am Inn) (Großbrannenburg)	– 18
8116	Post Eschenlohe	
8491	Post Wettzell	
8670	Hof, Saale	– 18 W
8729	Hofheim, Unterfr.	– 14
5850	Hohenlimburg	– 12
8126	Hohenpeissenberg	– 16 W
3450	Holzminden	– 12
4100	Homberg, Niederrh.	– 10 W
6380	Homburg, Bad	– 12
6650	Homburg, Saar	– 12
5142	Hückelhoven	– 10
5030	Hürth	– 10
2250	Husum, Nordsee	– 10 W

Tabelle 2. (Fortsetzung) Table 2 continued

Post-code	Town Stadt	Standard outside temperature °C
4530	Ibbenbüren	− 12 W
6580	Idar-Oberstein	− 12
8070	Ingolstadt, Donau	− 16
5860	Iserlohn	− 12
2210	Itzehoe	− 12 W
8756	Kahl am Main	− 12
6750	Kaiserslautern	− 12
4618	Kamen, Westf.	− 12
4132	Kamp-Lintford	− 10 W
8859	Karlshuld	− 16
7500	Karlsruhe	− 12
3500	Kassel	− 12
8950	Kaufbeuren	− 16
8960	Kempten, Allgäu	− 16
2300	Kiel	− 10 W
7312	Kirchheim, Teck	− 16
8730	Kissingen, Bad	− 14
4190	Kleve, Niederrhein	− 10 W
7209	Klippeneck (Denkingen, Württ.)	− 16 W
5400	Koblenz	− 12
5000	Köln	− 10
6240	Königstein, Taunus	− 12
8112	Kohlgrub, Bad	− 16 W
7750	Konstanz	− 12
7014	Kornwestheim	− 12
4150	Krefeld	− 10 W
6550	Kreuznach, Bad	− 12
8640	Kronach	− 16
7118	Künzelsau	− 14
8650	Kulmbach	− 16
7630	Lahr, Schwarzwald	− 12
6840	Lampertheim, Hessen	− 12
6740	Landau, Pfalz	− 12
8300	Landshut, Bay.	− 16
6070	Langen, Hessen	− 12
4010	Langenfeld, Rheinl.	− 10
3012	Langenhagen, Han.	− 14 W
2941	Langeoog	− 10 W
2950	Leer, Ostfriesland	− 10 W
3160	Lehrte	− 14 W
4920	Lemgo	− 12
4540	Lengerich, Westf.	− 12
7250	Leonberg, Württ.	− 12
5860	Latmathe	− 12
5090	Leverkusen	− 10
8990	Lindau, Bodensee	− 12
4450	Lingen, Ems	− 10 W
4780	Lippstadt	− 12 W
2282	List	− 10 W
7850	Lörrach	− 12
5000	Lövenich b. Frechen	− 10
6223	Lorch, Rheingau	− 12
7140	Ludwigsburg, Württ.	− 12
6700	Ludwigshafen am Rhein	− 12
2400	Lübeck	− 10 W
5880	Lüdenscheid	− 12 W

Post-code	Town Stadt	Standard outside temperature °C
3140	Lüneburg	− 12 W
4670	Lünen	− 12 W
6500	Mainz	− 12
6800	Mannheim	− 12
3550	Marburg, Lahn	− 12
4370	Marl	− 10 W
7758	Meersburg, Bodensee	− 12
8940	Memmingen	− 16
5750	Mendan, Sauerland	− 12
7801	Mengen, Baden	− 14
7252	Merklingen Kr. Leonberg (Weil der Stadt)	− 16 W
8354	Metten, Niederbay.	− 18
4020	Mettmann	− 12
4950	Minden, Westf.	− 12
8961	Mittelberg b. Oy	− 18 W
8102	Mittenwald	− 16 W
4050	Mönchengladbach	− 10
4130	Moers	− 10 W
4019	Monheim, Rheinl.	− 10
4330	Mühlheim, Ruhr	− 10
8000	München	− 16
7420	Münsingen, Württ.	− 16 W
4400	Münster, Westf.	− 12 W
6350	Nauheim, Bad	− 14
5760	Neheim-Hüsten	− 12
6078	Neu-Isenburg	− 12
4133	Neukirchen-Vluyn	− 10 W
2161	Neuland, Kr. Stade (Neuland-Waterneversdorf)	− 10 W
2350	Neumünster	− 12 W
6680	Neunkirchen, Saar	− 12
4040	Neuss	− 10 W
6730	Neustadt, Weinstraße	− 10
7910	Neu-Ulm	− 14
5450	Neuwied	− 12
5620	Neviges	− 12
3070	Nienburg, Weser	− 12 W
8860	Nördlingen	− 16
2890	Nordenham	− 10 W
2982	Norderney	− 10 W
4460	Nordhorn	− 10 W
5489	Nürburg	− 14 W
8500	Nürnberg	− 16
7440	Nürtingen	− 14
8203	Oberaudorf	− 18
4200	Oberhausen, Rheinland	− 10 W
7818	Oberrotweil	− 12
8980	Oberstdorf	− 20
6370	Oberursel, Taunus	− 12
8474	Oberviechtach	− 16
7110	Öhringen	− 14
4353	Oer-Erkenschwick	− 10 W
6050	Offenbach, Main	− 12
7600	Offenburg	− 12
2900	Oldenburg, Oldb.	− 10 W

Tabelle 2. (Fortsetzung) Table 2 Continued.

Post-code	Town Stadt	Standard outside temperature °C
5090	Opladen	– 10
4500	Osnabrück	– 12 W
4790	Paderborn	– 12
8433	Parsberg, Oberfr.	– 16
8390	Passau	– 14
3150	Peine	– 14 W
7530	Pforzheim	– 12
2080	Pinneberg	– 12 W
6780	Pirmasens	– 12
5970	Plettenberg	– 12
8561	Pommelsbrunn	– 14
5000	Porz	– 10
8080	Puch (Post Fürstenfeldbruck)	– 16
2224	Quickborn (Post Burg) (Burg, Dithmarschen)	– 12 W
5608	Radevormwald	– 12
7550	Rastatt	– 12
4030	Ratingen	– 10 W
7980	Ravensburg	– 14
4350	Recklinghausen	– 10 W
8400	Regensburg	– 16
5630	Remscheid	– 12
2370	Rendsburg	– 10 W
7410	Reutlingen	– 16
4440	Rheine	– 12 W
4100	Rheinhausen, Niederrh.	– 10 W
4100	Rheinkamp	– 10 W
4130	Rheydt	– 10
5000	Rodenkirchen	– 10
5106	Roetgen, Eifel,	– 12 W
8200	Rosenheim, Oberbay.	– 16
8803	Rothenburg ob der Tauber	– 14
6090	Rüsselsheim	– 12
6600	Saarbrücken	– 12
6630	Saarlouis	– 12
3320	Salzgitter	– 14 W
7822	St. Blasien	– 16 W
6670	St. Ingbert	– 12
2380	Schleswig	– 10 W
7298	Schömberg Kr. Freudenstadt (Loßburg)	– 14 W
7294	Schopfloch	– 16 W
7060	Schorndorf, Württ.	– 16
6479	Schotten, Hess.	– 12
8540	Schwabach, Mittelfr.	– 16
7070	Schwäbisch Gmünd	– 16
7170	Schwäbisch Hall	– 16
8720	Schweinfurt	– 14
5830	Schwelm	– 12
7220	Schwenningen, Neckar	– 18 W
5840	Schwerte, Ruhr	– 12
2360	Segeberg, Bad	– 10 W
8672	Selb	– 18 W
5200	Siegburg	– 12
5900	Siegen	– 12
5210	Sieglar	– 10
7480	Sigmaringen	– 14 W
7032	Sindelfingen	– 14
7700	Singen, Hohentwiel	– 14
4770	Soest, Westf.	– 12 W
5650	Solingen	– 12
3040	Soltau	– 12 W
6720	Speyer	– 12
2160	Stade	– 10 W
8729	Steinbach bei Eltmann	– 14
5190	Stolberg, Rheinl.	– 12
8440	Straubing	– 18
7000	Stuttgart	– 12
6603	Sulzbach, Saar	– 12
8170	Tölz, Bad	– 18
5500	Trier	– 10
7400	Tübingen	– 16
7200	Tuttlingen	– 16 W
5132	Übach-Palenberg	– 12
3110	Uelzen	– 14 W
7900	Ulm, Donau	– 14
4750	Unna	– 12 W
5620	Velbert	– 12
6806	Viernheim	– 12
4060	Viersen	– 10 W
7730	Villingen, Schwarzwald	– 16 W
6620	Völklingen, Saar	– 12
4223	Voerde, Niederrh.	– 10 W
7050	Waiblingen	– 12
3544	Waldeck, Hess.	– 14 W
4100	Walsum	– 10 W
4355	Waltrop	– 12 W
4690	Wanne-Eickel	– 10
8090	Wasserburg a. Inn	– 16
	Wasserkuppe	– 16 W
4630	Wattenscheid	– 10
2000	Wedel, Holstein	– 10 W
8480	Weiden, Oberpf.	– 16
6290	Weilburg	– 12
6940	Weinheim, Bergstraße	– 10
8832	Weissenburg in Bay.	– 16
8501	Wendelstein, Mittelfr.	– 20 W
5980	Werdohl	– 12
5632	Wermelskirchen	– 12
4712	Werne a. d. Lippe	– 12 W
6980	Wertheim	– 14
4230	Wesel	– 10 W
5047	Wesseling, Rheinl.	– 10
6330	Wetzlar	– 12
6200	Wiesbaden	– 10
7547	Wildbad	– 14
2940	Wilhelmshaven	– 10 W
3542	Willingen, Upland	– 14 W
5810	Witten	– 12
3430	Witzenhausen	– 14

Table 2 (continued)

Post-code	Town Stadt	Standard outside temperature in °C
3340	Wolfenbüttel	– 14 W
3180	Wolfsburg	– 14 W
6520	Worms	– 12
5603	Wülfrath	– 12
5102	Würselen	– 12
8700	Würzburg	– 12
5600	Wuppertal	– 12
8100	Zugspitze	– 24 W
6660	Zweibrücken	– 12

Table 3. Standard interior temperatures [1] for heated rooms.
Unless the client stipulates explicitely different values the following standard inside temperatures are to be used as bases for the calculations.

Serial Nr.	Type of Room	Standard Inside Temperature °C
1	DWELLING HOUSES	
	Living and bed rooms	+ 20
	Kitchen	+ 20
	Bathrooms	+ 24
	Toilets	+ 20
	Heated subsidiary rooms (halls, etc.)[2]	+ 15
	Staircases	+ 10
2	ADMINISTRATIVE BUILDINGS.	
	Offices, meeting rooms, exhibitions, counter rooms etc, main stair cases	+ 20
	Toilets	+ 15
	subsidiary rooms and staircases as in section 1.	
3	STORES.	
	Sales rooms and shops in general, principal staircases	+ 20
	Food halls	+ 18
	Store rooms (general)	+ 18
	Stores for cheese	+ 12
	Stores for saussages, meet preparation rooms and sales rooms	+ 15
	Toilets, subsidiary rooms etc. as in section 2	

1) For rooms with installations which come under the scope of DIN 1946 the requirements of that standard apply.

2) inside halls in flats are, as a rule, not heated.

Serial Nr.	Type of Room	Standard inside temperature ° C
4	HOTELS AND RESTAURANTS	
	Hotel rooms	+ 20
	Baths	+ 24
	Hotel halls, meeting rooms, dance halls, principal stair cases	+ 20
	Toilets, subsidiary rooms etc as in section 1	
5	SCHOOLS AND SIMILAR INSTITUTIONS	
	General class rooms (lecture rooms), teachers' rooms, libraries, administrative rooms, halls, etc. nurseries	+ 20
	Teaching kitchens	+ 18
	Work rooms dependend on the type of work	+ 15 to 20
	Baths and shower rooms	+ 24
	Medical examination rooms	+ 24
	Gymnasian	+ 20
	Toilets, subsidiary rooms, stairs as section 2	
6	THEATERS AND CONCERT HALLS.	
	including entrance halls,	+ 20
	Toilets, subsidiary rooms, stairs etc. as section 1	
7	CHURCHES.	
	General church halls	+ 15
	Churches of historical importance	as agreed
	Toilets, subsidiary rooms, stairs etc. as in section 2.	
8	HOSPITALS [3)]	
	Operation theaters, preparation & anaesthetic rooms, rooms for premature babies	+ 25
	all other rooms	+ 22
9	FACTORIES AND WORKSHOPS	
	in general at least	+ 15
	for sitting people	+ 20
10	BARRACKS	
	Occupied rooms	+ 20
	all other rooms as section 5	
11	SWIMMING BATHS	
	Baths halls (at least 2 ° warmer than the water)	+ 28
	other bath rooms (shower rooms)	+ 24
	Changing rooms, subsidiary rooms, etc,	+ 22

3) See also DIN 1946/4; Ventilation plants for hospitals.

Serial Nr.	Type of Room	Standard inside Temperature • C
12	PRISONS	
	Occupied rooms	+ 20
	all other rooms as section 5	
13	EXHIBITION HALLS	
	According to clients' instructions, but at least	+ 15
14	MUSEUMS AND GALLERIES	
	general	+ 20
15	RAILWAY STATIONS	
	Reception-, booking halls, closed construction as well as occupied rooms other than buffets	+ 15
16	AIR PORTS.	
	Reception, departure and waiting rooms	+ 20
17	GARRAGES AND OTHER ROOMS TO BE KEPT FREE OF FROST	+ 5

In all other types of buildings the temperatures, on which the calculations are to be based have to be agreed with the client.

Table 4. Calculation Values for temperatures t_i' in neighbouring rooms.

Rooms	Standard Outside Temperatures • C				
	-10	-12	-14	- 16	- 18
not heated neighbouring rooms 1)					
without outside doors (including basements	+ 7	+6	+ 5	+ 4	+ 3
with outside doors (e.g. entrance halls, porches built-in garrages	+ 4	+3	+ 2	+ 1	0
separate staircases 2)	- 5	-7	-9	-10	- 11
independently heated neighbouring rooms	+ 15	+15	+15	+15	+ 15
boiler rooms	+ 20	+20	+20	+ 20	+ 20

1) The tabulated values apply mainly for the case that the neighbouring rooms are outside rooms; otherwise the temperatures are to be calculated to sec.8.6 or they have to be assumed.

