The Netherlands National Report
on Activities within Step 5

Windows and Space Heating Requirements; Parameter studies leading to a simplified calculation method

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pages 22 and 23:

in equations (27) and (29) the expression:

$$\frac{1 - \Sigma_e \, A_e . U_e}{A_t . h_{ri}}$$

should be replaced by:

$$\left\{ 1 - \frac{\Sigma_e \, A_e . U_e}{A_t . h_{ri}} \right\}$$

page 50, line 14
page 51, table 13, final three rows
page 64, lines 9 and 13

$\left.\vphantom{\begin{array}{c}a\\a\\a\end{array}}\right\}$ $C_{NWH}=1$ should be replaced by
$C_{NWH}=0$.

INTERNATIONAL ENERGY AGENCY

Energy Conservation in Buildings and
Community Systems Programme

Annex XII, WINDOWS AND FENESTRATION

The Netherlands' National Report from Step 5

WINDOWS AND SPACE HEATING REQUIREMENTS
Parameter studies leading to a simplified method

This report is part of the work of the IEA Energy Conservation in Buildings & Community Systems Programme

Annex XII - Windows and Fenestration

Participants in this task:

Belgium, FR-Germany, Italy, The Netherlands (Operating Agent), Norway, Switzerland, United Kingdom, United States of America.

The complete list of representatives who participated in the task is given in Appendix 1.

Delft, December 1987

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SUMMARY

The project "Windows and Fenestration" (1983-1986) is one of about 14 projects ("Annexes") of the International Energy Agency (IEA) R&D Programme "Energy Conservation in Buildings and Community Systems". Eight countries participated in this project. Activities were divided into 4 Steps.
Step 5, dealing with calculation series to find the influence of windows on the energy consumption, was carried out in het form of national studies by USA, Switzerland, Germany and the Netherlands.
This report documents the activities and results of the Netherlands within Step 5.

The report starts with a brief introduction into the thermal and solar properties of windows and its relation with the heating requirements and energy consumption. This chapter is followed by the presentation of the main terms in the heat balance of a heated space. A method is introduced to calculate by hand monthly heat losses and gains. Simple correction factors have been developed to deal with special situations. Particular attention is given to the influence of various types of window systems.
Correlation factors are proposed to take into account unsteady state effects; the gain utilization factor η_G as function of the gain loss ratio GLR and the correction factor for thermostat set-back during night (G_N) or during non-office hours (G_{NWH}). Furthermore a parameter dT_R, the mean relative overheating has been introduced; the latter quantity gives some indication of the overheating due to non-utilized gains.
Novel aspects of the methods compared to other existing methods are:
- the applicability of the method for office buildings without mechanical cooling;
- the applicability of the method in a multi-zone situation with exchange of heat by transmission and/or ventilation between different spaces;
- the rough indication of thermal comfort by the introduction of the relative overheating.

The main limitation of the method in comparison with some of the other methods is that passive solar elements other than "direct gain" fenestration, like collector storage walls have not (yet) been included.

Series of parameter studies using the unsteady state computer model DYWON are reported. The results of these calculations made it possible to quantify the correlation factor mentioned above.
With the correlation factors a simplified calculation method has come available to calculate the space heating requirments for a wide range of situations.
The method received the name TCM-heat (TPD Correlation based on Multizone calculation method to calculate the monthly heating requirements).

The simplified method has been verifief against a calculation with DYWON for twh complicated multizone situations in a highly insulated dwelling.
Although the selected cases were quite extreme, the agreement in annual heating requirements for the whole dwelling is good.
Some deviation occurs in the distribution over the months and over the zones. The first is due to the fact that for some months the heat demand is the very small difference between the much largler heat losses and almost equal gains; the lattier is due to the strong interaction between the zones in a well insulated building.

Finally, examples are presented of one of the possible applications of the method, namely to show the influence of window size, type and orientation on the energy consumption for space heating in a selected number of typical situations.

These examples illustrate that the influence of a change in window size, type or orientation may depend on the actual conditions like for instance climate, type of use of the considered zone, insulation level and also the conditions in the adjacent zones.

With TCM-heat the influence of the window on energy consumption can be calculated "tailor-made" to a particular situation.

Although TCM-heat is basically a hand calculation method, the calculation is inevitably complicated in case of a multizone situation. With the Fortran-version of TCM-heat, however, also complex multizone situations can be dealt with easily.

PREFACE

INTERNATIONAL ENERGY AGENCY

In order to strengthen co-operation in the vital area of energy policy, an Agreement of an International Energy Programme was formulated among a number of industrialized countries in November 1974. The International Energy Agency (IEA) was established as an autonomous body within the Organization for Economic Co-operation and Development (OECD) to administer that agreement. Twenty-one countries are currently members of the IEA, with the Commission of the European Communities participating under special arrangement.

As one element of the International Energy Programme, the Participants undertake co-operative activities in energy research, development and demonstration. A number of new and improved energy technologies which have the potential of making significant contributions to our energy needs were identified for collaborative efforts. The IEA Committee on Energy Research and Development (CRD) assisted by a small Secretariat staff, co-ordinates the energy research, development and demonstration programme.

ENERGY CONSERVATION IN BUILDINGS AND COMMUNITY SYSTEMS

As one element of the Energy Programme, the IEA encourages research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is encouraging various exercises to predict more accurately the energy use of buildings, including comparison of existing computer programmes, building monitoring, comparison of calculation methods, as well as air quality and inhabitant behaviour studies.

THE EXECUTIVE COMMITTEE

Overall control of the R&D Programme energy conservation in buildings and community systems is maintained by an Executive Committee, which not only monitors existing projects but identifies new areas where collaborative effort may be beneficial. The Executive Committee ensures all projects fit into a predetermined strategy without unnecessary overlap or duplication but with effective liaison and communication.

ANNEX XII

In June 1982 the Executive Committee approved Annex XII, 'Windows and Fenestration' as a new joint effort project, with the Netherlands acting as 'Operating Agent' to co-ordinate the work.
The following countries are participating in this project:

BELGIUM, FEDERAL REPUBLIC OF GERMANY, ITALY, THE NETHERLANDS, NORWAY, SWITZERLAND, UNITED KINGDOM, UNITED STATES.

The project consists of 5 steps:

Step 1: Survey the state-of-the-art in all types of existing windows and future designs (including glazing and combinations of glazing and insulating and/or sunshading systems).

Step 2: Survey the state-of-the-art in thermal and solar properties of windows and compare definitions, test methods, calculation procedures and measured, calculated or assumed data, wherever possible converted into one or several sets of standardized conditions. The aim: to try and cover all existing (and sometimes conflicting) information in this field in an extensive report for 'expert groups'.
A separate report contains summarized information for general use among architects, consultants and manufacturers.

Step 3: Review and analyse existing simplified steady-state calculation methods dealing with gains and losses through window systems. These methods can provide a preliminary and global figure for the influence of the window on energy consumption without considering the interaction with the building, occupants and climate in a detailed way.

Step 4: Adapt and compare existing dynamic calculation methods dealing with the influence of window type, size and orientation on energy consumption and thermal comfort in buildings.

Normally, a good window design will often be treated with a global approximation, with the consequence that specific features of the design cannot be revealed properly. With a study specifically focussed on windows complex systems also can be simulated, like multi-layer systems with foils, coatings and/or gas fillings and e.g. systems at which the control of an openable window, insulation panel, or sunshading is associated with indoor temperature and/or time and/or intensity of solar radiation. A thorough consideration of the effect of windows calls for a calculation model that can handle such simulation.

Step 5: Apply unsteady state models in a series of selected, general sensitivity studies and thereby produce extensive information on optimal window design from an energy point of view for different buildings (mass, insulation), occupants' behaviour schemes (control of equipment, internal heat) and climatic zones. The results are aimed at groups like architects, manufacturers and policy makers.

This publication is the result of the activities by the Dutch participant within the framework of Step 5.

TERMINOLOGY AND SYMBOLS **

	symbol	unit

Heat: quantity of heat — symbol Q — unit J^*

Heat flow rate: the quantity of heat transferred
to or from a system per unit time: — symbol ϕ — unit W

$$\phi = \frac{dQ}{dt}$$

Density of heat flow rate: heat flow rate divided
by area: — symbol q — unit W/m^2

$$q = \frac{d\phi}{dA}$$

Thermal resistance: temperature difference divided
by the areal density of heat flow rate in the
steady state condition: — symbol R — unit $(m^2.K)/W$

$$R = \frac{T_1 - T_2}{q}$$

NOTE: For a plane layer for which the concept of
thermal conductivity applies and when this property
is constant or linear with temperature:

$$R = \frac{d}{\lambda}$$

where d is the thickness of the layer.

These definitions assume the definition of two
reference temperatures, T_1 and T_2, and the area
through which the density of heat flow rate is
uniform.

* Or MJ or kWh; from MJ to kWh: divide value by 3.6.
** This list is, wherever possible, based on ISO draft standard
   DIS 7345/1 [1].

	symbol	unit

Surface coefficient of heat transfer: density of heat flow rate at a surface in the steady state divided by the temperature difference between that surface and the surroundings: h   W/(m².K)

$$h = \frac{q}{T_s - T_a}$$

Thermal transmittance: the heat flow rate per unit area in the steady state divided by the temperature difference between the surroundings on each side of a system: U   W/(m².K)

$$U = \frac{\phi}{(T_1 - T_2)A}$$

Thermodynamic temperature   T   K

Celsius temperature θ °C

Area   A   m²

Volume   V   m³

Overall specific heat loss coefficient: the sum of heat flow rates by steady state transmission and ventilation divided by the temperature difference between the considered space and the surroundings: H_L W/K

$$H_L = \sum_j \phi_j / (T_1 - T_j)$$

Emissivity: the ratio of the emitted radiant intensity to the radiant intensity emitted by a black body at the same temperature and in the same direction or with the same angular distribution: ε --

	symbol	unit
Solar absorptivity: the density of absorbed solar energy in a surface divided by the intensity of incident solar radiation:	a	--
Total solar energy transmission coefficient: or: total solar energy transmittance or: solar factor		
The density of transmitted total solar energy through a window divided by the intensity of incident solar radiation:	g	--
	or: SF	--
Gain Loss Ratio: the total heat gains divided by the steady state or minimum heat loss:	GLR	--
Utilization factor for gains: the ratio of the utilized gains to the total heat gains:	η_G	--
Time interval: the length of a considered period, e.g. month:	dt	Ms

SPECIFIC DIMENSIONLESS PARAMETERS AND CORRECTION FACTORS

for the relation η_G(GLR)   : K, D (defined in chapter 5)

for thermostat setback correction: C_N, C_{NWH}, F_{WD} (chapter 4)

for night insulation   : r, FT_{EN}, FT_{WH} (chapter 4)

for solar shading   : z, FQ(j) (chapter 4)

SUBSCRIPTS

interior	i
exterior	e
surface or sky	s
interior surface	si
exterior surface	se
convection	c
radiation	r
ambient or air (!)	a
setpoint	set
window	w
opaque	op
transmission	T
ventilation	V
internal sources	I
solar	S
loss	L
gain	G
heat demand or heat supply	HD

INDICES

month	m
orientation	j
other zone, space	k
construction	1

1. INTRODUCTION

The parameter studies within Step 5 of the IEA research project
Annex XII, Windows and Fenestration, were carried out in the form
of national studies, in which U.S.A., Switzerland, Germany and the
Netherlands are involved. Reference calculation cases and standard
variations were specified to optimize the exchange of results. Each
involved laboratory further selected the calculation cases on the
basis of the national situation. The evaluation of results was
carried out also on a national basis. Preliminary results, however,
were presented and discussed during the project's experts meetings
over the years 1984-1986.

Moreover, the parameter studies were preceded by a comparison of
computer programs selected for the calculations (Step 4, [2]) and
by a review and analysis of existing simplified steady state
calculation methods (Step 3, [3]); the activities within Step 3
resulted in a number of recommendations to be used in the
evaluation of the Step 5 results.

This report describes the activities within Step 5 by the Dutch
participant in the project.

The report starts with a brief introduction into the thermal and
solar properties of windows and its relation with the heating
requirements and energy consumption. This chapter is followed by
the presentation of the main terms in the heat balance of a heated
space. A method is introduced to calculate by hand monthly heat
losses and gains. Simple correction factors have been developed to
deal with special situations. Particular attention is given to the
influence of various types of window systems. Correlation factors
are proposed to take into account unsteady state effects.

Series of parameter studies using the unsteady state computer model
DYWON are reported. The results of these calculations made it
possible to quantify the correlation factors mentioned above.

With the correlation factors a simplified calculation method has
come available to calculate the space heating requirements for a
wide range of situations.

The simplified method has been verified against a calculation with
DYWON for two complicated multi zone situations.

Finally, examples are presented of one of the possible applications
of the method, namely to show the influence of window size, type
and orientation on the energy consumption for space heating in a
selected number of typical situations.

In figure 1 the main contents of the report are presented
schematically.

I   Development of the simplified method:
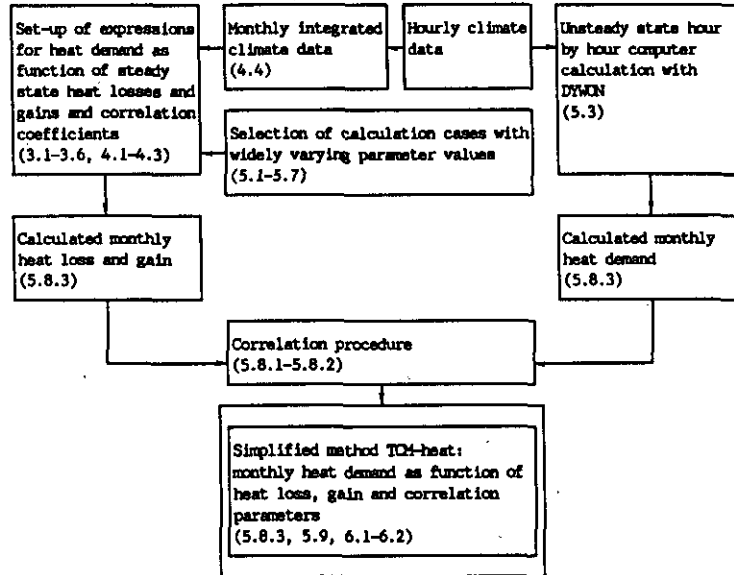
II   Verification of the simplified method:
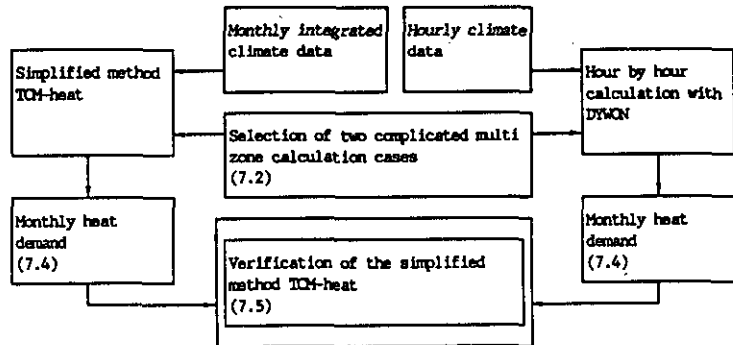
III   Selected sensitivity study using the simplified method:
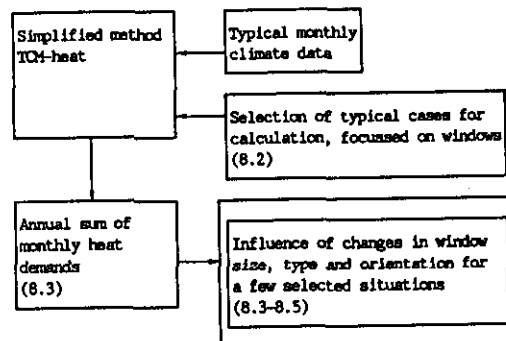
Figure 1: Schematic survey of the main contents of the report.

2. THERMAL AND SOLAR PROPERTIES OF WINDOWS

The energy consumption for space heating in buildings is determined on the one hand by the heat loss by transmission through the envelope and by ventilation, on the other hand by the heat gain from solar radiation and from internal heat sources (persons, lighting, equipment), see figure 2. In addition the efficiency of the heating installation plays a role (figure 3).
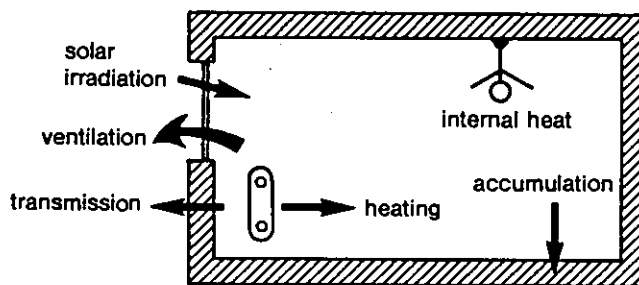
Figure 2: Apart from the efficiency of the heating installation, the heat balance of a building determines the energy consumption for space heating.

1 primary energy
2 net heat demand
3 useful gains
   (solar, occupants)
4 building heat loss
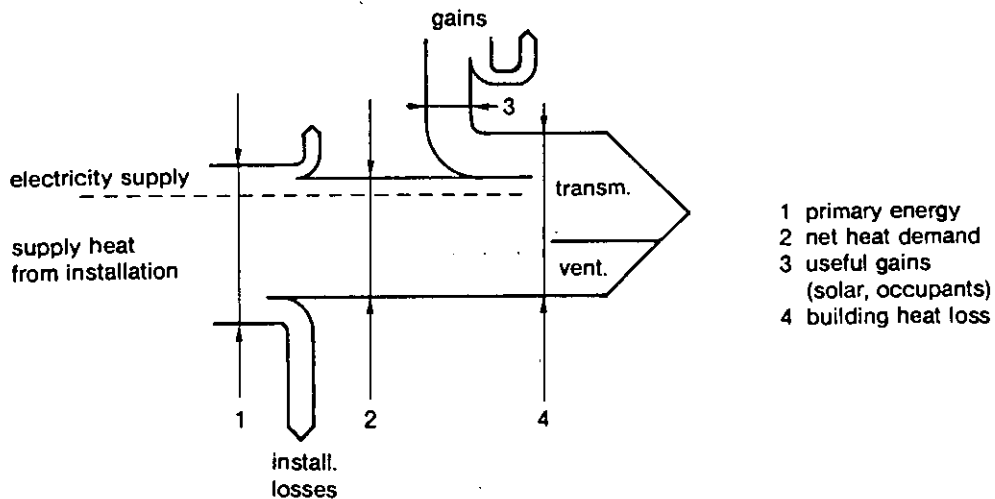
Figure 3: Thermal balance including installation.

The window system accounts for part of the heat losses (transmission) and part of the gains (solar) (figure 4). Moreover, also the ventilation losses could partly be attributed to the window (infiltration).
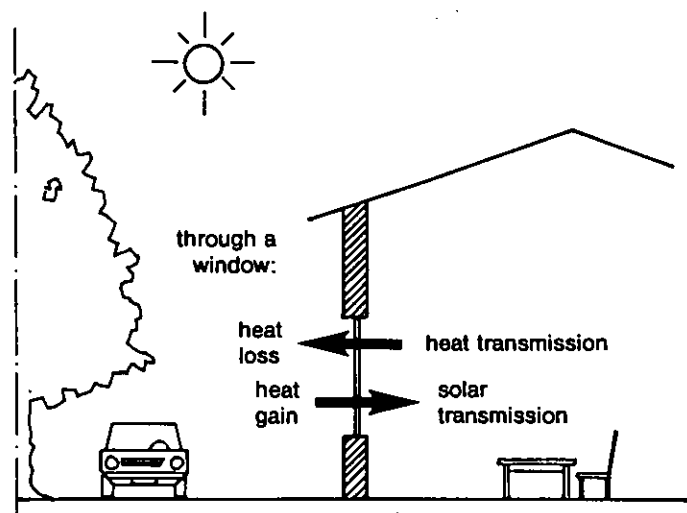
Figure 4: The window accounts for part of the losses and gains.

The heat balance of the window is integrated in the heat balance of the building or room under consideration.
Therefore, when looking for a method to determine heat loss and gain through windows the thermal characteristics of the building involved play an important role.

The heat loss per unit of window area and per K temperature difference between indoor and outdoor environment is described by the thermal transmittance or U-value:

$$U = \frac{\text{heat flow density through window}}{\text{indoor-outdoor temperature difference}} \quad (W/m^2K)$$

In the usual definition of U-value, the effect of solar radiation is not included. The latter effect is described by the so-called (total) solar energy transmission coefficient, here presented with the symbol g:

$$g = \frac{\text{total solar energy entering the room through the window}}{\text{solar radiation incident on the window}} \quad (-)$$

So the solar energy transmission coefficient includes both directly transmitted short wave solar radiation (primary part) and the indirect heat transfer by the part of the solar radiation which is absorbed in the window and transfered to the indoor space by infrared radiation and free convection (figure 5).
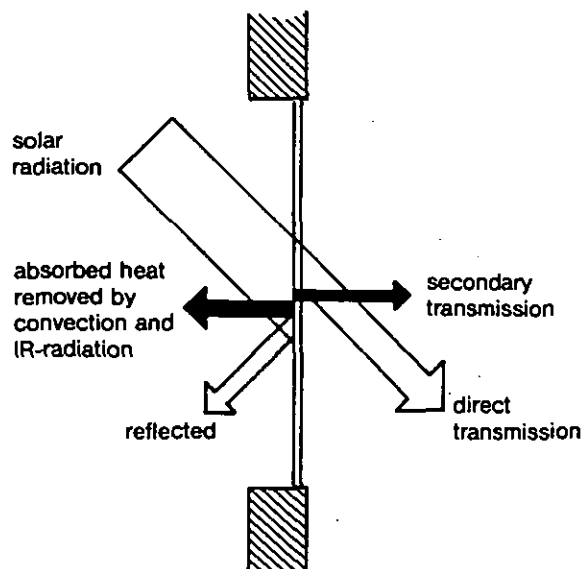
Figure 5: Illustration of the transmission of solar energy through a window.

Within Step 2 of the IEA research project reports have been prepared which deal specifically with the thermal and solar properties of windows ([4], [5], [6]).

3. HEAT BALANCE EQUATIONS FOR SPACE HEATING

3.1 Instantaneous balance

The instantaneous thermal balance for a heated space can be made
with the following terms (see also figures 2 and 3):

$$\phi_{HD} = \phi_L + \phi_{ACC} - \phi_G \qquad \text{(W) (1)}$$

where: ϕ_{HD} = heat supplied by the heating system (W)

ϕ_L = heat losses by transmission and ventilation (W)

ϕ_{ACC} = accumulation of heat into the mass inside or
surrounding the space (W)

ϕ_G = heat gains from internal sources and sun (W)

The terms ϕ_L and ϕ_{ACC} depend on temperature differences.
The accumulation is a complex function of the temperatures within
the constructions and the indoor air and mean surface temperatures.
The unsteady state effects inside heat loss giving constructions
can be considered as accumulation effects; the remaining steady
state heat loss can be written as:

$$\phi_L = H_L \cdot (\theta_i - \theta_a) \qquad \text{(W) (2)}$$

where: H_L = overall specific heat loss coefficient of room i
(W/K)

θ_i = indoor temperature of the room (°C)

θ_a = ambient temperature (°C)

If during a certain time interval the right hand side of equation
(1) tends to become less than zero, then there is no heat demand.
In that case the indoor temperature will rise: overheating. The
overheating leads to increased loss and accumulation, as equation
(2) for the heat loss illustrates. The increase in loss and
accumulation continues until an equilibrium is reached.
In an ideal situation the potential for accumulation would be so
large that the overheating remains negligible also in case of
incidental high gains.

The accumulation also plays another - less beneficial - role: when the thermostat setpoint is set back for the night (dwellings) or e.g. weekend (offices), the heat accumulated during the day is given off to the room, while there is no heat demand; when the thermostat is reset to its higher value in the morning or after the weekend, the heating system must compensate the loss of accumulated heat, unless the sun is already there to take over the role.

3.2 Monthly heat balance

If the terms of equation (1) are integrated over large time intervals, say a month, then the accumulation term becomes negligible: it is a more or less diurnal fluctuation of positive and negative values.

So the monthly heat balance can be written as:

$$\underline{Q_{HD} = Q_{L,real} - Q_G} \qquad\qquad \text{(MJ) (3)}$$

with Q_{HD}, $Q_{L,real}$ and Q_G the integrated heat flows (MJ or kWh).

The loss term Q_L has been provided with the index "real", because the term $Q_{L,real}$ is the integration of instantaneous losses ϕ_L over all hours, including hours on which ϕ_L is increased due to the overheating described above:

$$\underline{Q_{L,real} = H_L \cdot (\bar{\theta}_{i,real} - \bar{\theta}_a) \cdot dt} \qquad\qquad \text{(MJ) (4)}$$

where $\bar{\theta}_{i,real}$ = real mean indoor temperature (°C)

$\bar{\theta}_a$ = mean ambient temperature (°C)

dt   = time interval; dt = D.24.0.0036 MJ

        with D = number of days of the considered period

So part of the gains, integrated in Q_G have not been used to diminish the heat supply by the system. This unutilized part has led to overheating of the space above the thermostat setpoint level.

3.3 Utilization factor for the gains η_G and gain loss ratio GLR

If we define the utilization factor for the gains as the ratio of utilized to total gains, then equation (3) can be written in another - but fully equivalent - way:

$$Q_{HD} = Q_L - \eta_G \cdot Q_G \qquad \text{(MJ) (5)}$$

Here, the term Q_L is introduced, being the integrated heat losses in the situation without overheating (low gains or effective accumulation):

$$Q_L = H_L \cdot (\bar{\theta}_{i,min} - \bar{\theta}_a) \cdot dt \qquad \text{(MJ) (6)}$$

with $\bar{\theta}_{i,min}$ = minimum indoor temperature based on thermostat setpoint (°C).

In case of high gains compared to the losses the monthly heat demand Q_{HD} will become zero; for instance in late spring or early autumn.

If we define the gain loss ratio GLR as:

$$GLR = Q_G / Q_L \qquad \text{(-) (7)}$$

then equation (5) shows that the utilization factor becomes:

$$\text{for high GLR } (Q_{HD} = 0): \eta_G = \frac{1}{GLR} \qquad \text{(-) (8a)}$$

We already saw that the utilization factor is a function of mass, now we see it is also a function of the value of GLR in a particular situation.

In case of low gain loss ratio GLR it can be expected that the gains will never lead to overheating, so in that case:

$$\text{for low GLR: } \eta_G = 1 \qquad \text{(-) (8b)}$$

Thus the shape of the utilization factor as a function of GLR in <u>an</u> <u>ideal situation</u> will be:

in ideal situation: $\eta_G = 1$ for GLR $\leq$ 1

                 $\eta_G = 1/GLR$ for GLR $\geq$ 1   (9)

For any <u>real situation</u> η_G will have lower values in the intermediate region of GLR values.

See figure 6.
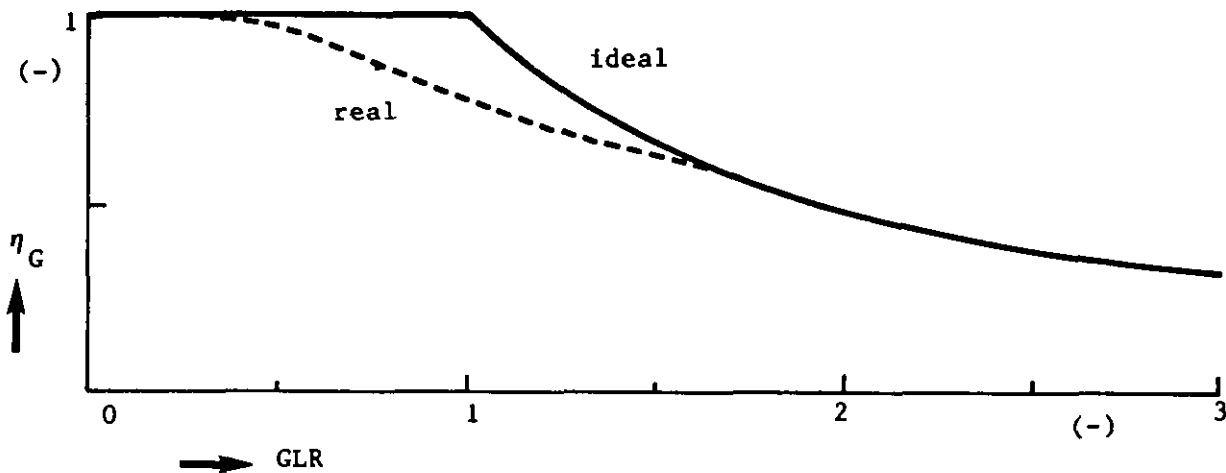
Figure 6: The utilization factor η_G in the ideal and in a real situation as a function of the gain loss ratio GLR.

3.4 Unsteady state calculations and simplified method

One of the major aims of the series of unsteady state computer calculations is to quantify the η_G-functions for various categories of situations. With a known η_G-function the heating requirements can be calculated by hand for a wide range of situations using equation (5).

In the next chapter the procedure to determine Q_L and Q_G will be described.

As a time interval for the derivation of the utilization factor and thus also for the application of the simplified method one month has been selected (offices: 4 weeks).

This period is long enough to avoid too much "carry-over" of heat from one period to the next due to the accumulation.

On the other hand, a month is short enough to provide the distribution of heating requirements or solar gains over the year and to determine the actual length of the heating season. The direct use of monthly results could, however, be subject for discussion, because the monthly results will inevitably suffer from larger inaccuracies than the integrated results over all months of the heating season, as the results of the correlations presented in chapter 5 will show.

Finally, by the monthly approach each selected case will provide about 7 monthly results, with as much different values of the gain loss ratio. This is a much better basis for curve fitting of the utilization factor versus gain loss ratio than the single result in case the whole heating season is integrated. In the latter approach the outdoor climate (weather) is no varying parameter, thus the results cannot be transferred to other climate or weather conditions. Of course, for a one climate situation the annual approach can be very useful, with a minimum of computations to be carried out; see for instance the TPD-method described in [3], [13] and [14] and used also in the publications [15] and [16].

3.5 Utilization of gains versus overheating

The equivalence of equations (3) and (5) leads to the following observation:
the real heat losses are higher than the heat losses without overheating. The ratio between both losses quatifies the increase in temperature difference between the considered room and the ambient to which the transmission and ventilation heat flows.

If we define the mean ambient temperature as experienced by the room as $\bar{\theta}_a$, then the ratio of $Q_{L,real}$ to Q_L can be defined as the mean relative overheating dT_R, with:

$$dT_R \equiv \frac{\bar{\theta}_{i,real} - \bar{\theta}_a}{\bar{\theta}_{i,min} - \bar{\theta}_a} \qquad\qquad (-) \quad (10)$$

where: dT_R = mean relative overheating of room i (-)

$\bar{\theta}_{i,real}$ = monthly mean real indoor temperature (°C)

$\bar{\theta}_{i,min}$ = monthly mean indoor temperature in case of no overheating (°C)

$\bar{\theta}_a$ = monthly mean ambient temperature experienced by the room (°C)

N.B. if the room has only losses to outside: $\bar{\theta}_a = \bar{\theta}_e$, the outdoor temperature.

The <u>absolute overheating dT_A</u> can be defined as:

$$dT_A \equiv (\bar{\theta}_{i,real} - \bar{\theta}_{i,min}) \qquad (°C) \quad (11)$$

It can easily be shown that the relative overheating can directly be calculated when GLR and η_G are known:

$$dT_R = 1 + (1 - \eta_G).GLR \qquad (-) \quad (12)$$

or, substituting the definitions for η_G and GLR, it can be expressed as a function of Q_{HD}, Q_G and Q_L:

$$dT_R = (Q_G + Q_{HD})/Q_L \qquad (-) \quad (13)$$

The absolute overheating can be calculated with:

$$dT_A = \frac{(1 - \eta_G).Q_G}{H_L.dt} \qquad (°C) \quad (14)$$

or expressed as:

$$dT_A = (dT_R - 1).(\bar{\theta}_{i,min} - \bar{\theta}_a) \qquad (°C) \quad (15)$$

The values for dT_R or dT_A give some quantitative information about the discomfort due to overheating and thus of the need to take measures against it.

Of course it is only a mean monthly temperature indication without any information concerning peak temperatures.

Note, that for η_G = 1 there is no overheating (dT_R = 1 and dT_A = 0°C).

The advantage of dT_R over dT_A is that it can be presented like the utilization factor as a function of the gain loss ratio only, for any category of situations for which an η_G (GLR) function has been determined (equation(12)). The mean overheating in °C (dT_A) requires more specific information about the situation, like the overall specific heat loss coefficient or the mean ambient temperature (equations (14) and (15)).

3.6 Literature

Approaches more or less similar to the utilization factor/gain loss ratio approach described in section 3.3 can be found in other publications proposing or describing simplified calculation methods for space heating requirements. For instance proposals in ISO [7] and "Eurocode" [8], descriptions by Barakat [9], [10] and in the method 5000 [11]. See section 5.8.2 for some detailed comparison with these other methods.

Other approaches are also based on correlations between series of unsteady state calculations and steady state equations, but with different types of correlation coefficients. For instance the ASHRAE/Los Alamos method [11] uses the "solar savings fraction" (SSF) in combination with the "solar-load ratio" (SLR) instead of utilization factor and GLR. The value of SSF determines the fraction of the losses which are compensated by the solar energy. The Los Alamos approach has its origin in active solar energy systems. This led to a decoupling of the solar element from the building, which makes the method unnecessarily complicated and less transparant than the methods mentioned above.

