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Thermal insulation — Calculation of space heating requirements for residential buildings

Isolation thermique — Calculs des besoins en chauffage pour les bâtiments résidentiels

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Contents

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 9164 was prepared by Technical Committee ISO/TC 163, *Thermal insulation.*

Annex A forms an integral part of this International Standard. Annexes B to G are for information only.

Introduction

Estimates of the space heating requirements for residential buildings may be needed for several purposes. These include judging compliance with regulations written in terms of energy targets, assessing the effect of possible energy-conserving measures or checking the effectiveness of measures which have been carried out and, on a wider national or international scale, predicting future energy resource requirements.

There exist many detailed and complex computer programs which simulate heat interchange within buildings and with their external environment. Often the use of these is not convenient as they usually require very detailed input information. This International Standard provides a relatively simple calculation procedure which will give sufficiently reliable results for the purposes mentioned above.

The method predicts the annual heating requirements. It is based on the fundamental equations for heat transfer in which a number of simplifying assumptions are made, the principal one being to replace continuously varying quantities by appropriate averages. Where the data required cannot be obtained by simple calculation, this International Standard uses or refers to tabulated data.

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Thermal insulation — Calculation of space heating requirements for residential buildings

1 Scope

This International Standard identifies the terms in the heat balance equation, and describes a method for the calculation of the annual energy requirements for the space heating of residential buildings. The method cannot be applied to special buildings such as those incorporating passive solar design, greenhouses or sunspaces.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 6946-1 : 1986, *Thermal insulation — Calculation methods — Part 1 : Steady state thermal properties of building components and building elements.*

ISO 6946-2 : 1986, *Thermal insulation — Calculation methods — Part 2 : Thermal bridges of rectangular sections in plane structures.*

ISO 7345 : 1987, *Thermal insulation — Physical quantities and definitions.*

3 Definitions and symbols

The terms, symbols and units used are in accordance with ISO 7345. The following additional symbols are specific to this International Standard.

Term and definition		Symbol	Unit
3.1 accumulated temperature difference (to a base temperature):	Sum of (base temperature less mean daily external temperature, if positive) over all days in period considered.	ATD (θ_b)	°C
3.2 base temperature:	Internal temperature less temperature increment produced by internal and solar gains.	θ_b	°C
3.3 external temperature		θ_e	°C
3.4 internal gains:	Average rate of heat input to dwelling from internal sources other than space heaters.	Φ_i	W
3.5 internal temperature		θ_i	°C
3.6 space heating requirement (annual):	Energy output from space heaters in one year.	Q_h	J, MJ, GJ, (kWh, MWh)
3.7 space heating requirement (monthly):	Energy output from space heaters in one month.	$Q_{h,m}$	J, MJ, GJ, (kWh, MWh)
3.8 solar gains:	Average rate of heat input to dwelling from solar radiation.	Φ_s	W
3.9 specific heat loss:	Total heat loss from dwelling (by fabric transmission and ventilation) divided by the difference between the internal and external temperatures.	H	W/K
3.10 time step:	Period of integration of the heat balance equation.	t	s
3.11 utilization factor:	Proportion of the internal and solar gains which contribute to reducing the space heating requirements.	η_m	

Conversion factors:

1 W = 0,024 kWh/day
1 kWh/day = 41,7 W
1 MJ = 0,278 kWh
1 kWh = 3,6 MJ

4 General considerations

4.1 The factors which together contribute to space heating energy requirements are

a) characteristics of the house — transmission and ventilation heat losses (allowing for any heat recovery), and thermal capacity;

b) characteristics of the heating system — particularly control systems and ability to respond to changes in heat requirements;

c) internal temperatures — the temperature level required by the user and variations in this level both in different parts of the house and at different times of the day;

d) internal heat gains other than from the heating system — from occupants, cooking and hot water, lighting and electrical appliances;

e) solar gains;

f) external weather conditions — principally temperature.

4.2 This International Standard specifies a method which takes account of these factors, and it follows that data for each of them are required for a calculation. In many cases the necessary information may be contained in national standards or other suitable documents, and these should be used where available. Annexes to this International Standard are provided, however, giving representative values or methods for obtaining representative values for use when the required information is not otherwise available.

There is very wide variation in energy consumption in houses. This can be ascribed to variations in the factors listed above; in principle, to the extent that precise information is available, the calculation can be applied to a single specific dwelling.

However, it should be noted that large variations in consumptions have been observed over groups of nominally identical houses attributable to variations in user requirements and living patterns (e.g. internal temperatures, window opening). Where there is no detailed knowledge of user requirements and living patterns, the calculation is made for a "typical" household.

The calculation can be made either for an "average" year using weather data for the locality concerned averaged over a number of years, or for a particular year using the recorded weather data for that year, depending on the purpose of the calculation. The former would be appropriate for predictive purposes, and the latter when comparing with recorded fuel consumption.

This International Standard gives a method for the calculation of space heating requirements; the energy requirements for other purposes are not included.