2) Staircases inside the building see table 5.

Table 5. Calculation values for temperatures t_i' in not heated stair cases which are part of the building, having one outside wall.
(Abbreviations used in the table: EG = Ground floor; KG=Basement OG = upper floor, thus 1.OG = first floor; 2.OG 2nd floor etc.)

Thermal linkage to the Building	Height of Building m	Floor level	Standard outside temperature −10	−12	−14	−16	−18
normal 1)	up to 20	EG u. KG	+ 6	+ 5	+ 4	+ 3	+ 2
		1. OG	+ 11	+ 10	+ 9	+ 9	+ 8
		2. OG	+ 12	+ 11	+ 11	+ 10	+ 10
		3.-4. OG	+ 12	+ 12	+ 11	+ 11	+ 10
		5.-7. OG	+ 13	+ 12	+ 12	+ 11	+ 11
	over 20	EG u. KG	+ 1	− 1	− 2	− 3	− 4
		1. OG	+ 6	+ 5	+ 4	+ 3	+ 2
		2. OG	+ 9	+ 8	+ 7	+ 6	+ 5
		3.-4. OG	+ 10	+ 10	+ 9	+ 8	+ 7
		5.-7. OG	+ 11	+ 11	+ 10	+ 10	+ 9
		over 7. OG	+ 12	+ 12	+ 11	+ 11	+ 10
poor 2)	up to 20	EG u. KG	+ 4	+ 3	+ 1	0	− 1
		1. OG	+ 7	+ 6	+ 5	+ 4	+ 3
		2. OG	+ 8	+ 7	+ 6	+ 5	+ 4
		3.-4. OG	+ 8	+ 7	+ 6	+ 6	+ 5
		5.-7. OG	+ 8	+ 7	+ 6	+ 6	+ 5
	over 20	EG u. KG	− 1	− 2	− 4	− 5	− 6
		1. OG	+ 3	+ 2	+ 1	0	− 1
		2. OG	+ 6	+ 5	+ 4	+ 3	+ 2
		3.-4. OG	+ 7	+ 6	+ 5	+ 4	+ 3
		5.-7. OG	+ 7	+ 7	+ 6	+ 5	+ 4
		over 7. OG	+ 8	+ 7	+ 6	+ 6	+ 5

1) Assumption $\frac{\sum\left(\frac{A}{R}\right)_b}{\sum\left(\frac{A}{R}\right)_a} = 3{,}0$ (single windows on the short side, 2 m^2 per floor)

2) Assumption $\frac{\sum\left(\frac{A}{R}\right)_b}{\sum\left(\frac{A}{R}\right)_a} = 1{,}5$ (e.g. single window on the short side over the entire surface).

where R is the equivalent heat transmission resistance (including ventilation heat loss)

A area.

index a: towards the outside

index b: to heated rooms.

Table 6. Calculation Values for the Temperature t_i' in not heated neighbouring attic rooms and in the air layer in ventilated flat roofs.

Rooms: Closed Attic Rooms [1] — Outside Roof Surface	Heat transmission resistance R; m^2K/W — to the outside	Heat transmission resistance R; m^2K/W — to the heated room	Standard Outside Temperatures, °C: −10	−12	−14	−16	−18
not sealed undicht 2)	0,2	0,8	−6	− 8	−10	−12	−13
		1,6	−8	−10	−12	−14	−15
	0,4	0,8	−4	− 6	− 7	− 9	−11
		1,6	−7	− 9	−10	−12	−14
sealed dicht 3)	0,2	0,8	−6	− 8	− 9	−11	−13
		1,6	−8	−10	−11	−13	−15
	0,4	0,8	−3	− 4	− 6	− 7	− 9
		1,6	−6	− 8	− 9	−11	−13
	0,8	0,8	+ 1	0	− 1	− 3	− 4
		1,6	−3	− 5	− 6	− 8	− 9
	1,6	0,8	+ 5	+ 4	+ 3	+ 2	+ 1
		1,6	0	− 1	− 2	− 4	− 5
Air layer in ventilated flat roofs			−7	− 9	−11	−13	−15

1) The table was calculated for average attic room heights of 1 to 2 m and an area ratio A_a (to the outside) to A_b (to the heated room) $A_a/A_b = 1{,}5$. The general connexion is explained in section 8.6.

2) Assumed number of airchanges per hour $\beta = 2{,}5\ m^3/h.m^3$

3) Assumed number of air changes per hour $\beta = 0{,}5\ m^3/h.m^3$

4) The thermal resistance is to be calculated from the room-interior up to the air layer. The external heat transmission resistance $R_a = 0{,}09\ m^2K/W$ is to be used.

Table 7. Addition for outside walls z_A

$D \frac{W}{m^2 K}$	0 0,26	0,27 0,43	0,44 0,60	0,61 0,76	0,77 0,91	0,92 1,05	1,06 1,19	1,20 1,32
z_A	0,02	0,04	0,06	0,08	0,10	0,12	0,14	0,16

For higher Krischer factor values D see fig. 2 (For details see Explanations)

Table 8. Additions for the points-of-compass z_H

Compass quadrant	N	O	S	W
z_H	+ 0,05	0,00	− 0,05	0,00

Compare fig. 3.

Tall 9: Heat Transmission Resistances R of Windows & French Windows

Tabelle 9. Wärmedurchgangswiderstände *R* für Fenster und Fenstertüren

Windows and French Windows	Heat Transmission Resistance of the glass area R m^2K/W	Wood or Plastic Frames R>0,34 m^2K/W		Heat Insulated Metal Frames 0,2 < R < 0,34 m^2K/W		Not-insulated Metal-concrete Frames R < 0,2 m^2K/W	
		Frame Component 1)	R m^2K/W	Frame Component 1)	R m^2K/W	Frame Component 1)	R m^2K/W
1. Single glazing	0,18	0,3 bis (to) 0,5	0,21	0,1 bis (to) 0,4	0,19	0,1 bis (to) 0,4	0,18
2. Double glazing, 6mm	0,30		0,31		0,29		0,25
3. Double glazing, 12 mm	0,34		0,34		0,31		0,27
4. Triple glazing, 12 mm	0,51		0,43		0,40		0,34
5. Double glazing (sealed) <4cm	0,37		0,36		0,33		0,29
6. Double glazing (sealed) <7cm	0,38		0,36		0,34		0,29
7. Double windows > 7cm		0,4 bis 0,6	0,44				
8. Heat-insulating glazing (with certificate for the R-value of the glazing)	0,3	0,3 bis (to) 0,5	0,31	0,1 bis (to) 0,4	0,29	0,1 bis (to) 0,4	0,25
	0,5		0,42		0,40		0,34
	0,7		0,49		0,48		0,39
	0,9		0,54		0,55		0,43
9. Shop windows, glass doors	0,18	0 bis (to) 0,1	0,18				
10. Glass blocks, single walled	0,20		0,20				
11. Glass blocks, double walled	0,30		0,30				
12. Skylights, flat or domed, single	0,18		0,18				
13. Skylights, flat or domed, double	0,30		0,30				

1) For differing frame components the heat transmission resistances have to be calculated to section 7.2; the quoted heat transmission resistances of the glass surfaces are to be used unless there is good evidence for differing values, and the mean heat transmission resistances of the three types of frame construction (R = 0,34, or 0,25 or 0,18

Table 10. Heat Transmission Resistances R for exterior and interior doors.

Type of Door	R m^2K/W
Exterior Doors [1]	
Wood, Plastic	0,30
Metal, heat insulated	0,25
Metal, not insulated	0,18
Internal doors	0,43

1) If the proportion of glass exceeds 50 % the values for windows shall be used.

Table 11. Calculating values for the Gap Permeability of Building Components. 1),6)

Serial Nr.	Designation			Quality Characteristic	Gap Permeabilit[y] 2) Permeability coefficient a $m^3/mhPa^{2/3}$
1	Window	openable		Stress groups B,C,D 4)	0,3
2				" " A	0,6
3		not openable		normal	0,1
4	Doors	external	turning & sliding	very tight, with recessed seating all round	1
5				normal, with threshold	2
6			swing doors	normal	20
7			revolving d.	normal	30
8		internal		tight, with threshold	3
9				normal, without thresh.	9
10	External wall components	continuous gaps between prefabricated components 3)		very tight, with guarantee	0,1
11				without guarantee	1
12,	roller shutter	mechanics accessible from outside		normal	-
13		mechanics accessible from inside		normal	-
14	Ventilation	opening, closed		very tight	4 5)
15				normal	7 5)

1) The quality- & functional characteristics have to be specified by the client. Lower gap permeabilities than those to table 11 may be used only if these can be assured under consideration of the leakage gaps due to the construction for a reasonable time.
2) The permeabilities of possible constructional gaps are included in these gaps.
3) Using prefabricated units the gaps on both sides of the pillars and of the ties have to be assumed.
4) To DIN 18055/2
5) and 6) see next page

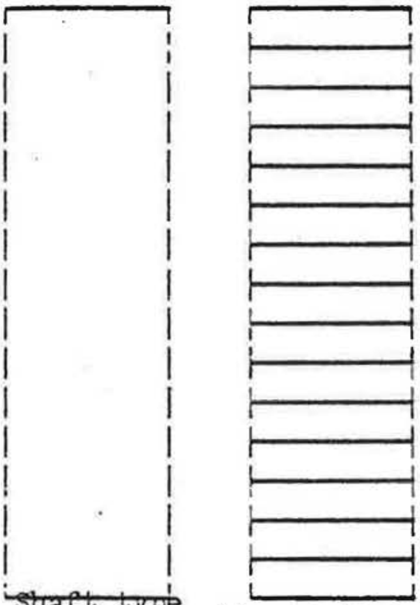


Fig.8 Building Types
Bild 8. Gebäudetypen

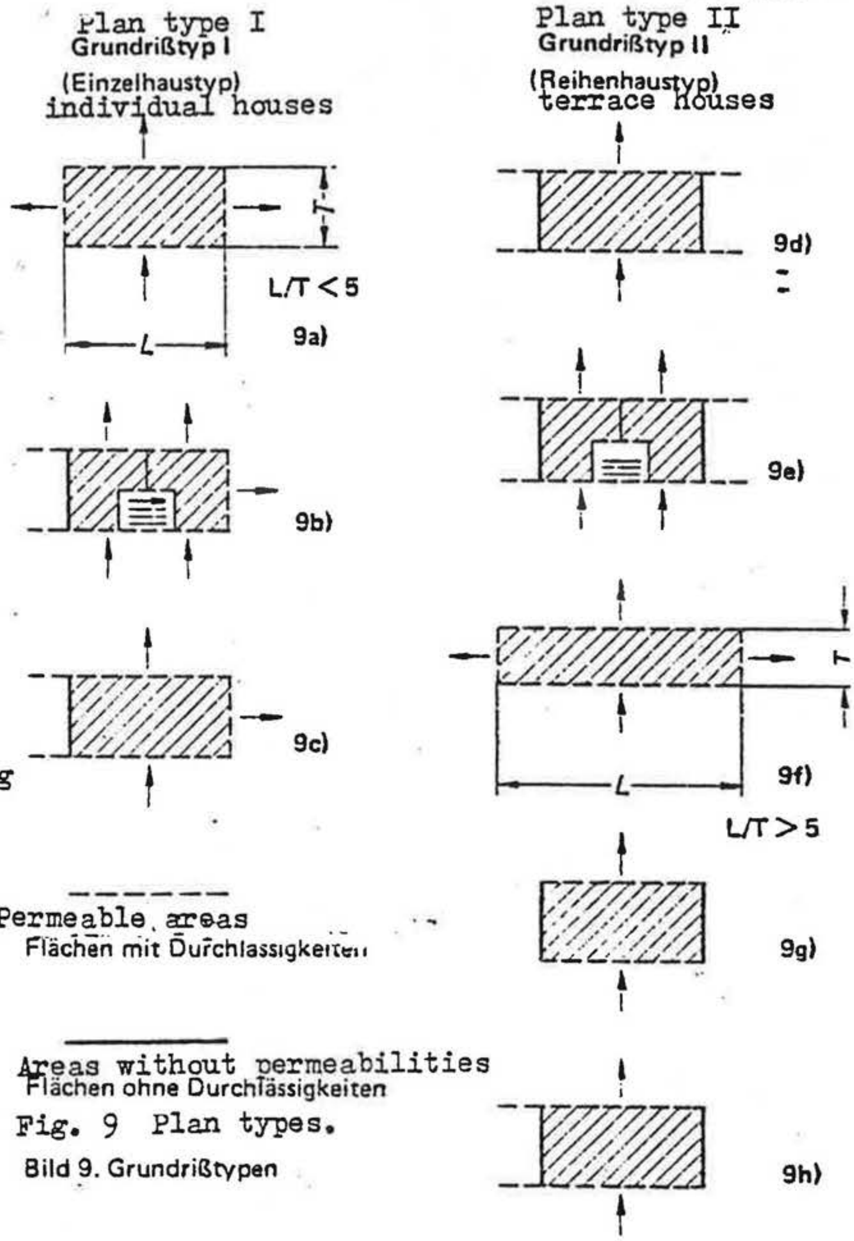


Fig. 9 Plan types.
Bild 9. Grundrißtypen

Table 12 Standard House Characteristics H_{G10}

District	Position of the Building	Standard House Characterist. H_{G10} $WhPa^{2/3}/m^3K$		Windspeed used as Bases m/s
		Plan Type I[1)]	Plan Type II[2)]	
Districts exposed to weak winds	normal position	0,71	o,50	2
	exposed position	1,8	1,3	4
Districts exposed to strong winds	normal position	1,8	1,3	4
	exposed position	3,1	2,2	6

1) Individual houses to fig. 9a to 9c
2) Terrace houses to fig. 9d to 9h

5) The values refer to a slide length of 1 m and a height of 100 mm.
6) Bases for other components: Esdorn H., Rheinländer J: Contribution to the mathematical evaluation of gap permeabilities and pressure exponents for gaps between components. HLH 29 (1978) Nr. 3