The main novel aspects of the method presented in this report are:
- the special attention for widely varying types of window systems, with movable shading and insulation provisions;
- the possibility to assume thermostat night setback;

- the applicability of the method for office buildings without mechanical cooling;
- the applicability of the method in a multi-zone situation with exchange of heat by transmission and/or ventilation between different spaces;
- the rough indication of thermal comfort by the introduction of the relative overheating.

The main limitation of the method in comparison with some of the other methods is that passive solar elements other than "direct gain" fenestration, like collector storage walls have not (yet) been included.

4. DETERMINATION OF THE ELEMENTS OF THE THERMAL BALANCE

4.1 Heat losses

4.1.1 Main equations

For each month or 4 weeks period:

the heat loss for no gain situation:

$$Q_L = Q_{T,W} + Q_{T,OP} + Q_V \qquad \text{(MJ)} \quad (16)$$

With:

heat transmission through windows:

$$Q_{T,W} = A_W \cdot U_W \cdot (\bar{\theta}_{i,min} - \bar{\theta}_e) \cdot dt \qquad \text{(MJ)} \quad (17)$$

where A_W : window area (m²);

$\quad U_W$: window U-value (W/m²K);

$\quad \bar{\theta}_{i,min}$: mean minimum indoor temperature (°C);

$\quad \bar{\theta}_e$: mean outdoor temperature (°C)

$\qquad$ or temperature of adjacent space.

The values for A_W, U_W are to be found in the building specifications; in case of night insulation: see section 4.1.3.

The value for $\bar{\theta}_{i,min}$ is the thermostat setpoint; in case of a thermostat setback a downward correction is needed, see section 4.1.2.

The values for $\bar{\theta}_e$ and dt can be derived from climate data, see for De Bilt and other Dutch locations section 4.4.

Heat transmission through opaque constructions:

$$Q_{T,OP} = A_{OP} \cdot U_{OP} \cdot (\bar{\theta}_{i,min} - \bar{\theta}_e) \cdot dt \qquad \text{(MJ)} \quad (18)$$

where A_{OP}: area of the opaque construction (m²);

$\quad U_{OP}$: construction U-value (W/m²K).

The values for A_{OP}, U_{OP} are to be found in the building specifications.

N.B.: Sometimes an individual heat loss component is negative; for instance the positive heat flow to (thus negative heat loss from) a North room through the partition wall separating the room from a South zone. These negative heat losses then lead to a lower sum of heat losses according to equation (16). Negative losses should not be regarded as part of the gains, because they respond to changes in temperatures like the positive losses and unlike the solar or internal gains.

Ventilation heat loss:

$$Q_V = 0.336.\dot{V}.(\bar{\theta}_{i,min} - \bar{\theta}_e).dt \qquad (MJ) \quad (19)$$

Where: $\dot{V}$: mean ventilation rate (m^3/h).

The value for $\dot{V}$ is the assumed sum of infiltration and ventilation. The factor 0.336 is the thermal capacity of air (J/m^3) divided by 3600 (s/h).

N.B.1: Only air flow from outside or from another indoor space have to be taken into account.

N.B.2: In case the ventilation pattern shows a significantly uneven distribution over the day, equation (19) should be calculated for each part of the day separately, on the basis of $\theta_{i,min}$, dt and θ_e (if available) for that part of the day.
This is for instance the case in office buildings where mechanical ventilation is used only during the office hours when $\theta_{i,min}$ is high (and the outdoor temperature somewhat higher than the average value).

4.1.2 Correction for thermostat setback

a. Dwellings

For dwellings a parameter, C_N, has been defined which makes it possible to correct the mean minimum indoor temperature in case of a night set back of the thermostat. For offices a similar parameter, C_{NWH}, has been defined to take into account the thermostat setback during the non working hours and the weekends. The value of C_N and C_{NWH} respectively is to be derived in the correlation process together with the η_G (GLR) function (see chapter 5).

For the night setback in __dwellings__ the following correction is introduced:

$$\overline{\theta}_{i,min} = C_N \cdot \theta_{i,set,day} + (1 - C_N) \cdot \overline{\theta}_e \qquad (°C) \quad (20)$$

where: $\overline{\theta}_{i,set,day}$: the daytime (mean daytime and evening) thermostat setpoint (°C).

N.B.: the temperature $\overline{\theta}_e$ is the real mean __outdoor temperature__, __also__ in multi-zone situations in which one could be tempted to replacing $\overline{\theta}_e$ by the mean ambient temperature $\overline{\theta}_a$ as experienced by the room. See for a more extensively discussion on the night setback correction the last part of this section.

b. Offices

For the setback before and after the working hours and during the weekends in __offices__ another correction formula is introduced:

$$\overline{\theta}_{i,min} = (FT_{WH} + (1 - FT_{WH}) \cdot C_{NWH}) \cdot \theta_{i,set,WH}$$

$$+ (1 - FT_{WH}) \cdot (1 - C_{NWH}) \cdot \theta_{i,set,NWH} \qquad (°C) \quad (21)$$

where: FT_{WH} : ratio of "degree hours" over the working hours to the "degree hours" over all hours of the considered period. See equation (22);

$\theta_{i,set,WH}$: thermostat setpoint during working hours (°C);

$\theta_{i,set,NWH}$: idem, non working hours (°C).

The term FT_{WH} can be derived from hourly climate data, from:

$$FT_{WH} = \frac{\sum_{WH} (\theta_{i,set,WH} - \theta_e)}{\sum_{all\ hrs} (\theta_{i,set,WH} - \theta_e)} \qquad (-)\ (22)$$

The value for FT_{WH} can be found in the tables of section 4.4 for the Dutch climate.

For both C_N and C_{NWH} goes, that the value ranges between 1 and 0.

A value 1 means that $\overline{\theta}_{i,min}$ is equal to the high thermostat setpoint;

A value 0 means the strongest possible drop in temperature.

The difference in approach between dwellings and offices originates from the fact that for typical situations in dwellings the nightly (low) setpoint is hardly ever reached, so the temperature drop during the night can not be considered as a function of this non-active setpoint.

For offices, the setback periods are longer: evenings and weekends are within the set back regime. The lower setpoint will be reached often, particularly for the no gain situation. Remember that overheating by gains is treated separately via de term dT_A (e.g. equation (15)). The lower setpoint is therefore a decisive parameter for offices.

c. Discussion on adequacy of the correction factor; dwellings

If the thermostat in a dwelling is set back for eight hours from 20°C to 15°C then it can easily be calculated that the minimum value of the correction factor C_N in case of monthly mean outdoor temperatures between 0 and 10°C ranges from 0.92 to 0.83. The real value will be significantly higher because in many situations the lower setpoint will not be reached, and certainly not during the first hours after the setback.

The C_N-value to be derived by correlation (chapter 5) is supposed to be a constant value for a whole category of situations. The category is mainly defined by type of building (dwelling), thermal mass category (heavy versus light weight) and type of heating system and control. It is expected that a more refined approach could lead only to a marginal improvement of the accuracy, with the risk that the parameter values then found by correlation are too much disturbed by other second order effects.

In theory, however, the temperature drop after the setback of the thermostat is a function of the thermal losses and the thermal capacity of the considered building zone. The thermal capacity is taken into account by allowing different C_N-values for the different categories of situations. The losses are not taken into account in C_N.

N.B. The gains play no role, because possible overheating by gains is superposed separately (see e.g. equation (12)).

The following equation can be derived:

$$C_N^* = 1 - \alpha . H_L / C \qquad (-) \ (23)$$

where: C: is the overall thermal capacity of the room (J/K);

N.B. in fact only the effective capacity: that part of the mass in which a diurnal temperature swing can penetrate;

α: is a proportionality constant (s); its value depends mainly on the length of the setback interval and on the shape of the temperature decrease (e.g. whether the nightly setpoint is reached or the temperature usually remains significantly above the setpoint); a typical value for α is e.g. α = 5000 s.

The symbol C^*_N is used instead of C_N because C_N is a correction based on $(\theta_{i,set,day} - \bar{\theta}_e)$ with $\bar{\theta}_e$ the monthly mean <u>outdoor</u> temperature, while C^*_N is a correction based on $(\theta_{i,set,day} - \bar{\theta}_a)$ with $\bar{\theta}_a$ the weighted mean <u>ambient</u> temperature which in a multi-zone situation may be different from $\bar{\theta}_e$.

So, for special cases it could be considered in the future to try to find the best fitting α-value (equation (23)) by correlation and to use instead of C_N the correction factor C_N^*. One should however not forget that the values for C_N or C^*_N will be within the range of 0.90-1.00, so any refinement in the correction would only have a very limited effect on the result.

4.1.3 Correction for night insulation

In case of movable night insulation applied on windows between sunset and sunrise the thermal transmission coefficient U_W in equation (17) is not a constant value for the whole period. A good approximation of the effect on the transmission is found by defining:

the U-value reduction factor:

$$r = \frac{U_W \text{ (with night insulation)}}{U_W \text{ (without night insulation)}} \qquad (-) \ (24)$$

and:

$$FT_{EN} = \frac{\sum_{ev.+night} (\theta_{i,set,day} - \bar{\theta}_e)}{\sum_{all\ hrs} (\theta_{i,set,day} - \bar{\theta}_e)} \qquad (-) \ (25)$$

The ratio FT_{EN} can simply be found by once going through all hourly climate values for each month.

The value for r depends of course on the type of window.

The value for FT_{EN} can be found for dwellings for De Bilt and other Dutch locations in the tables of section 4.4 for $\theta_{i,set,day} \approx 20\pm2°C$; equation (25) is very insensitive for a few degrees different $\theta_{i,set,day}$.

With these two quantities the heat loss through the window can be corrected for night insulation applied on the window between sunset and sunrise:

$$\underline{Q_{T,W}(corrected) = (1 - (1 - r).FT_{EN}).Q_{T,W}(uncorrected)} \quad (MJ) \quad (26)$$

4.1.4 Correction for cold surfaces

In general the temperatures of the internal surfaces in a room will deviate from the air temperature:

- by absorption of solar heat and radiative heat from internal sources; this is to be taken into account by the gain utilization factor η_G;
- by cooling off due to transmission: particularly the window will have an internal surface which is in a no gain situation much colder than the indoor air; this, in turn, leads to a radiation exchange with other surfaces in the room which will therefore cool down too.

A heating system with heat supplied partly as radiative heat (radiator panels, floorheating, a.s.) will compensate for these cold surfaces.

A purely convective heating system with a thermostat which senses some mean value of air and surface temperatures will automaticly compensate the cold surfaces by supplying extra heat to the air (increased air temperature).

In both cases the setpoints are more or less representative for the temperature that is to be used in the calculation of the heat losses.

However, in case of a <u>convective heating system with a thermostat controlling the indoor air temperature</u> there is no compensation for cold surfaces. With the surfaces significantly colder than the air temperature a calculation of the heat loss based on the air temperature setpoint would overestimate the heat losses. Therefore a correction is introduced.

N.B. In the latter situation the thermal comfort requirements may not have been fulfilled although the heating system is switched off by the thermostat action.

The correction for cold surfaces in case of convective heating and thermostatic control of air temperature amounts:

$$Q_L \text{ (corrected)} = \frac{1 - \sum_e A_e \cdot U_e}{A_t \cdot h_{ri}} \cdot Q_L \text{ (uncorrected)} \qquad \text{(MJ)} \quad (27)$$

where: A_e : area of heat loss giving surface (m²)

U_e : U-value of heat loss giving surface (W/m²K)

A_t : total surrounding area of the room (loss giving and not loss giving)

h_{ri} : radiative heat transfer coefficient at the internal surfaces; h_{ri} = 5 W/m²K.

Values for A_e, U_e, A_t are to be found from the building specifications.

4.1.5 Determination of overall specific heat loss coefficient

H_L and mean ambient temperature $\bar{\theta}_a$

For the determination of the mean absolute overheating, dT_A the value for the overall specific heat loss coefficient, H_L, or the mean ambient temperature, $\bar{\theta}_a$, is needed (see equations (14) and (15)).

Later on a procedure will be introduced to use the simplified method in a multi-zone situation (chapter 6).

It will then appear to be useful firstly to calculate H_L and θ_a and via those to determine Q_L, according to equation (6).

H_L can easily be calculated by taking equations (17)-(27) and ignoring the temperature differences and time interval there, so:

$$H_L = \sum_{1w}\{(1 - (1 - r)FT_{EN}).A_W.U_W\}_{1w} \qquad \text{for each window 1w}$$

$$+ \sum_{1o}\{A_{OP}.U_{OP}\}_{1o} \qquad \text{for each opaque construction 1o}$$

$$+ \sum_{1v}\{0.336.\overset{\circ}{V}\}_{1v} \qquad \text{for each ventilation opening 1v}$$

$$(W/K) \quad (28)$$

In case the special correction for cold surfaces is required (see previous section):

$$H_{L\ corrected} = \frac{1 - \sum_e A_e.U_e}{A_t.h_{ri}} . H_{L\ uncorrected} \qquad (W/K) \quad (29)$$

The mean ambient temperature for the considered zone is equal to the outdoor temperature $\overline{\theta}_e$ in case all heat exchange takes place to the outside.

Often, this will not be the case, due to heat loss to the ground floor, heat exchange with other rooms, etc.

In that case the mean ambient temperature has to be calculated with an equation very similar to equation (28) for H_L, but with the addition of the mean temperature in the adjacent space and with the division by the value H_L:

$$\overline{\theta}_a = \frac{1}{HL} . \sum_{1w}\{(1 - (1 - r)FT_{EN}).A_W.U_W.\overline{\theta}_e\}_{1w} \qquad \text{for each window 1w}$$

$$+ \sum_{lo} \{A_{OP} \cdot U_{OP} \cdot \bar{\theta}_e\}_{lo} \qquad \text{for each opaque construction lo}$$

$$+ \sum_{lv} \{0,336 \cdot \dot{V} \cdot \bar{\theta}_e\}_{lv} \qquad \text{for each ventilation opening lv}$$

where: $\theta_{e,lw}$, $\theta_{e,lo}$, $\theta_{e,lv}$: temperature of the adjacent space (°C). And again, if applicable, a similar special correction for cold surfaces should be applied on $\bar{\theta}_a$ as presented in equation (29) for H_L.

4.2 Heat gains

4.2.1 Main equations

For each month or 4 weeks period:
the heat gains are:

$$Q_G = Q_I + Q_S \qquad \text{(MJ) (30)}$$

with:
internal gains:

$$Q_I = \bar{\phi}_{int.} \cdot dt \qquad \text{(MJ) (31)}$$

where: $\bar{\phi}_{int.}$ = mean heat flow from internal sources (W)

The value for $\bar{\phi}_{int.}$ is the assumed internal heat production.

For offices with $\bar{\phi}_{int}$ only during 10 office hours:

$$Q_I = FWD \cdot (10/24) \cdot \bar{\phi}_{int} \cdot dt \qquad \text{(MJ) (31a)}$$

with FWD the ratio of working days over total number of days.

Solar heat gains through windows:

$$Q_S = A_W \cdot g \cdot \bar{q}_s(j) \cdot dt \qquad \text{(MJ) (32)}$$

where: g   : total solar transmission factor of the window (-)

$\bar{q}_s(j)$: the mean solar radiation incident on the plane
of the window (W/m²)

In case of different windows in one room the solar heat gains
should be summated. In case of a large opaque area exposed to solar
radiation, *for instance a roof, see section 4.2.3 for a correction*
on Q_S.

The values for A_W and g are to be found in the building
specifications; in case of movable shading: see section 4.2.2.

The values for $\bar{q}_s(j)$ and dt can be derived from hourly climate
data, see for De Bilt and other Dutch locations the tables of
section 4.4.

4.2.2 Correction for movable solar shading

In case of movable solar shading on windows the value g is not
constant. If we neglect the effect of shading on the U-value of the
window a good approximation of the effect on the solar gains is
found by defining:

the shading factor:

$$z = \frac{g \text{ (with shading)}}{g \text{ (without shading)}} \qquad\qquad (-) \ (33)$$

and:

$$Fq^{qtrh}(j) = \frac{\displaystyle\sum_{\text{hrs with shading active}} \bar{q}_s(j)}{\displaystyle\sum_{\text{all hrs}} \bar{q}_s(j)} \qquad\qquad (-) \ (34)$$

where the superscript qtrh stands for the level of hourly incident
solar radiation which is chosen as the threshold above which the
shading is assumed to become active.

The ratio $Fq^{qtrh}(j)$ can simply be found by once going through all hourly climate values for each month and the required orientation.

The value for z depends of course on the type of window.

The value for $Fq^{qtrh}(j)$ can be found for De Bilt and other Dutch locations in section 4.4 for threshold levels of qtrh = 500 W/m² and 300 W/m² incident solar radiation intensities.

With these two quantities the heat gain through the window can be corrected for movable shading applied at hours with incident solar radiation exceeding qtrh (W/m²):

$$Q_G \text{ (corrected)} = (1 - (1 - z) \cdot Fq^{qtrh}(j)) \cdot Q_G \text{ (uncorrected)}$$

$$(MJ) \quad (35)$$

4.2.3 Correction for solar radiation absorbed by opaque surfaces

In cases of a large opaque area exposed to the sun, like a roof, a correction might be needed for solar heat entering the room via opaque constructions.

The correction amounts:

$$Q_S \text{ (corrected)}_{lo} = \left\{ \sum \frac{a_{op} \cdot A_{op} \cdot \bar{q}_s(j) \cdot dt}{(\frac{1}{U_{op}} - \frac{1}{h_e}) \cdot h_e} \right\} + QS \text{ (uncorrected)}_{lo}$$

$$(MJ) \quad (36)$$

where for each opaque construction:

A_{op} : area of opaque construction exposed to solar radiation (m²) at orientation j;

a_{op} : solar absorption coefficient of the exposed outdoor surface (-);

U_{op} : U-value of the construction (W/m²K);

h_e : exterior surface heat transfer coefficient (W/m²K);
h_e = 23 W/m²K.

Values for A_{op}, a_{op}, U_{op} are te be found from the building specifications.

4.3 Heating requirements and simplified method

The monthly heating requirements Q_{HD} can be determined with equation (5) presented before:

$$Q_{HD} = Q_L - \eta_G \cdot Q_G$$

Q_L, η_G and Q_G can be determined with the use of the equations from the previous sections.

The information needed to be able to fill in these equations can be subdivided into three types:

-a- specifications of building, occupants' behaviour and heating installation

-b- monthly integrated climate data

-c- correlation parameters

- the utilization factor curve η_G (GLR)
- the thermostat setback correction C_N or C_{NWH}

For the _development_ of the simplified method series of calculations using the unsteady state computer model DYWON were run for various types of building, occupants' behaviour and heating installation, for a heating season (7 months) representative for the Netherlands. These series were subdivided into different categories and for each category the parameters η_G (GLR) and C_N (or C_{NWH}) were determined by correlating the calculation results with the known specifications as mentioned under -a- and the known integrated climate date (-b-).

The monthly climate data are presented in the next section (section 4.4), the specifications of the calculation cases are presented in 5.4 - 5.7 and the results of the correlation process are given in section 5.8.

If a specific situation fits into one of the categories for which the correlation parameters have been determined, then the simplified method can be _used_ directly (see chapter 6).

If not, a new category can be created for which the correlation parameters could be determined in the same way as presented in chapter 5.

4.4 Climate data for the Netherlands

The series of unsteady state computer calculations have been carried out with the use of the hourly climate data from the Royal Dutch Meteorological Institute (KNMI) for location De Bilt over the period October 1, 1964 - April 30, 1965. This period has been used in most studies and design calculations throughout the years as the period with the most representative outdoor climate for the Netherlands.

The monthly values which are needed for the simplified calculation have been derived from the hourly data. The results are presented in table 1.

Table 2 presents the values integrated over 4 week periods from October 5, 1964 - April 26, 1965 needed for offices.

Recently, "Test Reference Years" (TRY's) have been generated for a number of countries within the CEC ([17]). These years have been composed by selecting for each month the statistically most representative one out of a number of years with known hourly climate data.

For the Netherlands TRY's have been generated for the locations De Bilt (central part), Vlissingen (South West) and Eelde (North East).

Because in recent studies the TRY is used as reference outdoor climate the monthly integrated values have been determined for these Test Reference Years too: table 3 for De Bilt and tables 4 and 5 for Vlissingen and Eelde respectively. Tables 6 - 8 present the values in 4 week periods for the situation in offices.

<u>Table 1</u>: Climate data for De Bilt, the Netherlands.
October 1, 1964 – April 30, 1965;
monthly integrated (for dwellings).

	Oct.	Nov.	Dec.	Jan.	Febr.	Mrch.	Apr.
$\bar{\theta}_e$ [°C]	7.9	6.3	2.4	2.7	2.1	4.3	7.7
$\bar{q}_s$ (j) [W/m²]							
j = south	90.7	35.2	29.4	34.1	69.9	105.2	99.6
j = north	27.4	12.0	9.3	12.4	26.1	38.0	51.7
j = east	50.5	15.1	14.1	17.0	37.8	64.6	76.6
j = west	46.3	18.1	12.0	16.5	36.5	66.3	83.5
Fq_{500} (j) [-]							
j = south	0.51	0.46	0.28	0.36	0.34	0.51	0.33
j = north	0	0	0	0	0	0	0
j = east	0.19	0	0	0	0	0.13	0.24
j = west	0	0	0	0	0	0	0
Fq_{300} (j) [-]							
j = south	0.75	0.64	0.55	0.57	0.61	0.73	0.63
j = north	0	0	0	0	0	0	0
j = east	0.46	0.15	0.03	0.07	0.16	0.42	0.37
j = west	0.33	0.12	0	0.12	0.22	0.45	0.42
D	31	30	31	31	28	31	30
dt [Ms]	2.7	2.6	2.7	2.7	2.4	2.7	2.6
FT_{EN} [-]	0.61	0.66	0.70	0.66	0.58	0.54	0.48

<u>Table 2</u>: Idem, integrated over periods of 4 weeks (for offices).

	Oct.	Nov.	Dec.	Jan.	Febr.	Mrch.	Apr.
$\bar{\theta}_e$ [°C]	7.4	5.6	2.4	2.9	1.5	5.7	7.5
$\bar{q}_s$ (j) [W/m²]							
horizontal	47.7	21.6	18.2	20.0	51.9	92.8	99.6
j = south	68.6	36.8	37.7	25.3	74.3	115.1	87.4
j = north	24.5	11.8	9.9	12.3	27.4	39.5	50.5
j = east	39.6	15.6	16.2	15.2	40.9	70.3	68.8
j = west	37.5	17.4	14.2	14.9	39.4	73.4	77.9
Fq_{300} (j) [-]							
j = south	0.47	0.47	0.37	0.14	0.47	0.57	0.38
j = north	0	0	0	0	0	0	0
j = east	0.23	0.14	0.10	0	0.18	0.32	0.18
j = west	0.18	0.05	0.03	0	0.22	0.40	0.29
D	30	31	31	28	31	30	22
dt [Ms]	2.6	2.7	2.7	2.4	2.7	2.6	1.9
FT_{WH} [-]	0.27	0.30	0.27	0.29	0.29	0.24	0.24
F_{WD} [-]	0.73	0.74	0.68	0.71	0.74	0.70	0.68

Tables 3 – 5 Climate data Test Reference Years for three locations
in The Netherlands; monthly integrated (for
dwellings).

Table 3: TRY location De Bilt.

	Oct.	Nov.	Dec.	Jan.	Febr.	Mrch.	Apr.
$\bar{\theta}_e$ (°C)	11.2	6.0	3.4	2.5	2.7	5.6	8.0
$q_e(j)$ [W/m²]							
horizontal	65.5	31.0	19.9	25.2	46.9	98.3	146.1
j = south	74.4	44.8	29.6	34.4	52.1	94.9	117.8
j = north	28.9	14.2	9.8	12.5	21.8	40.8	56.1
j = east	40.6	20.1	12.4	17.2	29.1	63.2	89.2
j = west	42.5	20.5	15.3	16.5	29.4	58.7	95.6
$Pq_{500}(j)$ [-]							
j = south	0.41	0.33	0.33	0.34	0.40	0.46	0.44
j = north	0	0	0	0	0	0	0
j = east	0.02	0	0	0	0	0.13	0.30
j = west	0.02	0	0	0	0	0.13	0.31
$Pq_{300}(j)$ [-]							
j = south	0.66	0.67	0.55	0.58	0.61	0.69	0.65
j = north	0	0	0	0	0	0	0
j = east	0.22	0.04	0	0.07	0.20	0.39	0.46
j = west	0.21	0.04	0	0.11	0.15	0.31	0.48
D	31	30	31	31	28	31	30
dt [Ms]	2.7	2.6	2.7	2.7	2.4	2.7	2.6
PZ_{en} [-]	0.62	0.60	0.59	0.57	0.56	0.56	0.55

Table 4: TRY location Vlissingen.

	Oct.	Nov.	Dec.	Jan.	Febr.	Mrch.	Apr.
θ_e (°C)	11.0	7.7	6.0	3.3	4.8	6.0	8.1
$q_e(j)$ [W/m²]							
horizontal	77.1	32.2	20.3	28.3	56.1	97.1	140.6
j = south	91.5	44.7	29.5	39.6	69.0	93.6	117.6
j = north	32.3	15.0	10.1	13.6	24.5	41.7	61.0
j = east	50.4	20.5	13.1	18.1	36.4	59.6	91.5
j = west	49.7	21.5	14.1	18.7	34.9	64.1	93.9
$Pq_{500}(j)$ [-]							
j = south	0.49	0.45	0.34	0.42	0.50	0.45	0.41
j = north	0	0	0	0	0	0	0
j = east	0.07	0	0	0	0	0.12	0.26
j = west	0.01	0	0	0	0	0.17	0.24
$Pq_{300}(j)$ [-]							
j = south	0.70	0.66	0.56	0.70	0.74	0.66	0.63
j = north	0	0	0	0	0	0	0
j = east	0.37	0.13	0.03	0.08	0.28	0.32	0.43
j = west	0.32	0.16	0	0.05	0.29	0.38	0.43
D	31	30	31	31	28	31	30
dt [Ms]	2.7	2.6	2.7	2.7	2.4	2.7	2.6
PZ_{en} [-]	0.56	0.58	0.59	0.57	0.54	0.51	0.45

Table 5: TRY location Eelde

	Oct.	Nov.	Dec.	Jan.	Febr.	Mrch.	Apr.
$\bar{\theta}_e$ (°C)	10.8	5.8	2.3	2.7	1.3	3.9	7.3
$q_e(j)$ [W/m²]							
horizontal	66.3	28.5	19.1	21.3	47.9	84.6	158.3
j = south	74.6	38.5	33.8	24.5	59.1	78.4	127.9
j = north	29.2	13.5	8.7	11.0	20.7	37.1	60.3
j = east	43.1	18.7	13.0	13.6	31.2	58.2	95.8
j = west	43.8	19.0	12.9	13.5	30.0	52.6	100.8
$Pq_{500}(j)$ [-]							
j = south	0.39	0.29	0.27	0.28	0.46	0.31	0.48
j = north	0	0	0	0	0	0	0
j = east	0.06	0	0	0	0	0.19	0.33
j = west	0	0	0	0	0	0.10	0.29
$Pq_{300}(j)$ [-]							
j = south	0.63	0.57	0.60	0.52	0.71	0.59	0.68
j = north	0	0	0	0	0	0	0
j = east	0.26	0.10	0	0.03	0.26	0.38	0.47
j = west	0.24	0.04	0	0	0.21	0.30	0.48
D	31	30	31	31	28	31	30
dt [Ms]	2.7	2.6	2.7	2.7	2.4	2.7	2.6
PZ_{en} [-]	0.61	0.61	0.59	0.59	0.56	0.53	0.48

Tables 6 – 8 Climate data Test Reference Years for three locations in The Netherlands; integrated over periods of 4 weeks (for offices).

Table 6: TRY location De Bilt.

	Oct.	Nov.	Dec.	Jan.	Febr.	Mrch.	Apr.
$\bar{\theta}_e$ [°C]	11.6	6.5	3.2	3.9	0.3	4.4	8.1
q_e (j) [W/m²]							
horizontal	67.7	33.1	21.7	22.5	29.6	71.7	139.4
j = south	75.7	47.1	34.0	32.0	29.0	75.9	126.4
j = north	29.9	15.1	10.4	11.2	15.5	32.3	53.2
j = east	42.1	21.6	12.7	16.1	17.7	47.8	88.1
j = west	44.2	21.7	16.7	14.5	18.6	43.5	87.1
Fq_{300} (j) [-]							
j = south	0.55	0.49	0.47	0.45	0.39	0.410	0.43
j = north	0	0	0	0	0	0	0
j = east	0.20	0.04	0	0.08	0	0.13	0.29
j = west	0.20	0	0	0.03	0.09	0.12	0.22
D	28	28	28	28	28	28	28
dt [Ms]	2.4	2.4	2.4	2.4	2.4	2.4	2.4
FT_{WH} [-]	0.25	0.27	0.30	0.28	0.29	0.28	0.27
r_{WD} [-]	0.70	0.70	0.70	0.70	0.70	0.70	0.70

Table 7: TRY location Vlissingen.

	Oct.	Nov.	Dec.	Jan.	Febr.	Mrch.	Apr.
$\bar{\theta}_e$ [°C]	11.2	8.3	6.3	2.6	5.2	4.5	7.9
q_e (j) [W/m²]							
horizontal	78.4	37.0	18.6	28.2	38.0	78.4	138.7
j = south	91.5	52.9	21.9	44.9	48.2	84.7	122.1
j = north	32.8	16.6	9.8	13.2	17.6	34.6	55.1
j = east	51.2	23.3	11.9	18.5	26.0	48.9	85.3
j = west	50.2	25.3	12.3	19.1	23.6	49.9	90.8
Fq_{300} (j) [-]							
j = south	0.51	0.59	0.33	0.53	0.44	0.43	0.46
j = north	0	0	0	0	0	0	0
j = east	0.27	0.04	0.04	0.04	0.17	0.16	0.30
j = west	0.25	0.18	0	0.03	0.09	0.15	0.27
D	28	28	28	28	28	28	28
dt [Ms]	2.4	2.4	2.4	2.4	2.4	2.4	2.4
FT_{WH} [-]	0.29	0.28	0.30	0.29	0.29	0.30	0.29
r_{WD} [-]	0.70	0.70	0.70	0.70	0.70	0.70	0.70

Table 8: TRY location Eelde

	Oct.	Nov.	Dec.	Jan.	Febr.	Mrch.	Apr.
$\bar{\theta}_e$ [°C]	10.9	6.5	2.1	2.6	1.0	5.1	4.5
$\bar{q}_e$ (j) [W/m²]							
horizontal	68.5	32.4	20.8	16.4	30.9	62.6	133.3
j = south	76.8	43.3	35.3	20.8	35.2	68.9	117.2
j = north	30.0	15.2	9.6	8.5	15.1	27.5	53.5
j = east	45.1	20.6	14.0	10.4	21.0	40.4	86.0
j = west	45.3	21.9	13.6	11.2	17.5	40.4	86.8
Fq_{300} (j) [-]							
j = south	0.52	0.40	0.40	0.50	0.47	0.41	0.36
j = north	0	0	0	0	0	0	0
j = east	0.18	0.02	0	0.04	0.05	0.18	0.27
j = west	0.21	0.06	0	0	0	0.15	0.24
D	28	28	28	28	28	28	28
dt [Ms]	2.4	2.4	2.4	2.4	2.4	2.4	2.4
FT_{WH} [-]	0.27	0.27	0.28	0.28	0.29	0.28	0.27
r_{WD} [-]	0.70	0.70	0.70	0.70	0.70	0.70	0.70

5. SERIES OF UNSTEADY STATE CALCULATIONS TO DERIVE THE CORRELATION PARAMETERS

5.1 Introduction

Series of parameter studies using the unsteady state computermodel DYWON were carried out to find for different categories of situations the correlation parameters C_N (offices: C_{NWH}) for the thermostat setback correction and the relation between the gain utilization factor η_G and the gain loss ratio GLR. If the C_N (or C_{NWH}) factor and the η_G function are known for a certain category then for any situation which fits into that category the monthly heating requirements can be easily calculated using equation (5): $Q_{HD} = Q_L - \eta_G \cdot Q_G$, with the equations of sections 4.1 and 4.2 to determine Q_L and Q_G.

5.2 Distinction into categories of situations

As discussed before (4.1.2 and 4.3) the correlation parameter C_N (or C_{NWH}) and the function η_G (GLR) will depend on a few typical characteristics of building, heating installation and occupants:

- building : type of use (dwelling, office, ...);
  thermal mass (heavy weight, light weight);

- installation : e.g. convective heating or radiator heating;

- occupants' behaviour: yes/no (night) setback of thermostat;
  criterium for the use of solar shading;
  criterium for the use of night insulation;
  criterium for extra ventilation in case of overheating.

5.3 The unsteady state model DYWON

The computer programme DYWON, developed by TNO Institute of Applied Physics, Delft, for the unsteady state simulation of the energy consumption for heating of buildings is specifically suited for the often complicated situation of dwellings.

The dwelling can be divided into a number of rooms, with the possibility to exchange heat between the rooms by transmission and ventilation.

The thermal conduct of the wall elements is simulated by means of a finite difference method (RC−network). For each room a number of such constructive elements can be introduced, with for each element a menu of possibilities with respect to type (e.g. groundfloor, window, separation wall, etc.) and level of complexity for calculation (e.g. single layer, ventilated multi−layer system, with movable insulation, etc.).