The energy balance on which the calculation method is based is defined as including the following:

a) transmission and ventilation losses from the internal to the external environment;

b) the net output from the heating system (which differs from the energy input when the fan conversion efficiency is other than unity);

c) the net internal heat gains, that is the heat actually released to the house from the factors in 4.1 d), which in the case of appliances involving water heating is somewhat less than the energy input to these appliances (the difference being lost in waste water);

d) the net solar gains, not including any proportion either lost through increased ventilation during periods of high solar gain or contributing to the temperature rising above the set point.

5 Calculation method

5.1 Introduction

The calculation method is based on a steady-state energy balance for the house with an allowance for the dynamic effect of internal and solar gains. Part of the energy needed to maintain a given internal temperature θ_i comes from the internal and solar gains. The method calculates the remainder which is needed from the space heating system.

The calculation basis, described in annex A, allows for day-by-day variations in external temperature, and month-by-month variations in mean solar radiation. The heating requirement for one month is obtained from a summation of the heating requirement for each day in the month, using the average daily values of the temperatures and average monthly values of the gains, thus

$$Q_{h,m} = \Sigma\,[H(\theta_i - \theta_e) - \eta_m(\Phi_i + \Phi_s)]_{d,pos}\,t \qquad \ldots\ (1)$$

where

$Q_{h,m}$ is the space heating requirement for month, in joules;

H is the specific heat loss, in watts per kelvin;

θ_i is the daily average internal temperature, in degrees Celsius;

θ_e is the daily average external temperature, in degrees Celsius;

η_m is the utilization factor for gains;

Φ_i are the average internal gains over month, in watts;

Φ_s are the average solar gains over month, in watts;

t is the number of seconds in a day (86 400);

$_{d,pos}$ signifies that the sum is carried out for all days in the month for which the expression is positive.

NOTE — In equation (1) the daily average internal temperature, θ_i, can be assumed to be the same for each day in the month, calculated from the monthly average temperatures. Thus only θ_e varies on a day-by-day basis in the equation.

Equation (1) is conveniently evaluated as

$$Q_{h,m} = H \times \mathrm{ATD}(\theta_b)$$

where $\mathrm{ATD}(\theta_b)$ represents the accumulated daily mean temperature difference to base θ_b for the locality and month concerned[1].

The annual space heating requirement is obtained from a summation of the requirements for individual months.

NOTE — The above procedure gives the energy output required from the space heaters. This differs from the energy delivered to the dwelling because

a) the space heating appliance may have a conversion efficiency other than unity;

b) the delivered energy also includes that required for water heating, lighting and electrical appliances.

5.2 Zones

When the house is heated to the same temperature throughout, it shall be treated as a single zone and the space heating requirement obtained in accordance with 5.3.

1) Also known as "variable-base degree-days".

If different design temperatures apply in different parts of the house, it shall be determined on a national basis whether the calculation is made

a) with the house as a single zone, or

b) with the house divided into two zones of different temperature standards.

In the case of a single zone calculation, the internal temperature θ_i shall be a spatial average over the house.

In the case of a two-zone calculation, the procedure of 5.3 shall be followed for each zone and the space heating requirements for each zone added together. In this case the specific heat loss, the internal gains and solar gains shall be divided appropriately between the zones.

5.3 Calculation procedure

The annual space heating requirement shall be calculated as follows.

5.3.1 Define the building envelope and calculate the specific thermal loss H in watts per kelvin (see 6.1).

5.3.2 Specify the design internal temperature, $\theta_{i,d}$.

5.3.3 For each month

a) calculate the mean value over the month of the gross internal and solar gains $\Phi_i + \Phi_s$ (see 6.2);

b) determine the utilization factor η_m for these gains (see 6.3);

c) for continuous heating, set the mean internal temperature θ_i equal to $\theta_{i,d}$: otherwise determine the mean internal temperature (see 6.4);

d) find the base temperature θ_b from

$$\theta_b = \theta_i - \frac{\eta_m (\Phi_i + \Phi_s)}{H}$$

e) find the accumulated temperature difference to this base temperature ATD(θ_b), for the climate concerned (see 6.5);

f) obtain the space heating requirement for the month from

$$Q_{h,m} = H \times \text{ATD}(\theta_b)$$

NOTE — Any consistent system of units can be used in the above expression for $Q_{h,m}$. With H expressed in watts per kelvin, then ATD(θ_b) expressed in degrees Celsius multiplied by day must be multiplied by 86 400 to obtain $Q_{h,m}$ in joules.

5.3.4 Total the space heating requirements for each month in the heating season to obtain the annual requirement, Q_h :

$$Q_h = \Sigma\, Q_{h,m}$$

NOTE — The heating season is defined to include all months for which the following apply:

a) the accumulated temperature difference to the applicable base temperature is greater than zero; and

b) the gross internal and solar gains do not exceed 2,5 times the heat loss:

$$\Phi_i + \Phi_s \leqslant 2{,}5H(\theta_i - \theta_e)$$

6 Factors in equations

Where national standards exist, these should be used to obtain the data required for the calculation, having regard to the considerations given below. If an appropriate national standard does not exist, or contains insufficient information, the necessary data can be obtained from the annexes to this International Standard.