Exposure	Situation	Standard House Charactristic H_{G10} $WhPa^{2/3}/m^3K$	Height of Build. in m	ε	Height z above ground level in m.																				
					0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
				ε_{GA}	1,0			1,2	1,4	1,5	1,6	1,7	1,8	1,9	2,0	2,1	2,2	2,3	2,4		2,5	2,6		2,7	
Region of Weak wind expo-sane wind-schwach	normal	0,72	100	ε_{SA}	9,4	8,8	8,1	7,5	6,8	6,1	5,3	4,5	3,6	2,6	1,4	0									
				ε_{SN}	9,1	8,5	7,8	7,0	6,2	5,4	4,5	3,5	2,4	0,76	0										
			80	ε_{SA}	8,2	7,5	6,7	6,0	5,3	4,5	3,6	2,6	1,3	0											
				ε_{SN}	7,9	7,1	6,4	5,6	4,7	3,7	2,5	1,1	0												
			60	ε_{SA}	6,8	6,0	5,2	4,4	3,5	2,5	1,2	0													
				ε_{SN}	6,5	5,7	4,8	3,8	2,7	1,3	0														
			40	ε_{SA}	5,3	4,4	3,4	2,4	1,1	0															
				ε_{SN}	4,9	4,0	2,9	1,6	0																
			20	ε_{SA}	3,5	2,4	0,86	0																	
				ε_{SN}	3,1	1,8	0																		
			10	ε_{SA}	1,0																				
				ε_{SN}	0																				
	exposed frei	1,82	100	ε_{SA}	3,9	3,7	3,4	3,2	3,1	2,9	2,7	2,5	2,3	2,0	1,8	1,5	1,2	0,81	0,33	0					
				ε_{SN}	3,4	3,2	2,9	2,5	2,2	1,8	1,4	0,88	0,11	0											
			80	ε_{SA}	3,4	3,2	2,9	2,7	2,5	2,3	2,1	1,9	1,6	1,3	0,99	0,60	0								
				ε_{SN}	2,9	2,6	2,3	1,9	1,5	1,0	0,42	0													
			60	ε_{SA}	2,9	2,6	2,3	2,1	1,9	1,7	1,4	1,1	0,78	0,32	0										
				ε_{SN}	2,4	2,0	1,7	1,2	0,66	0															
			40	ε_{SA}	2,4	2,0	1,7	1,5	1,2	0,89	0,50	0													
				ε_{SN}	1,7	1,4	0,89	0,04	0																
			20	ε_{SA}	1,8	1,4	0,90	0,58	0,37																
				ε_{SN}	0,99	0,40	0																		
			10	ε_{SA}	1,0																				
				ε_{SN}	0																				

Table 13. Continued

Tabelle 13. (Fortsetzung)

Exposure	Position	Standard House Characteristic H_{G10} Wh Pa$^{2/3}$/m^3 K	Height of Building in m	ε	Height z above ground level in m ~~Höhe z über Terrain in m~~																				
					0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
				ε_{GA}		1,0		1,2	1,4	1,5	1,6	1,7	1,8	1,9	2,0	2,1	2,2	2,3	2,4		2,5	2,6		2,7	
wind-stark (Region of strong wind exposure)	normal	1,82	100	ε_{SA}	3,9	3,7	3,4	3,2	3,1	2,9	2,7	2,5	2,3	2,0	1,8	1,5	1,2	0,81	0,33	0					
				ε_{SN}	3,4	3,2	2,9	2,5	2,2	1,8	1,4	0,88	0,11	0											
			80	ε_{SA}	3,4	3,2	2,9	2,7	2,5	2,3	2,1	1,9	1,6	1,3	0,99	0,60	0								
				ε_{SN}	2,9	2,6	2,3	1,9	1,5	1,0	0,42	0													
			60	ε_{SA}	2,9	2,6	2,3	2,1	1,9	1,7	1,4	1,1	0,78	0,32	0										
				ε_{SN}	2,4	2,0	1,7	1,2	0,66	0															
			40	ε_{SA}	2,4	2,0	1,7	1,5	1,2	0,89	0,50	0													
				ε_{SN}	1,7	1,4	0,89	0,04	0																
			20	ε_{SA}	1,8	1,4	0,90	0,58	0,37																
				ε_{SN}	0,99	0,40	0																		
			10	ε_{SA}	1,0																				
				ε_{SN}	0																				
	frei (exposed)	3,13	100	ε_{SA}	2,4	2,3	2,1				2,0			1,9	1,8		1,7	1,6	1,5		1,4	1,3	1,2	1,1	0,99
				ε_{SN}	1,8	1,6	1,5	1,2	0,95	0,65	0,25	0													
			80	ε_{SA}	2,2	2,0	1,9		1,8			1,7		1,6	1,5		1,4	1,3	1,2	1,1	1,0				
				ε_{SN}	1,5	1,3	1,1	0,85	0,52	0															
			60	ε_{SA}	1,9	1,8	1,6			1,5		1,4		1,3	1,2		1,1								
				ε_{SN}	1,2	0,99	0,76	0,39	0																
			40	ε_{SA}	1,6	1,5	1,3			1,2		1,1													
				ε_{SN}	0,84	0,58	0,24	0																	
			20	ε_{SA}	1,4	1,2	0,98	0,97	0,95																
				ε_{SN}	0,43	0																			
			10	ε_{SA}	1,0																				
				ε_{SN}	0																				

correction factors for height & plan type II

Esposure	Position	Standard House Charactristic H_{G10} $WhPa^{2/3}/m^3K$	Height of Building in m	ε	Height z above ground level ~~Höhe über Terrain~~ in m																				
					0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
				ε_{GA}	1,0			1,2	1,4	1,5	1,6	1,7	1,8	1,9	2,0	2,1	2,2	2,3	2,4		2,5	2,6		2,7	
Region of Weak Wind Exposure ~~wind schwach~~	normal	0,52	100	ε_{SA}	13	12	11	10	9,2	8,2	7,2	6,0	4,7	3,2	1,3	0									
				ε_{SN}	13	12	11	9,5	8,4	7,3	6,0	4,5	2,8	0											
			80	ε_{SA}	11	10	9,1	8,2	7,1	6,0	4,7	3,2	1,8	0											
				ε_{SN}	11	9,7	8,6	7,5	6,2	4,8	3,2	0,78	0												
			60	ε_{SA}	9,3	8,2	7,0	5,9	4,6	3,2	1,1	0													
				ε_{SN}	8,8	7,7	6,5	5,1	3,5	1,3	0														
			40	ε_{SA}	7,2	6,0	4,5	3,1	1,0	0															
				ε_{SN}	6,7	5,3	3,8	1,8	0																
			20	ε_{SA}	4,8	3,2	0,86	0																	
				ε_{SN}	4,1	2,3	0																		
			10	ε_{SA}	1,0																				
				ε_{SN}	0																				
exposed	frei	1,31	100	ε_{SA}	5,1	4,7	4,3	4,1	3,9	3,6	3,3	3,0	2,6	2,3	1,9	1,4	0,89	0							
				ε_{SN}	4,4	4,0	3,6	3,1	2,5	2,0	1,3	0,22	0												
			80	ε_{SA}	4,4	4,0	3,6	3,4	3,1	2,8	2,5	2,1	1,7	1,2	0,66	0									
				ε_{SN}	3,7	3,3	2,8	2,2	1,6	0,77	0														
			60	ε_{SA}	3,8	3,3	2,9	2,6	2,3	1,9	1,5	1,0	0,37	0											
				ε_{SN}	3,0	2,5	1,9	1,2	0																
			40	ε_{SA}	3,0	2,5	2,0	1,7	1,3	0,75	0														
				ε_{SN}	2,1	1,5	0,74	0																	
			20	ε_{SA}	2,2	1,6	0,93	0,37	0																
				ε_{SN}	1,1	0																			
			10	ε_{SA}	1,0																				
				ε_{SN}	0																				

Tabelle 14. (Fortsetzung) Table 14 cont.

Exposure	Situation	Standard House Characteris. $H_{G\,10}$ Wh Pa$^{2/3}$/m^3 K	Height of Build. in m	ε	Height above Ground level ~~Höhe z über Terrain~~ in m																				
					0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
				ε_{GA}	1,0			1,2	1,4	1,5	1,6	1,7	1,8	1,9	2,0	2,1	2,2	2,3	2,4		2,5	2,6		2,7	
wind-stark (Region of strong wind exposure)	normal	1,31	100	ε_{SA}	5,1	4,7	4,3	4,1	3,9	3,6	3,3	3,0	2,6	2,3	1,9	1,4	0,89	0							
				ε_{SN}	4,4	4,0	3,6	3,1	2,5	2,0	1,3	0,22	0												
			80	ε_{SA}	4,4	4,0	3,6	3,4	3,1	2,8	2,5	2,1	1,7	1,2	0,66	0									
				ε_{SN}	3,7	3,3	2,8	2,2	1,6	0,77	0														
			60	ε_{SA}	3,8	3,3	2,9	2,6	2,3	1,9	1,5	1,0	0,37	0											
				ε_{SN}	3,0	2,5	1,9	1,2	0																
			40	ε_{SA}	3,0	2,5	2,0	1,7	1,3	0,75	0														
				ε_{SN}	2,1	1,5	0,74	0																	
			20	ε_{SA}	2,2	1,6	0,93	0,37	0																
				ε_{SN}	1,1	0																			
			10	ε_{SA}	1,0																				
				ε_{SN}	0																				
	frei (exposed)	2,24	100	ε_{SA}	2,8	2,6	2,4		2,3		2,2		2,1	2,0	1,9	1,8	1,7	1,6	1,4	1,3	1,1	0,97	0,79	0,58	0,48
				ε_{SN}	1,9	1,6	1,3	0,83	0,18	0															
			80	ε_{SA}	2,5	2,3	2,0				1,9	1,8	1,7	1,6	1,5	1,4	1,3	1,1	0,99	0,82	0,61				
				ε_{SN}	1,5	1,2	0,80	0,07	0																
			60	ε_{SA}	2,2	2,0	1,7			1,6	1,5	1,4	1,3	1,2	1,1	0,98	0,82								
				ε_{SN}	1,1	0,67	0,06	0																	
			40	ε_{SA}	1,9	1,6	1,4	1,3		1,2		1,1													
				ε_{SN}	0,58	0																			
			20	ε_{SA}	1,6	1,3	0,95	0,94	0,92																
				ε_{SN}	0																				
			10	ε_{SA}	1,0																				
				ε_{SN}	0																				

Table 15. Room Characteristics r[1]

Interior Doors		Permeability of the facades – $\Sigma(a \cdot l)_A + \Sigma(a \cdot l)_N$ [3) 4)] $m^3/h\ Pa^{2/3}$	Room Charac... r
Quality	Number		
normal without Threshold	1	≤ 17 > 17	0,9 0,7
	2	≤ 34 > 34	0,9 0,7
	3	≤ 43 > 43	0,9 0,7
Tight, with Threshold	1	≤ 7 > 7	0,9 0,7
	2	≤ 14 > 14	0,9 0,7
	3	≤ 21 > 21	0,9 0,7

1) The values quoted here (r) apply for rooms with doors of the usual size and gap permeability.
In all other cases the room characteristic has to be determined to equ. (16)

2) For rooms without inside doors between incoming and outgoing air (e.g. halls, open plan offices etc) r = 1.

3) a = gap permeability coefficient
l = length of gap

4) A Forced ventilation
N Natural ventilation

Those values of $\sum(a.l)$ are to be used which have been used for the calculation of Q_L

Table 16. Heat Conductivity Coefficients λ_R & Thermal Resistances R_λ of Building Materials 8)

Line Zeile	Material Stoffe	Rough density kg/m³	λ_R 1) W/m K	Thermal resistance R_λ for usual layer thicknesses d in m Wärmeleitwiderstand R_λ für gebräuchliche Schichtdicken d in m m² K/W											
	a	b	c	d	e	f	g	h	i	k	l	m	n	o	p
			d =	0,020	0,030	0,040	0,050	0,100	0,150	0,200	0,250	0,300	0,400	0,500	
1	NATURAL STONES & EART														
1.1	~~Natural stone~~ and soil														
1.1.1	Dense stones (granite basalt, marble etc.)		3,49	0,006	0,009	0,011	0,014	0,029	0,043	0,057	0,072	0,086	0,115	0,143	
1.1.2	Porous natural stones (sandstone, shell lime stone, etc.)		2,33	0,009	0,013	0,017	0,021	0,043	0,064	0,086	0,107	0,129	0,172	0,215	
1.1.3	Sand and gravel usual moisture cont.		1,40	0,014	0,021	0,029	0,036	0,072	0,107	0,143	0,179	0,215	0,287	0,358	
1.1.4	cohesive soil, natural moisture cont.		2,09	0,010	0,014	0,019	0,024	0,048	0,072	0,096	0,119	0,143	0,191	0,239	
1.2	Clay														
1.2.1	Heavy clay, moulded clay pieces (briquets)		0,93	0,021	0,032	0,043	0,054	0,107	0,161	0,215	0,269	0,322	0,430	0,537	
1.2.2	Clay with straw		0,70	0,029	0,043	0,057	0,072	0,143	0,215	0,287	0,358	0,430	0,573	0,717	
1.2.3	Light loam		0,47	0,043	0,064	0,086	0,107	0,215	0,322	0,430	0,537	0,645	0,860	1,075	
1.2.4	Clay with straw on laths		0,47	0,043	0,064	0,086	0,107	0,215	0,322	0,430	0,537	0,645	0,859	1,075	
1.3	Loose filling materia airdry, in ceilings etc.														
1.3.1	Sand		0,58	0,034	0,052	0,069	0,086	0,172	0,258	0,344	0,430	0,516	0,688	0,860	
1.3.2	Gravel, chippings		0,81	0,025	0,037	0,049	0,061	0,123	0,184	0,246	0,307	0,369	0,491	0,614	
1.3.3	Pumice gravel		0,19	0,107	0,161	0,215	0,269	0,537	0,806	1,075	1,343	1,612	2,149	2,687	
1.3.4	Slag (coal)		0,19	0,107	0,161	0,215	0,269	0,537	0,806	1,075	1,343	1,612	2,149	2,687	

1) Fußnoten siehe Seite 50 Foot notes see p. 68

Tabelle 16. (Fortsetzung) Table 16 (continued)