For the radiation exchange between the constructions the programme is provided with a simple approximation in which the surfaces are assumed being part of complex geometries. If needed, (more) exact view factors can be used as input data or separately calculated. With the known view factors, the radiation exchange factors are calculated; in case of e.g. movable blinds this calculation is repeated when the surface properties are changed.

The convective and radiative heat transfer coefficients are considered temperature dependent.

The heating installation consists of boiler−unit coupled with radiators or convectors and/or separate heating units. The required temperature level is determined by given values for local and/or central thermostats or manually operated controls.

The various boundary conditions by occupants' behaviour can be specified as 24 hours patterns of hourly values. This is the case for

− natural ventilation (option: windspeed dependent);

− mechanical ventilation (option: pre−heated);

− internal heat loads (convective, radiative);

− set point of thermostatic valve per radiator/convector;

− room thermostat;

− window treatments: use of night insulation and/or solar shading
  (option: solar intensity dependent).

The calculation procedure can be done on an hourly basis or in shorter time steps if desired.

The thermal balance for the room air is found by an iteration process in which the heating installation plays an important role: depending on the type of control, the heat supply to the (central) heating system and/or the (e.g. water) flows through the ornaments are adapted iteratively until a weighted mean of air and radiant temperature corresponds to the set-point of the thermostat involved. In case of no heat supply the system or individual ornaments (e.g. closed radiators) will gradually give off the heat accumulated in the (part of the) system.

If the option of shorter time steps is chosen the iteration can be replaced by a straight forward calculation in which for each short time step the heating system and/or the ornaments are switched on and off.

The heat flows for each constructive element are calculated directly by matrix-inversion.

This calculation process has the advantage over e.g. a response method, that it allows all kind of changes in the room network during calculation, like temperature dependent coefficients or movable shadings, curtains, a.s., without practical limitations. Moreover, all temperatures and heat flows at each node are in principle accessible for analysis. The disadvantage is the higher computer time per calculation; the computer time can however be restricted by exploiting the flexibility of DYWON, by a.o. appropriate choice in number of constructions and their complexity level.

Results from comparisons with other unsteady state computer models can be found in the report IEA Annex III, Subtask A [18] and the report on step 4 of this Annex XII [2].

5.4 Calculation series

The calculations can be divided into three categories, each category containing calculation cases belonging to different subcategories of situations as mentioned under 5.2.

Category -a- concerns a large serie of calculations on dwellings. These series were focussed on the influence of windows. To this extend calculations were performed with 17 different combinations of glazing, solar shading and night insulation. Also other characteristics were varied, to detect the window's influence under widely varying indoor conditions.

In fact this series of calculations was carried out within the framework of a previous national study. However, in that study the annual heat demand values were used to derive a correlation based simplified method, valid for the Netherlands only, (see [13], [19], [20], [21]; here we used the also available monthly results).

Category -b- concerns a shorter series of calculations which consists of variations around a reference case calculation used for the comparison of computermodels within step 4 of the project [2]. The reference case concerns a highly insulated room. In contrast with the reference case, these calculations were carried out with a radiator heating system instead of convective heating and with the De Bilt climate instead of Geneva.

Varied were window type, size and orientation, the control of the heating system and the mass of the room.

Category -c- concerns again a larger series of calculations on typical office rooms. These calculations, as category -a-, were performed within the framework of a previous national study ([14]). In this study a correlation based simplified method was derived on a seasonal basis, valid for the Netherlands only. Again, here we used the still available monthly results. This series of calculations was not focussed on the influence of windows. Nevertheless, apart from a high number of variations in the other characteristics, also window size, type and orientation were varied.

5.5 Category dwellings -a-

Main characteristics:

Dwellings (both single family and appartment).

- Convective heating system.
- Thermostat controlled by air temperature.
- If present, shadings down when incident solar radiation exceeds 300 W/m² on the window.
- No increased ventilation in case of overheating.
- Night insulation present between sun set and sun rise.

Subcategories:

a-1: - Masonry type (heavy weight),
     - Night set back;

a-2: - Masonry type,
     - Continuous heating;

a-3: - Wooden frame type (light weight),
     - Night set back;

a-4: - Wooden frame type (light weight),
     - Continuous heating.

Calculation cases:

The characteristics of the 17 different window combinations can be found in table 9.

Table 10 shows a survey of all calculation cases with the description of the characteristics which were varied.

In appendix 2 a table can be found with all the steady state characteristics which were required for the calculation of the heat loss Q_L and heat gain Q_G.

Table 9. Characteristics*) of the 17 different window combinations
        used in category -a-

	Type	Description			Thermal transmit-tance U(W/m²K)	Solar factor g(-)	r-value night insul. r(-)	z-value shading z(-)
		Glazing	Solar shading	Night insulation				
	1	single clear	none	none	5.9	0.80	1	1
	2	as 1	internal blinds light colour	none	5.9	0.80	1	0.58
	3	as 1	as 2	internal blinds, slats closed	5.9	0.80	0.75	0.58
	4	as 1	internal blinds black/ reflect.	internal blinds, black/re- flect., slats clo- sed	5.9	0.80	0.61	0.59
	5	as 1	none	well closed curtain	5.9	0.80	0.64	1
	6	as 1	none	well closed curtain, Al.-coated	5.9	0.80	0.41	1
	7	as 1	as 4	blinds as 4 curtain as 6 but not well closed	5.9	0.80	0.47	0.59
	8	as 1 with low E coating	as 4	as 7	3.6	0.71	0.58	0.70
	9	as 1	as 4	as 4, but with insu- lated slats	5.9	0.80	0.44	0.59
	10	double clear	none	none	3.2	0.70	1	1
	11	as 10	as 2	none	3.2	0.70	1	0.69

Table 9. continued.

		Description		Thermal transmittance	Solar factor	r-value night insul.	z-value shading
	Type	Glazing	Solar shading	Night insulation	U(W/m²K)	g(-)	r(-)	z(-)
	12	as 10	as 4	as 6	3.2	0.70	0.63	0.70
	13	as 10 with low E	none	none	1.8	0.66	1	1
	14	triple clear	none	none	2.2	0.57	1	1
	15	as 14	as 4	as 4	2.2	0.57	0.82	0.81
	16	as 10	as 9	as 9	3.2	0.70	0.59	0.67
	17	as 10	none	external roller blinds, insulated	3.2	0.70	0.66	1

*) the presented thermal and solar properties are typical values for
the indicated type; the values will in general differ from product
to product, depending on the actual specifications.

Table 10. Survey of the calculation cases category -a-

Cate-gory	Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Identifi-cation
a-1	-base case, dwelling in appartm. bld.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	F
	-variants: orientation N-S → E-W	x		x			x				x			x	x			x	FE
	-internal heat evening doubled	x					x							x				x	} FI+
	-internal heat increased all hrs.	x					x							x				x	FI+
	-no internal heat	x					x							x				x	FI-
	-infiltration tripled						x							x				x	FV+
	-base case, house in a row	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	W
	-variant: internal heat halvened	x					x							x				x	WI-
	-25% window area moved N → S										x			x				x	WG+
	-idem and infiltration halvened	x					x		x		x			x				x	WG+ V-
a-2	-appartment, variants: continuous heating 21°C	x					x							x				x	FT+
	-idem at 15°C	x					x				x							x	FT-
	-house in a row, variants: continuous heating 20°C	x					x											x	WT+
	-idem at 15°C	x					x											x	WT-
	-continuous heating 20°C, infiltration halvened and 25% window moved N → S	x					x							x				x	WG+ V- T+
	-idem, but continuous heating at 15°C	x					x							x				x	WG+ V- T-
a-3	-appartment, variants: building mass decreased to 10%	x		x			x				x			x	x			x	FM-
	-house in a row variants: building mass decreased to 10%	x					x											x	WM-
	-idem, plus infiltration halvened and 25% window moved N → S	x					x				x			x					WG+ V- M-

Table 10. continued.

Category	Description	Window combination				Identification
		1 2 3 4 5	6 7 8 9	10 11 12 13	14 15 16 17	
a-4	-appartment, variants: bld. mass decreased to 10% and cont. heating at 21°C	x			x	FM- T+
	-bld. mass decreased to 10% and cont. heating at 15°C	x		x	x	FM- T-
	-house in a row, variants: bld. mass decreased to 10%, infiltr. halvened, 25% window moved N → S, cont. heating at 20°C	x	x	x	x	WG+V-M-T+
	-idem, but heating at 15°C	x	x	x	x	WG+V-M-T-

5.6 Category dwellings -b-

Main characteristics:

- Dwellings (individual rooms considered).

- Radiator heating (radiators underneath window).

- Thermostat controlled by comfort temperature.

- If present, shadings down when incident solar radiation exceeds 500 W/m² on the window.

- Increased ventilation in case of overheating.

Subcategories:

b-1: - Heavy mass,

     - Night set back;

b-2: - Heavy mass,

     - Continuous heating;

b-3: - Light weight mass,

     - Night set back;

b-4: - Light weight mass,

     - Continuous heating.

<u>Calculation cases:</u>

Table 11 shows a survey of the calculation cases. Only the window
size, type and orientation were varied.
More details can be found in <u>appendix 2</u>.

Table 11. Survey of the calculation cases in category -b-

Cate-gory	Building type H= heavyw. mass L= lightw. mass.	Heating regulation C= continuous N= night set back	Window* Type of glazing	Size in % of floor-area	Orienta-tation N= North S= South	Identi-fication code
b-1	H	N	single clear	20	N	HNN 21
	H	N	single clear	20	S	HSN 21
	H	N	double clear	10	S	HSN 12
	H	N	double clear	20	S	HSN 22
	H	N	double clear	30	S	HSN 32
	H	N	triple with low E	20	S	HSN 25
	H	N	triple with low E	20	N	HNN 25
b-2	H	C	double clear	20	S	HSC 22
b-3	L	N	single clear	20	S	LSN 21
	L	N	triple clear	20	S	LSN 24
	L	N	triple with low E	20	S	LSN 25

* All with internal blinds down at hours with incident radiation
  $\geq$ 500 W/m².

5.7 Category offices -c-

Main_characteristics:

- Office rooms, not mechanically cooled.
- Convective heating system.
- Thermostat controlled by air temperature.
- If present, shadings down when incident solar radiation exceeds 300 W/m² on the window, excluding on weekend days.
- No increased ventilation in case of overheating.
- Thermostat set back outside office hours and during weekends.

Subcategories:

c-1: Heavy weight;

c-3: Light weight;

c-5: Extra heavy weight.

Calculation_cases:

The office room is a conventional, moderately insulated office module.

In appendix 2 and in reference [14] more detailed information can be found.

The main types of variations were:
- window area, type (single/double, shading) and orientation;
- mechanical ventilation and infiltration;
- transmission;
- internal gains.

The total number of calculations was 82. A few cases have been deleted here, because they were irrealistic and therefore difficult to fit into the categories; this concerned cases with extremely high window area in an office room at the corner of a building. Table 12 shows which characteristics were varied and how.

Table 12. Survey of the varied characteristics in the calculations of category offices -c-

Orientation of the façade	for room at center of building façade: N = North O = East Z = South W = West for room at corner of building façade: combinations: NO, ZO, ON, OZ.
Glass area	1 = 30% of internally measured façade area 2 = 55% 3 = 75%
Window type	1 = single glazing, internal blinds 2 = single glazing, external blinds 3 = double glazing, internal blinds 4 = double glazing, external blinds blinds down during office hours at $q_s > 300$ W/m².
Lighting	0 = 0 W/m² 1 = 15 W/m² 2 = 30 W/m²

Special cases	L = building mass = 0.1 x original mass
	H = building mass = 3.0 x original mass
	D = room under roof
	V = infiltration and mechanical ventilation
	  increased with factor 3
	VC = infiltration constantly 240 m³/h,
	  mechanical ventilation 0 m³/h
	VN = infiltration increased with factor 3

The symbols refer to the codes used to identify each case; see appendix 2	

5.8 <u>Results</u>

5.8.1 Correlation process

For each category of situations the monthly heat demand values, Q_{HD}, obtained by the unsteady state calculations are compared with the total amounts of gain Q_G and losses Q_L, which are determined with the equations from chapter 4.

According equations (5) and (7) the correlation can be carried out on η_G against GLR, for η_G is simply $\eta_G =$ $(Q_L - Q_{HD})/Q_G$ and GLR is, also by definition, equal to Q_G/Q_L. Each month of each calculation case yields a point η_G, GLR; the best fit curve through these points leads to a $\eta_G(GLR)$ curve like the curve presented in figure 6 (section 3.3).

There are, however, two complications:

Complication 1, error analysis:

for small values of Q_G (e.g. months with little solar radiation) the value of Q_{HD} will be almost equal to the value of Q_L. In the determination of η_G (see above) the small difference between Q_{HD} and Q_L will be divided by the small value for Q_G. The effect is that minor deviations in Q_L or Q_{HD} will be blown up in η_G.

For example, if GLR = 0.10 it is expected that $\eta_G = 1.0$,

which means that $Q_{HD}/Q_G = 9.0$

$$\eta_G = (Q_L - Q_{HD})/Q_G$$
$$= Q_L/Q_G - Q_{HD}/Q_G$$
$$= 10.0 - 9.0 = 1.0$$

If, by second or third order effects, Q_{HD}/Q_G

deviates only one percent from the value 9.0, then η_G

deviates 10 percent from the expected value 1.0.

One will observe this effect in the figures of the next sections.

A better basis for finding a best fit curve is by taking the relation between <u>the relative overheating dT_R</u> and GLR:

for each month of each calculation case the value of dT_R is determined with the help of equation (13): $dT_R = (Q_G + Q_{HD})/Q_L$.

Now, a deviation in Q_{HD} in case of small Q_G will appear in dT_R in a realistic way.

Only in case Q_{HD} is small, then a <u>large</u> relative error in Q_{HD} (though small in absolute terms) will change into a <u>small</u> relative error in dT_R.

For example, if GLR = 0.90 and Q_{HD}/Q_L = 0.19 : dT_R = 1.09;

   a deviation of 10 percent in Q_{HD} leads to a deviation of less than 2 percent in dT_R.

However, this is exactly the tendency which one would like to see: a small <u>absolute</u> error in Q_{HD}, though large in relative terms when Q_{HD} is small, will appear as a small error in dT_R.

The η_G (GLR) curve can be derived easily from the relation between dT_R and GLR (see equation (12)).

Complication 2, Q_L and the parameter for thermostat setback

The parameter for thermostat setback, C_N (or C_{NWH} for offices) has yet to be determined.

However, the value for C_N (or C_{NWH}) is already needed in Q_L. Therefore, the full procedure is as follows: a whole range of possible C_N (or C_{NWH}) values is scanned; for each value of C_N (C_{NWH}) the points dT_R, GLR are determined and the best fit curve dT_R as function of GLR is calculated. The C_N-value which yields the best fit curve with the least root mean square deviation is selected as the "true" value.

5.8.2 Selected function to describe the utilization curve

Figures 7 and 8 show the shapes of the expected curves for η_G (GLR) and dT_R (GLR) respectively:

I   low GLR:

   the utilization of gains is 100 percent in case of low gains compared to the losses: η_G = 1;

   there is no overheating   : dT_R = 1.

III high GLR:

   the gains are (much) larger than the losses; the heat demand is zero;

   from the equation (5) it follows: $0 = Q_L - \eta_G \cdot Q_G$,

   so: η_G = 1/GLR;

and with equation (12) $(dT_R = 1 + (1 - \eta_G)GLR)$:
$$dT_R = GLR.$$

II intermediate zone:

in the ideal situation all gains are utilized 100 percent until the gains exceed the losses (GLR $\geq$ 1); from that point the heat demand is zero: so there is no intermediate zone. In a real situation however, the utilization factor will decrease gradually, see figure 7. The relative overheating will gradually rise, see figure 8.
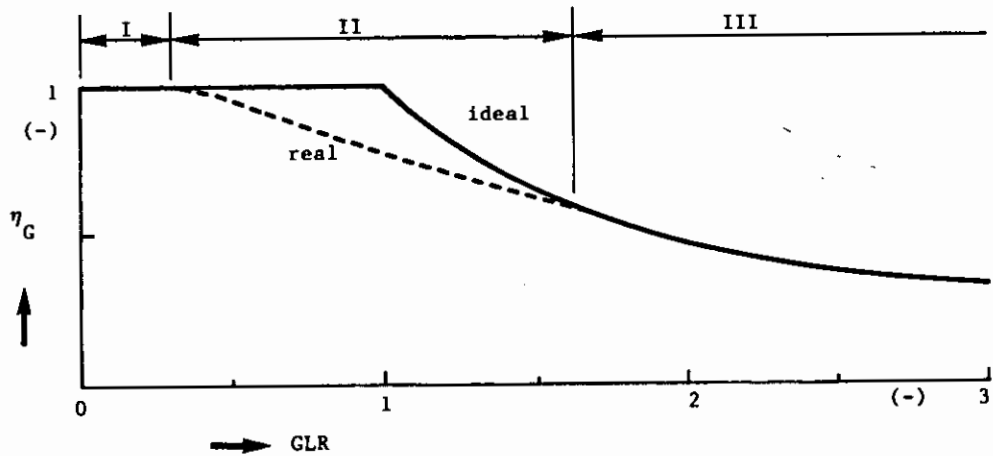
Figure 7. The gain utilization factor η_G as function of the gain loss ratio GLR
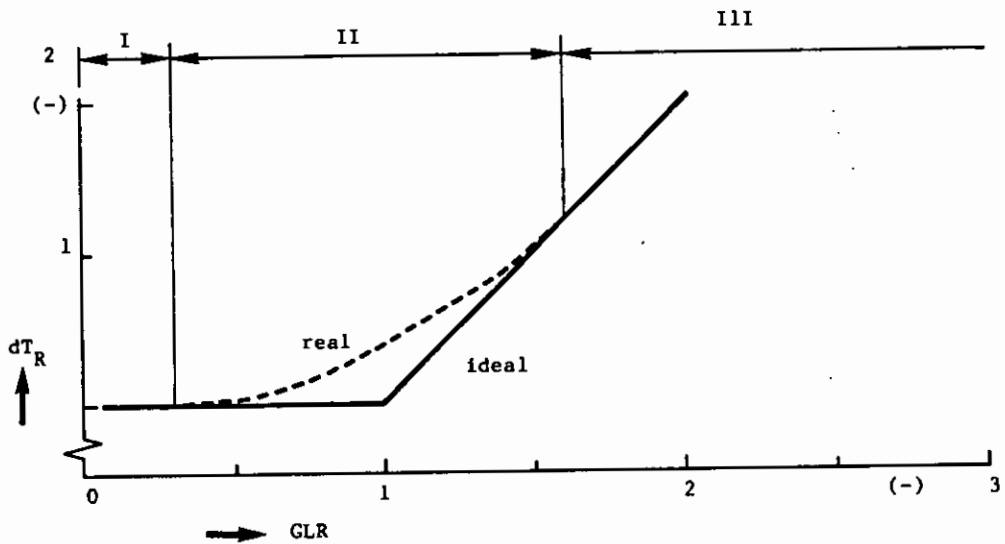
Figure 8. The relative overheating dT_R as function of the gain loss ratio GLR

An appropriate function has to be chosen to describe the utilization curve in the second zone in mathematical terms. The function should meet the following demands:

The function should:

- be continuous;
- not show abrupt changes at the transition point between zone I and II (first derivative should be continuous);
- not be too complex;
- be sufficiently flexible to cover a wide range of possible curve shapes;
- yield a good fit through the points.

A few possible functions will be discussed:

a. $\eta_G = a - b.GLR$ 　　　　　　　　　(37a)

　$dT_R = 1 + (1 - a).GLR + b.GLR^2$ 　　　(37b)

See figures 9 and 10.

The η_G (GLR) curve is a straight line; for most categories this appeared to lead to unsatisfactory results.

b. $\eta_G = b + (1 - a)/GLR$ 　　　　　　(38a)

　$dT_R = a + (1 - b).GLR$ 　　　　　　　(38b)

This type of function was used in the <u>seasonal</u> simplified methods developed at the TPD (see [13], [14], [15], [16]):

　$Q_{HD} = a.Q_{out} - b.Q_{in}$; a and b were derived from the best fit straight line through the points representing the seasonal dT_R as function of Q_{in}/Q_{out}. Q_{in} is identical with Q_G, Q_{out} is slightly different from Q_L.

However, figure 9 clearly shows that the <u>monthly</u> utilization factor is not represented satisfactory with a curve according to this function, because of the abrupt change from the value $\eta_G = 1$.
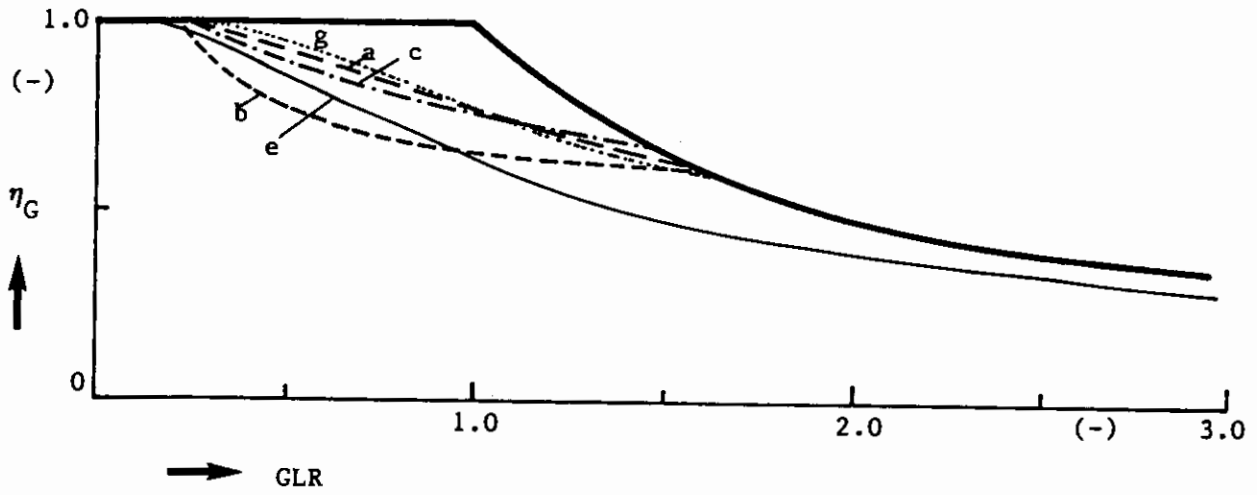
Figure 9. Illustration of the effect of the choice of mathematical
function for the utilization curve.
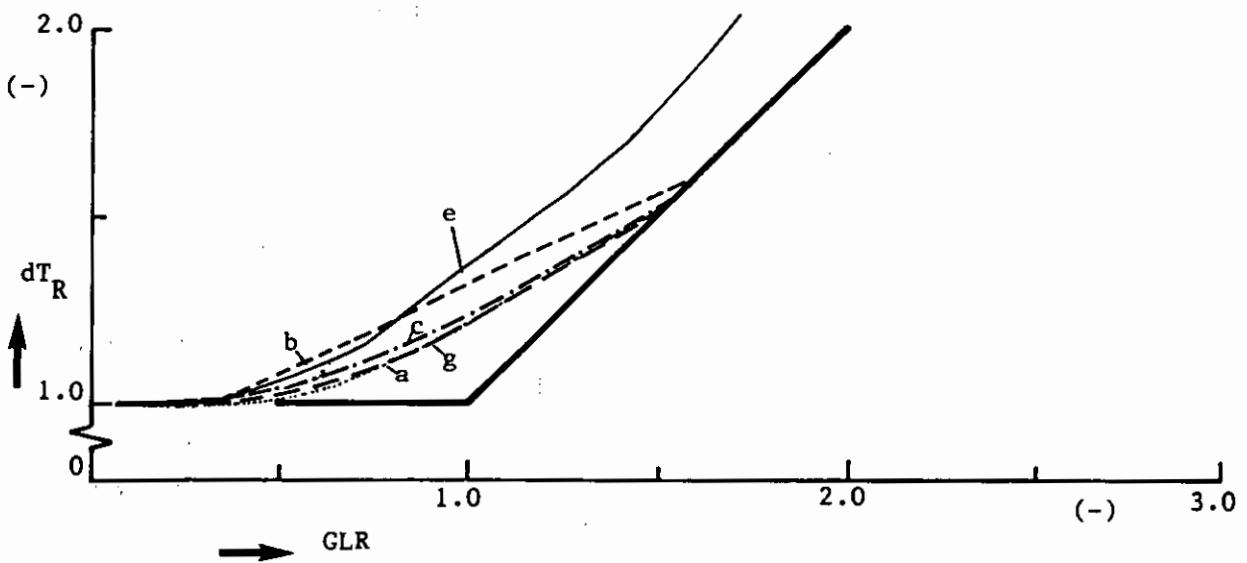
Figure 10. Illustration of the effect of the choice of mathematical
function for the relative overheating curve.

c. $\eta_G = a/GLR + b + c.GLR$ (39a)

$dT_R = (1 - a) + (1 - b).GLR - c.GLR^2$ (39b)

See figures 9 and 10.

The change from $\eta_G = 1$ to $\eta_G < 1$ appeared too abrupt.

d. $\eta_G = \dfrac{P_1 + P_2 \; . \; GLR^{P3}}{1 + P_2 \; . \; GLR^{P3+1}}$ (40)

This type of function is used by Barakat to get best fit curves for similar kinds of utilization factor versus gain loss ratio curves. See [9], [10]. In [9] and [10] it is shown that this type of function leads to very satisfactory curves. However, the function is rather complex; it is in general not possible to understand the kind of difference between two utilization curves from a comparison of the respective parameter values.

e. $\eta_G = 1 - e^{-1/GLR}$

$(dT_R = 1 + GLR.e^{-1/GLR})$ (41)

This type of function can be found in an annex to a recent ISO draft proposal [7]. See figures 9 and 10. The function is simple and clear; however, in this form it leaves no room to distinguish between different categories. Therefore, in [8] it is proposed to add a parameter K:

f. $\eta_G = 1 - e^{-K/GLR}$ (42)

$(dT_R = 1 + GLR.e^{-K/GLR})$

The function is however still not flexible enough. Therefore, for the analysis of the results of this study a similar function was tried, with a second parameter D:

g. $\eta_G = 1 - e^{-K/(GLR-D)}$ (43a)

$dT_R = 1 + GLR.e^{-K/(GLR-D)}$ (43b)

See figures 9 and 10.

This function appeared to be a quite satisfactory compromise with respect to the requirements mentioned before. Therefore the correlations were carried out with this function and thus the parameter values K and D were derived for each category of situations.

5.8.3 Results

In table 13 the results of the correlation procedure are presented: for each of the categories the value for the thermostat setback correction C_N (offices C_{NWH}) and the parameters for the utilization curve, K and D.

For the category -c-, offices, it appeared necessary to apply the correction for cold surfaces, introduction section 4.1.4. Again for offices a value $C_{NWH} = 1$ for the thermostat setback correction has been used as a basis for the correlation procedure; no attempts have been made to optimize the C_{NWH}-value.

A graphical presentation is given in the figures 11-20. Each of the figures gives for a certain category the following curves:

a. the monthly gain utilization factor, η_G, as function of gain loss ratio GLR;

b. the monthly relative overheating, dT_R, as function of gain loss ratio GLR;

c. the monthly heat demand, Q_{HD}, - divided by the heat loss Q_L to get a dimensionless number - as function of gain loss ratio GLR;

d. the annual heat demand as a summation of monthly heat demands calculated with the simplified method, compared to the annual heat demand calculated with the unsteady state computermodel DYWON. In the figures the standard deviation is presented as an indicator for the mean deviation.
Unit: MWh.

Table 13. The results of the correlation procedure for each of categories of situations.

Category -a-:
 * dwellings
 * convective heating
 * thermostat controlled
   by air temp.
	* threshold for solar shading:
	   incident rad. 300 W/m²
	 * no increased ventilation
	   in case of overheating		

Subcategories:	C_N	K	D
a-1. - masonry type - night setback	0.91	1.36	0.29
a-2. - masonry type - continuous heating	0.97	1.35	0.27
a-3. - wooden frame type - night setback	0.88	1.22	0.13
a-4. - wooden frame type - continuous heating	0.97	1.19	0.00

Category -b-:
 * dwellings
 * radiator heating
 * thermostat controlled
   by comfort temp.
	* threshold for solar shading:
	   incident rad. 500 W/m²
	 * increased ventilation in
	   case of overheating		

Subcategories:	C_N	K	D
b-1. - heavy mass - night setback	0.90	1.19	0.45
b-2. - heavy mass - continuous heating	1.00	1.70	0.02
b-3 - lightweight mass - night setback	0.92	1.10	0.37

Category -c-:
 * offices (not mechanically
   cooled)
 * convective heating
 * thermostat controlled by
   air temp.
	* threshold for solar shading:
	   300 W/m² (only office hours)
	 * no increased ventilation in
	   case of overheating		

Subcategories:	C_{NWH}	K	D
c-1. - heavy weight	1.0	1.55	- 0.16
c-3. - light weight	1.0	1.14	- 0.05
c-5. - extra heavy weight	1.0	1.64	- 0.16
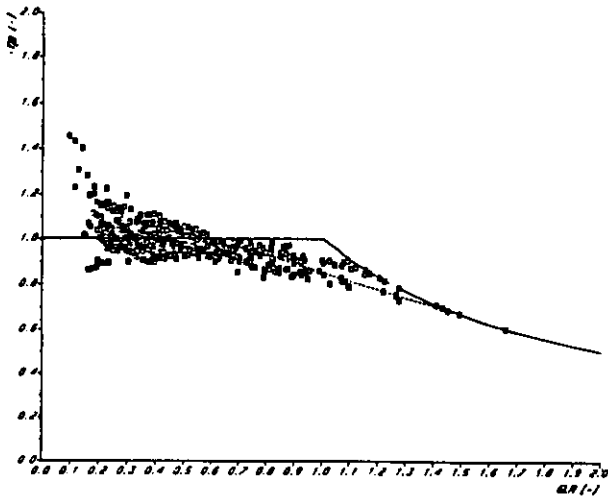
a. gain utilization factor η_G as function of GLR.
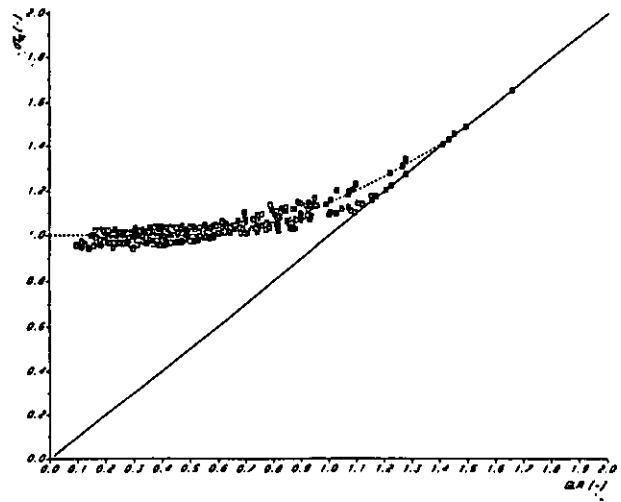
b. relative overheating dT_R as function of GLR
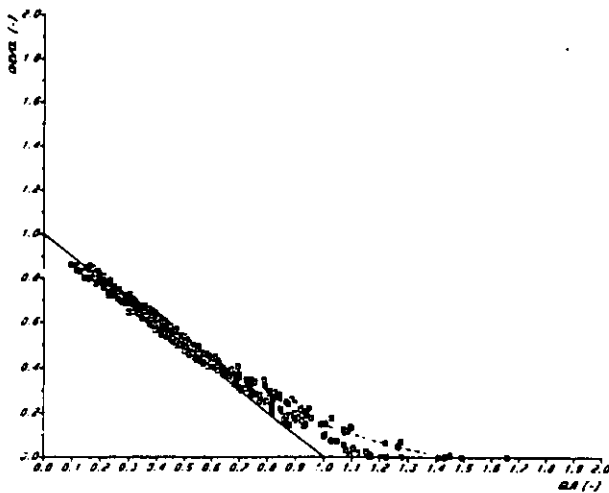
c. dimensionless monthly heat demand Q_{HD}/Q_L as function of GLR.

d. verification of annual heat demand calculated with the simplified method against original computer calculation results.