6.1 Transmission and ventilation heat losses

The parameter H is given by

$$H = H_T + H_V$$

where

$$H_T = \Sigma A U + \Sigma l U_l$$

in which

A is the area of exposed fabric, in square metres;

U is the thermal transmittance of exposed fabric, in watts per square metre kelvin;

l is the length of thermal bridge, in metres;

U_l is the linear thermal transmittance of thermal bridge, in watts per metre kelvin;

and

$$H_V = c\varrho\dot{V}$$

in which

c is the specific heat capacity of air, in joules per kilogram;

ϱ is the density of air, in kilograms per cubic metre;

$\dot{V}$ is the volumetric air change rate, in cubic metres per second.

6.1.1 Transmission losses

Simple U-values can be calculated by the methods given in ISO 6946-1. For other values a relevant national standard should be used to calculate U-values or to obtain suitable values from tabulated data.

Effects of thermal bridges should be included for structures where thermal bridges are present. U_l for rectangular-shaped thermal bridges can be calculated by the methods given in ISO 6946-2.

Effective U-values for ground floors can be used in climates where the heating season is sufficiently long (that is, several months of the year), so that it is reasonable to make an approximation of steady-state conditions. In such cases there may be large proportionate errors near either end of the heating season, but at these times the losses are small compared with the annual total.

6.1.2 Ventilation losses

Ventilation rates vary with wind speed and direction, and with temperature differences. An appropriate average value is required. Where there is ventilation heat recovery this should be taken account of in determining the ventilation heat loss. Further guidance is given in annex B.

During periods of high solar gain, windows may be opened to increase the ventilation. This is allowed for in the utilization factor for the solar gains and should not be allowed for in the determination of average air change rate.

6.2 Internal heat gains and solar gains

Internal heat gains should include

- metabolic gains (from people);
- gains to the house from hot water system;
- gains to the house from cooking;
- the power consumption of electrical appliances;
- the power consumption of artificial lighting.

All of these vary during the day, but average daily values are appropriate for the present purpose. With the exception of lighting, the average daily values will be relatively constant throughout the year.

Further guidance on internal heat gains is given in annex C.

Solar gains should take account of the normally available sunshine in the locality concerned, the orientation of the windows, shading, and the solar transmission characteristics of the glazing. Further guidance is given in annex D.

Solar radiation also affects the heat transmission through walls and roofs, but this is usually small compared with solar gains through windows, and for the purposes of this International Standard need not be included.

6.3 Utilization factor

It is not usually appropriate to count the gross internal and solar gains as useful (in the sense of contributing to reducing the space heating requirement). This is because during periods of high heat gain, the gains may exceed the instantaneous loss rate, or gains may be received during periods when heating is not required. For this reason the internal and solar gains must be reduced by a utilization factor, the magnitude of which depends on the relative sizes of the gains and losses and on the thermal mass of the building. Further guidance on utilization factors is given in annex E.

6.4 Internal temperatures

The value of internal temperature θ_i required for the calculation method is a spatial average over the house or, in the case of a two-zone calculation, over the zone (where the whole house or zone is not at a uniform temperature), and it is also a temporal average over each month (when the internal temperature is not constant, that is when the heating is not operated continuously).

For heating 24 h per day, the design internal temperature is used.

When heating is switched off at night, the design internal temperature will apply during the daytime. At night the temperature will gradually fall. The rate of fall of temperature depends on the transmission and ventilation losses, the thermal capacity, the external temperature, and the responsiveness of the heating system, and these factors must be allowed for in determining the appropriate value of θ_i. Further guidance on internal temperatures is given in annex F.

During periods of high solar gain, the internal temperature may rise above the design value. This is allowed for in the utilization factor for the solar gains, and should not be allowed for in the determination of average internal temperature.

6.5 Accumulated temperature difference

Accumulated temperature differences, calculated from the difference between base temperature and mean daily external temperature, to the appropriate base temperature are required for each month. A different base temperature will normally apply in each month. Accumulated temperature difference data may be calculated; it will form the subject of a future International Standard.

NOTE — "Accumulated temperature difference" used in this standard is also known as "variable-base degree-days". Accumulated temperature difference to fixed base, which are tabulated for many climates (for example to base 20 °C, 18 °C or 15,5 °C), are inappropriate and should not be used.

A good approximation to the accumulated temperature difference can in many cases be obtained from monthly mean external temperatures. Further information is provided in annex G.

In some climates it is a sufficient approximation to take

$$\mathrm{ATD}(\theta_b) = N\,(\theta_b - \theta_e)$$

where N is the number of days in the month. This method of calculation can be adopted on a national basis.

7 Report

A report giving the space heating requirements obtained in accordance with this International Standard shall include

a) a description of the dwelling and its construction;

b) reference to any International Standards, national standards or other documents used to obtain climatological data and utilization factors, or reference to the appropriate annexes to this International Standard;

c) assumptions made in regard to ventilation rates, occupancy, heating patterns, internal temperatures;

d) whether the house was treated as one zone or two zones, and if two zones, the zone division (that is, the allocation of rooms to each zone) shall be stated.