Line Zeile	Material Stoffe	Rough density kg/m³	λ_R [1)] W/m K	Thermal Resistance R_λ for usual Layer thicknesses d in m ~~Wärmeleitwiderstand R_λ für gebräuchliche Schichtdicken d in m~~ m² K/W											
	a	b	c	d	e	f	g	h	i	k	l	m	n	o	p
			d =	0,020	0,030	0,040	0,050	0,100	0,150	0,200	0,250	0,300	0,400	0,500	
1.3.5	Foamed blast furnace slag		0,14	0,143	0,215	0,287	0,358	0,716	1,074	1,433	1,791	2,149	2,865	3,582	
1.3.6	Brick chippings		0,41	0,049	0,074	0,098	0,123	0,246	0,368	0,491	0,614	0,737	0,983	1,228	
2	Mortar & Concrete														
2.1	Plasterwork, inside & out; floorings		d =	0,005	0,010	0,015	0,020	0,025	0,030	0,035	0,040	0,050	0,060	0,070	
2.1.1	Lime mortar, lime-cement mortar, mortar made of hydraulic lime		0,87	0,006	0,011	0,017	0,023	0,029	0,034	0,040	0,046	0,057	0,069	0,080	
2.1.2	Cement mortar		1,40	0,004	0,007	0,011	0,014	0,018	0,021	0,025	0,029	0,036	0,043	0,050	
2.1.3	Lime-plaster mortar plaster mortar, pure plaster, anhydride m.		0,70	0,007	0,014	0,021	0,029	0,036	0,043	0,050	0,057	0,072	0,086	0,100	
2.2	Concrete, light-weight concrete in gapless components or large plates		d =	0,050	0,100	0,120	0,140	0,160	0,180	0,200	0,220	0,240	0,250	0,300	0,350
2.2.1	Light-weight concrete & reinforced lightweight concrete with closed structure	1000	0,47	0,043	0,064	0,086	0,107	0,215	0,322	0,430	0,537	0,645	0,860	1,075	
		1200	0,59	0,034	0,051	0,067	0,084	0,169	0,253	0,337	0,421	0,506	0,674	0,843	
		1400	0,72	0,028	0,042	0,055	0,069	0,139	0,208	0,277	0,347	0,416	0,555	0,693	
		1600	0,87	0,023	0,034	0,046	0,057	0,115	0,172	0,229	0,287	0,344	0,459	0,573	
		1800	0,99	0,020	0,030	0,040	0,051	0,101	0,152	0,202	0,253	0,303	0,405	0,506	
		2000	1,16	0,017	0,026	0,034	0,043	0,086	0,129	0,172	0,215	0,258	0,344	0,430	
2.2.2	Crushed brick concrete with closed structure	1600	0,76	0,066	0,132	0,159	0,185	0,212	0,238	0,265	0,291	0,317	0,331	0,397	0,463
		1800	0,93	0,054	0,107	0,129	0,150	0,172	0,193	0,215	0,236	0,258	0,269	0,322	0,376
2.2.3	Crushed brick concrete for reinforced concrete structures.	2000	1,05	0,048	0,096	0,115	0,134	0,153	0,172	0,191	0,210	0,229	0,239	0,287	0,334

Fußnoten siehe Seite 60 Footnotes see p 68

Table 16 (continued)

Tabelle 16. (Fortsetzung)

Line / Zeile	Material / Stoffe	Rough density ρ kg/m³	λ_R 1) W/m K	Thermal Resistance R_λ for usual layer thicknesses d in m ~~Wärmeleitwiderstand R_λ für gebräuchliche Schichtdicken d in m~~ m² K/W											
	a	b	c	d	e	f	g	h	i	k	l	m	n	o	p
			d =	0,050	0,100	0,120	0,140	0,160	0,180	0,200	0,220	0,240	0,250	0,300	0,350
2.2.4	rough porous concrete with nonporous aggregate, e.g. gravel	1500	0,64	0,078	0,156	0,188	0,219	0,250	0,281	0,313	0,344	0,375	0,391	0,469	0,547
		1700	0,81	0,061	0,123	0,147	0,172	0,197	0,221	0,246	0,270	0,295	0,307	0,369	0,430
		1900	1,11	0,045	0,091	0,109	0,127	0,145	0,163	0,181	0,199	0,217	0,226	0,272	0,317
2.2.5	Crushed brick concrete & coal-slag concrete, with rough pores	1200	0,47	0,107	0,215	0,258	0,301	0,344	0,387	0,430	0,473	0,516	0,537	0,645	0,752
		1400	0,58	0,086	0,172	0,206	0,241	0,275	0,310	0,344	0,378	0,413	0,430	0,516	0,663
		1600	0,76	0,066	0,132	0,159	0,185	0,212	0,238	0,265	0,291	0,317	0,331	0,397	0,463
2.2.6	Pumice concrete, foamed concrete & concrete made of foamed or granulated blast furnace slag	800	0,29	0,172	0,344	0,413	0,481	0,550	0,619	0,688	0,757	0,825	0,860	1,032	1,204
		1000	0,35	0,143	0,287	0,344	0,401	0,459	0,516	0,573	0,631	0,688	0,717	0,860	1,003
		1200	0,47	0,107	0,215	0,258	0,301	0,344	0,387	0,430	0,473	0,516	0,537	0,645	0,752
2.2.7	Steam-hardened aerated & gas concrete light lime concrete	400	0,14	0,358	0,716	0,860	1,003	1,146	1,289	1,433	1,576	1,719	1,791	2,149	2,507
		500	0,19	0,269	0,537	0,645	0,752	0,860	0,967	1,075	1,182	1,290	1,343	1,612	1,881
		600	0,23	0,215	0,430	0,516	0,602	0,688	0,774	0,860	0,946	1,032	1,075	1,290	1,505
		700	0,27	0,187	0,374	0,449	0,523	0,598	0,673	0,748	0,822	0,897	0,935	1,121	1,308
		800	0,29	0,172	0,344	0,413	0,481	0,550	0,619	0,688	0,757	0,825	0,860	1,032	1,204
		1000	0,35	0,143	0,287	0,344	0,401	0,459	0,516	0,573	0,631	0,688	0,717	0,860	1,003
2.2.8	Wood-chip concrete	800	0,41	0,123	0,246	0,295	0,344	0,393	0,442	0,491	0,540	0,590	0,614	0,737	0,860
		1000	0,52	0,096	0,191	0,229	0,267	0,306	0,344	0,382	0,420	0,459	0,478	0,573	0,669
2.3	Concrete- & Plaster Board		d =	0,004	0,006	0,008	0,010	0,012	0,018	0,020	0,050	0,075	0,100	0,125	0,150
2.3.1	Asbestos-cement board	1800	0,35	0,011	0,017	0,023	0,029	0,034	0,052	0,057	0,143	0,215	0,287	0,358	0,430

Fußnoten siehe Seite 50 Footnotes see p 68

Tabelle 16. (Fortsetzung) *Continued*

Line Zeile	Material Stoffe	Rough density kg/m³	λ_R [1] W/m K	Thermal Resistance R_λ for usual Layer thicknesses d in m Wärmeleitwiderstand R_λ für gebräuchliche Schichtdicken d in m m² K/W											
	a	b	c	d	e	f	g	h	i	k	l	m	n	o	p
			d =	0,004	0,006	0,008	0,010	0,012	0,018	0,020	0,050	0,075	0,100	0,125	0,150
2.3.2	Light-weight wall building board of concrete (DIN 18162)														
2.3.2.1	Natural pumice wall building board (Pumice board)	800	0,29	0,014	0,021	0,028	0,034	0,041	0,062	0,069	0,172	0,258	0,344	0,430	0,516
2.3.2.2	Expanded blast furnace slag; wall board of aerated concrete	1000	0,35	0,011	0,017	0,023	0,029	0,034	0,052	0,057	0,143	0,215	0,287	0,358	0,430
2.3.2.3	Slag wall boards	1200	0,47	0,009	0,013	0,017	0,021	0,026	0,039	0,043	0,107	0,161	0,215	0,269	0,322
2.3.2.4	Wall board made of sintered pumice, crushed brick, tuff, lava Light-weight wall board made of mixed aggregate	1400	0,58	0,007	0,010	0,014	0,017	0,021	0,031	0,034	0,086	0,129	0,172	0,215	0,258
2.3.3	Plaster wall boards (DIN 18163														
2.3.3.1	Plaster wall boards, porous, with cavities, fillers or aggregate	600	0,29	0,014	0,021	0,028	0,034	0,041	0,062	0,069	0,172	0,258	0,344	0,430	0,516
		750	0,35	0,011	0,017	0,023	0,029	0,034	0,052	0,057	0,143	0,215	0,287	0,358	0,430
		900	0,41	0,010	0,015	0,020	0,025	0,029	0,044	0,049	0,123	0,184	0,246	0,307	0,368
		1000	0,47	0,009	0,013	0,017	0,021	0,026	0,039	0,043	0,107	0,161	0,215	0,269	0,322
		1200	0,58	0,007	0,010	0,014	0,017	0,021	0,031	0,034	0,086	0,129	0,172	0,215	0,258
2.3.3.2	Plaster wall board	1200	0,58	0,007	0,010	0,014	0,017	0,021	0,031	0,034	0,086	0,129	0,172	0,215	0,258
2.3.4	Plaster-paper board (DIN 18180) up to 18 mm thick		0,21	0,019	0,029	0,038	0,048	0,057	0,086						
2.4	Concrete block masonry including mortar joints		d =	0,052	0,071	0,100	0,115	0,150	0,175	0,200	0,240	0,300	0,365	0,490	

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Tabelle 16. ~~(Fortsetzung)~~ (continued)

Line Zeile	Material Stoffe	Rough density kg/m³	λ_R 1) W/m K	Thermal Resistance R_λ for usual layer thicknesses d in m ~~Wärmeleitwiderstand R_λ für gebräuchliche Schichtdicken d in m~~ m² K/W											
	a	b	c	d	e	f	g	h	i	k	l	m	n	o	p
			d =	0,052	0,071	0,100	0,115	0,150	0,175	0,200	0,240	0,300	0,365	0,490	
2.4.1	Sand-lime bricks to DIN 106/1														
2.4.1.1	Solid sand-lime bricks	1600	0,79	0,066	0,090	0,126	0,145	0,190	0,221	0,253	0,303	0,379	0,462	0,620	
		1800	0,99	0,053	0,072	0,101	0,116	0,152	0,177	0,202	0,243	0,303	0,369	0,496	
		2000	1,11	0,047	0,064	0,091	0,104	0,136	0,158	0,181	0,217	0,272	0,330	0,443	
2.4.1.2	Perforated sand-lime bricks	1200 2)	0,56	0,093	0,127	0,179	0,206	0,269	0,314	0,358	0,430	0,537	0,654	0,878	
		1400 2)	0,70	0,075	0,102	0,143	0,165	0,215	0,251	0,287	0,344	0,430	0,523	0,702	
		1600 2)	0,79	0,066	0,090	0,126	0,145	0,190	0,221	0,253	0,303	0,379	0,462	0,620	
2.4.1.3	Sand-lime hollow blocks	1400	0,70	0,029	0,043	0,057	0,072	0,143	0,215	0,287	0,358	0,430	0,573	0,717	
		1600	0,79	0,025	0,038	0,051	0,063	0,126	0,190	0,253	0,316	0,379	0,506	0,632	
2.4.2	Slag bricks (DIN 398)														
2.4.2.1	Solid slag bricks	1800	0,76	0,069	0,094	0,132	0,152	0,198	0,231	0,265	0,317	0,397	0,483	0,648	
		2000	0,84	0,062	0,085	0,119	0,137	0,179	0,209	0,239	0,287	0,358	0,436	0,585	
		2200	1,05	0,050	0,068	0,096	0,110	0,143	0,167	0,191	0,229	0,287	0,349	0,468	
2.4.2.2	Perforated slag bricks	1400	0,58	0,089	0,122	0,172	0,198	0,258	0,301	0,344	0,413	0,516	0,628	0,843	
		1600	0,64	0,081	0,111	0,156	0,180	0,234	0,274	0,313	0,375	0,469	0,571	0,766	
2.4.3	Solid lightweight concrete blocks DIN 18152	800	0,41	0,128	0,174	0,246	0,282	0,368	0,430	0,491	0,590	0,737	0,890	1,204	
		1000	0,47	0,112	0,153	0,215	0,247	0,322	0,376	0,430	0,516	0,645	0,785	1,053	
		1200	0,52	0,099	0,136	0,191	0,220	0,287	0,334	0,382	0,459	0,573	0,697	0,936	
		1400	0,64	0,081	0,111	0,156	0,180	0,234	0,274	0,313	0,375	0,469	0,571	0,766	
		1600	0,79	0,066	0,090	0,126	0,145	0,190	0,221	0,253	0,303	0,379	0,462	0,620	

Fußnoten siehe Seite 50 Footnotes see p. 68

Tabelle 16. (~~Fortsetzung~~) continued

Line Zeile	Material Stoffe	Rough density kg/m³	λ_R 1) W/m K	Thermal Resistance R_λ for usual Layer thicknesses in m ~~Wärmeleitwiderstand R_λ für gebräuchliche Schichtdicken d in m.~~ m² K/W											
	a	b	c	d	e	f	g	h	i	k	l	m	n	o	p
			d =	0,052	0,071	0,100	0,115	0,150	0,175	0,200	0,240	0,300	0,365	0,490	
2.4.4	Light-weight concret hollow blocks(DIN18151)														
2.4.4.1	Two-cavity blocks	1000 3)	0,44	0,118	0,161	0,226	0,260	0,339	0,396	0,453	0,543	0,679	0,826	1,109	
		1200 3)	0,49	0,106	0,145	0,205	0,235	0,307	0,358	0,409	0,491	0,614	0,747	1,003	
		1400 3)	0,56	0,093	0,127	0,179	0,206	0,269	0,314	0,358	0,430	0,537	0,654	0,878	
2.4.4.2	Three cavity blocks	1000	0,44	0,045	0,068	0,091	0,113	0,226	0,339	0,453	0,566	0,679	0,905	1,131	
		1200	0,49	0,041	0,061	0,082	0,102	0,205	0,307	0,409	0,512	0,614	0,819	1,023	
2.4.5	Gas & foam concrete blocks (DIN4165) & light-weight lime-cement blocks, steam-hardened	700	0,38	0,052	0,078	0,104	0,130	0,261	0,391	0,521	0,651	0,782	1,042	1,303	
2.4.6	Gas & foam concrete blocks and light lime-concrete blocks, air-hardened	800	0,44	0,118	0,161	0,226	0,260	0,339	0,396	0,453	0,543	0,679	0,826	1,109	
		1000	0,56	0,093	0,127	0,179	0,206	0,269	0,314	0,358	0,430	0,537	0,654	0,878	
		1200	0,70	0,075	0,102	0,143	0,165	0,215	0,251	0,287	0,344	0,430	0,523	0,702	
2.4.7	Wood-chip concrete blocks	800	0,44	0,118	0,161	0,226	0,260	0,339	0,396	0,453	0,543	0,679	0,826	1,109	
		1000	0,56	0,093	0,127	0,179	0,206	0,269	0,314	0,358	0,430	0,537	0,654	0,878	
2.4.8	Hollow blocks & T-hollow blocks made of concrete with closed structure DIN 18153	1400	0,76	0,026	0,040	0,053	0,066	0,132	0,198	0,265	0,391	0,397	0,529	0,661	
		1600	0,87	0,023	0,034	0,046	0,057	0,115	0,172	0,229	0,287	0,344	0,459	0,573	
3	Bricks & Tiles		d =	0,004	0,008	0,015	0,020	0,052	0,071	0,115	0,175	0,240	0,300	0,365	0,490
3.1	Brick masonry (DIN 105) including mortar gaps 2)														
3.1.1	Building clinker	≥1900	1,05	0,004	0,008	0,014	0,019	0,050	0,068	0,110	0,167	0,229	0,287	0,349	0,468
3.1.2	Perforated building clinker		0,79	0,005	0,010	0,019	0,025	0,066	0,090	0,145	0,221	0,303	0,379	0,462	0,620