Figure 11. Category a-1; explanation: see table 13.
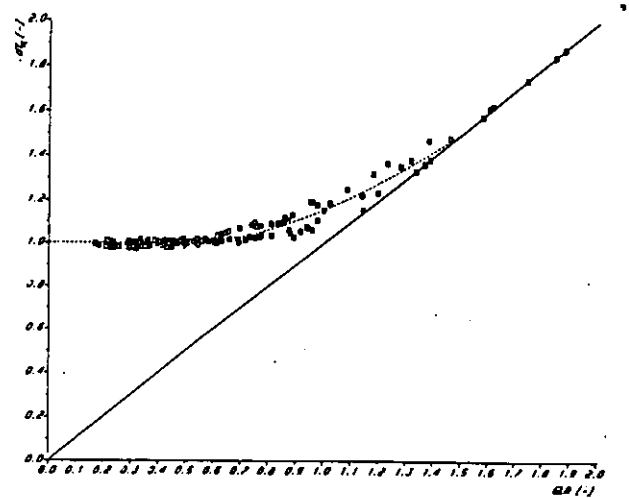
a. gain utilization factor η_G
   as function of GLR.

b. relative overheating
   dT_R as function of GLR
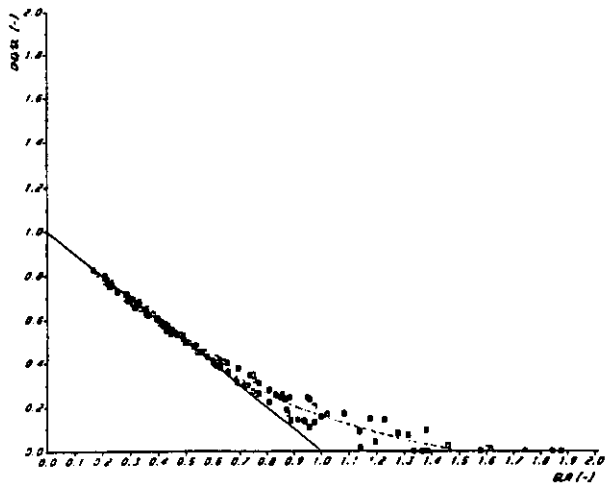
c. dimensionless monthly heat
   demand Q_{HD}/Q_L as function
   of GLR.
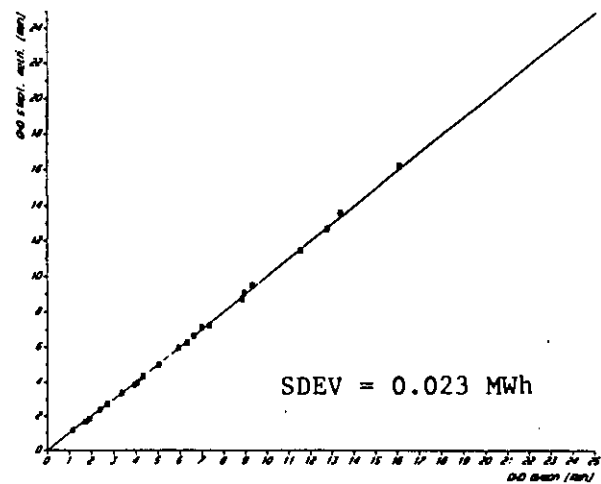
d. verification of annual heat
   demand calculated with the
   simplified method against
   original computer calcula-
   tion results.

Figure 12. Category a-2; explanation: see table 13.
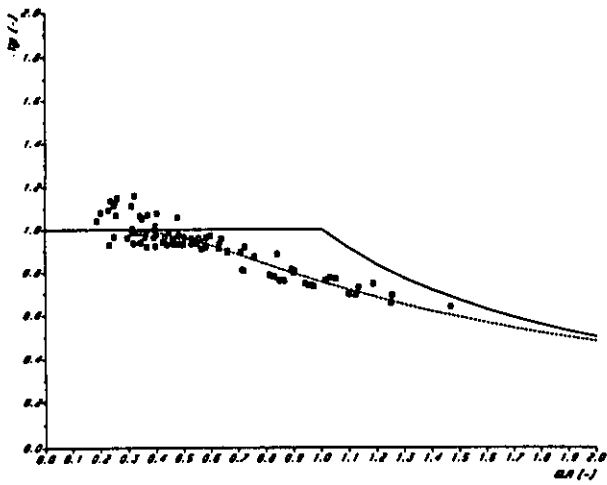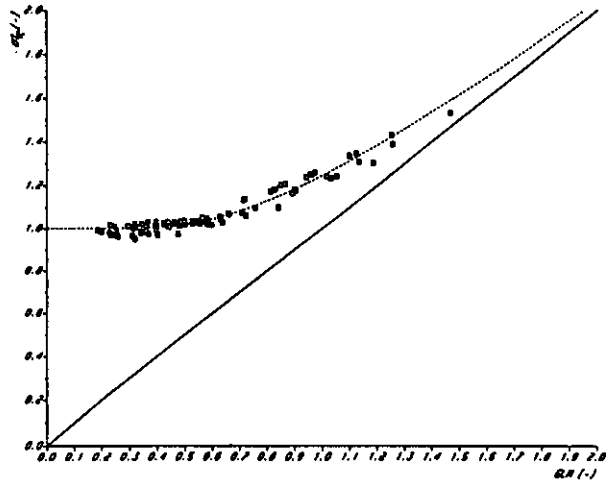
a. gain utilization factor η_G
   as function of GLR.

b. relative overheating
   dT_R as function of GLR.
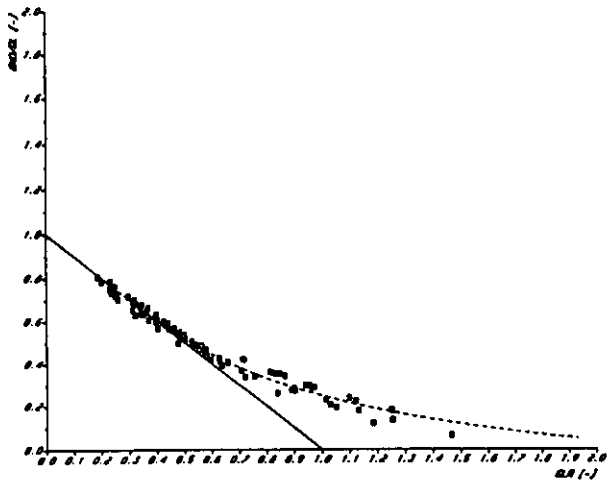
c. dimensionless monthly heat
   demand Q_{HD}/Q_L as function
   of GLR.
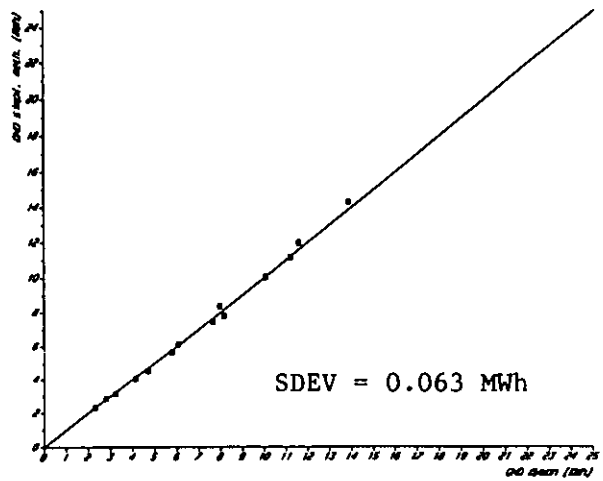
d. verification of annual
   demand calculated with the
   simplified method against
   original computer calcula-
   tion results.

Figure 13. Category a-3; explanation: see table 13.
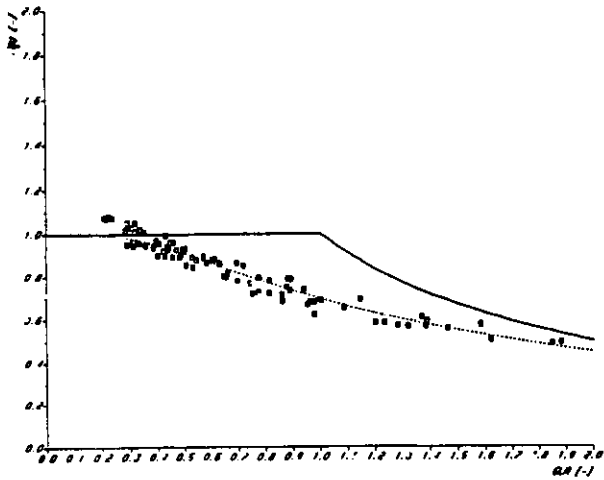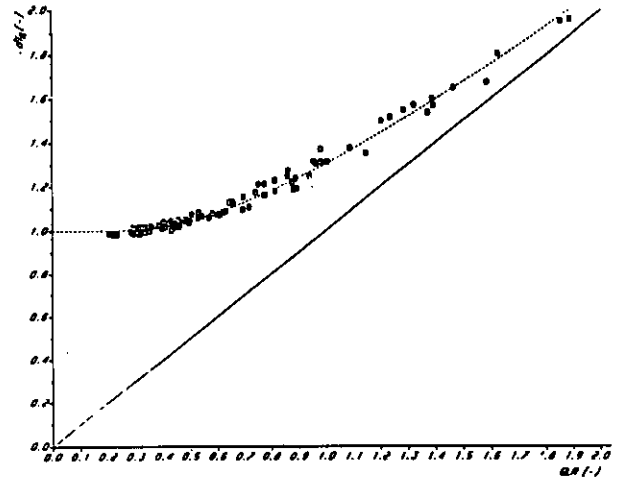
a. gain utilization factor η_G
   as function of GLR.

b. relative overheating
   dT_R as function of GLR.
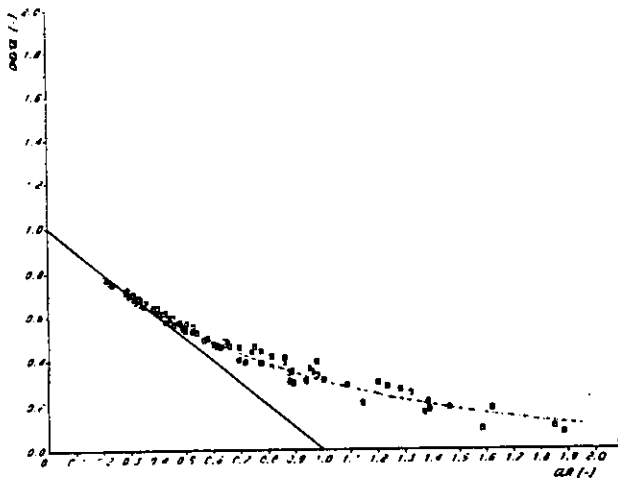
c. dimensionless monthly heat
   demand Q_{HD}/Q_L as function
   of GLR.
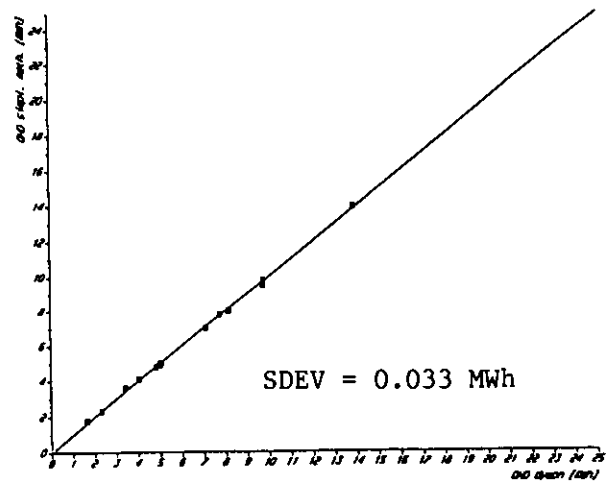
d. verification of annual
   demand calculated with the
   simplified method against
   original computer calcula-
   tion results.

Figure 14. Category a-4; explanation: see table 13.
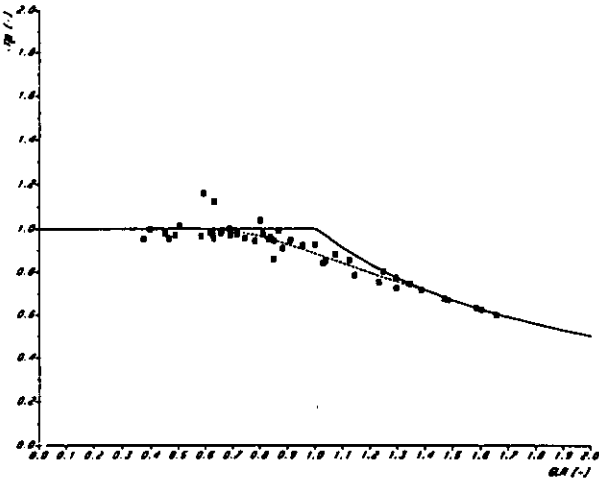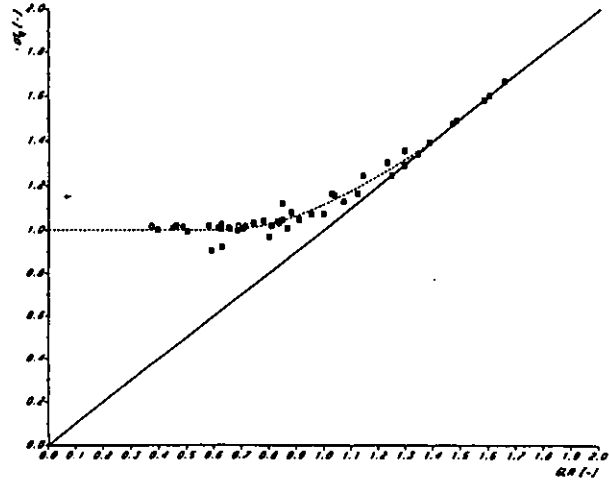
a. gain utilization factor η_G as function of GLR.

b. relative overheating dT_R as function of GLR.

c. dimensionless monthly heat demand Q_{HD}/Q_L as function of GLR.

SDEV = 0.017 MWh
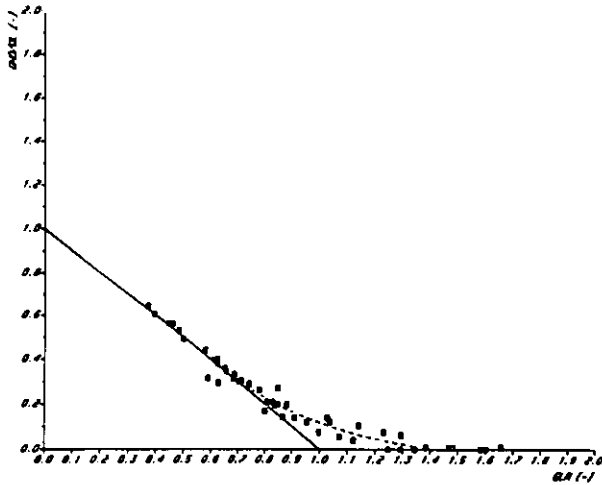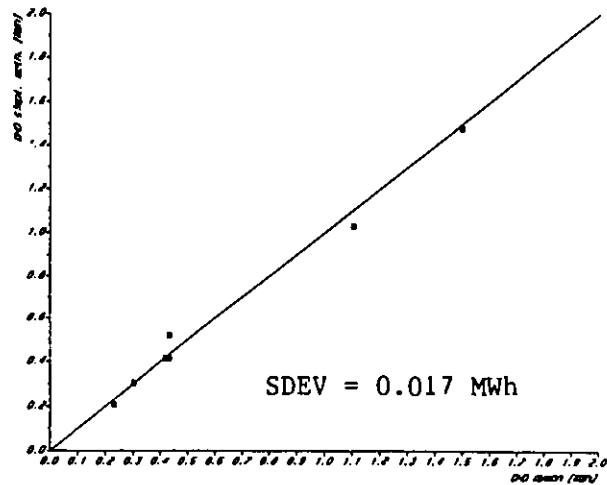
d. verification of annual demand calculated with the simplified method against original computer calculation results.

Figure 15. Category b-1; explanation: see table 13.
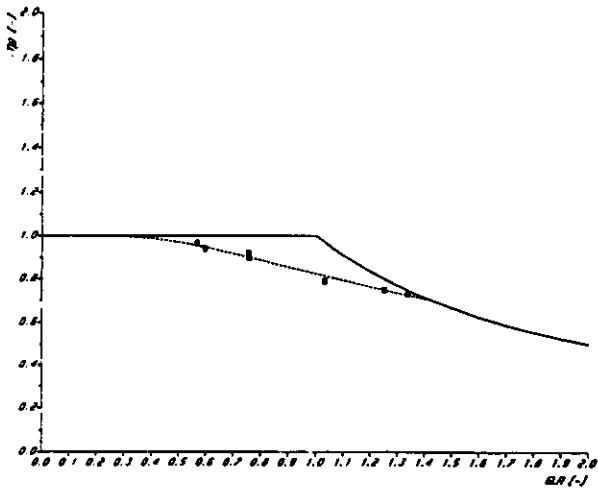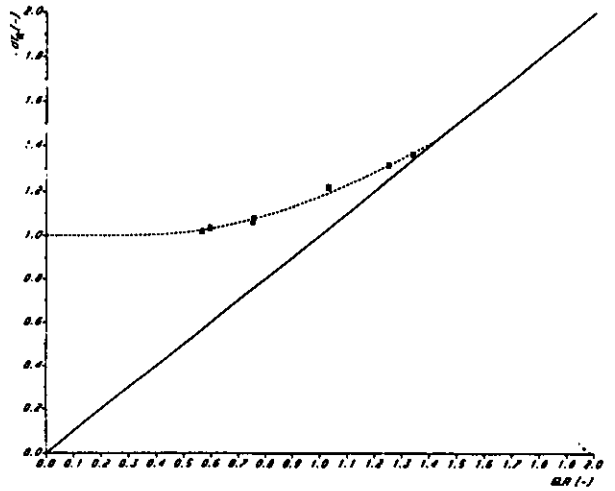
a. gain utilization factor η_G as function of GLR.

b. relative overheating dT_R as function of GLR.
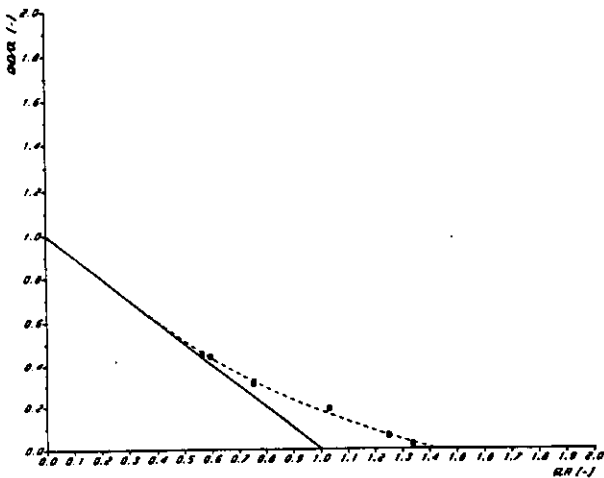
c. dimensionless monthly heat demand Q_{HD}/Q_L as function of GLR.
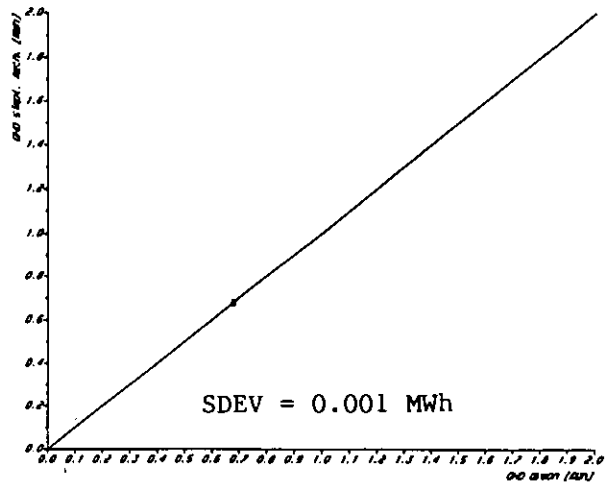
d. verification of annual demand calculated with the simplified method against original computer calculation results.

Figure 16. Category b-2; explanation: see table 13.
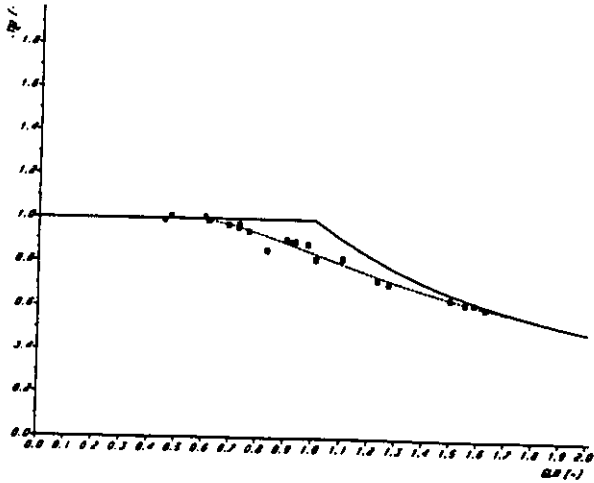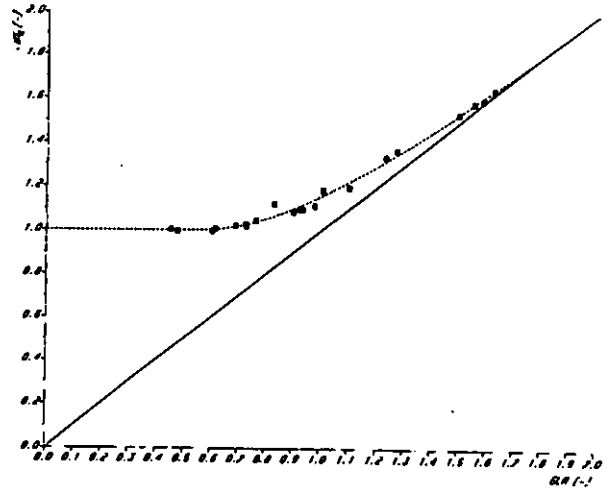
a. gain utilization factor η_G
   as function of GLR.

b. relative overheating
   dT_R as function of GLR.

c. dimensionless monthly heat
   demand Q_{HD}/Q_L as function
   of GLR.

d. verification of annual
   demand calculated with the
   simplified method against
   original computer calcula-
   tion results.

SDEV = 0.008 MWh
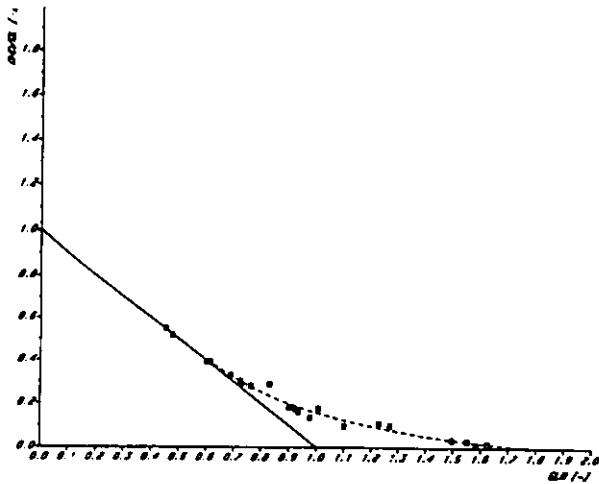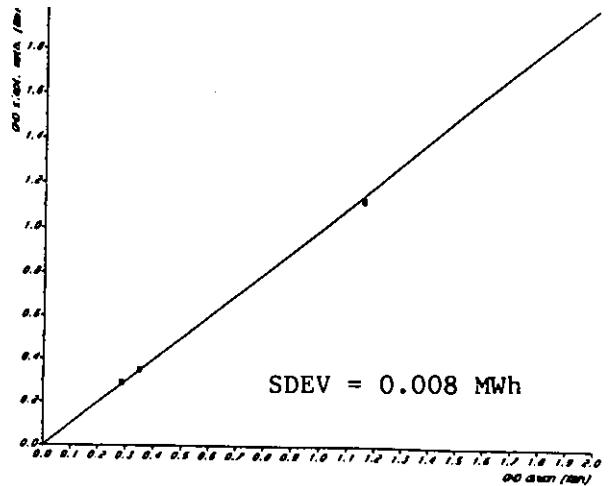
Figure 17. Category b-3; explanation: see table 13.
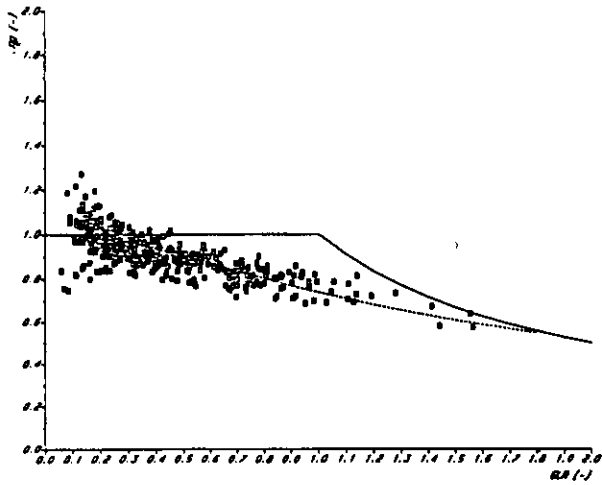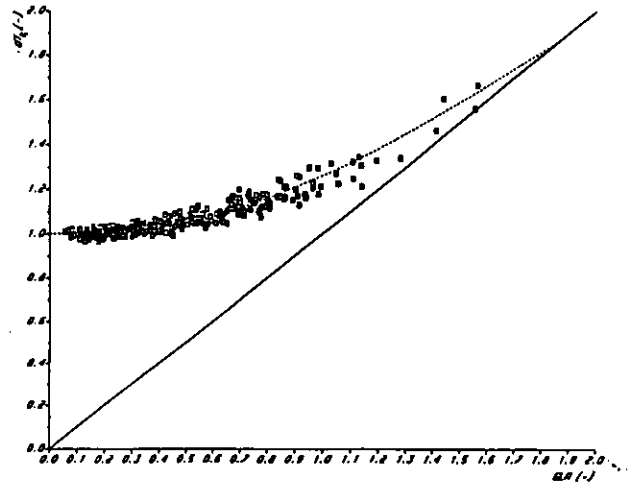
a. gain utilization factor η_G as function of GLR.

b. relative overheating dT_R as function of GLR.
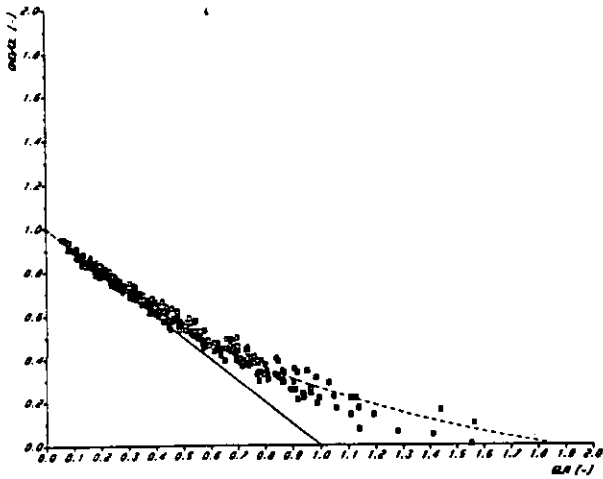
c. dimensionless monthly heat demand Q_{HD}/Q_L as function of GLR.
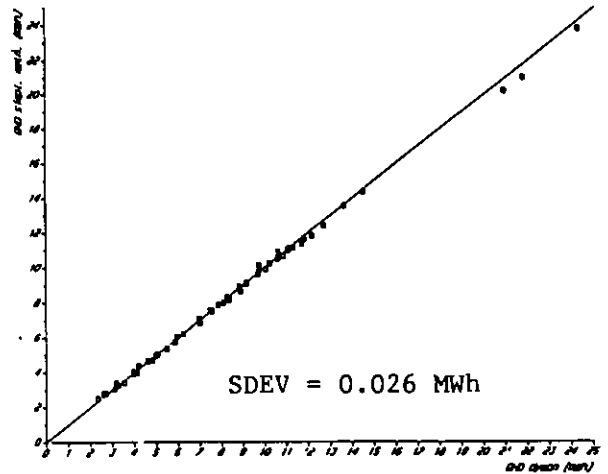
d. verification of annual demand calculated with the simplified method against original computer calculation results.

Figure 18. Category c-1; explanation: see table 13.
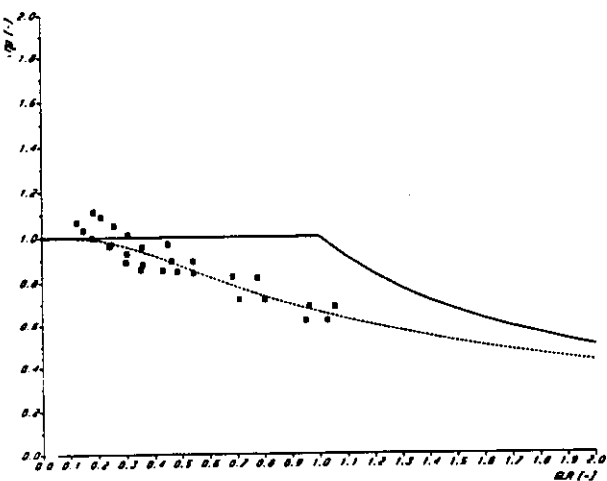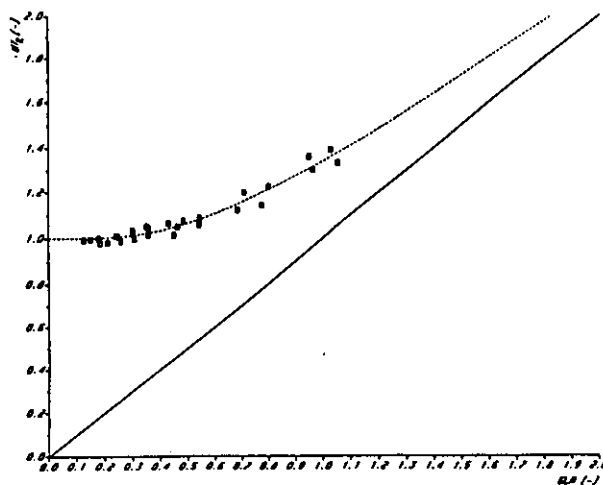
a. gain utilization factor η_G as function of GLR.

b. relative overheating dT_R as function of GLR.
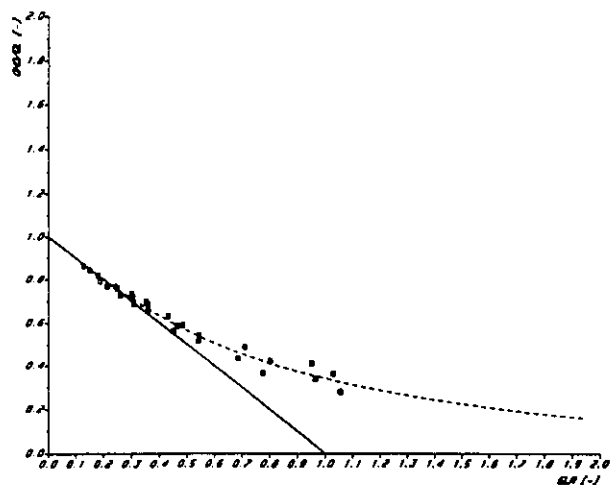
c. dimensionless monthly heat demand Q_{HD}/Q_L as function of GLR.
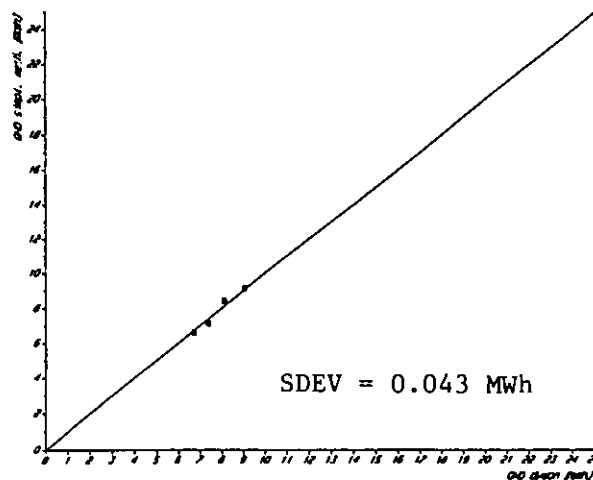
d. verification of annual demand calculated with the simplified method against original computer calculation results.

Figure 19. Category c-3; explanation: see table 13.
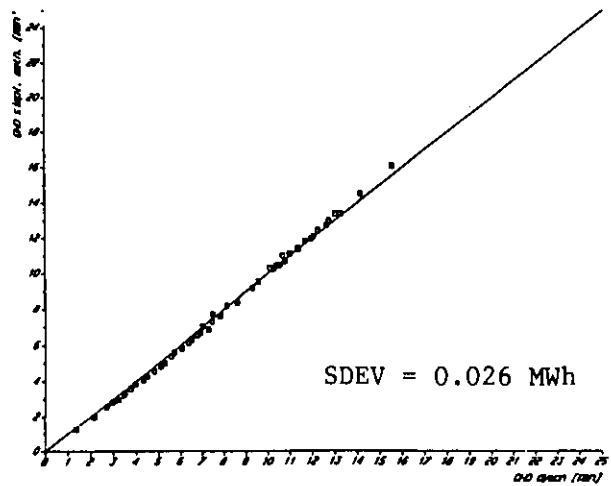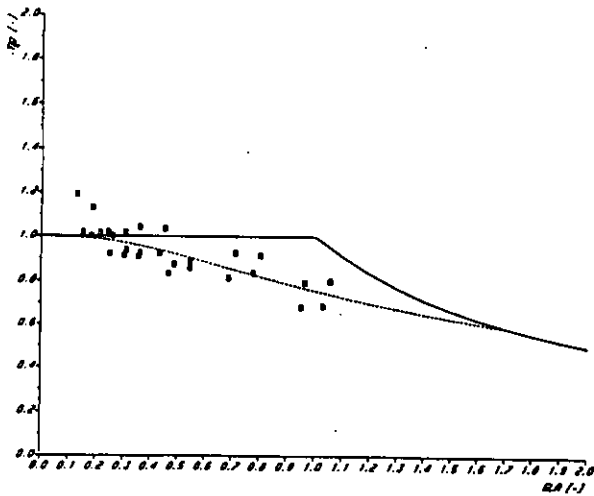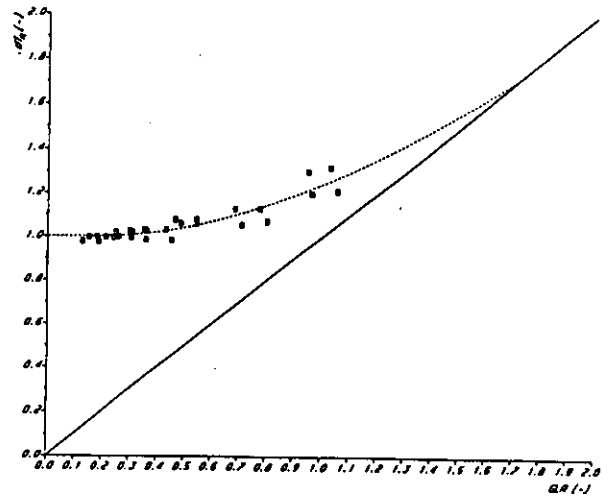
a. gain utilization factor η_G
   as function of GLR.

b. relative overheating
   dT_R as function of GLR.
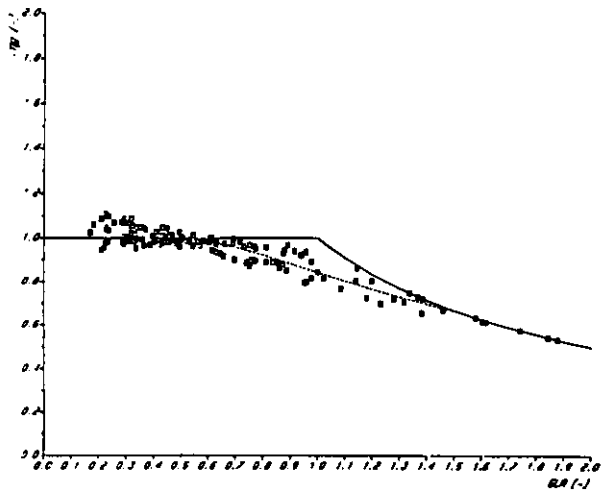
c. dimensionless monthly heat
   demand Q_{HD}/Q_L as function
   of GLR.

d. verification of annual
   demand calculated with the
   simplified method against
   original computer calcula-
   tion results.