Fußnoten siehe Seite 50 Footnotes on p 68

Tabelle 16. (Fortsetzung) Continued

Line Zeile	Material Stoffe	Rough Density ρ kg/m³	λ_R 1) W/m K	Thermal Resistance R_λ for usual Layer Thicknesses in m ~~Wärmeleitwiderstand R_λ für gebräuchliche Schichtdicken d in m~~ m² K/W											
	a	b	c	d	e	f	g	h	i	k	l	m	n	o	p
			d =	0,004	0,008	0,015	0,020	0,052	0,071	0,115	0,175	0,240	0,300	0,365	0,490
3.1.3	Solid Bricks, Facing Bricks	1000	0,47	0,009	0,017	0,032	0,043	0,112	0,153	0,247	0,376	0,516	0,645	0,785	1,053
		1200	0,52	0,008	0,015	0,029	0,038	0,099	0,136	0,220	0,334	0,459	0,573	0,697	0,936
		1400	0,61	0,007	0,013	0,025	0,033	0,086	0,117	0,190	0,289	0,397	0,496	0,604	0,810
		1600	0,70	0,006	0,011	0,021	0,029	0,075	0,102	0,165	0,251	0,344	0,430	0,523	0,700
		1800	0,79	0,005	0,010	0,019	0,025	0,066	0,090	0,145	0,221	0,303	0,379	0,462	0,620
		2000	1,05	0,004	0,008	0,014	0,019	0,050	0,068	0,110	0,167	0,229	0,287	0,349	0,468
3.1.4	Perforated bricks, perforated facing bricks.	1000 4)	0,47	0,009	0,017	0,032	0,043	0,112	0,153	0,247	0,376	0,516	0,645	0,785	1,053
		1200 4)	0,52	0,008	0,015	0,029	0,038	0,099	0,136	0,220	0,334	0,459	0,573	0,697	0,936
		1400 4)	0,61	0,007	0,013	0,025	0,033	0,086	0,117	0,190	0,289	0,397	0,496	0,604	0,810
		1600 4)	0,70	0,006	0,011	0,021	0,029	0,075	0,102	0,165	0,251	0,344	0,430	0,523	0,700
		2000 4)	1,05	0,004	0,008	0,014	0,019	0,050	0,068	0,110	0,167	0,229	0,287	0,349	0,468
3.1.5	Light weight bricks	600	0,35	0,011	0,023	0,043	0,057	0,149	0,203	0,330	0,502	0,688	0,860	1,046	1,404
		700	0,38	0,010	0,021	0,039	0,052	0,135	0,185	0,300	0,456	0,625	0,782	0,951	1,277
		800	0,41	0,010	0,020	0,037	0,049	0,128	0,174	0,283	0,430	0,590	0,737	0,897	1,204
3.2	Tiles	2000	1,05	0,004	0,008	0,014	0,019	0,050	0,068	0,110	0,167	0,229	0,287	0,349	0,468
4	Glass		d =	0,002	0,003	0,004	0,005	0,006	0,008	0,010	0,012				
4.1	Flat glass (window glass, average values)		0,81	0,002	0,004	0,005	0,006	0,007	0,010	0,012	0,015				
5	Metals		d =	0,0006	0,0008	0,0010	0,0012	0,0014	0,0020	0,0030	0,0040	0,0050	0,0060	0,0100	0,0200
5.1	Cast iron & steel		58	$10 \cdot 10^{-6}$	$14 \cdot 10^{-6}$	$17 \cdot 10^{-6}$	$21 \cdot 10^{-6}$	$24 \cdot 10^{-6}$	$34 \cdot 10^{-6}$	$52 \cdot 10^{-6}$	$69 \cdot 10^{-6}$	$86 \cdot 10^{-6}$	$10 \cdot 10^{-5}$	$17 \cdot 10^{-5}$	$34 \cdot 10^{-5}$
5.2	Copper		384	$2 \cdot 10^{-6}$	$2 \cdot 10^{-6}$	$3 \cdot 10^{-6}$	$3 \cdot 10^{-6}$	$4 \cdot 10^{-6}$	$5 \cdot 10^{-6}$	$8 \cdot 10^{-6}$	$10 \cdot 10^{-6}$	$13 \cdot 10^{-6}$	$16 \cdot 10^{-6}$	$26 \cdot 10^{-6}$	$52 \cdot 10^{-6}$

Fußnoten siehe Seite 50 Footnotes see p 68

Line Zeile	Material Stoffe	Rough density ϱ kg/m³	λ_R 1) W/m K	Thermal Resistance R_λ of usual Layer thicknesses d in m Wärmeleitwiderstand R_λ für gebräuchliche Schichtdicken d in m m² K/W											
	a	b	c	d	e	f	g	h	i	k	l	m	n	o	p
			d =	0,0006	0,0008	0,0010	0,0012	0,0014	0,0020	0,0030	0,0040	0,0050	0,0060	0,0100	0,0200
5.3	Bronze, gun metall		64	$9 \cdot 10^{-6}$	$13 \cdot 10^{-6}$	$16 \cdot 10^{-6}$	$19 \cdot 10^{-6}$	$22 \cdot 10^{-6}$	$31 \cdot 10^{-6}$	$47 \cdot 10^{-6}$	$63 \cdot 10^{-6}$	$78 \cdot 10^{-6}$	$94 \cdot 10^{-6}$	$17 \cdot 10^{-5}$	$31 \cdot 10^{-5}$
5.4	Aluminium		204	$3 \cdot 10^{-6}$	$4 \cdot 10^{-6}$	$5 \cdot 10^{-6}$	$6 \cdot 10^{-6}$	$7 \cdot 10^{-6}$	$1 \cdot 10^{-5}$	$15 \cdot 10^{-6}$	$2 \cdot 10^{-5}$	$25 \cdot 10^{-6}$	$3 \cdot 10^{-6}$	$49 \cdot 10^{-6}$	$98 \cdot 10^{-6}$
6	Wood, airdry 5)			0,004	0,006	0,008	0,010	0,012	0,015	0,018	0,020	0,024	0,030	0,050	0,100
6.1	Oak		0,21	0,019	0,029	0,038	0,048	0,057	0,072	0,086	0,096	0,115	0,143	0,239	0,478
6.2	Beech		0,18	0,023	0,034	0,046	0,057	0,069	0,086	0,103	0,115	0,138	0,172	0,287	0,573
6.3	pine & other soft wood		0,14	0,029	0,043	0,057	0,072	0,086	0,107	0,129	0,143	0,172	0,215	0,358	0,716
6.4	wood products														
6.4.1	Ply wood		0,14	0,029	0,043	0,057	0,072	0,086	0,107	0,129	0,143	0,172	0,215	0,358	0,716
6.4.2	wood fibre board (hard, DIN 68750&-51)		0,18	0,023	0,034	0,046	0,057	0,069	0,086	0,103	0,115	0,138	0,172	0,287	0,573
6.4.3	Porous woodfibre insulating board	200	0,047	0,086	0,129	0,172	0,215	0,258	0,323	0,387	0,430	0,516	0,645	1,075	2,151
6.4.4	wood chip board	300	0,058	0,069	0,103	0,137	0,172	0,206	0,258	0,309	0,344	0,412	0,515	0,859	1,718
6.4.4.1	Chipboard, flat pulpwood plates to DIN 68761, 68762, 68763	300	0,087	0,046	0,067	0,092	0,115	0,138	0,172	0,206	0,229	0,275	0,344	0,573	1,147
		400	0,099	0,040	0,061	0,081	0,101	0,121	0,152	0,182	0,202	0,243	0,303	0,506	1,011
		500	0,12	0,034	0,052	0,069	0,086	0,103	0,129	0,155	0,172	0,206	0,258	0,430	0,860
		600	0,13	0,031	0,047	0,063	0,078	0,094	0,117	0,141	0,156	0,188	0,235	0,391	0,782
		700	0,14	0,029	0,043	0,057	0,072	0,086	0,107	0,129	0,143	0,172	0,215	0,358	0,716
6.4.4.2	Chip board, extrusion moulded board to DIN 68764		0,18	0,023	0,034	0,046	0,057	0,069	0,086	0,103	0,115	0,138	0,172	0,287	0,573
7	Plastics & Floorings		d =	0,002	0,003	0,004	0,005	0,010	0,015	0,020	0,025	0,030	0,035	0,040	0,050
7.1	Linoleum	1200	0,19	0,011	0,016	0,021	0,027								

Fußnoten siehe Seite 50 Footnotes see p 68.

Tabelle 16. (Fortsetzung) Continued

Line Zeile	Material Stoffe	rough density ρ kg/m³	λ_R 1) W/m K	Thermal Resistance R_λ for usual Layer Thicknesses in m. Wärmeleitwiderstand R_λ für gebräuchliche Schichtdicken d in m m² K/W											
	a	b	c	d	e	f	g	h	i	k	l	m	n	o	p
			d =	0,002	0,003	0,004	0,005	0,010	0,015	0,020	0,025	0,030	0,035	0,040	0,050
7.2	Magnesite composition & similar floor cov. DIN 272														
7.2.1	Sub-floors & lower layer double layer floors		0,47	0,004	0,007	0,009	0,011	0,022	0,032	0,043	0,054	0,065	0,075	0,086	0,108
7.2.2	Industrial floors & walkways		0,70	0,003	0,004	0,006	0,007	0,014							
8	Bituminous Materials														
8.1	Asphalt	2100	0,70	0,003	0,004	0,006	0,007	0,014	0,022	0,029	0,036	0,043	0,050	0,057	0,072
8.2	Bitumen	1050	0,18	0,011	0,017	0,023	0,029	0,057	0,086	0,115	0,143	0,172	0,201	0,229	0,287
8.3	Roofing felt	1100	0,19	0,011	0,016	0,021	0,027								
9	Heat Insulating Materials														
9.1	Mineral-fibre insulation(see-grass, coconut-, wood- & peet fibres DIN 18165) 6)	30 bis 200	0,041	0,049	0,074	0,098	0,123	0,246	0,369	0,491	0,614	0,737	0,860	0,983	1,229
9.2	Vegetable fibre insulation (glass-rock-wool & slagwool fib. to DIN 18165) 6)	30 bis 200	0,047	0,043	0,065	0,086	0,108	0,215	0,323	0,430	0,538	0,645	0,753	0,860	1,075
9.3	Building slagwool, loose		0,070	0,029	0,043	0,057	0,072	0,143	0,216	0,287	0,358	0,430	0,501	0,573	0,716
9.4	Light woodwool building board(DIN1101) 15 mm thick		0,14	0,014	0,021	0,029	0,036	0,072	0,107	0,143	0,179	0,215	0,251	0,287	0,358
	25 & 35 mm thick		0,093	0,022	0,032	0,043	0,054	0,108	0,161	0,215	0,269	0,323	0,376	0,430	0,538
	50 mm thick or more		0,081	0,025	0,037	0,049	0,061	0,123	0,184	0,246	0,307	0,369	0,430	0,491	0,614
9.5	Wood fibre board	200	0,047	0,043	0,065	0,086	0,108	0,215	0,323	0,430	0,538	0,645	0,753	0,860	1,075
		300	0,058	0,034	0,052	0,069	0,086	0,172	0,258	0,344	0,430	0,516	0,601	0,687	0,687

Fußnoten siehe Seite 50 Footnotes see p68

Tabelle 16. (Fortsetzung) Continued

Line Zeile	Material Stoffe	Rough density ϱ kg/m³	λ_R 1) W/m K	Thermal Resistance R_λ for usual Layer Thicknesses in m ~~Wärmeleitwiderstand R_λ für gebräuchliche Schichtdicken d in m~~ m² K/W											
	a	b	c	d	e	f	g	h	i	k	l	m	n	o	p
			d =	0,002	0,003	0,004	0,005	0,010	0,015	0,020	0,025	0,030	0,035	0,040	0,050
9.6	Cork board	120	0,041	0,049	0,074	0,098	0,123	0,246	0,369	0,491	0,614	0,737	0,860	0,983	1,229
		160	0,044	0,045	0,068	0,090	0,113	0,226	0,339	0,452	0,566	0,679	0,792	0,905	1,131
		200	0,047	0,043	0,065	0,066	0,108	0,215	0,323	0,430	0,538	0,645	0,753	0,860	1,075
9.7	Corkinlaid flooring	450	0,064	0,031	0,047	0,063	0,078	0,156	0,234	0,313	0,391	0,469	0,547	0,625	0,781
9.8	Corrugated paper board, impregnated with bitumen	55	0,047	0,043	0,065	0,086	0,108	0,215	0,323	0,430	0,538	0,645	0,753	0,860	1,075
9.9	Foam plastics		0,041	0,049	0,074	0,098	0,123	0,246	0,369	0,491	0,614	0,737	0,860	0,983	1,229
9.9.1	in plates, frames & flakes (general)		0,041	0,049	0,074	0,098	0,123	0,246	0,369	0,491	0,614	0,737	0,860	0,983	1,229
9.9.2	Hard polyurethane foam to DIN 18159/1 & 18159/2														
9.9.2.1	Boards to DIN18164	≥ 30	0,035	0,057	0,086	0,115	0,143	0,287	0,430	0,573	0,716	0,860	1,003	1,146	1,437
9.9.2.2	Building components prefabricated, foam between 2 diffusion proof coatings 7)	≥ 30	0,029	0,069	0,103	0,138	0,172	0,345	0,517	0,690	0,862	1,034	1,207	1,379	1,724

1) λ_R Rechenwert für praktischen Feuchtigkeitsgehalt und + 10 °C Mitteltemperatur nach DIN 4108 Teil 4.