SDEV = 0.043 MWh
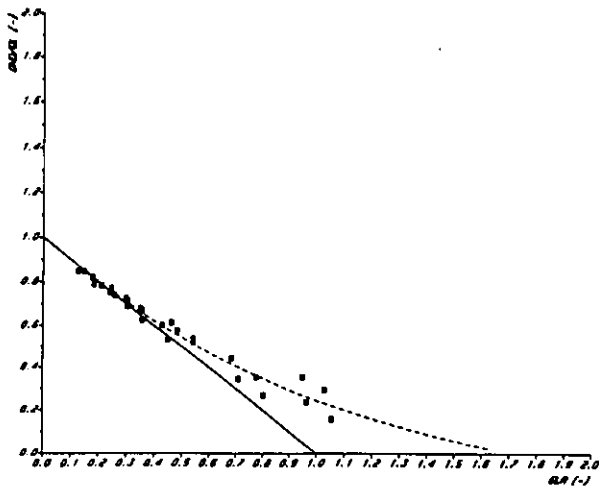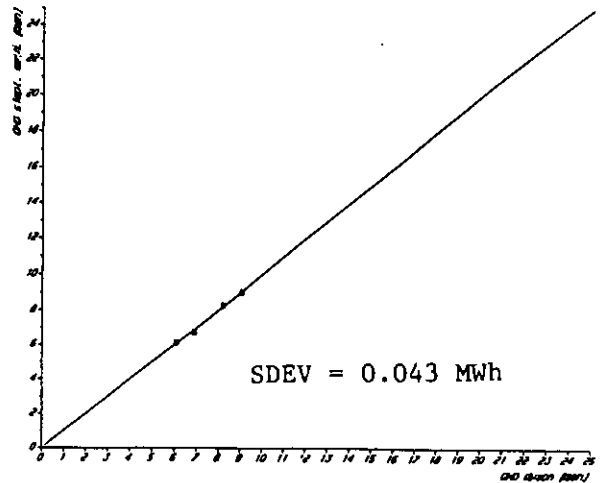
Figure 20. Category c-5; explanation: see table 13.

5.9 Discussion

From the figures 11-20 the following general conclusions can be drawn:

distinction between categories:

the distinction in categories appears to be well chosen: each category is represented by a distinct set of parameters C_N, K and D, resulting in utilization factor and relative overheating curves which are typical for that category;

accuracy of annual heat demand:

the agreement between the summation of monthly heat demands calculated with the simplified method and the annual heat demand from the original DYWON unsteady state calculations is good, as the figures 11d-20d show. Both the individual deviations and the standard deviation are small.

reliability of monthly results:

the scatter of the points in the presentation of the monthly results indicate that despite a good agreement on an annual basis, the discrepancies on a monthly basis are not negligible.

Firstly, however, one should realize, that the deviation in η_G in the low GLR range may be large, but their influence on the heat demand is small, because the gain itself is small; as already pointed out in section 5.8.1 the dT_R (GLR) function shows the scatter around the curves in a better proportion.

Possible causes for the scatter are:

- some "carry-over" effect between the months: heat accumulated in one month and utilized in the next month;
- second order effects in the unsteady state calculations, like:
  - U-values and solar transmittance factors are temperature dependent; in the simplified method a fixed value is used;
  - bandwidth of 0.5 K in thermostat control in case of radiator heating;
  - distinct temperatures for indoor air and surface temperature of each construction, so the various heat loss terms have different indoor temperatures;

   ° hourly patterns of e.g. internal heat gains, which may have a
     different effect for different cases.
 - simplifications in the equations of he simplified method, like:
   ° the correction factor for thermostat setback (see discussion in
     section 4.1.2);
   ° the change in the window's U-value in case of solar shading is
     neglected for simplicity reasons.
From the scatter in the figures 11c-20c it can be concluded that
the inaccuracies in monthly heat demands are in general 5 percent
or less <u>of the heat loss</u>. This means that in case of a small heat
demand, in case of high amount of gains, the <u>relative</u> error in the
heat demand can be much larger. One should however realize that the
result of any method to predict the heat demand would be subject to
percentually large uncertainties: the heat demand is a small
difference between two large numbers. The <u>absolute</u> error will be
small.
Therefore, an error in monthly Q_{HD} of 5 percent of the value of
Q_L is quite satisfactory.

A comparison of the results for the various categories leads to the
following observations:

effect_of_building_mass:

a higher building mass leads to a higher utilization factor,
particularly in case of continuous heating (category a-2 versus
a-4). In case of thermostat setback the positive effect of a better
accumulation of solar energy is combined with the negative effect
of a less effective setback; the heavy weight building cools off
less quickly, but loses more heat during the night.
A comparison of categories c-3 and c-5 shows, that adding extra
mass into an already heavy weight building does not have a
significant influence.

effect_of_building_type:

particularly in case of a heavy weight building, the utilization
factor is for offices much lower than for dwellings: the solar heat
accumulated during daytime cannot be utilized during the evenings
because of the thermostat setback during non-working hours.

effect_of_thermostat_setback:

it is difficult to read from the presented curves the effect of the thermostat setback on the utilization factor; this is due to the fact that the thermostat setback influences, via Q_L, the position on the GLR-axis.

The values in table 13 for C_N for the categories with night setback compared with the values with continuous heating show the influence on the heat losses: the heat loss is 6-10% lower, depending on building mass and type of heating installation.

One would expect for continuous heating a value $C_N = 1$; however, for the categories a-2 and b-4 the best fit was reached for slightly lower values, probably compensating for other, second order, effects.

For offices, the value $C_{NWH} = 1$ has been used as a basis for the correlation procedure; no attempts have been made to optimize the C_{NWH}-value.

effect_of_type_of_heating_system_and_control:

in case of night setback the utilization factor is higher for the category -b- (radiator heating) than for the category -a- (convective heating); in case of continuous heating the situation is reversed. The differences are, however, only significant for the light weight mass situations (b-3 versus a-3).

6. APPLICATION OF THE SIMPLIFIED METHOD

6.1 Single zone situation

If a specific situation fits into one of the categories for which
the correlation parameters have been derived (C_N or C_{NWH},
for the thermostat setback, and K and D for the utilization factor
curve), then the simplified method can directly be applied to
calculate the monthly heating requirements.
To this extend the specifications of the building, occupants'
behaviour and type of heating installation and control are to be
used as well as the monthly integrated climate data (e.g. from the
tables in section 4.4) in the equations of sections 4.1 and 4.2.
This leads to monthly values of the total heat loss in a no gain
situation, Q_L, and the total heat gain, Q_G.
With equation (5): $Q_{HD} = Q_L - \eta_G \cdot Q_G$
and the relation between the utilization factor η_G and the gain
loss ratio GLR $= Q_G/Q_L$ the monthly heating requirements
Q_{HD} are easily determined.

The derivation of the correlation parameters was based on series of
calculations with the unsteady state model DYWON. DYWON has the
capability to deal with situations in which different zones (rooms
or other spaces), with different conditions have an interaction by
exchange of ventilation or transmission heat flows.
Nevertheless, all calculations have been carried out with single
zone situations, with only heat exchange between the considered
zone and the outdoor environment. Whereever relevant, also heat
losses to the ground via the groundfloor were taken into account;
also accumulation of heat into walls, floor or ceiling separating
the zone from identical zones was taken into account, but on a
monthly basis the integrated heat flows through these zone
boundaries are negligible.

Real multizone situations would have made it unnecessarily complicated to determine the correlation parameters: complicated, because the interaction between the conditions in the different zones would disturb the correlation process severely (the variables are not independent); unnecessarily complicated, because there is no principle difference between a single and a multi-zone situation.

The next section describes how to use the simplified method in a multi-zone situation.

In chapter 7 results of the application of the method in a multi-zone situation are presented and compared with multi-zone DYWON runs carried out on the same cases.

Final remark:

The correlation parameters have been derived for different categories of situations, some of these with a large variety of widely different cases. All calculations, however, have been carried out for the Dutch climate.

Nevertheless, there is no reason to expect that application for other climatic conditions would lead to significantly different η_G (GLR) curves. This confidence is based on the fact that each calculation case of the previous chapter consisted of seven monthly results with quite a spread in weather conditions. A different climate just means a different position on the GLR-axis.

Of course, one should be cautious in extrapolating to conditions which differ basicly from those assumed in the calculations.

6.2 <u>Multi-zone situation: the TPD Correlation based Multi-zone</u>
    <u>calculation method TCM-heat</u>

In principle the set up of the heat balance for a particular zone in a multi-zone situation is not different from the set up in a single zone situation. The heat losses by transmission and/or ventilation to other indoor spaces are an inseparable part of the sum of all transmission and ventilation heat losses of the considered zone. The term $\overline{\theta}_e$ in the equations of section 4.1 is the temperature of the adjacent space.

If the temperature of the adjacent space is higher than the temperature of the considered room the particular heat loss term is negative. It would, however, be wrong to consider such negative losses as part of the heat gains to the considered room: the heat loss terms, either "positive" or "negative", are a lineair function of the temperature difference; the internal and solar gains are independent of the temperature difference, as shown in the equations of sections 4.1 and 4.2.

NB: actually, it would have been more correct (but less transparant) to use the terms autonomous heat flows (gains) versus temperature dependent heat flows (± losses).

The only practical difficulty is, that in a multi-zone situation the temperature $\bar{\theta}_e$ of the adjacent zones may not be known beforehand, but have to be calculated by applying the simplified method to those zones too. Due to the interaction between the zones an iterative procedure is needed to solve the heat balances for all zones.

The following procedure leads to the desired results:

1. For each <u>heated</u> zone the most appropriate curve η_G (GLR) and setback correction C_N– or C_{NWH}–values are selected (for example from table 13). Calculate the mean minimum temperature (see section 4.1.1 and 4.1.2). As a first approximation it is assumed that $\bar{\theta}_{i,real} = \bar{\theta}_{i,min}$.

2. For each of <u>all</u> zones the sum of solar and internal gains Q_G are calculated (see section 4.2) and the overall specific heat loss coefficient per degree K temperature difference, H_L (see section 4.1.5).

3. For each of <u>all</u> zones the weighted mean ambient temperature, θ_a is calculated (see section 4.1.5).

4. For each <u>heated</u> zone the minimum heat losses Q_L can now be calculated simply with equation (4):

$$Q_L = H_L \cdot (\bar{\theta}_{i,min} - \bar{\theta}_a)dt$$

As a next step the value for GLR can be determined and the utilization factor, η_G from the selected curve. Equation (10) introducing the relative overheating dT_R can be used in this stage to calculate the real mean zone temperature, $\bar{\theta}_{i,real}$:

$$\bar{\theta}_{i,real} = \bar{\theta}_a + dT_R \cdot (\bar{\theta}_{i,min} - \bar{\theta}_a) \qquad (°C) \quad (44)$$

with dT_R determined according to equation (12).

For each <u>unheated</u> zone the real mean zone temperature can easily be derived from the heat balance equation (3), with zero heat demand, and equation (4) for the heat loss Q_L,real:

$$0 = H_L \cdot (\bar{\theta}_{i,real} - \bar{\theta}_a)dt - Q_G \qquad (MJ)$$

$$\text{So: } \bar{\theta}_{i,real} = (Q_G + H_L \cdot dt \cdot \bar{\theta}_a)/H_L \cdot dt \qquad (°C) \quad (45)$$

The temperatures according to equations (44) and (45) are the newly approximated temperatures which are only valid if the assumed mean ambient temperatures are valid. So:

5. Repeat the procedure starting from 2, using as $\bar{\theta}_e$ in case of adjacent zone the newly approximated temperature for that zone.This iteration can be stopped if the newly approximated temperatures are not different from the temperatures used at the start of the last iteration step.

6. For the heated zones the heat demand can be determined with equation (3).

7. The procedure can be repeated for the next month or 4 weeks period. The procedure of this <u>TPD Correlation based Multi-zone calculation method</u> which has received the name <u>TCM-heat</u> has been illustrated with a flow-chart in figure 21.
   Although it is basicly a hand calculation method the procedure as shown in figure 21 can only be carried out by hand in case of single zone situations, or multi-zone situations with a minimum of interactions between the zones.
   In general, a computerized version of the procedure will be required. A Fortran-version of TCM-heat has been written in order to be able to carry out the calculations with TCM-heat which are presented in the next two chapters.

The listing of the programme is given in <u>appendix 3</u>. The main data sets presented in the previous chapters, like the monthly climate data, various window types and the correlation parameters for the different categories have been adopted in the programme.
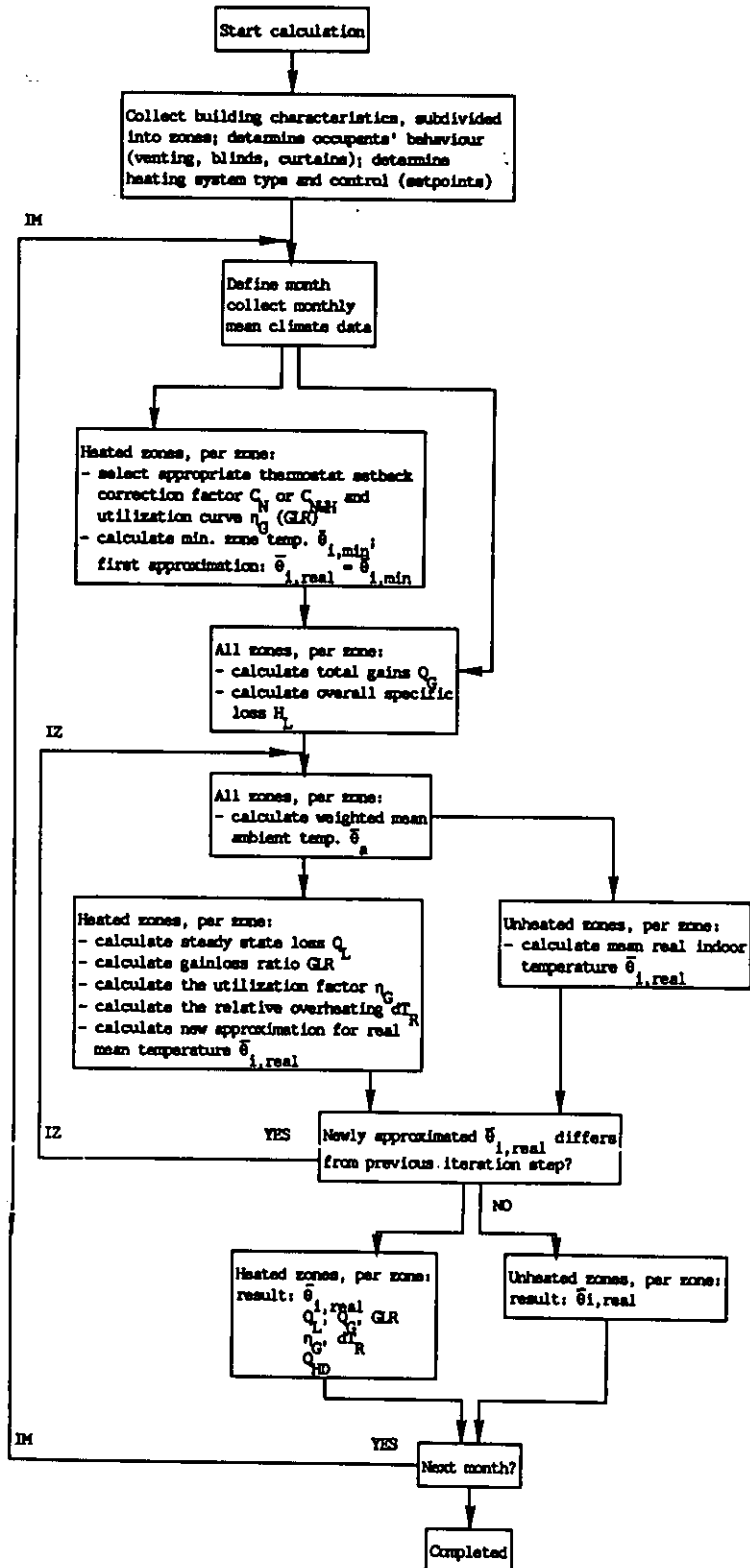
Figure 21. Flow chart to illustrate the calculation procedure of the TPD Correlation based Multi-zone calculation method (TCM-heat).
In a single zone application the iteration loop IZ is a single step calculation.

7. VERIFICATION OF THE SIMPLIFIED METHOD TCM-HEAT IN A MULTI-ZONE CALCULATION AGAINST DYWON

7.1 Introduction

The developed simplified method TCM-heat could be validated against measured energy consumption in a real building. However, it would require an extreme effort to measure sufficient quantities in order to be able to compare the measured and calculated results and to evaluate possible discrepancies.

Instead of a comparison with measurements TCM-heat has been compared with the result of an hour by hour computercalculation in a complicated multi-zone situation, using the computer programme DYWON which also was used to develop the simplified method.

For a description of DYWON: see section 5.3.

Of course, with this approach possible deviations of DYWON results from a real situation remain undetected. Nevertheless, a verification in a complicated multi-zone situation will reveal the sensitivity of the results for the simplifications and approximations in the simplified method.

7.2 Description of the selected calculation cases

For the comparison a situation has been selected which has a maximum of possibilities for the simplified method to fail:

- dwelling subdivided into 5 zones (living room, kitchen, bedrooms North and South and attic);
- highly insulated heavy mass house in a row (with relatively large mutuel influences between the zones); see figure 22;
- radiator heating system with thermostatic valves on the radiators and a room thermostat in the living room controlling the burner;
- radiators placed in front of the façades underneath the windows;
- thermostat night set back on all thermostats;
- indoor venetian blinds on the windows, used during hours with incident insolation exceeding 500 W/m²;
- curtains on all windows closed between sunset and sunrise;
- increased ventilation at mean dwelling temperature above 26°C;
- unheated attic;

DHV   6

3.   WONINGONTWERP

S   N

VOORGEVEL   ACHTERGEVEL   DOORSNEDE A-A

BEGANE GROND   VERDIEPING   ZOLDER
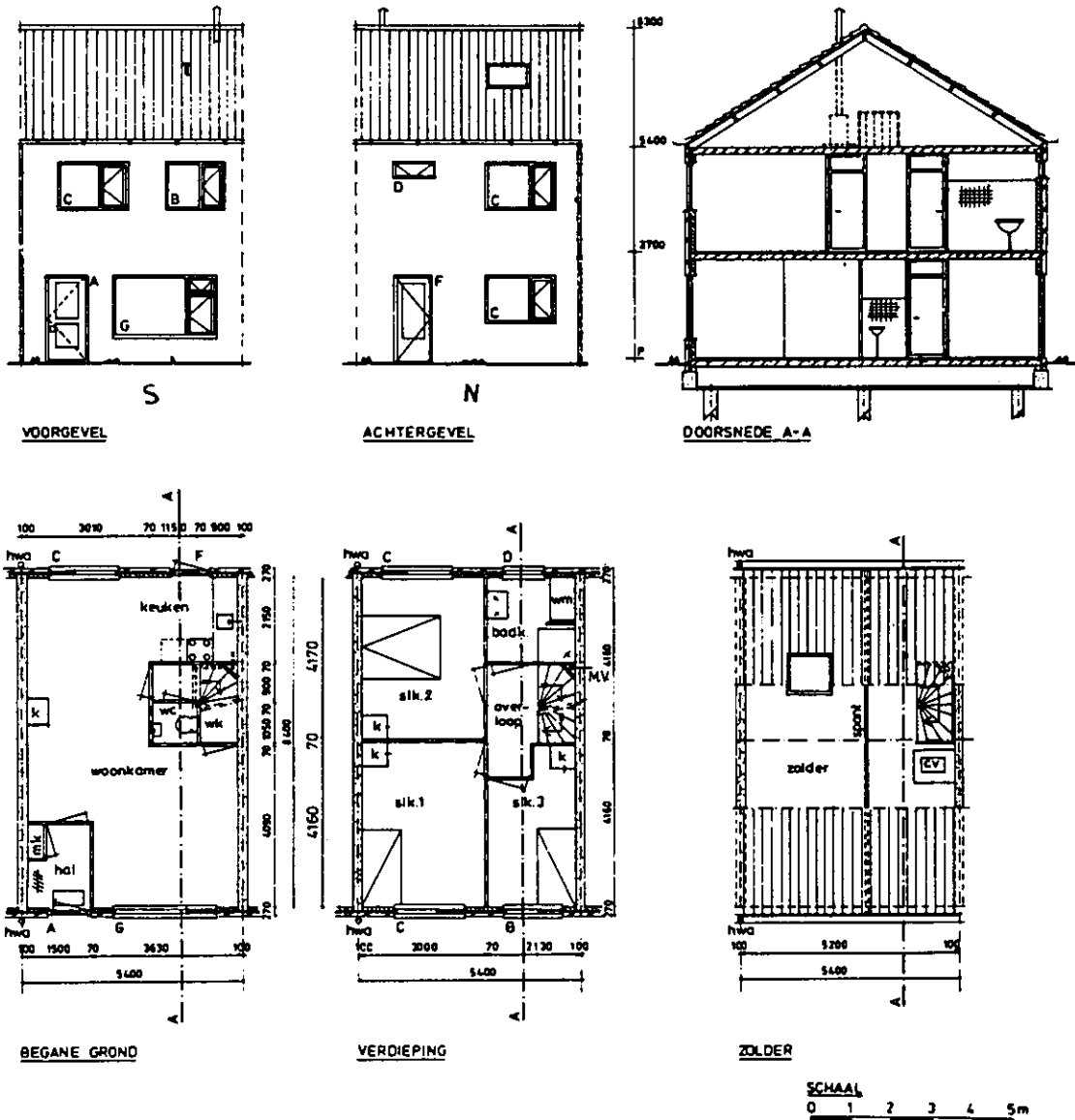
SCHAAL
0   1   2   3   4   5m

Opdrachtgever :	Schaal :	**DHV**	Red. datum
Ontwerper :		DHV Raadgevend Ingenieursbureau BV Technisch Adviesbureau voor de Vereniging van Nederlandse Gemeenten	Blad nr.
REFERENTIEWONING			Copyright DHV

Figure 22. Example of the type of dwelling selected for the multi-
          zone calculations: one of the DHV Dutch reference dwellings
          [22].

- two variations: case A: unheated bedrooms;

                       case B: heated bedrooms;

- daily internal heat patterns different per zone;

- ventilation exchange between zones.

The geometrical data have been based on one of the Dutch "DHV-reference dwellings" for newly built dwellings ([22]), with some minor modifications. For the calculation the dwelling has been divided into 5 zones:

- living room, with a large South and a smaller North window;

- kitchen, North façade;

- bedroom, South façade (in fact two South bedrooms combined);

- bedroom, North façade (in fact one bedroom plus bathroom combined);

- attic, unheated, without window.

The main characteristics can be found in table 14.

7.3 Results of the DYWON unsteady state calculations

The monthly results of the hour by hour calculation with DYWON are shown in the figures together with the results of the simplified method TCM-heat. As an illustration of the unsteady state behaviour hourly results are shown in figures 23 and 24 for a (cloudy) day in autumn. Figure 23 shows the hourly heat supplied by the radiators in living room (a) and the bedrooms (b and c) and the energy consumed by the boiler (d). The living room temperature is regulated by a room thermostat controlling the boiler; the kitchen and bedrooms have thermostatic valves on the radiators. The figure clearly shows, for instance, how the radiators still give off heat while the boiler is already switched off (at 9.00 and 23.00 o'clock).

Figure 24 shows the various indoor temperatures, in comparison with the thermostat settings. The presented temperatures are the average values between air and mean surfaces (including the radiators) of the zone.

Table 14. Main characteristics of the selected calculation cases.

Main geometry:

Room	Floor area (m²)	Window area (m²) South	North
Living room	40.20	5.50	3.00
Kitchen	7.80	--	2.50
Bedroom S.	22.62	3.50	--
Bedroom N.	22.62	--	3.50
Attic	45.24	--	--

Typical U-values (W/m²K)
    Window = 2.90
    Wall   = 0.40
    Roof   = 0.20

Ground floor: underneath insulated floor:
parallel conductances of 0.12 W/m²K to groundwater (10°C) and 0.50 W/m²K to monthly averaged outdoor temperature.

Main occupants' data:	thermostat setpoints (°C)			internal heat kWh/24hr.	ventilation m3/hour	
	day	evening	night		from outside	from other zones
Living room	18.50	20.00	14.50	5.54	31	0
Kitchen	18.50	20.00	14.50	5.04	14	47
Bedroom S.	18.00*	18.00*	12.00*	1.12	23	21
Bedroom N.	18.00*	18.00*	12.00*	0.56	19	0
Attic	–	–	–	0.00	39	0

* case B only

Temperatures: thermostat setpoints: hysteresis 0.5 K;
              room thermostat   : senses 60% air temperature and
                                   40% mean surface temperature
                                   (including radiators);
              radiator valves   : 70 and 30% respectively;
              comfort temperature defined as 60% air, 40% mean
                                   surface temperature (included
                                   radiators).

Climate: De Bilt, October 1964 – April 1965

The course of the temperatures also illustrates - even for such cloudy day - the unsteady state character. The peak temperature in the kitchen between 17.00 and 19.00 hour is, for instance, caused by the increased internal heat gains assumed during these hours for that zone. Also it is clearly to see how slowly the indoor temperatures drop during the night setback period.

7.4 Results obtained with the simplified method TCM-heat

A calculation has been carried out with TCM-heat, for all 7 months, for both cases A and B. The category for the night setback correction and for the η_G (GLR) curve is category b-1 (see table 13).

The results are presented in the figures 25-28, together with the monthly results of the DYWON.

In the next section the differences between the results with TCM-heat and DYWON will be discussed. Figure 25b, however, reveals already one of the dominant features of the selected calculation cases: the gain loss ratio GLR is high, particularly in autumn and spring. For instance in March the heat gains are almost as high as the losses and almost eight times as high as the heat demand! Figures 26 and 28 show another dominant feature of the selected cases: the mean ambient temperatures as seen by the respective zones is much higher than the outdoor temperature. This is due to the large interaction between the zones. The small temperature difference between zone and ambient temperature implies that the real mean zone temperature is very sensitive for minor changes in the situation or for minor deviations in the ambient conditions.

7.5 Verification of TCM-heat against DYWON

7.5.1 Main results

In tables 15 and 16 the results of the calculations with DYWON and with TCM-heat are summarized. The difference in annual heat demand is only about 10 percent. This difference is very small, considering the very low absolute value of the heat demand: the energy consumption for space heating is, conversed to natural gas, in the order of a few hundred m³ per year only.
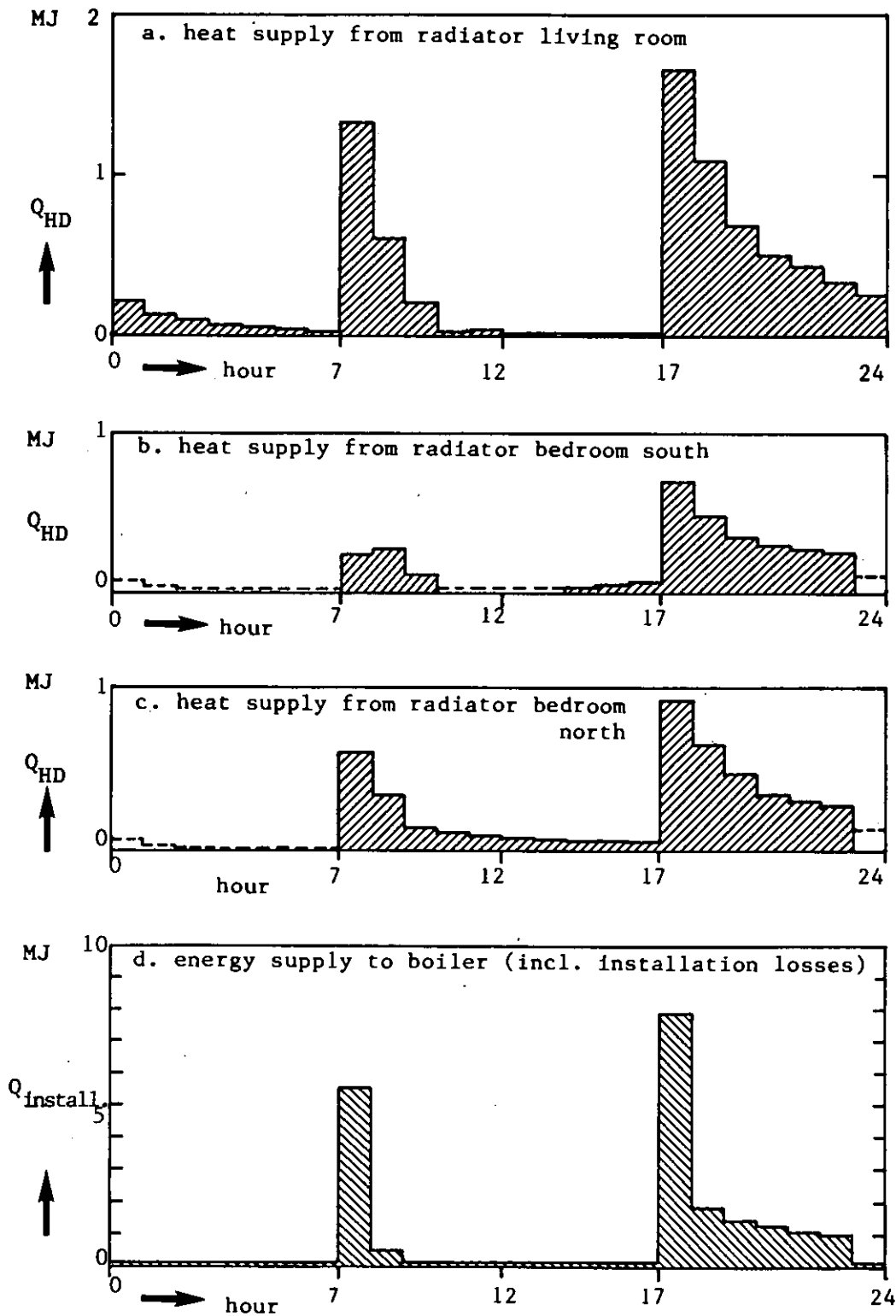
fig. a-c ————— : radiator fully or
partly open

－－－－－ : radiator closed

Figure 23. Illustration of energy consumption and heat supply by
the central heating system. Calculated hourly values
for a typical day in autumn (October 22, 1964); case
with heated bedrooms.
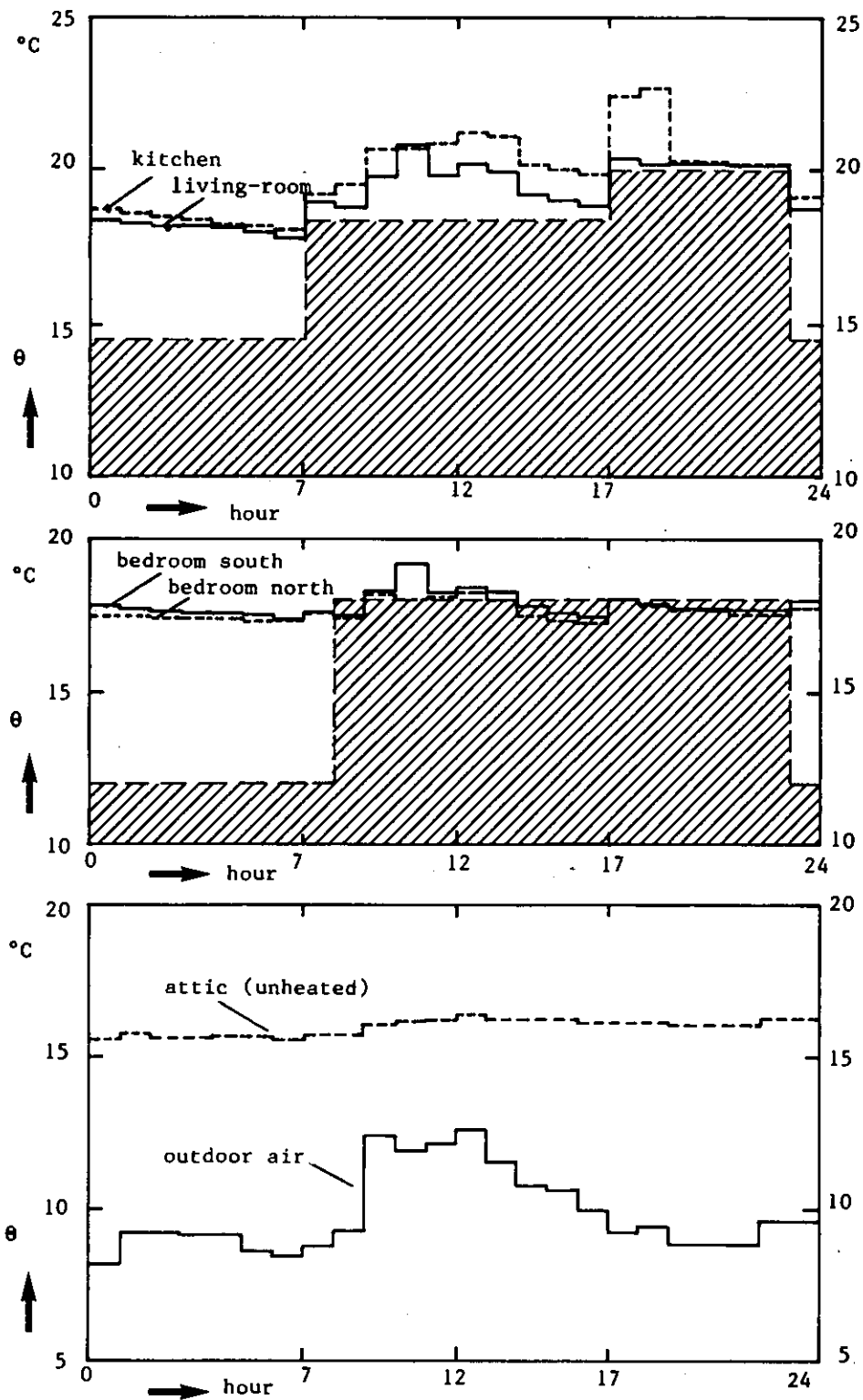
Figure 24. Illustration of room temperatures compared with thermostat settings and outdoor air temperature. Calculated hourly values for a typical day in autumn (October 22, 1964); case with heated bedrooms. Presented room temperatures are comfort temperatures (weighted average of air and surfaces).