2) Die genannten Rohdichten beziehen sich, soweit nichts anderes angegeben ist, auf die Steine, nicht auf das Mauerwerk.

3) Rohdichte bezogen auf den ganzen Stein, einschließlich der Hohlräume.

4) Rohdichte bezogen auf den Beton ohne Hohlräume.

5) DIN 4074 Teil 1 und DIN 4074 Teil 2

6) Gilt auch für Faserdämmstoffe im zusammengedrückten Zustand (z. B. unter schwimmenden Estrichen). Näheres siehe DIN 18 165 – Faserdämmstoffe für den Hochbau. Für die Berechnung des Wärmeleitwiderstandes unter schwimmenden Estrichen ist die Dicke unter Belastung einzusetzen.

7) Deckschichten gelten als diffusionsdicht, wenn sie aus metallischen Werkstoffen einer Dicke von mindestens 50 µm bestehen. Bei Bauelementen, deren Randflächen kleiner sind als 10% der Gesamtoberfläche, braucht die Deckschicht die Randfläche nicht zu bedecken.

8) Abweichende Rechenwerte für Wärmeleitfähigkeiten dürfen nur auf Grund eines amtlichen Prüfzeugnisses eingesetzt werden.

Footnotes see p: 68

Footnotes to Table 16.

1) λ_R Calculation figure for the practical moisture content and +10 °C average temperature to DIN 4108/4

2) The quoted rough densities refer, unless something different is stipulated to the blocks not to the masonry.

3) Rough density with reference to the entire block including cavities.

4) Rough density with reference to the concrete without cavities.

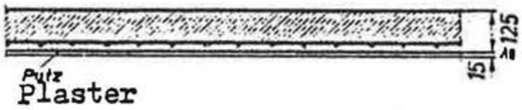
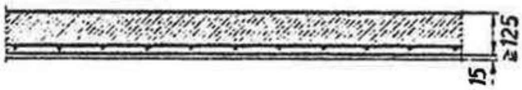
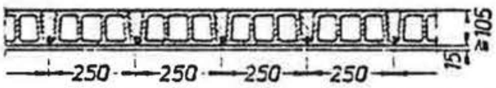
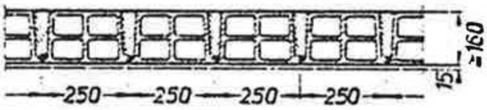
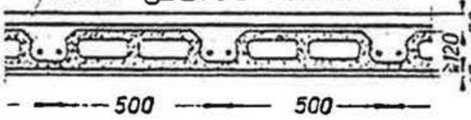
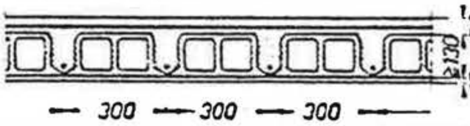
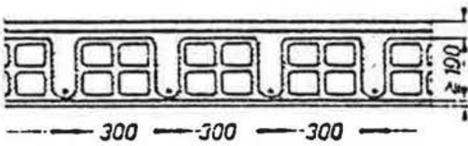
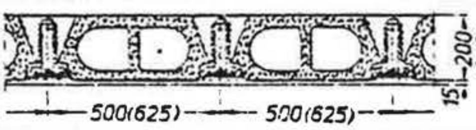
5) DIN 4074/1 and DIN 4074/2

6) Applies also to fibre insulating materials in the compressed state (e.g. below floating floors). For details see DIN 18165 Fibrous insulating material for buildings. The thickness under load is to be used for the calculation of thermal resistances below floating floors.

7) Coatings are considered as diffusion proof if they consist of metallic materials at least 50 μm thick. In building components the edge surfaces of which are less than 10 % of the total surface the coating layer need not cover the edge surfaces.

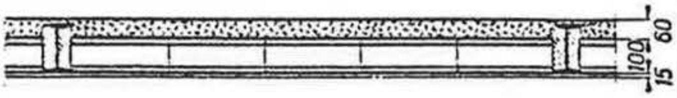
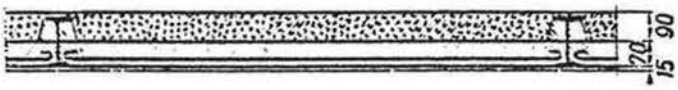
8) Differing calculation figures for thermal conductivities may be used only if based on an official test certificate.

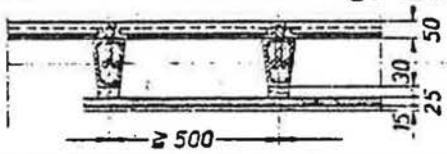
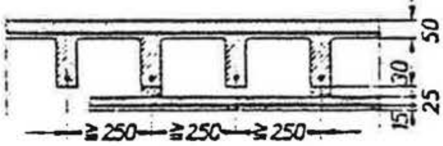
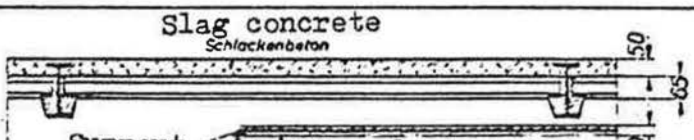
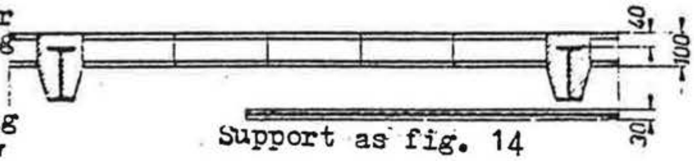
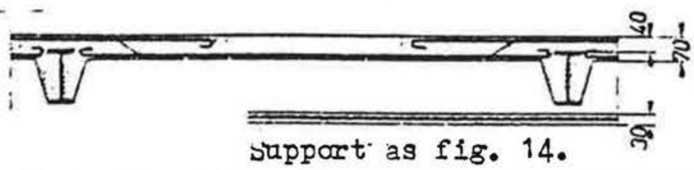
Table 17. Thermal resistances Rλ of Floors & Ceilings. 1)

Design Nr.	Designation and Sketch		Thickness mm	Rλ m^2K/W	Weight per Unit area kg/m^2
	Single layer, massiv ceilings; lower surface plastered				
	Reinforced concrete slabs to DIN 1045				
1	 Putz Plaster	aus Kiesbeton Gravel-concrete	125	0,08	320
			150	0,10	380
			175	0,10	440
			200	0,11	500
			225	0,13	560
			250	0,14	620
2		aus Ziegelsplittbeton crushed brick concrete	125	0,14	270
			150	0,16	320
			175	0,18	370
			200	0,21	420
			225	0,23	470
			250	0,26	520
	Stahlsteindecken nach DIN 1046 Hollow Block Floor DIN 1046 reinforced				
3		made off perforated bricks to DIN 4159 — without cross-webb	105	0,15	160
			120	0,16	180
			140	0,16	205
4		with cross webb	160	0,22	230
			180	0,24	260
			200	0,25	290
			225	0,26	320
			250	0,28	350
			280	0,29	370
	Stahlbetonrippendecken nach DIN 1045 Ribbed reinforced concrete floor to DIN 1045				
5	Kiesbeton gravel concrete 	with bricks of light-weight concrete to DIN 4158 (pumice, slag, crushed brick) without webb	120+50	0,24	270
			140+50	0,25	285
			160+50	0,26	305
			180+50	0,27	320
			200+50	0,28	340
			220+50	0,28	360
			250+50	0,30	380
			280+50	0,31	400
			320+50	0,32	430
6		made off perforated bricks to DIN 4160 — without cross webb	130+50	0,20	280
			150+50	0,21	300
			170+50	0,22	320
7		with cross webb	190+50	0,28	350
			210+50	0,29	380
			230+50	0,30	400
			250+50	0,31	420
			270+50	0,32	440
	Prefabricated reinforced concrete beam ceilings to DIN 4233				
8		with fillers of light-weight concrete (pumice, slag, crushed brick) without cross webb	200	0,22	220
			240	0,28	270

1) Table 17 contains some ceiling constructions which, partly, do not conform to the now valid DIN standards. Such ceilings may exist in standing buildings and it must be possible for the heating engineer to carry out calculations.

Tabelle 17. (Fortsetzung) (Continued)

Design Nr.	Designation and Sketch		Thickness mm	Rλ m²K/W	Weight per unit area kg/m²
	Ceilings between I-Girders with slag concrete filling γ = 1600 kg/m³				
9	Slag concrete 	Hollow steel & concrete floor	65+110	0,23	300
			80+95	0,22	
			100+75	0,21	
10		Steel & concrete block ceilings	100+60	0,22	260
			150+10	0,22	
11		Reinforced concrete ceiling slabs to DIN 1045	70+90	0,17	340
			100+60	0,15	365
			120+40	0,13	390

Ausführung Nr	Designation and Sketch			Rλ m²K/W without lower ceiling	Rλ m²K/W with lower ceiling	Weight per unit area kg/m² without lower ceiling	Weight per unit area kg/m² with lower ceiling
	Twin layer solid ceilings, lower face plastered Ribbed reinforced concrete ceilings without filler						
12 (12a)	with / without lower ceiling of lightweigth wood-wool slabs		to DIN 1045	0,03	0,47	220	250
13 (13a)	with / without					250	280
	Stilted ceilings between I-girders						
14 (14a)	with / without suspended wired plaster ceiling or reed ceiling	Slag concrete  Support of wired plaster ceilings to DIN 4121 on hooks, of reed ceilings on wooden laths.	hollow steel and concrete floor	0,13	0,34	230	280
15 (15a)	with / without	 Support as fig. 14	Steel and concrete block ceiling			180	230
16 (16a)	with / without	 Support as fig. 14.	Reinforced concrete ceiling to DIN1045	0,03	0,24	220	270

T...lle 17. (~~Fortsetzung~~) (Continued)

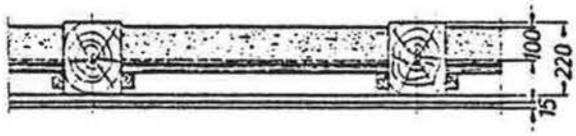
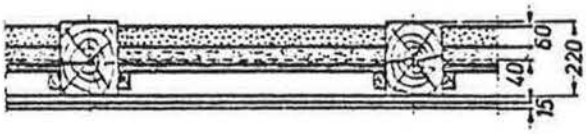
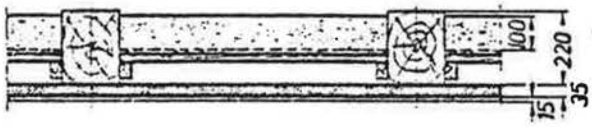
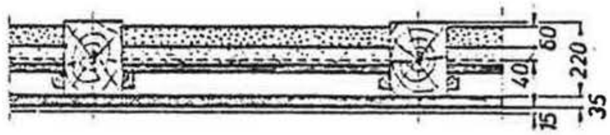
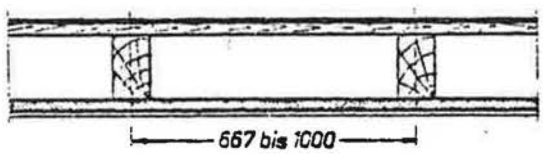
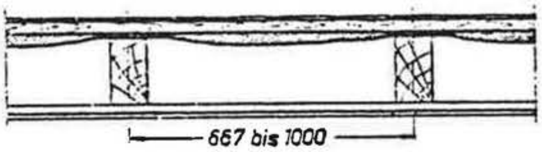
Design Nr.	Designation and Sketch ~~Bezeichnung und Darstellung~~			R_λ m² K/W
	Wood Beam Ceilings, underside plastered.-			
17		with stakes smooth clay facing and clay fill	plaster support: lath & reed matting	0,43
18		with stakes smooth clay facing & clay & coke-ash fill		0,69
19		with stakes, smooth clay facing and clay fill	plaster support: wood-wool light-weight building board, 35 mm	0,82
20		with stakes smooth clay facing and clay & coke ash fill		1,08
	Flachdächer, Decken unter Terrassen (Außendecken) Flat Roofs, Ceilings under Terraces			
21		Roofing felt Boarding Heat insulating layer under ceiling carcas, plaster; in types B &C on plaster support		0,39
		Roofing felt Boarding Heat insulating layer on top of ceiling carcass Lath, reed mats, plaster		

Table 18. Equivalent Thermal Resistances R_λ of still Air Layers.

Position of the air layer and direction of the heatflow	Thickness of Airlayer d mm	R_λ $m^2 K/W$
Air layer vertical	10	0,140
	20	0,160
	50	0,180
	100	0,170
	150	0,160
Air layer horizontal		
Heatflow upwards	10	0,140
	20	0,150
	> 50	0,160
Heat flow downwards	10	0,150
	20	0,180
	> 50	0,210

Table 19. Heat Transmission resistances R_i, R_a

	R_i m^2K/W	R_a m^2K/W
On the inside of enclosed rooms with natural air movement on walls & windows	0,130	-
Floors & ceilings heatflow upwards 1)	0,130	-
heatflow upwards 1)	0,170	-
on the outside of buildings for average wind velocity	-	0,50
In ventilated cavities with loosely connected facades or in flat roofs (the thermal resistance of the loosely connected facade or of the upper section of the roof is not to be considered separately)	-	0,90

1) Note by translator: This is an obvious error of printing: one of the two values must refer to "heat flow downwards".

7. CALCULATION OF THE HEAT TRANSMISSION RESISTANCE.

The equations for the calculation of the transmission heat requirement presuppose an one-dimensional heat flow. Deviations from these assumptions in the border zones of building components (e.g. corners of rooms, window recesses) can be neglected considering the overall accuracy of these calculations.