This confirms that the chosen calculation cases are indeed quite extreme; certainly for the current building tradition in The Netherlands.

Table 15 also shows that some deviation occurs in the distribution of the heat demand (in fact: the heat supplied by the radiators) over the zones. This is not surprising because of the high interaction between the zones: the zones are separated by uninsulated floors and walls and are furthermore interconnected by ventilation heat flows.

Table 16 shows the distribution of the discrepancy in heat demand over the months. The month March is the largest contributor to the discrepancy of 10 percent in annual heat demand. As pointed out in the previous section, the calculated heat demand in March is almost eight times smaller than the heat gains during that month.

Table 15. Verification of the simplified method TCM-heat against DYWON unsteady state calculations in a complicated multi-zone situation; heating requirements over the heating season for the total dwelling and the distribution over the heated rooms.

Case	Method	Seasonal heating requirements total dwelling (MJ)	Distribution over the heated rooms (%)				
			living room	kitchen	bed-room South	bed-room North	attic
unheated	DYWON	8249	90	10	--	--	--
	TCM-heat	7457	86	14	--	--	--
bedrooms	diffe-rence (%)	- 10					
heated	DYWON	10547	47	3	25	25	--
	TCM-heat	9597	36	3	25	35	--
bedrooms	diffe-rence (%)	- 9					

Table 16. Verification of the simplified method TCM-heat against DYWON
unsteady state calculations in a complicated multi-zone
situation; distribution over the months of the discrepancy
in calculated heating requirements for the total dwelling.

Case	Distribution over the months of discrepancy in calculated heating requirements between DYWON and TCM-heat for the total dwelling (% of seasonal QHD*)							
	Season	Oct.	Nov.	Dec.	Jan.	Febr.	Mrch.	Apr.
unheated bedrooms	- 9.6	- 2.1	- 0.0	+ 0.5	- 0.4	- 1.4	- 5.5	- 0.6
heated bedrooms	- 9.0	- 2.0	- 0.5	- 0.2	- 0.8	- 1.2	- 4.0	- 0.4

*): defined as: $100*(Q_{HD,month}^{TCM} - Q_{HD,month}^{DYWON} / Q_{HD,season}^{DYWON}$.

7.5.2 Discussion of the results in detail

The figures 25-28 present a comparison of <u>monthly heating
requirements and mean temperatures</u>. Concerning the <u>heat demand</u>
for the total dwelling the discrepancies are only significant
for March and - to a less extend - for October. The monthly
heat demand is calculated with the equation:

$Q_{HD} = (Q_L - \eta_G \cdot Q_G)$. As figure 25 clearly shows,
the values for Q_L and Q_G are an order of magnitude
higher than Q_{HD}, so any minor deviation in the
determination of Q_L, Q_G or η_G will result in a
strongly exagerated high <u>relative</u> error in Q_{HD} for that
month. In absolute terms, and certainly in comparison with
Q_L and Q_G, the deviation is small.

NB: the fact that Q_{HD} in relative terms is so sensitive for
minor deviations, is not a matter of applied procedure; it is
purely a physical phenomenon which will occur in real
situations too: in such case as assumed in this chapter any
small change in e.g. occupants' behaviour or e.g. temperature
of adjacent buildings may result in a <u>relatively</u> large change
in the (still small) heat demand.

Figure 27 shows the discrepancies in the distribution of heat demand over the various zones, which was already discussed in the previous section.

The <u>mean temperatures</u> calculated with TCM-heat are generally in good agreement with the mean comfort temperature calculated with DYWON, though in some months the values are too low. The DYWON results are presented as a band; this band represents the difference between air and mean surface temperature. The simplified method TCM-heat knows only one indoor temperature. This is one of the possible causes for the deviation: the zone temperature calculated with TCM-heat is the temperature on which the heat losses are based. For instance, if ventilation losses are dominant the calculated temperature represents the air temperature. Or if, for instance, a window with high transmission losses 'sees' a cold floor surface inside the zone then the calculated temperature is more close to the low temperature of that floor.

A combination of underestimated temperatures and underestimated heat demand for the same month is an indication that the utilization factor for the gains is overestimated. This might be another cause for the deviations revealed by the figures. As figure 15a showed one should allow some uncertainty around the utilization factor curve: $\pm$ 5 percent of the value of Q_L (see section 5.9).

A plausible third cause for deviation is the correction factor for the thermostat night setback. In section 4.1.2 the correction factor C_N was discussed. It was concluded that a refinement could improve the adequacy of the correction for night setback to deal particularly with complicated multi-zone situations. The effect of a refinement would be limited, but would probably for the presented cases lead to a slight increase of mean indoor temperature, accompagnied with an increase in heat demand.

The control of the heating system may also be a cause for some deviation. In figure 23 it can clearly be seen that if the burner is switched off, the radiator in the living room continues to give off heat until the water is cooled off. In fact, one could call this unutilized heat supply from the heating system; like the unutilized solar and internal gains it will lead to an increased mean indoor temperature (overheating). The original single zone DYWON calculations on which the parameters of category B1 are based would show the same phenomenon. One can, however, imagine that the influence of the inertia of the heating system can vary easily from situation to situation. Also the hysteresis of 0.5K in the thermostatic valves and room thermostat may lead for the DYWON results to incidental minor deviations from the setpoints (see figure 23).

Furthermore: the room thermostat in the living room controls the burner. On hours in which the living room has no heat demand, other rooms may experience a shortage of heat.

Finally, the deviation might partly be due to the difference in window and other building component characteristics. In DYWON the thermal and solar transmitted heat flows are calculated on an hourly basis. The indoor surface heat transfer coefficients are calculated each hour on the basis of the actual local temperature differences. The thermal and solar transmittances in the simplified method are <u>constant</u> U- and g-values, based upon assumed mean heat transfer coeficients. For example: the window U-value is assumed to be U = 2.9 W/m²K, based upon indoor heat transfer coefficient

$h_i = 8$ W/m²K.

<u>If</u>, for the selected calculation case, the mean coefficient $h_i = 6$ instead of 8, then the mean thermal transmittance of

the window is 10 percent lower than expected ($\overline{U} = 2.6$ W/m²K).

Summarizing, the following possible causes for the deviations can be identified:

- different "definition" of indoor temperature;
- error band around the utilization curve;
- inadequacy of the night setback correction approach.
- inertial effects of the radiator heating system;
- type of control of the heating system;
- deviation from nominal steady state characteristics
  (U and g).

Nevertheless, the overall agreement between the results of TCM-heat and DYWON is quite satisfactory, if one takes into account that the deviations in distribution of heat demand over the zones and over the months and the deviations in mean zone temperatures are caused by the high gainloss ratio in the concerned zone and month.
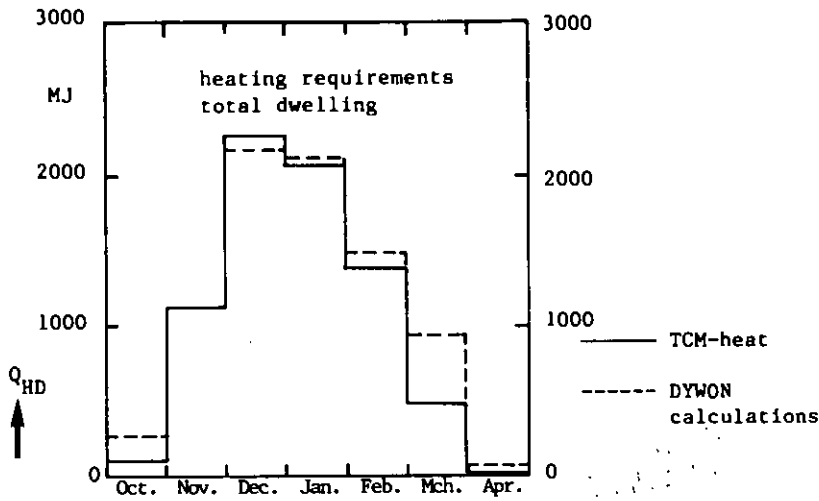
a. total heat supplied by the radiators; comparison of unsteady
   state calculation with the simplified method.
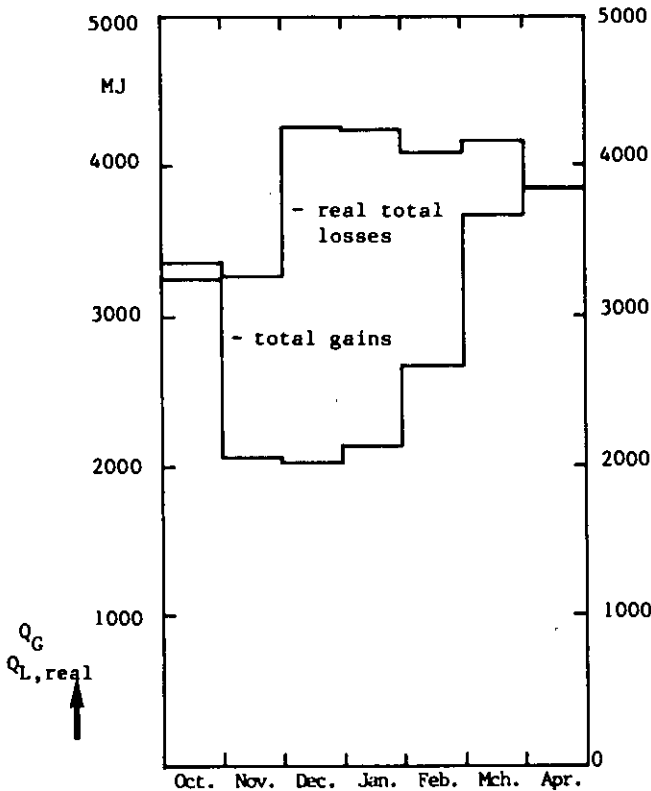
b. total gains versus losses, showing that in autumn and spring the
   heat demand is a very small difference of two large numbers.

Figure 25. Verification of TCM-heat against DYWON unsteady state
　　　　　　calculations in a complicated multi-zone situation; case
　　　　　　with unheated bedrooms.
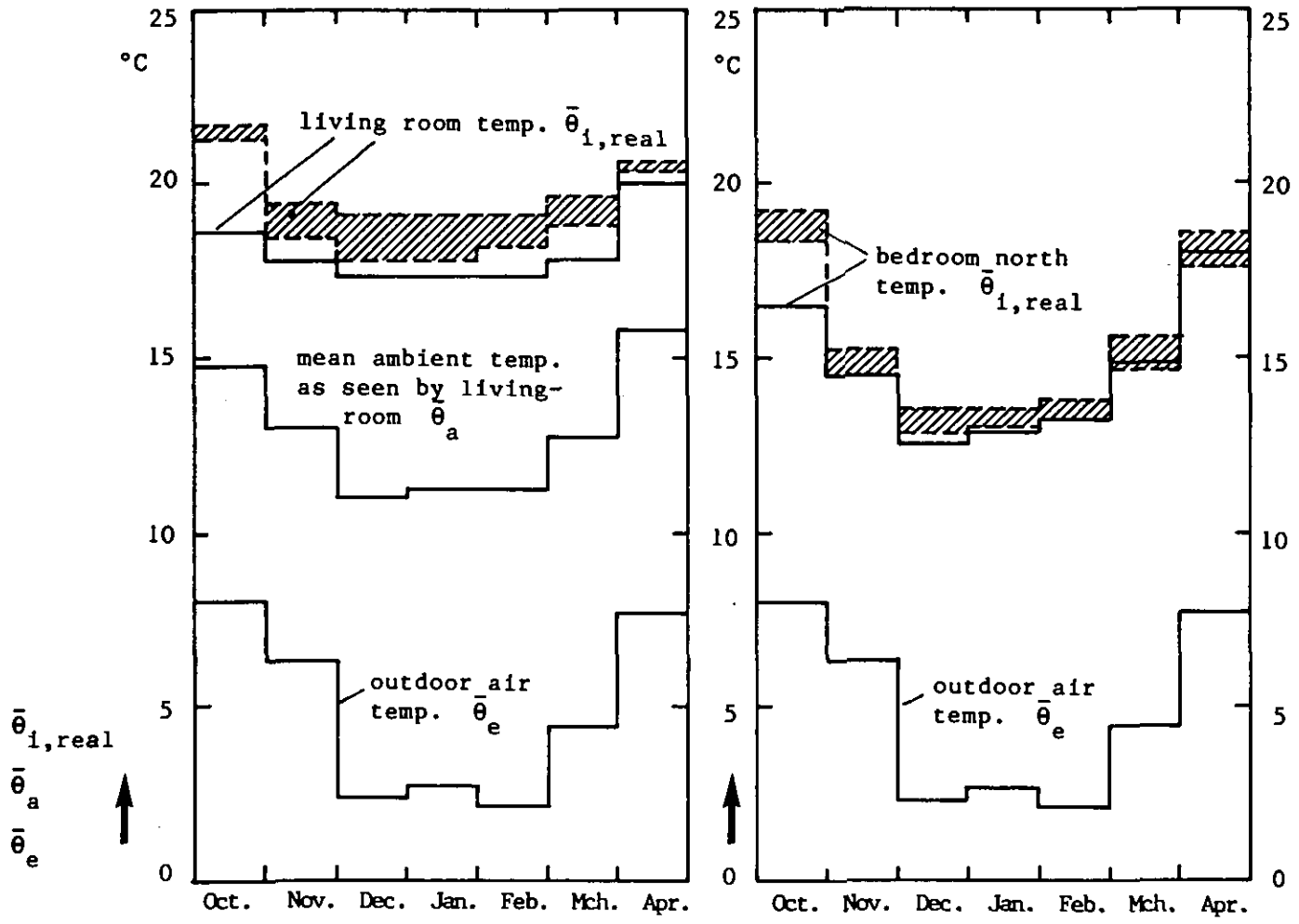
Figure 26. Verification of TCM-heat against DYWON unsteady state
calculations in a complicated multi-zone situation; case
with unheated bedrooms; mean indoor temperature of the
living room and bedroom North.

The figure also shows the weighted mean ambient tempe-
rature, θ_a as experienced by the living room
(weighted mean of outdoor, ground and adjacent rooms).
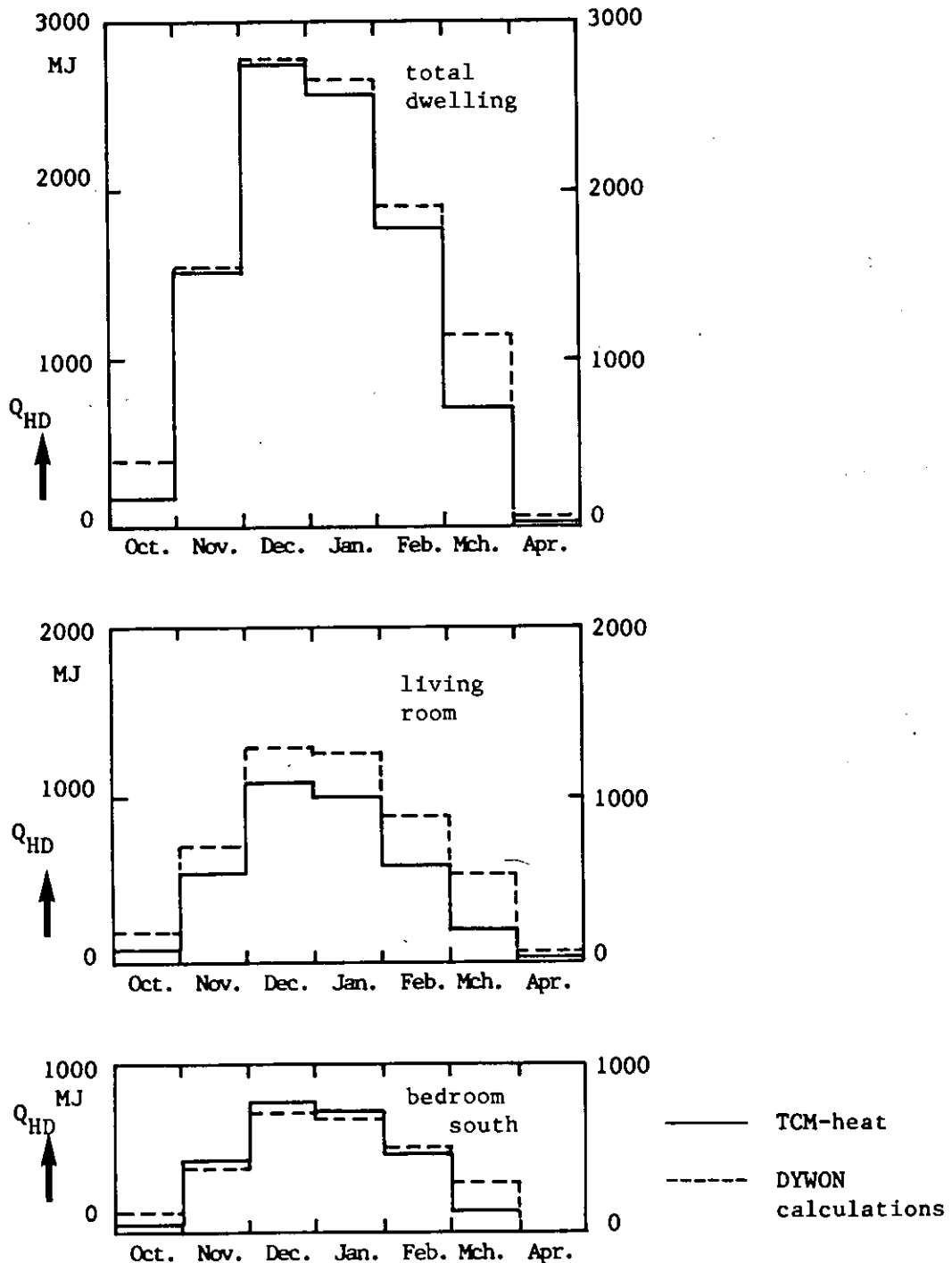
Figure 27. Verification of TCM-heat against DYWON unsteady state
calculations in a complicated multi-zone situation; case
with heated bedrooms. Presented are the heating
requirements for the total dwelling, for the living room
and for the South bedroom; the heating requirements are
the amounts of heat supplied by the radiators.
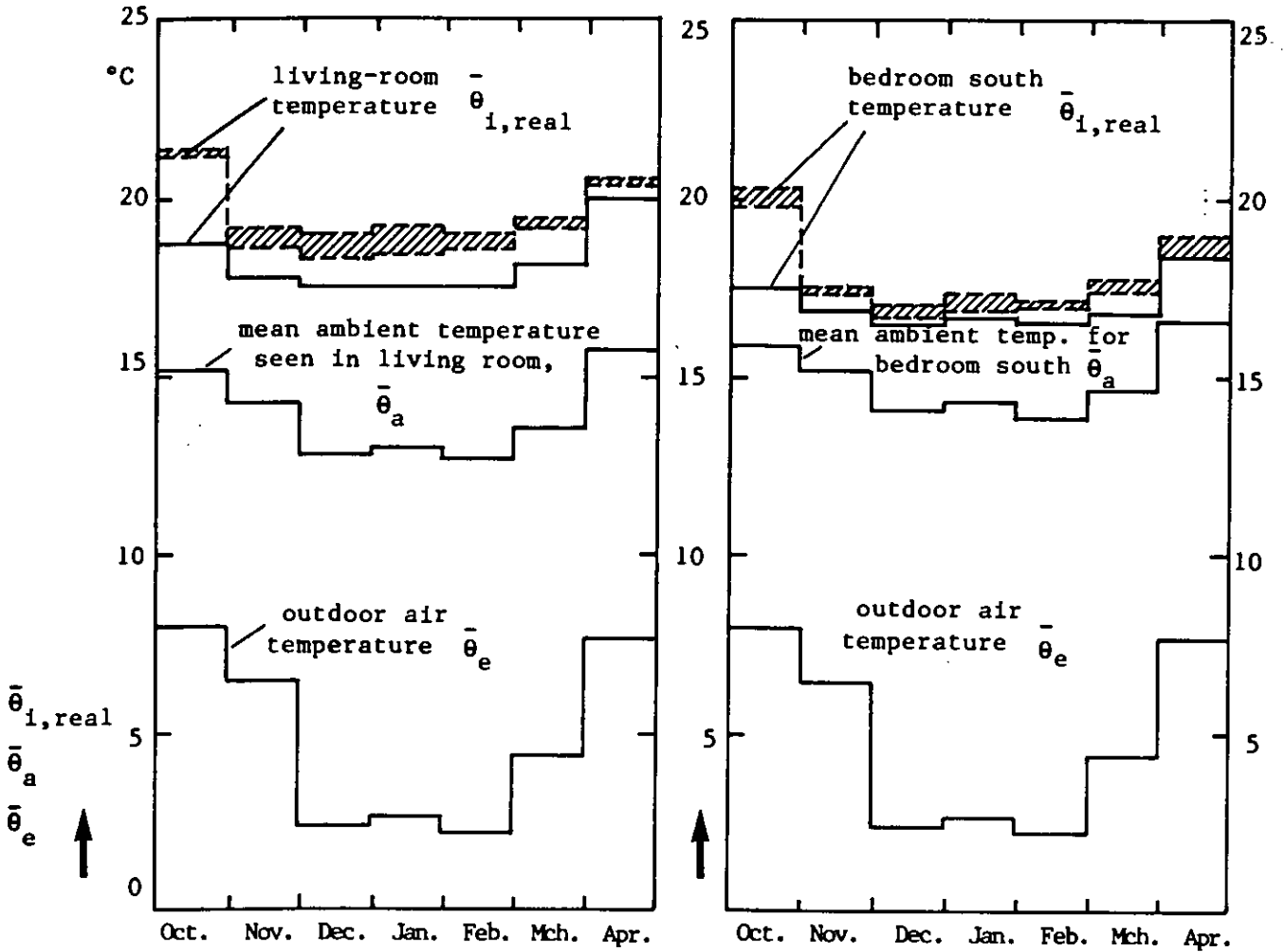
Figure 28. Verification of TCM-heat against DYWON unsteady state calculations in a complicated multi-zone situation; case with heated bedrooms; mean indoor temperature of the living room and bedroom South.

The figure also shows the weighted mean ambient temperatures as experienced by both rooms (weighted mean of outdoor, ground and adjacent rooms).

8. <u>SENSITIVITY STUDIES WITH TCM-HEAT TO ILLUSTRATE THE INFLUENCE OF</u>
   <u>WINDOWS IN TYPICAL SITUATIONS</u>

8.1 Introduction

As illustration of the possibilities of the simplified method TCM-
heat a number of calculations have been performed. A reference
dwelling has been selected and a number of characteristics have
been varied which show the influence of the changes on the heat
demand. In the selection of variations the emphasis was put on the
effect of windows.

The number of variations is kept limited for two reasons:

1. the simplified method is easy to use for similar sensitivity
   analyses, using different assumptions or conditions;

2. a high number of variations would suggest that all possible
   situations have been covered; one of the most attractive aspects
   of TCM-heat is, however, that it provides the heat demand
   'tailor-made' to a specific situation, taking into account from
   month to month the gain utilization factor as a function of the
   specific gainloss ratio, and the interaction with other zones.

8.2 Description of the reference case and the variations

The reference case has been based upon the dwelling used for the
verification of TCM-heat in the previous chapter. Some details
have, however, been modified to turn the quite "extreme" case into
a "typical" case for highly insulated dwellings.

The modifications are:

- the ventilation rate has been changed from 0.50 to 0.80 air
  changes per hour;

- the house is assumed to be at the end of a row (semi-detached),
  instead of in the middle;

- the groundwater level is 3 meters below the groundfloor instead
  of 10 meters, resulting in a conductance of 0.33 instead of 0.12
  W/m²K (see table 14).

The data for the reference case as used for the input in TCM-heat
are presented in table 17. Figure 29 presents the 35 variations
which were selected for the sensitivity analysis. The window type
variations are explained in table 18.

Table 17. Reference case for the sensitivity studies: input data
the calculations with TCM-heat.
(see chapter 4 for the explanation of the symbols).

Zone	Cate-gory*	$\theta_{1,set}$ day (°C)	Av (m²)**					Aop (m²)				
			S	E	N	W	hor.	S	E	N	W	hor.
1. living-room	b-1	19.1	5.5	0	3.0	0	0	11.3	21.8	6.8	0	0
2. kitchen	b-1	19.1	0	0	2.5	0	0	0	0	4.5	0	0
3. bedroom South	b-1	18.0	3.5	0	0	0	0	12.1	10.1	0	0	0
4. bedroom North	b-1	18.0	0	0	3.5	0	0	0	10.1	12.1	0	0***
5. attic	-b-	unheated	0	0	0	0	0	0	10.7	0	0	58.6

* : acc. to table 13
** : actually: glazing area
***: in fact: tilted roof, but only relevant for solar absorption
　　　(influence is small).

Zone	Window type nr.*	Façade		Roof(=hor.)		Ground-floor**	To other zones U*A (W/K)				
		U_{op} (W/m²K)	a_{op} (-)	U_{op} (W/m²K)	a_{op} (-)	U_{fl} (W/m²K)	to 1	to 2	to 3	to 4	to 5
1. living room	46	0.40	0.80	--	--	0.31	--	31.9	49.8	33.8	0
2. kitchen	46	0.40	0.80	--	--	0.31	31.9	--	0	16.0	0
3. bedroom South	46	0.40	0.80	--	--	--	49.8	0	--	31.5	49.8
4. bedroom North	46	0.40	0.80	--	--	--	33.8	16.0	31.5	--	49.8
5. attic	--	0.40	0.80	0.20	0.50	--	0	0	49.8	49.8	--

* : see table 18
** : under floor: conduct. to 10°C : 0.33 W/m²K, to outdoor: 0.50 W/m²K.

Zone	$\bar{\phi}_{int}$ (W)	Ventilation (m³/h) from other zones					Idem from outdoor
		from 1	from 2	from 3	from 4	from 5	
1. living room	230	--	0	0	0	0	49.6
2. kitchen	210	24.0	--	8.0	14.4	28.8	22.4
3. bedroom South	47	11.2	0	--	8.0	14.4	36.8
4. bedroom North	23	0	0	0	--	0	30.4
5. attic	0	0	0	0	0	0	62.4

Climate: TRY De Bilt (see section 4.4, table 3).

1-15: ref. case, with variation of window size and orientation:

1-6: S-N

    1   2   3   4   5   6

7-15: E-W

  7   8   9   10   11   12

  13   14   15
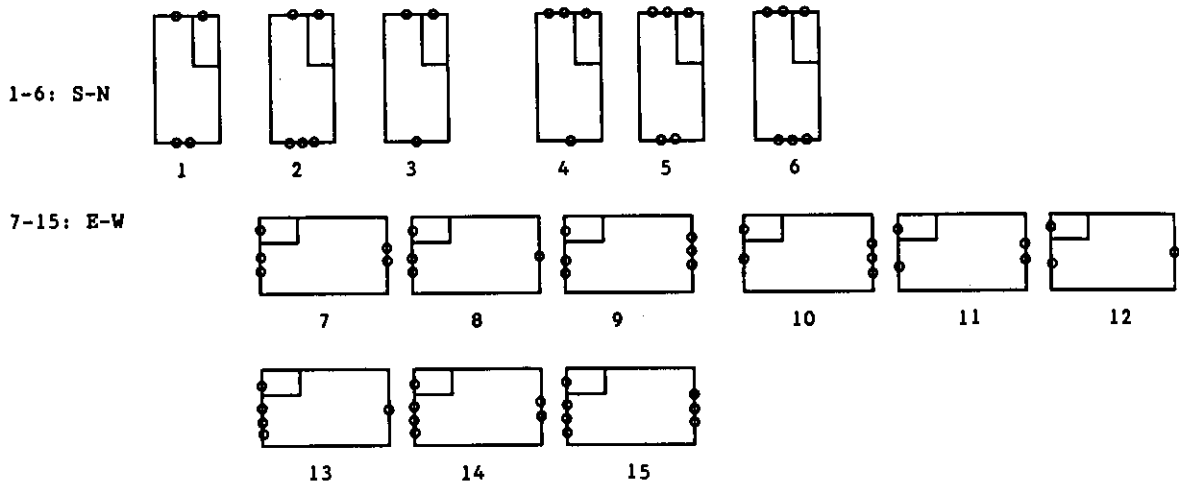
16-24: Window type variations in living room and kitchen only:
  16-18: glazing replaced by   19-21: as ref. case, but   22-24: as ref. case, but
         low U-glazing   not solar shading.   no night insulation
         (see table 18)

 16   17   18   19   20   21   22   23   24
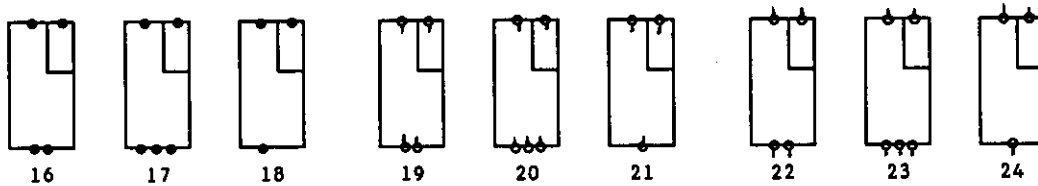
25-27: Variations in the bedrooms:
  25: South window size   26-27: glazing replaced by
                                        low U-glazing
                                        in whole dwelling

 1   25   26   27
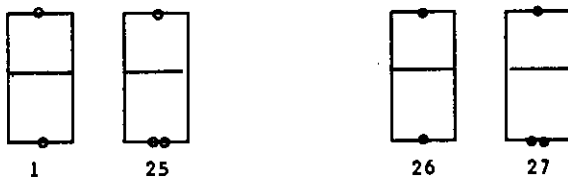
28-30: light weight building construction (cat. b-3):

 28   29   30
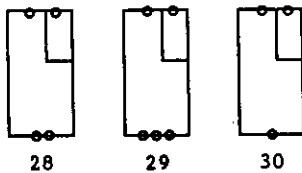
31-36: unheated bedrooms:
  31-33: as ref. case, but   34-36: unheated bedrooms with
         bedrooms unheated: 5 cm thermal insulation
                                         in bedroom floors
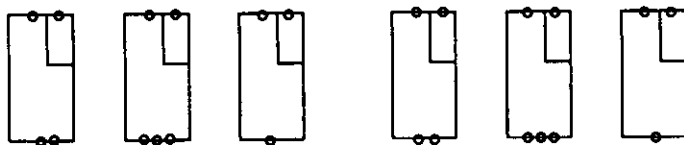
Figure 29.   The variations on the reference case.

EXPLANATION

ground floor

N

kitchen   bedroom backside

living   bedroom frontside

o   : small window size   ⎫ see
oo : medium window size   ⎬ also
ooo : large window size   ⎭ table 18
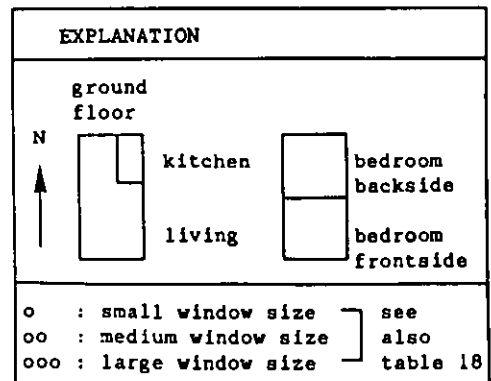
Table 18. The window types and glazing sizes used in the sensitivity
studies. (see chapter 4 for the explanation of the symbols).

Type and symbol in fig. 29	Description			U* (W/m^2k)	g* (-)	r* (-)	z* (-)
	glazing	solar shading	night insulation				
46	clear double glazing, d=12 mm.	internal blinds, light colour	well-closed curtain	2.9	0.70	0.78	0.68
47	idem as 46	none	idem as 46	2.9	0.70	0.78	1.00
48	idem as 46	idem as 46	none	2.9	0.70	1.00	0.68
51	double glazing, with low E coating on cavity side of inner pane	idem as 46	idem as 46	1.8	0.58	0.85	0.76

Glazing size (m²)	Living room frontside		Living room backside		Bedroom frontside	
	m²	% of floor area	m²	% of floor area	m²	% of floor area
-o- small	3.0	7	3.0*	7*	3.5*	15*
-oo- medium	5.5*	13*	5.5	13	5.5	23
-ooo- large	8.0	20	8.0	20	--	--
* = reference case						

* the presented properties are typical values for the indicated type;
the values will in general differ from product to product, depending
on the actual specifications.

Table 19. Three examples of monthly results to illustrate the kind of
output produced by TCM-heat; reference case.

January (Midwinter, low gains):

month	zone	Temp. C	Tamb. C	Te C	GLR –	ηG –	DTR –	DTA C	QL MJ	QLreal MJ	QG MJ	QHD MJ
1	1	17.4	11.9	2.5	0.39	1.00	1.00	0.00	2663	2633	1037	1626
1	2	17.4	13.9	2.5	0.72	0.99	1.01	0.03	862	870	623	247
1	3	16.5	13.1	2.5	0.23	1.00	1.00	0.00	1532	1532	349	1183
1	4	16.5	13.1	2.5	0.11	1.00	1.00	0.00	1412	1412	157	1255
1	5	12.7	12.7	2.5	0.00	0.00	0.00	0.00	0	24	24	0
total									6468	6501	2190	4311

March (Early spring, some overheating):

month	zone	Temp. C	Tamb. C	Te C	GLR –	ηG –	DTR –	DTA C	QL MJ	QLreal MJ	QG MJ	QHD MJ
3	1	17.9	13.2	5.6	0.82	0.96	1.03	0.15	2182	2252	1786	467
3	2	18.2	14.9	5.6	1.09	0.84	1.17	0.49	698	816	761	56
3	3	16.8	14.3	5.6	0.63	1.00	1.00	0.00	1148	1149	724	425
3	4	16.8	14.3	5.6	0.36	1.00	1.00	0.00	1045	1045	373	671
3	5	14.0	13.7	5.6	0.00	0.00	0.00	0.00	0	93	93	0
total									5072	5356	3737	1619

April (Spring, small heat demand):

month	zone	Temp. C	Tamb. C	Te C	GLR –	ηG –	DTR –	DTA C	QL MJ	QLreal MJ	QG MJ	QHD MJ
4	1	18.9	14.5	8.0	1.25	0.77	1.28	0.98	1641	2102	2048	54
4	2	19.4	16.0	8.0	1.73	0.58	1.73	1.44	468	808	808	0
4	3	17.4	15.4	8.0	1.21	0.79	1.25	0.40	703	880	849	31
4	4	17.0	15.5	8.0	0.79	0.97	1.02	0.04	600	614	475	139
4	5	15.1	14.7	8.0	0.00	0.00	0.00	0.00	0	132	132	0
total									3412	4536	4312	224

8.3 Calculated annual heat demands

In table 19 the monthly results are presented for three different months for the reference case, as an example of the kind of output produced by TCM-heat.

Table 20 shows the annual heat demand for each of the 36 cases calculated with the simplified method TCM-heat.

The results have been presented in figure 30 as a function of the glazing area. In figure 30a this is the glazing area of the South window in the living room, in figure 30b the same window, but now turned to the East orientation; in figure 30c the bedroom South glazing area is the variable on the horizontal axis.

Comparison of the results leads to the following observations:

curve a: reference case:
(1+2+3)   Effect of varying South glazing area: slight decrease in annual heat demand with increasing glazing area (roughly -125 MJ/m²).

curve b: as reference case, but increased glazing area on North
(4+5+6)   façade of the living room:
             Compared with reference: increased heat demand as North glazing area increases ($+175$ MJ/m²). Effect of varying South glazing area: same tendency as in reference case (roughly -110 MJ/m²).

curve c: as reference case, but orientation of whole dwelling
(10+11+12)   turned to East-West:
             Compared with reference: heat demand increased with about 1000 MJ; or: 57 MJ/m², mixed value for North-South and groundfloor + 1st floor. Effect of varying East glazing area: slight increase in heat demand with increasing glazing area (roughly $+60$ MJ/m²).

Table 20. Annual heat demand for the whole dwelling calculated with
TCM-heat.

VARIANT	Q_{HD} [MJ] annual	VARIANT	Q_{HD} [MJ] annual
1 (reference)	16432	19	15971
		20	15635
2	16165	21	16510
3	16785	22	17241
4	17205	23	17127
5	16876	24	17418
6	16645	25	16128
7	17624	26	14437
8	17449	27	13964
9	17861	28	17364
10	17637	29	17127
11	17465	30	17675
12	17324	31	12403
13	17613	32	12204
14	17855	33	12703
15	18156	34	9197
16	15167	35	9142
17	14680	36	9381
18	15770		

Figure 30a. As function of the glazing
area of the South façade of
the living room in
South/North orientation.

Figure 30. Annual heat demand for the whole dwelling as function
of the variations on the reference case.
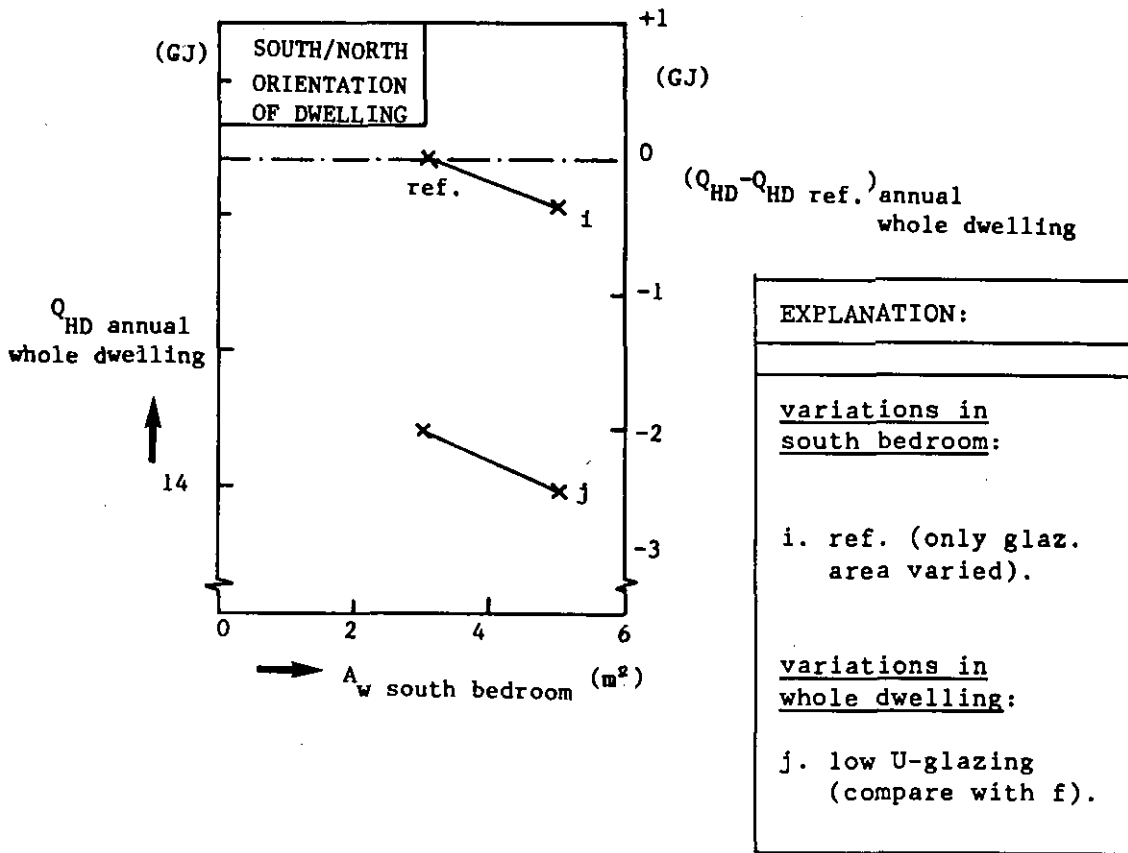
Figure 30b. As function of the glazing area of the South oriented
bedroom.
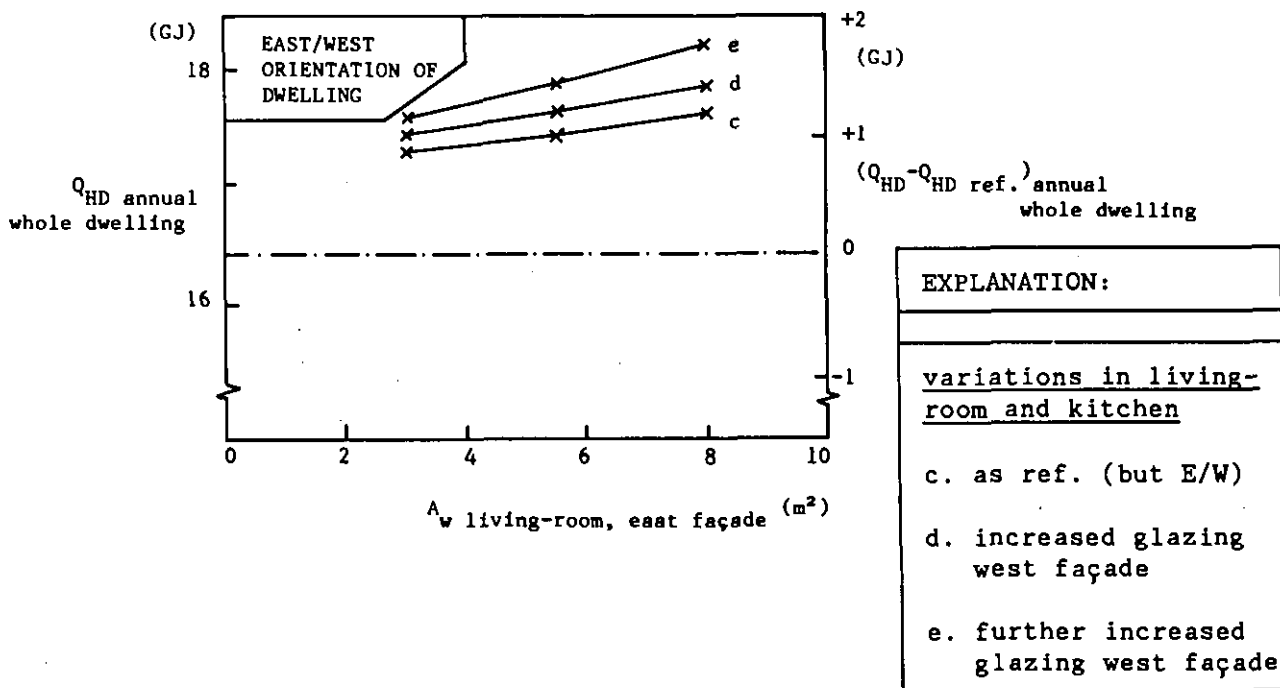
Figure 30c. As function of the glazing area of the East façade of the
living room in East/West orientation.

curve d: <u>as c, but increased glazing area on West façade of the</u>
(7+8+9)   <u>living-room</u>:

Compared with c: again, a slight increase with increasing glazing area (roughly +65 MJ/m²). Effect of varying East glazing area in this situation: roughly +80 MJ/m²).

curve e: <u>as d, but glazing area on West façade of living room</u>
(13+14+15)   <u>increased furthermore</u>:

Compared with d: heat demand increased with roughly +90 MJ/m². Effect of varying East glazing area now: roughly +110 MJ/m².

curve f: <u>as reference case, but glazing in living room and</u>
(16+17+18)   <u>kitchen replaced by glazing with better U-value</u>:

Compared with reference: decrease in heat demand roughly 1250 MJ; or:-115 MJ/m², mixed value for North + South. Effect of varying South glazing area: a strong decrease in heat demand with increasing glazing area (roughly -220 MJ/m2).

curve g: <u>as reference case, but no solar shading in the living</u>
(19+20+21)   <u>room and kitchen</u>:

Compared with reference: decrease in heat demand roughly 460 MJ, or -85 MJ/m² of the <u>South</u> window (for the North windows the climate factor FQ^{500} = 0: shading never used). Effect of varying South glazing area: a stronger decrease with glazing area compared to curve a: roughly -175 MJ/m².

curve h: <u>as reference case, but no night insulation in the living</u>
(22+23+24)   <u>room and kitchen</u>:

Compared with reference: increase in heat demand roughly +800 MJ; or: +75 MJ/m2 (mixed value for North + South). Effect of varying South glazing area: a weaker decrease with glazing area compared to curve a: roughly -60 MJ/m2.

curve i: <u>as reference case, but increased glazing area in South</u>
(1+25) <u>bedroom</u>:
Compared with reference: a decrease in heat demand of
-150 MJ/m².

curve j: <u>as reference case, but glazing in whole dwelling</u>
(26+27) <u>replaced by glazing with better U-value</u>:
Compared with reference: a decrease in heat demand of
around -2000 MJ; or: -110 MJ/m², mixed value for North +
South and groundfloor + 1st floor. Compared with f:
effect for the whole dwelling per m² about the same as
effect for only the groundfloor per m².

curve k: <u>as reference case, but lightweight construction instead</u>
(28+29+30) <u>heavy weight</u>:
Compared with reference: around 900 MJ increase in
annual heat demand. Effect of varying South glazing area
in the living room: slight decrease in heat demand of
around -110 MJ/m² with increasing glazing area.

curve l: <u>as reference case, but bedrooms unheated</u>:
(31+32+33) Compared with reference: a strong decrease in heat
demand, around -4000 MJ, or 25 percent of the original
amount. The calculated mean temperature in the bedrooms
in January is still 11-12 °C. Effect of varying South
glazing area in the living room: again a slight decrease
in heat demand with increasing glazing area
(-100 MJ/m2).

curve m: <u>as l, but with 5 cm. thermal insulation in the floor of</u>
(34+35+36) <u>the bedrooms</u>:
Compared with l: again a strong decrease in annual heat
demand: around -3000 MJ, or 25 percent of the value
without insulation of the intermediate floor, but the
mean temperature in the bedrooms in January has dropped
to 7-8 °C. Effect of varying South glazing area in the
living room: only a very slight decrease in heat demand
with increasing glazing area (around -50 MJ/m²).

8.4 Indication of overheating

The simplified method TCM-heat also provides the monthly values of dT$_A$ for each zone: the mean (absolute) overheating: the number of degrees K that the mean zone temperature exceeds the thermostat value, after correction for the temperature drop due to night setback (see definitions in section 3.5). In the examples in table 19 for the reference case typical values can be found. The highest value there is 1.4 °C, for the kitchen in April.

A number of variants have a lower annual heat demand. This is the result of one or more of the following effects:

- higher gain utilization curve (see k);
- lower thermostat values (see l);
- lower overall loss coefficient (various cases);
- higher ambient temperatures (various cases);
- more gains (various cases).

With the first two kinds of variations a decrease in monthly heat demand is not accompagnied with an increase of the monthly mean zone temperature. In the three last mentioned kinds of variations a decrease in monthly heat demand implies that the monthly mean zone temperature rises, unless the gainloss ratio is still sufficiently low to have a gain utilization factor $\eta_G = 1$.

A few examples of the mean overheating are presented in figure 31. The presented values are for the month April, for both the living room and the South bedroom. It is difficult to judge the results presented in figure 31, because the relation between peak temperatures and the presented mean values is (still) unknown. Nevertheless, the various cases can be compared on a relative basis. Some interesting cases (see figure 31):

curve m: The cases with the highest overheating in the living room are at the same time the cases with the lowest heat demand: unheated bedrooms and insulated intermediate floor. Despite the fact that the added insulation thickness is much less than the insulation already provided in ground floor, walls and roof.

curve g: The cases without the indoor blinds applied in the
living room and kitchen also lead to a relatively high
overheating, even more than the cases with low U-glazing
in those two zones (curve f), despite the fact that - on
an annual basis! - the latter cases have a lower heat
demand (see figure 30a). It is also typical to see the
influence of the absence of blinds in the living room on
the overheating in the South bedroom.

curve k: The influence of the building mass on the monthly mean
temperature rise appears to be very small: the influence
of the glazing area (and thus the GLR-value) is here much
larger than the effect of the lower gain utilization curve
η_G (GLR) itself.

8.5 Discussion

For the selected reference case an increase of the glazing area of
the double glazed South window has a (small) beneficial effect on
the annual heating requirements. This is valid for both the living
room and the South bedroom, if heated (curves a and i). If no night
insulation is applied the beneficial effect is les (curve h); if
glazing with a better U-value is applied the effect is larger
(curve f). But the effect of an increase of the glazing area also
depends on the particular situation. The values for the decrease in
annual heat demand presented in the previous section vary for the
same type of glazing (double glazing, with night insulation and
solar shading) between -50 MJ/m² (curve m) and -125 MJ/m² (curve
a). Figure 31 shows the effect on overheating: the potential
beneficial effect on an increased glazing area is in the cases of
curve m for a bigger part "dissipated" in the form of overheating
than in the cases represented by curve a.

This illustrates the advantage of the tool TCM-heat now being
available: the effect of a certain measure can be calculated
"tailor-made" to the particular situation.
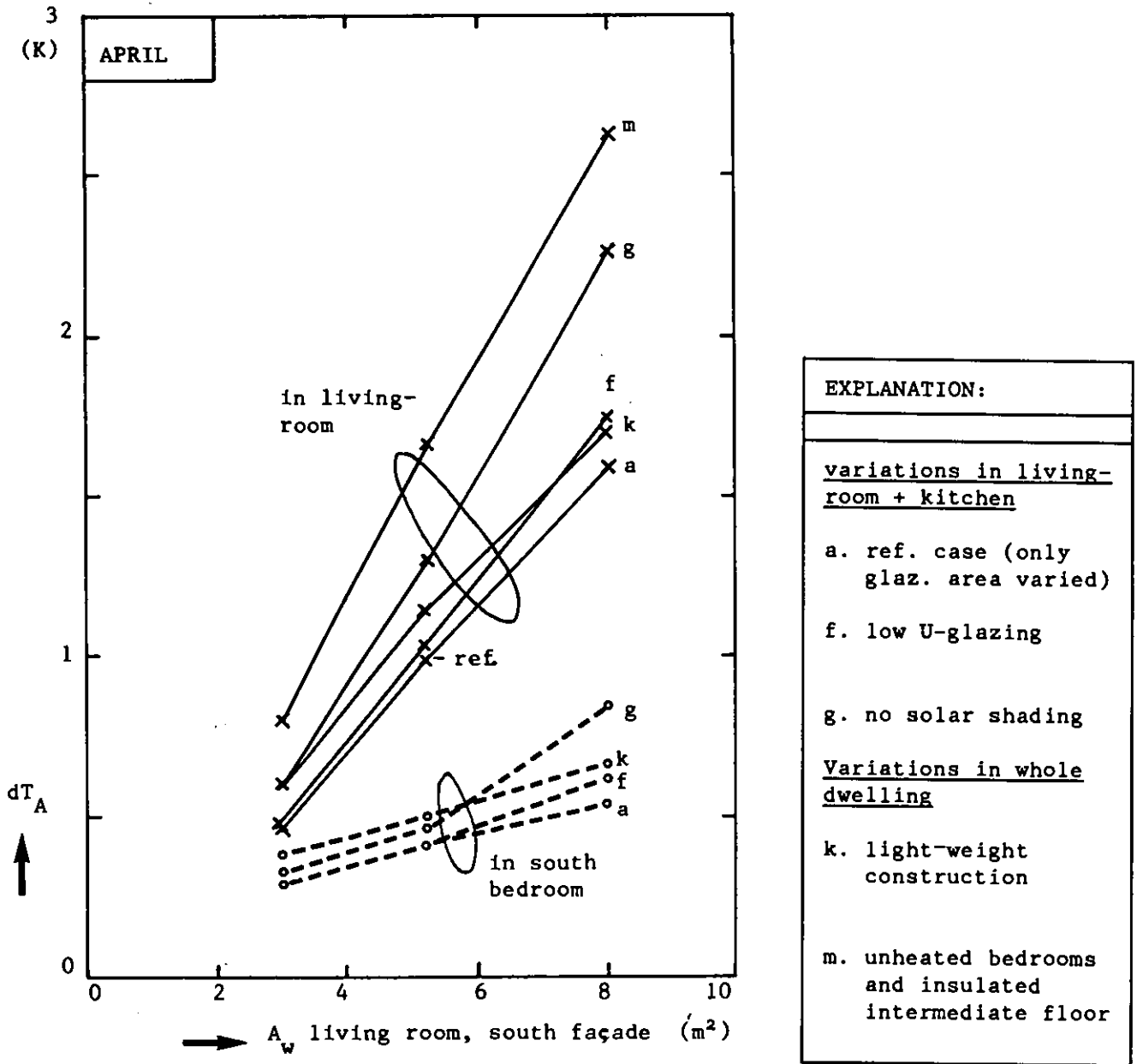
Figure 31a. As function of the glazing
area of the South façade of
the living room in South/
North orientation.

Figure 31. Some examples of the calculated value for the monthly mean
overheating dT_a in April, for the living room and the
South bedroom.
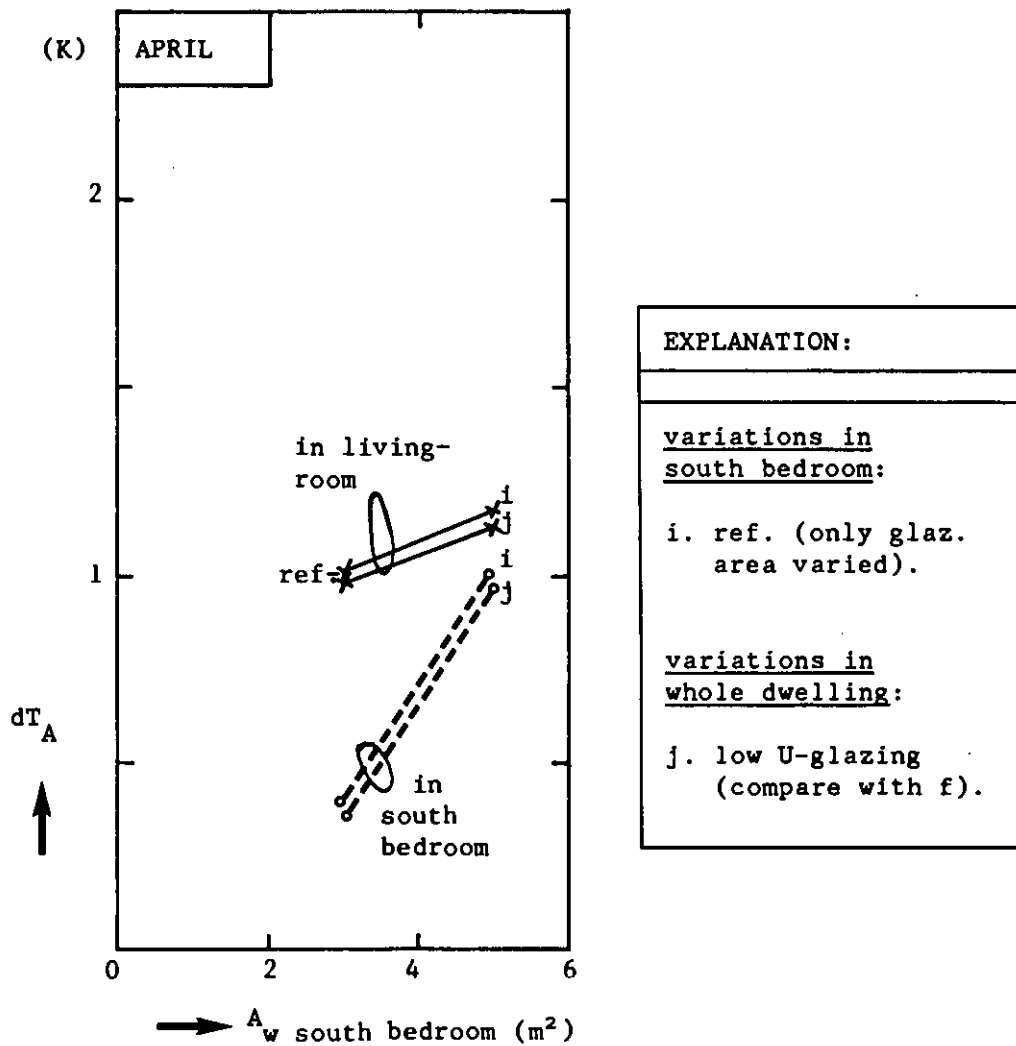
Figure 31b. As function of the glazing area of the South oriented
bedroom.

9. CONCLUSIONS

This report documented the activities and results of the Netherlands within Step 5 of the IEA R&D project "Windows and Fenestration".

A method has been introduced to calculate by hand monthly heat losses and gains. Simple correction factors have been introduced to deal with special situations. Particular attention was given to the influence of various types of window systems.

Correlation factors have been proposed to take into account unsteady state effects; the gain utilization factor η_G as function of the gain loss ratio GLR and the correction factor for thermostat setback during night (C_N) or during non-office hours (C_{NWH}). Furthermore a parameter dT_R, the mean relative overheating has been introduced, giving some indication of the overheating due to non-utilized gains.

The following novel aspects of the method compared to other existing methods were identified:

- the applicability of the method for office buildings without mechanical cooling;

- the applicability of the method in a multizone situation with exchange of heat by transmission and/or ventilation between different spaces;

- the rough indication of thermal comfort by the introduction of the relative overheating.

The main limitation of the method in comparison with some of the other methods is that passive solar elements other than "direct gain" fenestration, like collector storage walls, have not (yet) been included.

Series of parameter studies using the unsteady state computer model DYWON have been reported. The results of these calculations made it possible to quantify the correlation factors mentioned above.

With the correlation factors a simplified calculation method has come available to calculate the space heating requirements for a wide range of situations (TCM-heat).

The simplified method has been verified against a calculation with DYWON for two complicated multizone situations, in a highly insulated dwelling. Although the selected cases were quite extreme, the agreement in annual heating requirements for the whole dwelling appeared to be satisfactory. Some deviation occured in the distribution over the months due to the fact that for some months the heat demand is the very small difference between the much larger heat loss and almost equal gains. Some deviation also occured in the distribution over the zones, due to the strong interaction between the zones in the well insulated building.

Finally, examples have been presented of one of the possible applications of the method, namely to show the influence of window size, type and orientation on the energy consumption for space heating in a selected number of typical situations.
These examples illustrated that the influence of a change in window size, type or orientation may depend on the actual conditions like for instance climate, type of use of the considered zone, insulation level and also the conditions in the adjacent zones.
With TCM-heat the influence of the window on energy consumption can be calculated "tailor-made" to a particular situation.
The introduced quantities mean relative overheating, dT_R, and mean absolute overheating, dT_a, appeared to be useful indicators for the thermal comfort situation. The relation with peak temperature, however, has not been investigated.

Although TCM-heat is basically a hand calculation method, the calculation is inevitably complicated in case of a multizone situation. With the Fortran-version of TCM-heat, however, also complex multizone situations can be dealt with easily.

Technisch Physische Dienst

Ir. H.A.L. van Dijk

Delft, December 1987

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APPENDIX 1

7. LIST OF PARTICIPANTS IN ANNEX XII

The underlying report is a record of the activities carried out by the Netherlands within the framework of Step 5 of the IEA Research Project Annex XII, Windows and Fenestration.
The participants in Annex XII are:

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APPENDIX 2

Detailed description of the cases used in the series of unsteady state calculations.

Category a-1 Dwellings Masonry type(heavy weight)

model	A_{ws}	A_{wn}	A_{we}	A_{ww}	A_{fac}	A_r	V_n	Q_{int}	U_w	g	z	r	$\theta_{iset,day}$
	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^3/h]$	$[W]$	$[W/m^2K]$	$[-]$	$[-]$	$[-]$	$[^\circ C]$
F1	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	1.0	1.0	21.0
F2	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	.58	1.0	21.0
F3	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	.58	.75	21.0
F4	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	.59	.61	21.0
F5	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	1.0	.64	21.0
F6	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	1.0	.41	21.0
F7	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	.59	.47	21.0
F8	11.7	11.7	0	0	46.8	0	105	430	3.4	0.71	.70	.58	21.0
F9	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	.59	.44	21.0
F10	11.7	11.7	0	0	46.8	0	105	430	3.2	0.70	1.0	1.0	21.0
F11	11.7	11.7	0	0	46.8	0	105	430	3.2	0.70	.69	1.0	21.0
F12	11.7	11.7	0	0	46.8	0	105	430	3.2	0.70	.70	.63	21.0
F13	11.7	11.7	0	0	46.8	0	105	430	1.8	0.66	1.0	1.0	21.0
F14	11.7	11.7	0	0	46.8	0	105	430	2.2	0.57	1.0	1.0	21.0
F15	11.7	11.7	0	0	46.8	0	105	430	2.2	0.57	.81	.82	21.0
F16	11.7	11.7	0	0	46.8	0	105	430	3.2	0.70	.59	.59	21.0
F17	11.7	11.7	0	0	46.8	0	105	430	3.2	0.70	1.0	.66	21.0
FE2	0	0	11.7	11.7	46.8	0	105	430	5.9	0.80	.58	1.0	21.0
FE4	0	0	11.7	11.7	46.8	0	105	430	5.9	0.80	.59	.61	21.0
FE6	0	0	11.7	11.7	46.8	0	105	430	5.9	0.80	1.0	.41	21.0
FE10	0	0	11.7	11.7	46.8	0	105	430	3.2	0.70	1.0	1.0	21.0
FE13	0	0	11.7	11.7	46.8	0	105	430	1.8	0.66	1.0	1.0	21.0
FE15	0	0	11.7	11.7	46.8	0	105	430	2.2	0.57	.81	.82	21.0
FE17	0	0	11.7	11.7	46.8	0	105	430	3.2	0.70	1.0	.66	21.0
F1+2a	11.7	11.7	0	0	46.8	0	105	683	5.9	0.80	.58	1.0	21.0
F1+6a	11.7	11.7	0	0	46.8	0	105	683	5.9	0.80	1.0	.41	21.0
F1+13a	11.7	11.7	0	0	46.8	0	105	683	1.8	0.66	1.0	1.0	21.0
F1+17a	11.7	11.7	0	0	46.8	0	105	683	3.2	0.77	.81	.66	21.0
F1+2b	11.7	11.7	0	0	46.8	0	105	683	5.9	0.80	.58	1.0	21.0
F1+6b	11.7	11.7	0	0	46.8	0	105	683	5.9	0.80	1.0	.41	21.0
F1+13b	11.7	11.7	0	0	46.8	0	105	683	1.8	0.66	1.0	1.0	21.0
F1+17b	11.7	11.7	0	0	46.8	0	105	683	3.2	0.77	.81	.66	21.0
F1-2	11.7	11.7	0	0	46.8	0	105	0	5.9	0.80	1.0	1.0	21.0
F1-6	11.7	11.7	0	0	46.8	0	105	0	5.9	0.80	.58	.41	21.0
F1-13	11.7	11.7	0	0	46.8	0	105	0	1.8	0.66	1.0	1.0	21.0
F1-17	11.7	11.7	0	0	46.8	0	105	0	3.2	0.70	1.0	.66	21.0
FV+6	11.7	11.7	0	0	46.8	0	315	430	5.9	0.80	1.0	.41	21.0
FV+13	11.7	11.7	0	0	46.8	0	315	430	1.8	0.66	1.0	.41	21.0
FV+17	11.7	11.7	0	0	46.8	0	315	430	3.2	0.70	1.0	.41	21.0
W1	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	1.0	1.0	20.0
W2	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	.58	1.0	20.0
W3	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	.58	.75	20.0
W4	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	.59	.61	20.0
W5	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	1.0	.64	20.0
W6	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	1.0	.41	20.0
W7	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	.59	.47	20.0
W8	9.0	9.0	0	0	64.8	61.1	280	617	3.6	0.71	.70	.58	20.0
W9	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	.59	.44	20.0
W10	9.0	9.0	0	0	64.8	61.1	280	617	3.2	0.70	1.0	1.0	20.0
W11	9.0	9.0	0	0	64.8	61.1	280	617	3.2	0.70	.69	1.0	20.0
W12	9.0	9.0	0	0	64.8	61.1	280	617	3.2	0.70	.70	.63	20.0
W13	9.0	9.0	0	0	64.8	61.1	280	617	1.8	0.66	1.0	1.0	20.0
W14	9.0	9.0	0	0	64.8	61.1	280	617	2.2	0.57	1.0	1.0	20.0
W15	9.0	9.0	0	0	64.8	61.1	280	617	2.2	0.57	.81	.82	20.0
W16	9.0	9.0	0	0	64.8	61.1	280	617	3.2	0.70	.59	.59	20.0
W17	9.0	9.0	0	0	64.8	61.1	280	617	3.2	0.70	1.0	.66	20.0
W1-2	9.0	9.0	11.7	11.7	64.8	61.1	280	308	5.9	0.80	.58	1.0	20.0
W1-6	9.0	9.0	11.7	11.7	64.8	61.1	280	308	5.9	0.80	1.0	.41	20.0
W1-13	9.0	9.0	11.7	11.7	64.8	61.1	280	308	1.8	0.66	1.0	1.0	20.0
W1-17	9.0	9.0	11.7	11.7	64.8	61.1	280	308	3.2	0.70	1.0	.66	20.0
WG+10	18.0	6.0	11.7	11.7	64.8	61.1	280	617	3.2	0.70	1.0	1.0	20.0
WG+13	18.0	6.0	11.7	11.7	64.8	61.1	280	617	1.8	0.66	1.0	1.0	20.0
WG+17	18.0	6.0	11.7	11.7	64.8	61.1	280	617	3.2	0.70	1.0	.66	20.0
WG+V-1	18.0	6.0	0	0	64.8	61.1	140	617	5.9	0.80	1.0	1.0	20.0
WG+V-6	18.0	6.0	0	0	64.8	61.1	140	617	5.9	0.80	1.0	.41	20.0
WG+V-8	18.0	6.0	0	0	64.8	61.1	140	617	3.6	0.71	.70	.58	20.0
WG+V-10	18.0	6.0	0	0	64.8	61.1	140	617	3.2	0.70	1.0	1.0	20.0
WG+V-13	18.0	6.0	0	0	64.8	61.1	140	617	1.8	0.66	1.0	1.0	20.0
WG+V-17	18.0	6.0	0	0	64.8	61.1	140	617	3.2	0.70	1.0	.66	20.0