7.1 Components consisting of several layers in series.

In a component consisting of several layers arranged in series the heat transmission resistance R is the sum of the thermal resistances of all the layers R_λ (see tables 16, 17 and 18) and of the heat transmission resistances inside R_i and outside R_a (to table 19). It follows from eq.(4):

$$R = R_i + \sum R_\lambda + R_a$$

7.2 Components consisting of adjacent elements.

In components with adjacent elements of differing materials it is possible to assume one-dimensional heat flow for the usual types of construction as long as the ratio of the thermal resistances of the individual elements does not exceed 5 (see section 7.3). The heat flow through such components follows then as the sum of the partial flows through the individual elements. It is, therefore, possible to calculate an average thermal resistance as follows:

$$R = \frac{\sum A}{\sum \left(\frac{A}{R}\right)} \qquad (21)$$

7.3 Thermal Bridges.

The additional heat flow through a thermal bridge due to two-dimenional heat flow is to be considered in heat requirement calculations in exceptional cases only. This applies to geometrical bridges with increased heat flow e.g. Room corners or window recesses as well as for thermal bridges caused by the installation of girder reinforcements in walls. Such thermal bridges are to be insulated to DIN 4108 so that no significantly lower temperatures occur on the internal surface compared with the undisturbed wall face. In view of the general accuracy of heat requirement calculations it is, therefore, unnecessary to determine the additional heat flow through thermal bridges. In continuous thermal bridges without heat insulation one has to resort to very costly calculations. Two approximate formulae are, therefore, given for situations occurring more frequently.

7.3.1 I-Girder flush with the outside wall.

The heat flow through the girder has to be added to the flow through the homogenous wall calculated to eq. (3):

$$\Delta Q = \frac{A_{St}}{R} (t_i - t_a) \qquad (22)$$

but the planning engineer should examine carefully in every case the limits of applicability. The heat requirement so assessed is not called a S t a n d a r d Heat Requirement.

8.1 Heat Requirement of rarely heated rooms.

Assessing the heat requirement of rarely heated rooms one has to distinguish between heat storing and not heat storing components. While it is possible to calculate the heat losses of the latter ones with the help of the equations for the equilibrium state, for heat storing components the heating-up process and the corresponding material properties as well as the heating-up time affect the result of the calculation. The heat requirement is, therefore, calculated starting from from the following equation[12]:

$$Q = Q_f + Q_W + Q_L \qquad (29)$$

where; Q_f Heat requirement for windows and other not heat storing components to eq. (3)

Q_W Heat requirement for heating up heat storing components to eq. (30)

Q_L Ventilation heat requirement to eq. (11), (14), (15) or (17)

The heating-up requirement Q_W depends on the e n t i r e internal surface of the room, as far as it consists of heat storing materials, i.e. including the floor, any columns, if present, etc. The following equation applies:

$$Q_W = \sum \frac{A_W}{R_Z} \cdot (t_i - t_o) \qquad (30)$$

where: A_W Surface of the heat storing building component,

R_Z Mean heating up resistance depending on the heating-up period Z;

t_i Internal temperature at the end of the heating up period

t_o Internal temperature before starting the heating up.

Fig. 12 shows the values of R_Z for differing heat penetration coefficients $\sqrt{\lambda \cdot c \cdot \rho}$ as a function of the heating-up period.

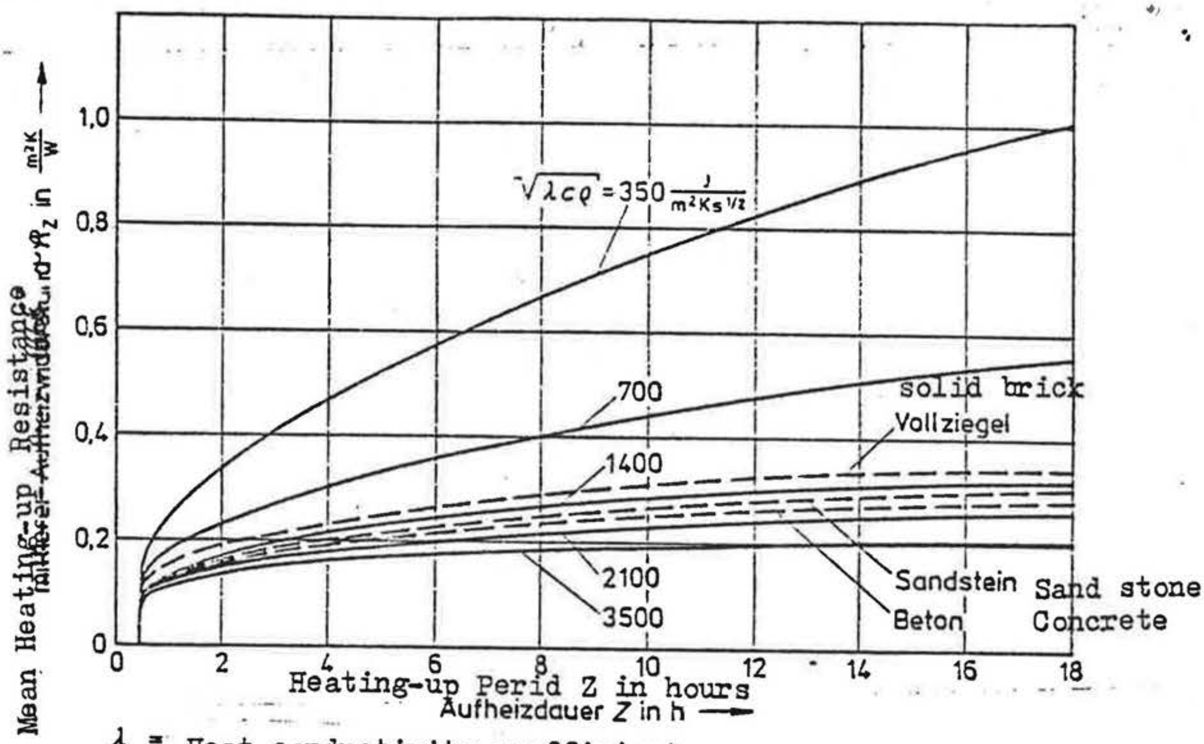
If heat storing building components are equipped inside with a heat insulating layer their mean heating up resistance R_{ZD} is assessed as follows:

$$R_{ZD} = R_Z + R_{\lambda D} \qquad (31)$$

where: $R_{\lambda D}$ Thermal resistance of the heat insulating layer,

For the occasional heating of churches, as a rule, $t_o = 0°C$ is taken as the basis. The data in table 2 are used for t_i.

12) Krischer O. and Kast W.: Contributions to the question of heat requirement during heating-up of rarely heated buildings. Ges.Ing 78 (1957) Nr. 21/22, p. 321-325.



λ = Heat conductivity coefficient
ϱ = Density
c = Specific heat capacity

Fig. 12. Mean Heating-Up Resistance R_Z 13)

8.2 Heat Requirement for very heavy types of building.

The heat requirement of very heavily built rooms (bunker above and below ground, under-ground rooms, enclosed subterranean garages etc.) is calculated as for normal cases.

Due to the great heat storage capacity of such rooms one may start from the fact that even during interrupted heating operations the heat requirement over 24 hours remains approximately the same as for continuous heating. The heating surfaces and the heat supply installations have to be so designed in case of a temporaryly interrupted heating operation that the output can reach $\frac{24}{Z_B} \cdot Q_T$ where Z_B is the time of operation in hours and Q_T the transmission heat requirement to eq. (3). Eq. (11),(14),(15) or (17) apply for the calculation of the ventilation heat requirement. For the correct design of the heating surfaces and the heat supply installation it is to be examined whether the ventilation heat loss occurs only during the period of operation or continuously. The required total output is to be designed accodingly.

8.3 Heat requirement of halls and similar rooms.

The heat requirement calculation differs in this case in two points from that for normal cases. In these rooms the heated internal surfaces, in radiation exchange with windows and outside walls, are largely absent. Further, it has

13) The use of the diagramme is restricted to the following maximum values for $Z_{max.}$ of the heating-up period as a function of the wall thickness.

Wallthickness d in m	0,1	0,2	0,4	0,6	0,8	1,0
maximum heating-up period $Z_{max.}$ in hours	1	3	12	30	50	75

to be considered that for most of the heating methods here included the air-temperature increases steeply with height.
In heating systems with a predominantly convective heat release (hot air haeting convectors) the internal heat transmission resistance on the outside walls and windows exceeds the normal case due to the reduced radiation heat exchange, so that the heat transmission resistances have to be increased accordingly.
If the heat requirement is satisfied mainly by radiation (ceiling radiators, radiation panels) it may occur that the reduction of the radiation heat exchange between the internal surfaces and the outside components is, according to the geometrical lay-out, balanced or even over compensated. In this case the internal heat transmission resistance has to be assessed between the maximum and the standard value.
It is also to be considered that radiant heat is lost from the occupied zone to the cold outside surfaces which has to be compensated by an addition [14].
It is convenient to include this addition into the heat transmission resistance.

Table 20 offers the limiting values of the internal heat transmission resistances and of the consequent heat transfer resistances of steelframed windows with single gazing.
The air temperature halfway up the room which determines the heat loss is, due to the mentioned dependency on height, to be assumed to be higher than the temperature in the occuied zone and, depending on the room height, the inside temperature and the heating system this difference is to be assumed to be between 1 and 4 K.

Table 20. Limiting values for the internal heat transmission coefficient R_i and for the heat transmission resistances R of single glazed steel framed windows in halls.

	R_i m^2K/W	R m^2K/W
Halls without partitions and open storeys in which the width is smaller than the clear height	0,21 - 0,12	o,21 - 0,14
Halls with partitions and halls in which width is greater than the clear height	00,17 - 0,12	0,19 - 0,16

The heat loss to the soil is to be calculated in the usual manner to sec.5.3.1. The additions to the heat requirement calculations for the normal situation are to be omitted.

14) Kast W. :Considerations concering the additions for interrupted operation and cold external surfaces to DIN 4701. Ges. Ing. 91 (1970),Nr.9,p.252-7

The ventilation heat requirement is calculated to eq.(14) and (15) provided this ensures an adequate exchange of air. Frequently the air in halls is subjected to special vitiation so that gap ventilation is not sufficient for the required exchange of air. In these cases the calculation has to be based on a minimum amount of fresh air or a minimum number of air changes in which case eq.(11),(17) or (20) are to be applied. The required volumina of outside air or the number of air changes are to be assessed according to the expected vitiation of air, i.e. according to previous experience.

A reliable calculation of the heat requirement is possible only for halls with closed doors. The effect of, possibly, open doors is to be assessed and considered according to the expected wind pressure differences and the other limiting conditions.

8.4 Heat requirement of green houses.

The calculation of the heat requirement of green houses differs from the standard case by the fact that the ventilation heat requirement is to be calculated for glass surfaces and that due to the other heat exchange conditions the internal heat-transfer resistances are lower.

The heat loss to the soil is generally not included since it is relatively small. Additionally, the usual additions to the transmission heat requirements can be omitted.

8.4.1 Transmission heat requirement.

The transmission heat requirement is determined analogous to eq.(3), without additions:

$$Q_T = Q_{T\ glas} + Q_{T\ Rest} \tag{32}$$

where:

$Q_{T\ Glas}$ Transmission heat requirement of the transparent glass surfaces

$Q_{T\ Rest}$ Transmission heat requirement of all the other surfaces

$$Q_{T\ Glas} = \frac{A_{Glass}}{R_{Glass}} \quad (t_i - t_a) \tag{33}$$

$$\text{with } R_{Glass} = R_{iglas} + R_{\lambda,\ Glass} + R_{a\ Glass} \tag{34}$$

where:

A_{Glass} Transparent area (including supporting construction)

R_{iGlass} internal heat transmission resistance on the transparent surfaces to table 21

$R_{\lambda Glass}$ Thermal resistance of the transparent surfaces to table 22

R_{aGlass} External heat transmission resistance on the transparent surfaces (0,05 m^2K/W)

Table 21. Internal heat transmission resistance R_{iGlass} of the transparent surfaces of green houses.

Heating System	R_{iGlass}, m^2K/W
Heating tubes in the roof space	0,09
Heating tubes on the front wall	0,09
Heating tubes under the tables	0,10
Heating tubes on the floor	0,12
Ceiling air heater	0,09
Hot air jet heater	0,10
Convectors	0,09
Mixed heating systems (tubes and air heater)	0,10

Able 22. Thermal resistances $R_{\lambda\,Glass}$ of the transparent surfaces of green houses.

Roofing	$R_{\lambda Glass}$ m^2K/W
Single gazing	0,01
Corrugated plastic plates GFK (glassfibre & plastic) 1 mm, with reference to the elevation area)	0,01
Double glazing in steel frames	
distance 15 mm	0,14
" 12 mm	0,11
" 6 mm	0,09
Double plastic plates, self supporting, without steel frame, thermal bridges to be calculated separately	
distance 12 mm	0,15
" 5 mm	0,08
Double foil, distance 10 mm	0,10
Single foil, o.2 mm (PVC, PE)	0,01

8.4.2 . Ventilation heat requirement

Differing from the standard situation the ventilation heat requirement is calculated analogous to the transmission heat requirement. The following applies:

$$Q_L = \left(\frac{A}{R_L}\right)_{Glass} \cdot (t_i - t_a) \quad (35)$$

where: A_{Glass} transparent area (including supporting construction)

R_{LGlass} Equivalent heat transmission resistance for gap ventilation to table 23.

Table 23. Equivalent heat transmission resistance for gap ventilation of green houses.

Type of Roofing	R_L, m^2K/W
Pushed-in panes, removable	0,5
Putty-sealed panes	1,0
Foil green house	2,0
Putty-less glazing in metall frames, with sealing strips	1,0

8.5 The non-stationary thermal behaviour of rooms of differing weights.

The heating-up and cooling-down behaviour of rooms depends in a complex manner on the thermal characteristics of the surrounding building components and their arrangements. Rooms of very different construction, in particular of differing weights should, therefore, not be connected to the same control group if the heating plant is to be operated with considerable interruptions.

8.6 Temperatures of unheated neighbouring rooms.

Temperatures of unheated neighbouring rooms are shown in tables 4, 5 and 6 for some more important cases. In general the temperature follows from eq. (36)

$$t_u = \frac{\sum\left(\frac{A}{R}\cdot t\right)_i + \sum\left(\frac{A}{R}\cdot t\right)_a + 0{,}36 \cdot V_R \cdot \beta \cdot t_a}{\sum\left(\frac{A}{R}\right)_i + \sum\left(\frac{A}{R}\right)_a + 0{,}36 \cdot V_R \cdot \beta} \text{ in } ^\circ C \qquad (36)$$

where:
- t_i standard inside temperature of the neighbouring heated rooms in °C
- t_a standard outside temperature in °C
- t_u temperature of the unheated room in °C.
- V_R volume of room in m^3
- β air changes in 1/h
- A area in m^2
- R heat transmission resistance in m^2K/W

index a : Components of the unheated room in contact with outside air

index i : Components of the unheated room in contact with heated rooms.

Further Relevant Standards.

DIN	105	Building bricks; solid bricks and perforated bricks.
DIN	105/2	Building bricks; light weight bricks
DIN	105/3	Building bricks, high strengtth bricks and clinker, (blue bricks)
DIN	105/4	Building bricks; ceramic blue bricks
DIN	106	Lime sandstone; solid blocks, perforated blocks and hollow blocks
DIN	272	Magnesia flooring; (floorings of magnesia cement)
DIN	398	Slag blocks; solid, perforated and hollow blocks.
DIN	1045	Concrete and reinforced concrete structures; dimensions and construction.
DIN	1052/1	Wooden buildings calculation and construction.
DIN	1053/1	Brickwork; calculation and construction.
DIN	1101	Wood-wool slabs; dimensions, requirements, testing.
DIN	1301/1	Units; unit designations and symbols.
DIN	1946/4	Room ventilation plants; (VDI Ventilation Rules); room ventilatio plants in hospitals.
DIN	4108	Heat insulation in buildings.
DIN	4108,Add.	as above, explanations and examples for increased heat insulat
DIN	4158	Inserted building components made of concrete for reinforced concrete and stressed concrete ceilings.
DIN	4159	Bricks for ceilings and wall panels,, static load bearing
DIN	4160	Ceiling bricks, not load bearing.
DIN	4165	Gas-concrete blocks.
DIN	4703/1	Heat output of room heaters; segmented radiators
DIN	4703/1	Heat output of room heaters; radiators.
DIN	4703/2	as above, steel heating panels.
DIN	4703/3	as above, general points, conversion calculations.
DIN	4704/1	Testing of room heaters (radiators); testing rules.
DIN	4704/2	as above; open test cabin
DIN	4704/3	as above; enclosed test room.
DIN	18055/2	Windows; gap permeabilities and protection against driving rain, requirements and testing
DIN	18151	Hollow blocks of light-weight concrete.
DIN	18152	Solid blocks of light-weight concrete.
DIN	18153	Hollow blocks and hollow T-blocks of concrete with closed structure.
DIN	18159/1	Foame-plastics, locally produced for building purposes; polyurethane foam, locally produced as thermal insulation; use, properties, production, testing.
DIN	18159/2	as above; urethane-formaldehyderesin foam for thermal insulatio use, properties, production, testing.

DIN 18161/1 Cork products as insulating material in buildings; thermal insulation.

DIN 18162 Wall plates of light weight concrete, not reinforced.

DIN 18164/1 Foam plastics as insulating material in buildings;thermal insulation.

DIN 18165/1 Fibrous insulating materials in buildings; thermal insulation

DIN 18180 Plaster box board; types, requirements, testing.

DIN 68750 Wood fibreboard, quality conditions.

DIN 68761 Chip board, flat press plates FPY, for general purposes; definitions, properties, testing.

DIN 68764/1 Chip board, extrusion molded board for building; definitions, properties, testing, supervision

VDI Guidline 2067 Economy of heat consuming installations.

EXPLANATIONS.

To section 5.4.1.2:

0,5 air changes per hour as a minimum for permanently occupied rooms has been used as the base in section 5.4.1.2, eq.(17). In this assumption the sensible heat loss of persons has not been considered.
Assuming an area of 10 m^2 per person and a temperature difference of 34 °C between inside and out this corresponds to about an additional airchange of 0,3 1/h. During occupation a greater air change than 0,5 1/h is thus thermally covered.

To section 6; Table 2.

Table 2 contains the standard outside temperatures in 2°-steps for all places with more than 20 000 inhabitants as well as for all meteorological stations the observations of which have been used in the compilation of the standard outside temperatures. After extensive comparative studies of the German Meteorological Service the lowest two-day avarage reached 10 times during the years from 1951 to 1970 was selected as the lowest outside temperature. Temperatures above - 10 °C, which may occurin the North-German coastal region and occasionally in Western and Southern Germany have been omitted. The upper limit of the standard outside temperature is thus - 10 °C.

The isotherms shown in the map apply according to the interpolation rules of meteorology for districts having equal integer degree values (e.g. the -12 °C isotherm for districts with - 12,0 to -12,9 °C). The isotherm map can, therefore, only be used as an aid to finding places with similar climatic conditions, as shown in table 2. The zones between the isotherms do, therefore, not represent defined climatic zones with firmly associated temperatures - as in the 1959 edition of this standard.

small islands of higher or lower temperature could not be entered in the map due to its size. Differences between the values in the map and the table may, therefore, occur. The values in the table take absolute precedence.

To Section 6; Table 3.

The standard inside temperatures which are forming the base of the heat requirement calculation are calculating figures which consider the air temperature as well as the mean temperature of the surrounding surfaces. They represent in a heat-physiological sense "sensed temperatures". The lower the mean surface temperature of a room is, the higher the air temperature has to be to compensate for the increased radiation loss of the occupants of the room.

Since the equations, used for the calculation of the heat requirement, are physically so constructed that a temperature close to the air temperature has to be inserted it follows that by using the - lower - inside standard temperature the result is a slightly low heat requirement. If one wishes to avoid this it would be necessary to calculate by successive approximation the required inside temperature - which is in turn depending on the heat requirement- (and of the adjacent rooms) and thus determine finally the heat requirement . This procedure is extremely involved, not only because one ought to consider also the correction due to heat flow between neighbouring rooms having the same sensed temperature (standard inside temperature) but slightly differing air temperatures. It is, therefore useful and within the framework of the other accuracies permissible to use instead the somewhat too low standard inside temperatures and to assess the necessary increase of the heat requirement by additions depending on the appropriate affecting factors.

This is done by the addition z_A to consider cold outside wall faces. It depends on the Krischer-Factor D - a measure of the mean temperature of the room boundaries. The reduction of the heat output due to higher air temperature with reference to the usual heating systems with mainly convective heat release is also considered in addition z_A.

The calculation of the heating surfaces is, therefore, as before to be based on the standard inside temperature. Compared with the last issue of this standard the additions z_A has been slightly increased by shifting the calculated reference point from the centre of the room nearer to the outside wall, since the experience with heating of exposed rooms made this change advisable.

An increase of the air temperature to compensate for the radiation loss to cold outside wall faces can lead to comfortable conditions only within defined limits, as experience has shown. If the Krischer-factor D in a room

exceeds about 1,3 it is, as a rule, not possible to reach comfort conditions in such a room with the usual heating systems and arrangements of radiators. The rules for the calculation of the heat requirement apply in such a room only with certain limitations.(see section 8.3).
The required up-lift of the air temperature and the reduction of the heat release of the heating surfaces depend, theoretically and up to a point, on the heating system, in particular on the proportion of radiant heat release. These connexions are not sufficiently understood, in particular as far as their practical applications are concerned.These problems are at present being investigated. The results may, if required, be published as an addendum to this standard.
According to the above explanations, the air temperature in a room - measured with a thermometer protected against radiation - depends in a very complex manner on the Krischer-Factor D of the room, on the number of outside walls and on the heating system. The temperature measured with an unprotected thermometer depends additionally - due to the radiation gain and - loss, which may vary from position to position - on the actual test point in the room. The standard inside temperature being a purely calculated figure is not itself measurable. It is, therefore, not possible to check the correctness of the heat requirement calculation by temperature determinations only. The proof of compliance with this standard can only be established by calculation.

To Section 6; Tables 4 to 6.

The calculation figures for the temperatures of the neighbouring rooms, which are not to be heated by the plant to be designed, are given in tables 4 to 6. Independend stairwells placed in front of the not heated neighbouring rooms have now been included in table 4.
In neighbouring rooms, which are as a rule heated but not supplied from the plant to be designed, the temperature is uniformly taken as being 15°C since the temperature will drop only infrequently below this value even if the heating is only partial or interrupted due to the close thermal linkage through partition walls.
The temperature in unheated stair cases built into the main building on 3 sides is given in table 5 as a function of the height of the building, the situati of the storeys and of the ratio of the heat transmission resistances to the heated rooms to those to the outside. The dependence on height follows from the ingress of air through the entrance door and it increases with the height of the building. The leakage air is heated on its way to the upper floors.

The temperatures of attic rooms depend on the heat transmission resistances of the roof surfaces, on those of the partition walls to neighbouring heated rooms and on the number of air changes.

To Section 6, Table 7.

It appeared to be justified to omit the so far used addition z_U for interruptions of operation in this revision since the reduced thermal inertia of the heating installations and the improved controllability make it possible to reach the desired temperatures comparatively quickly. At the lowest outside temperatures interruptions of the operation of the heating system are anyway not to be expected. In the present revision the addition $z_A = f(D)$ is the only correction factor used to reach comfort conditions in a room. Regarding the calculation of the heat output required to heat a room in a predetermined time reference is made to section 8.1.

To Section 6, Table 12.

The calculation of the house characteristic is based on daily averages of the wind velocity which had been observed in the locality once a year on the two coldest days during the period from 1951 to 1970. A distinction is made between localities exposed to weak winds only where a rounded off wind speed of less than 2 m/s is assumed and localities exposed to strong winds where this value is 4 m/s. As the map of isotherms shows "strong winds" predominate in the entire area of North Germany up to the edge of the central hills. Further south the "strong winds" are shifted to higher regions approaching the alps. The height data in the map of isotherms for the co-ordination of wind zones refer to " standard heights" with the exception of the alpine region . The heights there are given with reference to the valley bottoms since this datum is more significant.

The above mentioned values, based on meteorological observations of the wind velocity are used as bases for buildings "of normal situation". It is further assumed that the corresponding meteorological stations are also positioned in a "normal situation". For "exposed situations" the wind velocities used for the calculation of the house characteristic are assumed to be 2 m/s higher.

Prof. H. Esdorn, Dr. Ing.

Appendix A. Calculation of Heat Requirement to DIN 4701

Anhang A. Berechnung des Wärmebedarfs (nach DIN 4701)

Blatt Nr

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
			Calculation of the Transmission Heat Requirement													Calculation of Vent. Heat Requir.									
Symbol	Point-of-Compas	Wall thickness	Length	Height or Width	Area	Number	Deduction	Used in Calculation	Heat transmission Resistance	Temperature difference	Heat flow	Transmiss. Heat Requirement without additions	Addition for cold outside surface	Addit. for Point of Compass	Addition factor	Gap Permeabilit. coeffic.	Gap length	Number	$n(a.l)_A$	$\Sigma(a.l)_A$	Room Characterist.	Standard House Characteristic	Correction for Height	Temperature difference	Standard Heat Requirement $Q_N = Q_L + Q_T$
									R	Δt	$\frac{\Delta t}{R}$	Q_0	Z_A	Z_H	$1 + Z_A + Z_H$	a	l	h			r	H_{t0}	ϵ_H	Δt	
–	–	m	m	m	m^2	–	m^2	m^2	m^2K/W	K	W/m^2	W	–	–	–		m	–			–		–	K	W

and $R = R_i \cdot \frac{s}{b} + R_\lambda + R_a \cdot \frac{s}{b}$ (23)

and $R_\lambda = \frac{d}{\lambda}$ (24)

where: A_{St} Web area of the girder (thickness s . length l)

R equivalent heat transmission resistance of the girder

λ heat conductivity coefficient of the girder material

dimensions see fig. 10.

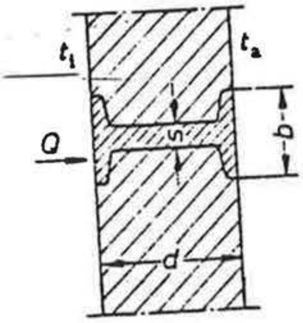


Fig. 10

7.3.2 Building element totally enclosed in a metal casing.

The heat flow through the casing has to be added to the heatflow, calculated in the usual manner to eq. (3), through the filling.

$$\Delta Q = \frac{U \cdot \delta}{R_a} (t_i - t_a) \quad (25)$$

$$U = 2\,(b + l) \quad (26)$$

$$R_U = \sqrt{R_i \cdot R_{\lambda U}} + R_{\lambda U} + \sqrt{R_a \cdot R_{\lambda U}} \quad (27)$$

$$R_{\lambda U} = \frac{d}{\lambda_U} \quad (28)$$

where λ_U Heat conductivity coefficient of the casing.

Dimensions see fig. 11.

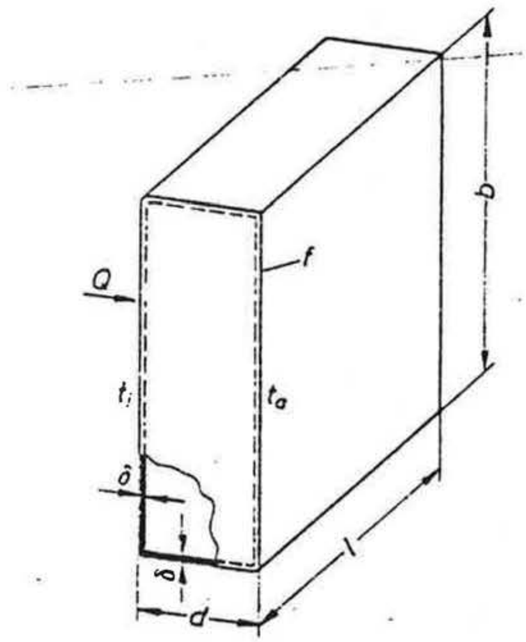


fig. 11.

8. SUGGESTIONS FOR THE CALCULATION OF THE HEAT REQUIREMENTS IN SPECIAL SITUATIONS.

Guidelines only can be given for the calculation of heat requirements in the special situations here to be considered, since the various factors concerned may vary in their importance and they have to be considered especially for each situation. Included in these factors are non-stationary heat exchanges, e.g. during heating up processes, strong temperature stratification e.g. in high rooms, special radiation conditions in a room etc. The calculation of these special conditions has been reduced as far as possible to their physical bases