All cases with nightsetback, U_r =0.69 W/m²K, for code F...: U_{fac} = 0.66 W/m²K, for code W...: U_{fac} = 0.69 W/m²K

Category a-2 Dwellings Masonry type(heavy weight)

model	A_{ws} [m²]	A_{wm} [m²]	A_{we} [m²]	A_{ww} [m²]	A_{fac} [m²]	A_r [m²]	V_n [m³/h]	Q_{int} [W]	U_w [W/m²K]	g [-]	z [-]	r [-]	$\theta_{i\,set,day}$ [°]
FT+2	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	.58	1.0	21.0
FT+6	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	1.0	.41	21.0
FT+13	11.7	11.7	0	0	46.8	0	105	430	1.8	0.66	1.0	1.0	21.0
FT+17	11.7	11.7	0	0	46.8	0	105	430	3.2	0.70	1.0	.66	21.0
FT-2	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	.58	1.0	15.0
FT-6	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	1.0	.41	15.0
FT-10	11.7	11.7	0	0	46.8	0	105	430	3.2	0.70	1.0	1.0	15.0
FT-17	11.7	11.7	0	0	46.8	0	105	430	3.2	0.70	1.0	.66	15.0
WT+2	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	.58	1.0	20.0
WT+6	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	1.0	.41	20.0
WT+17	9.0	9.0	0	0	64.8	61.1	280	617	3.2	0.70	1.0	.66	20.0
WT-2	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	.58	1.0	15.0
WT-6	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	1.0	.41	15.0
WT-17	9.0	9.0	0	0	64.8	61.1	280	617	3.2	0.70	1.0	.66	15.0
WG+V-T+2	18.0	6.0	0	0	64.8	61.1	140	617	5.9	0.80	.58	1.0	20.0
WG+V-T+6	18.0	6.0	0	0	64.8	61.1	140	617	5.9	0.80	1.0	.41	20.0
WG+V-T+13	18.0	6.0	0	0	64.8	61.1	140	617	1.8	0.66	1.0	1.0	20.0
WG+V-T+17	18.0	6.0	11.7	11.7	64.8	61.1	140	617	3.2	0.70	1.0	.66	20.0
WG+V-T-2	18.0	6.0	11.7	11.7	64.8	61.1	140	617	5.9	0.80	.58	1.0	15.0
WG+V-T-6	18.0	6.0	11.7	11.7	64.8	61.1	140	617	5.9	0.80	1.0	.41	15.0
WG+V-T-13	18.0	6.0	11.7	11.7	64.8	61.1	140	617	1.8	0.66	1.0	1.0	15.0
WG+V-T-17	18.0	6.0	11.7	11.7	64.8	61.1	140	617	3.2	0.70	1.0	.66	15.0

All cases without nightsetback, $U_r = 0.69$ W/m²K, for code F...: $U_{fac} = 0.66$ W/m²K, for code W...: $U_{fac} = 0.69$ W/m²K

Category a-3 Dwellings Masonry type(light weight,wooden frame)

model	A_{ws} [m²]	A_{wm} [m²]	A_{we} [m²]	A_{ww} [m²]	A_{fac} [m²]	A_r [m²]	V_n [m³/h]	Q_{int} [W]	U_w [W/m²K]	g [-]	z [-]	r [-]	$\theta_{i\,set,day}$ [°C]
FM-2	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	.58	1.0	21.0
FM-4	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	.59	.61	21.0
FM-6	11.7	11.7	0	0	46.8	0	105	430	5.9	0.80	1.0	.41	21.0
FM-10	11.7	11.7	0	0	46.8	0	105	430	3.2	0.70	1.0	1.0	21.0
FM-13	11.7	11.7	0	0	46.8	0	105	430	1.8	0.66	1.0	1.0	21.0
FM-15	11.7	11.7	0	0	46.8	0	105	430	2.2	0.57	.81	.82	21.0
FM-17	11.7	11.7	0	0	46.8	0	105	430	3.2	0.70	1.0	.66	21.0
WM-2	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	.58	1.0	20.0
WM-6	9.0	9.0	0	0	64.8	61.1	280	617	5.9	0.80	1.0	.41	20.0
WM-17	9.0	9.0	0	0	64.8	61.1	280	617	3.2	0.70	1.0	.66	20.0
WG+V-M-2	18.0	6.0	0	0	64.8	61.1	140	617	5.9	0.80	.58	1.0	20.0
WG+V-M-6	18.0	6.0	0	0	64.8	61.1	140	617	5.9	0.80	1.0	.41	20.0
WG+V-M-10	18.0	6.0	0	0	64.8	61.1	140	617	3.2	0.70	1.0	1.0	20.0
WG+V-M-13	18.0	6.0	0	0	64.8	61.1	140	617	1.8	0.66	1.0	1.0	20.0

All cases with nightsetback, $U_r = 0.69$ W/m²K. For code F...: $U_{fac} = 0.66$ W/m²K. For code W...: $U_{fac} = 0.69$ W/m²K

Category b-1 Dwellings Masonry type(heavy weight)

model	A_{ws}	A_{wn}	A_{we}	A_{ww}	U_{fac}	U_w	g	z
	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[W/m^2 K]$	$[W/m^2 K]$	$[-]$	$[-]$
BHNN21	0	4.5	0	0	.59	5.8	.78	.56
BHSN21	4.5	0	0	0	.59	5.8	.82	.56
BHSN12	2.1	0	0	0	.42	2.9	.71	.68
BHSN22	4.5	0	0	0	.59	2.9	.71	.68
BHSN32	7.2	0	0	0	.86	2.9	.71	.68
BHSN25	4.5	0	0	0	.59	1.4	.54	.81
BHNN25	0	4.5	0	0	.59	1.4	.49	.76

All cases with nightsetback

For all cases $A_{fac} = 12.5 \, m^2$, $V_n = 45 \, m^3/h$, $Q_{int} = 230 \, W$, $A_r = 0 \, m^2$, $r = 1, 0$, $\theta_{i \, set,day} = 19.4 \, {}^{\circ}C$

Category b-2 Dwellings masonry type(heavy weight)

model	A_{ws}	A_{wn}	A_{we}	A_{ww}	A_{fac}	U_{fac}	V_n	Q_{int}	U_w	g	z	r	A_r	$\theta_{i \, set,day}$
	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[W/m^2 K]$	$[m^3/h]$	$[W]$	$[W/m^2 K]$	$[-]$	$[-]$	$[-]$	$[m^2]$	$[{}^{\circ}C]$
BHSC22	4.5	0	0	0	12.5	.59	45	230	2.9	.71	.68	1.0	0	19.4

Case without Nightsetback

Category b-3 Dwellings Masonry type(light weight)

model	A_{ws}	A_{wn}	A_{we}	A_{ww}	U_w	g	z
	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[W/m^2 K]$	$[-]$	$[-]$
BLSN21	4.5	0	0	0	5.8	.82	.56
BLSN24	4.5	0	0	0	1.9	.62	.74
BLSN25	4.5	0	0	0	1.4	.54	.81

All cases with nightsetback

For all cases $A_{fac} = 12.5 \, m^2$, $V_n = 45 \, m^3/h$, $Q_{int} = 230 \, W$, $A_r = 0 \, m^2$, $r = 1.0$, $U_{fac} = 0.59 \, W/m^2 K$

Category c-1 Offices heavy weight

model	A_{vs} [m²]	A_{vn} [m²]	A_{ve} [m²]	A_{vw} [m²]	A_{fs} [m²]	A_{fn} [m²]	A_{fe} [m²]	A_{fw} [m²]	V_n [m³/h]	V_m [m³/h]	Q_{int} [W]	U_w [W/m³ K]	g [-]	z [-]	A_r [m²]
2313VN	7.88	0	0	0	10.5	0	0	0	30	70	308	5.9	0.80	0.58	0
2311VN	7.88	0	0	0	10.5	0	0	0	30	70	140	5.9	0.80	0.58	0
N313VN	0	7.88	0	0	0	10.5	0	0	30	70	308	5.9	0.80	0.58	0
N311VN	0	7.88	0	0	0	10.5	0	0	30	70	140	5.9	0.80	0.58	0
2313VC	7.88	0	0	0	10.5	0	0	0	240	0	308	5.9	0.80	0.58	0
2311VC	7.88	0	0	0	10.5	0	0	0	240	0	140	5.9	0.80	0.58	0
N313VC	0	7.88	0	0	0	10.5	0	0	240	0	308	5.9	0.80	0.58	0
N311VC	0	7.88	0	0	0	10.5	0	0	240	0	140	5.9	0.80	0.58	0
2313V	7.88	0	0	0	10.5	0	0	0	30	210	308	5.9	0.80	0.58	0
2311V	7.88	0	0	0	10.5	0	0	0	30	210	140	5.9	0.80	0.58	0
2113V	3.15	0	0	0	10.5	0	0	0	30	210	308	5.9	0.80	0.58	0
2111V	3.15	0	0	0	10.5	0	0	0	30	210	140	5.9	0.80	0.58	0
N313V	0	7.88	0	0	0	10.5	0	0	30	210	308	5.9	0.80	0.58	0
N311V	0	7.88	0	0	0	10.5	0	0	30	210	140	5.9	0.80	0.58	0
N113V	0	3.15	0	0	0	10.5	0	0	30	210	308	5.9	0.80	0.58	0
N111V	0	3.15	0	0	0	10.5	0	0	30·	210	140	5.9	0.80	0.58	0
2343	7.88	0	0	0	10.5	0	0	0	10	70	308	2.9	0.70	0.19	0
2341	7.88	0	0	0	10.5	0	0	0	10	70	140	2.9	0.70	0.19	0
2143	3.15	0	0	0	10.5	0	0	0	10	70	308	2.9	0.70	0.19	0
2141	3.15	0	0	0	10.5	0	0	0	10	70	140	2.9	0.70	0.19	0
2333	7.88	0	0	0	10.5	0	0	0	10	70	308	2.9	0.70	0.69	0
2331	7.88	0	0	0	10.5	0	0	0	10	70	140	2.9	0.70	0.69	0
2133	3.15	0	0	0	10.5	0	0	0	10	70	308	2.9	0.70	0.69	0
2131	3.15	0	0	0	10.5	0	0	0	10	70	140	2.9	0.70	0.69	0
N333	0	7.88	0	0	0	10.5	0	0	10	70	308	2.9	0.70	0.69	0
N331	0	7.88	0	0	0	10.5	0	0	10	70	140	2.9	0.70	0.69	0
N133	0	3.15	0	0	0	10.5	0	0	10	70	308	2.9	0.70	0.69	0
N131	0	3.15	0	0	0	10.5	0	0	10	70	140	2.9	0.70	0.69	0
W313	0	0	0	7.88	0	0	0	10.5	10	70	308	5.9	0.80	0.58	0
W311	0	0	0	7.88	0	0	0	10.5	10	70	140	5.9	0.80	0.58	0
W113	0	0	0	3.15	0	0	0	10.5	10	70	308	5.9	0.80	0.58	0
W111	0	0	0	3.15	0	0	0	10.5	10	70	140	5.9	0.80	0.58	0
2313	7.88	0	0	0	10.5	0	0	0	10	70	308	5.9	0.80	0.58	0
2311	7.88	0	0	0	10.5	0	0	0	10	70	140	5.9	0.80	0.58	0
2113	3.15	0	0	0	10.5	0	0	0	10	70	308	5.9	0.80	0.58	0
2111	3.15	0	0	0	10.5	0	0	0	10	70	140	5.9	0.80	0.58	0
0313	0	0	7.88	0	0	0	10.5	0	10	70	308	5.9	0.80	0.58	0
0311	0	0	7.88	0	0	0	10.5	0	10	70	140	5.9	0.80	0.58	0
0113	0	0	3.15	0	0	0	10.5	0	10	70	308	5.9	0.80	0.58	0
0111	0	0	3.15	0	0	0	10.5	0	10	70	140	5.9	0.80	0.58	0
N313	0	7.88	0	0	0	10.5	0	0	10	70	308	5.9	0.80	0.58	0
N311	0	7.88	0	0	0	10.5	0	0	10	70	140	5.9	0.80	0.58	0
N113	0	3.15	0	0	0	10.5	0	0	10	70	308	5.9	0.80	0.58	0
N111	0	3.15	0	0	0	10.5	0	0	10	70	140	5.9	0.80	0.58	0
2011130	3.15	0	5.40	0	10.5	0	18.0	0	10	70	308	5.9	0.80	0.58	20
2011ID	3.15	0	5.40	0	10.5	0	18.0	0	10	70	140	5.9	0.80	0.58	20
NO113D	0	3.15	5.40	0	0	10.5	18.0	0	10	70	308	5.9	0.80	0.58	20
NO111D	0	3.15	5.40	0	0	10.5	18.0	0	10	70	140	5.9	0.80	0.58	20
23130	7.88	0	0	0	10.5	0	0	0	10	70	308	5.9	0.80	0.58	20
2311D	7.88	0	0	0	10.5	0	0	0	10	70	140	5.9	0.80	0.58	20
2113D	3.15	0	0	0	10.5	0	0	0	10	70	308	5.9	0.80	0.58	20
N313D	0	7.88	0	0	0	10.5	0	0	10	70	308	5.9	0.80	0.58	20
N311D	0	7.88	0	0	0	10.5	0	0	10	70	140	5.9	0.80	0.58	20
N113D	0	3.15	0	0	0	10.5	0	0	10	70	308	5.9	0.80	0.58	20
N111D	0	3.15	0	0	0	10.5	0	0	10	70	140	5.9	0.80	0.58	20
ON113	0	5.40	3.15	0	0	18.0	10.5	0	10	70	308	5.9	0.80	0.58	0
ON111	0	5.40	3.15	0	0	18.0	10.5	0	10	70	140	5.9	0.80	0.58	0
20113	3.15	0	5.40	0	10.5	0	18.0	0	10	70	308	5.9	0.80	0.58	0
20111	3.15	0	5.40	0	10.5	0	18.0	0	10	70	140	5.9	0.80	0.58	0
NO113	0	3.15	5.40	0	0	10.5	18.0	0	10	70	308	5.9	0.80	0.58	0
NO111	0	3.15	5.40	0	0	10.5	18.0	0	10	70	140	5.9	0.80	0.58	0

For all cases : $U_{fac} = 0.61$ W/m² K , $U_r = 0.61$ W/m² K and $\theta_{i\,set,WH} = 22\,°C$

Category c-3 Offices light weight

model	A_{ws}	A_{wn}	A_{we}	A_{ww}	A_{fs}	A_{fn}	A_{fe}	A_{fw}	Q_{int}
	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[W]$
Z311L	7.88	0	0	0	10.5	0	0	0	140
Z313L	7.88	0	0	0	10.5	0	0	0	308
N311L	0	7.88	0	0	0	10.5	0	0	140
N313L	0	7.88	0	0	0	10.5	0	0	308

For all cases $U_{fac} = 0.61\ W/m^2 K$, $U_r = 0.61\ W/m^2 K$, $\Theta_{i\ set\ day} = 22\ ^oC$, $z = 0.58$, $g = 0.80$,
$U_w = 5.9\ W/m^2 K$, $V_n = 10\ m^3/h$, $V_m = 70\ m^3/h$, $A_r = 0\ m^2$

Category c-5 Offices extra heavy weight

model	A_{ws}	A_{wn}	A_{we}	A_{ww}	A_{fs}	A_{fn}	A_{fe}	A_{fw}	Q_{int}
	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[m^2]$	$[W]$
Z311H	7.88	0	0	0	10.5	0	0	0	140
Z313H	7.88	0	0	0	10.5	0	0	0	308
N311H	0	7.88	0	0	0	10.5	0	0	140
N313H	0	7.88	0	0	0	10.5	0	0	308

For all cases $U_{fac} = 0.61\ W/m^2 K$, $U_r = 0.61\ W/m^2 K$, $\Theta_{i\ set,\ NH} = 22\ ^oC$, $z = 0.58$, $g = 0.80$,
$U_w = 5.9\ W/m^2 K$, $V_n = 10\ m^3/h$, $V_m = 70\ m^3/h$, $A_r = 0\ m^2$

APPENDIX 3

Listing of the FORTRAN version of the TPD Correlation based Multizone calculation method TCM-heat.

This version has been written for the calculations with TCM-heat described in chapters 7 and 8 only.

No attempt has been made to produce a complete, widely applicable and user-friendly software version.

The listing of this FORTRAN-version is purely informative.

```
Program TCMHEAT
Created 870819
Version 87/12/04 TCMHEAT1:
 max. number of zones extended.
 other orientations added.
 input changed. for test: TCM.IN1  available
 climate as separate input file. For test: TCM.TRY1 available.
Author: H.A.L. van Dijk
Copyright:
        TNO Institute of Applied Physics
        Stieltjesweg 1, Delft, The Netherlands
Calculation of the HEAT requirements and temperatures in a Multizone situation
according to the TPD Monthly based calculation Method.
See publication IEA Annex XII, Step 5, December 1987


***********************************************************************
 program limitations
***********************************************************************


 see also report ! a.o. for the description of the various categories of
                    situations for which the given parametervalues and
                    equations are valid.
 other limitations of this program:
                * general:
                    - for windows and opaque surfaces: 9 orientations
                      have been defined: 8 vert. plus hor. ; opaque tilted roof
                      can be approximated by hor. or vert.: influence of absorbed
                      solar energy there is small.
                    - correction for cold surfaces not yet implemented:
                      this would require the input of all bounding surfaces; not
                      only surfaces with heat exchange.
                      this correction is needed only in case of convective heating
                      with room thermostat acting on air temp., which may lead to
                      uncomfortably cold zone conditions; therefore this corection
                      will only be used for comparison with other calculations whe
                      such combination is assumed.
                * offices:
                    - window insulation during non office hours not yet implemen-
                      ted.
                    - for mech. vent. and internal heat: 10 working hrs. per
                      working day assumed.
***********************************************************************
 declarations
***********************************************************************
   #################################
     CHARACTER FILNAM*17,CODEB*10,CODEC*10,TEXT*78
     INTEGER OR
     REAL    KK
     DIMENSION   TE1(12),TE2(12),QS1(12,9),QS2(12,9),
     #           FQ51(12,9),FQ52(12,9),FQ31(12,9),FQ32(12,9),
     #           D1(12),D2(12),FTN1(12),FTEN1(12),FWD2(12),FTWH2(12)
     DIMENSION   XUW(54),XGW(54),XRUN(54),XZSH(54)
     COMMON/CLIZO/TE(9),QS(9,9),FQ(9,9),
     #           D(9),FTN(9),FTEN(9),FWD(9),FTWH(9),DTFAC(9)
      COMMON/ZCHAR/AW(9,9),AOP(9,9),UFAC(9),UROOF(9),ABSF(9),ABSR(9),
     #           UAADJ(9,9),AFL(9),UFL(9),YGRC(9),YGRE(9),TGR(9),HL(9)
      COMMON/ZCOND/TI(10),TIOLD(9),TA(9),TG(9),TIMIN(9),TISET(9),
     #            TISNWH(9),QII(9),QIS(9),V(9,10),VM(9,10)
      COMMON/WIZO/KW(9),UW(9),GW(9),R(9),Z(9)
      COMMON/METH/KCAT(9),CN(9),CNWH(9),KK(9),DD(9),QL(9),QLREAL(9),
     #           QG(9),QHD(9),GLR(9),CG(9),DTR(9),DTA(9)
      COMMON/ZTOT/QLT(9),QLRLT(9),QGT(9),QHDT(9)
      COMMON/BLD/ QLB(12),QLRLB(12),QGB(12),QHDB(12)
      COMMON/BZTOT/QLBT,QLRLBT,QGBT,QHDBT
          Characteristics of window combinations, type (KW) 1-54 :
          types 1-20 : see report table 9 (used for category -a-)
```

        types 21-25: windowtypes used for category -b- ,
                       see table 11
        types 26-30: values for a North orientation
        types 31-35: values for a South orientation
        types 36-40: not used
        types 41-45: values used for category -c-, see report table 12
        types 46-55: values used in the verification (chapter 7) and
                       in the sensitivity studies (chapter 8 of the report)

```
     DATA XUW/7*5.9,3.6,5.9,3*3.2,1.8,2.2,2.2,3.2,3.2,3*0.,
    #        5.8,2.9,0.,1.9,1.4,5*0.,5.8,2.9,0.,1.9,1.4,
    #        5*0.,5.9,5.9,2.9,2.9,0.,2.9,2.9,2.9,2.9,0.,
    #        1.8, 1.8,1.8,1.8/
     DATA XGW/7*.80,.71,.80,3*.70,.66,.57,.57,.70,.70,3*0.,
    #        .78,.64,0.,.56,.49,5*0.,.82,.71,0.,.62,.54,
    #        5*0.,.80,.80,.70,.70,0.,.70,.70,.70,.70,.00,
    #        .58,.58,.58,.58/
     DATA XZSH/1.,.58,.58,.59,1.,1.,.59,.70,.59,1.,.69,.7,1.,1.,.81,
    #        .67,1.,3*0.,
    #        .56,.70,1.,.77,.76,5*0.,.56,.68,1.,.74,.81,
    #        5*0.,.58,.21,.69,.19,0.,.68,1.0,.68,1.00,0.,
    #        .76,1.0,.76,1.00/
     DATA XRUN/1.,1.,.75,.61,.64,.41,.47,.58,.44,1.,1.,.63,1.,1.,.82,
    #        .59,.66,3*0.,
    #        1.,1.,1.,1.,1.,5*0.,1.,1.,1.,1.,1.,
    #        5*0.,1.,1.,1.,1.,0.,.78,.78,1.00,1.00,0.,
    #        .85,.85,1.00,1.00/
```
 control of files
****
```
     LFNIB =10
     LFNIC =20
     LFNU =30
     LFNT1=3
     LFNT2=LFNT1
     OPEN(LFNT1)
     OPEN(LFNT2)


     WRITE(LFNT2,1)
   1 FORMAT(' give name of input file building data',/)
     READ(LFNT1,FMT='(A)',IOSTAT=IOS) FILNAM
     OPEN(LFNIB,FILE=FILNAM,STATUS='OLD',IOSTAT=IOS)


     WRITE(LFNT2,2)
   2 FORMAT(' give name of input file climata data',/)
     READ(LFNT1,FMT='(A)',IOSTAT=IOS) FILNAM
     OPEN(LFNIC,FILE=FILNAM,STATUS='OLD',IOSTAT=IOS)


     WRITE(LFNT2,3)
   3 FORMAT(' give name of output file',/)
     READ(LFNT1,FMT='(A)',IOSTAT=IOS) FILNAM
     OPEN(LFNU,FILE=FILNAM,STATUS='OLD',IOSTAT=IOS)
```


****
****
 KCATB: 29 or less: dwelling
        30 or greater: office
 MSTART,MEND: first and last month of calculation (e.g.: 10, 4 = oct.1-apr.30)

```
     READ (LFNIB,*) KCATB, MSTART, MEND
```

```
     WRITE (LFNU,600) KCATB,MSTART,MEND
 600 FORMAT ('0 general category:',I5,/,
    #         ' first month    :',I4,/,
    #         ' last           :',I4)
```
****
 input of climata data
 warning: for the time being only one type of climate:

```
                either "dwelling" or "office" climate data  can be used for the
                whole building
         READ (LFNIC,*) CODEC
         IF (KCATB.LT.30) THEN
--------------------------------------------------------------------------------
         READ (LFNIC,*) TE1,QS1,FQ51,FQ31,D1,FTN1,FTEN1
--------------------------------------------------------------------------------
         WRITE(LFNU,1050) CODEC,(M,M=1,12),
     #       (TE1(M),M=1,12),                    ((QS1(M,OR),M=1,12),OR=1,9),
     #       ((FQ51(M,OR),M=1,12),OR=1,9),((FQ31(M,OR),M=1,12),OR=1,9),
     #       (D1(M),M=1,12),      (FTN1(M),M=1,12),     (FTEN1(M),M=1,12)
1050  FORMAT('0',A10,/,
     #        '  month   :',12I8,/,
     #        '  Te      :',12F8.1,/,
     #     9('  Qs (or.):',12F8.1,/,),
     #     9('  Fq5(or.):',12F8.2,/,),
     #     9('  Fq3(or.):',12F8.2,/,),
     #        '  D       :',12F8.1,/,
     #        '  FTn     :',12F8.2,/,
     #        '  FTen    :',12F8.2)
       ELSE
--------------------------------------------------------------------------------
         READ (LFNIC,*) TE2,QS2,FQ52,FQ32,D2,FWD2,FTWH2
--------------------------------------------------------------------------------
         WRITE(LFNU,1051) CODEC,(M,M=1,12),
     #       (TE2(M),M=1,12),                    ((QS2(M,OR),M=1,12),OR=1,9),
     #       ((FQ52(M,OR),M=1,12),OR=1,9),((FQ32(M,OR),M=1,12),OR=1,9),
     #       (D2(M),M=1,12),      (FWD2(M),M=1,12),     (FTWH2(M),M=1,12)
1051  FORMAT('0',A10,/,
     #        '  month   :',12I8,/,
     #        '  Te      :',12F8.1,/,
     #     9('  Qs (or.):',12F8.1,/,),
     #     9('  Fq5(or.):',12F8.2,/,),
     #     9('  Fq3(or.):',12F8.2,/,),
     #        '  D       :',12F8.1,/,
     #        '  Fwd     :',12F8.2,/,
     #        '  FTwh    :',12F8.2)
       ENDIF
********************************************************************************
  numerical calculation control data
********************************************************************************
         NITER=max. nr. of iterations (e.g. 100)
         BALCRI=iteration criterium in degrees C (e.g. .001)
         KOUT=1:temperatures during iteration are listed in output(only for
               error-detection!!)
--------------------------------------------------------------------------------
         READ(LFNIB,*) NITER,BALCRI,KOUT
--------------------------------------------------------------------------------
********************************************************************************
  collect building characteristics, total and per zone;
  determine occupants'behaviour;
  determine heating system and control.
********************************************************************************
         NIR=number of zones
--------------------------------------------------------------------------------
         READ(LFNIB,*) CODEB,NIR
--------------------------------------------------------------------------------
         DO 10 IR = 1, NIR
          KCAT=category, see explanation further on
          TISET= min. thermostat setpoint; will be ignored in case of category
                for unheated zones.
                TISNWH=set min.temp.during non-office hours (offices; other cate-
                     gories: zero value).
          NOR= number of orientations with window and/or wall and/or roof
               (of this zone)
--------------------------------------------------------------------------------
```

```
      READ(LFNIB,*) IHE,KCAT(IR),TISET(IR),TISNWH(IR),NOR
```

```
check:
      IF(IHE.NE.IR) GOTO 99
      DO 6 IHE = 1, NOR
      A=area, W=window, OP=opaque
      orientation:1=S, 2=SE, 3=E, 4=NE,etc.,... 9=Hor.
```

```
      READ(LFNIB,*)OR,AHE1,AHE2
```

```
      AW(OR,IR) =AHE1
      AOP(OR,IR)=AHE2
   6 CONTINUE
      KW=window type number (see data), U=U-value, ABS=solar abs.coeff.,
      FAC=facade, ROOF=roof (flat roof only, see "Limitations" above.
```

```
      READ(LFNIB,*) KW(IR),UFAC(IR),ABSF(IR),UROOF(IR),ABSR(IR)
```

```
      IHE=KW(IR)
      UW(IR)=XUW(IHE)
      GW(IR)=XGW(IHE)
      R(IR)=XRUN(IHE)
      Z(IR)=XZSH(IHE)
      FL=groundfloor,
      GR=ground, Y=conductance from bottom of floor to:
                  C=ground water with constant temp. TGR, E=to outdoor temp.
      UFL=U-value excluding outdoor surface coefficient, because ground-
          floor is connected to the ground conductances YGRC and YGRE, not
          to outdoor.
      If no ground floor: zero values.
```

```
      READ(LFNIB,*) AFL(IR),UFL(IR),YGRC(IR),TGR(IR),YGRE(IR)
```

```
      UAADJ=UA to/from adjacent zones
      Attention: in case less than 9 zones: add zero values to get
                  still 9 values per line.
```

```
      READ(LFNIB,*) (UAADJ(IR,J),J=1,9)
```

```
      QII=internal heat, mean value in W., for dwellings: mean diurnal,
                                    for offices: mean during 10 working hours.
```

```
      READ(LFNIB,*) QII(IR)
```

```
      V= ventilation, mean diurnal values;"from zone 10" is "from outdoor".
       Warning: only ventilation TO the zone; FROM the zone is to be
                  ignored.              Value in m3/h.
       Attention: in case less than 9 zones: use zero values for the
                  ventilation from non-existent zones.
                  Ventilation from outdoor ALWAYS THE TENTH NR. OF THE LINE !
```

```
      READ(LFNIB,*) (V(IR,J),J=1,10)
```

```
      VM=mechanical vent., only during 10 working hrs.per working day.(cat.C);
          other categories: fill in zero values.
       Attention: see above (input V )
```

```
      READ(LFNIB,*) (VM(IR,J),J=1,10)
```

```
10   CONTINUE
*********************************************************************************
 output building data:
*********************************************************************************
  reset values summated for whole building:
      HTWB=0.
      HTOPB=0.
```

```
        HTAB=0.
        HTFB=0.
        HVEB=0.
        HVAB=0.
        HTOTB=0.
 heading :
        WRITE(LFNU,1150)
 1150 FORMAT('0 Output main thermal characteristics, per zone:   ',/,
      #  '        Sum of nominal heat loss coefficients (W/K)      ',/,
      #  '           Nominal: no correction for night insulation   ',/,
      #  '                    no weighting with temp. adjac.zone,a.s.',/,
      #  '        to outdoor:        gr.floor: to other zones:      ',/,
      #  ' Zone Transmiss. Vent. Transm.   Transm.Vent.  Total     ',/,
      #  '        Wind. Opaq.        floor                         ',/)
 per zone:
        DO 61 IR=1,NIR
         HTW=0.
         HTOP=0.
         HTA=0.
         HVE=0.
         HVA=0.
         HTOT=0.
         DO 62 OR=1,9
          HTW=HTW+AW(OR,IR)*UW(IR)
          IF (OR.LE.8) THEN
           HTOP=HTOP+AOP(OR,IR)*UFAC(IR)
          ELSE
           HTOP=HTOP+AOP(OR,IR)*UROOF(IR)
          ENDIF
 62      CONTINUE
         HTF=AFL(IR)*UFL(IR)
         DO 63 J=1,10
          HTA=HTA+UAADJ(IR,J)
          IF (J.LE.9) THEN
           HVA=HVA+.336*V(IR,J)+.336*VM(IR,J)*(10./24.)
          ELSE
           HVE=HVE+.336*V(IR,J)+.336*VM(IR,J)*(10./24.)
          ENDIF
 63      CONTINUE
 total for this zone; indiscriminate of temp. differences,a.s.!!:
         HTOT=HTW+HTOP+HTA+HTF+HVE+HVA
 addition to values for whole building; indiscrim. of zone temperatures!!:
         HTWB=HTWB+HTW
         HTOPB=HTOPB+HTOP
         HTAB=HTAB+HTA
         HTFB=HTFB+HTF
         HVEB=HVEB+HVE
         HVAB=HVAB+HVA
         HTOTB=HTOTB+HTOT
         WRITE(LFNU,1151)IR,HTW,HTOP,HVE,HTF,HTA,HVA,HTOT
 1151   FORMAT(' ',I5,4F6.1,4X,2F6.1,F8.1)
 61     CONTINUE
        WRITE(LFNU,1152)    HTWB,HTOPB,HVEB,HTFB,HTAB,HVAB,HTOTB
 1152 FORMAT(' ',/,' ',47('-'),/,  ' ','total',4F6.1,4X,2F6.1,F8.1)
 ************************************************************************
 monthly calculation
 ************************************************************************
   reset of total values for the heating season:
        DO 51 IR=1,NIR
         QLT(IR)=0.
         QLRLT(IR)=0.
         QGT(IR)=0.
         QHDT(IR)=0.
 51     CONTINUE
        QLBT=0.
        QLRLBT=0.
```

```
      QGBT=0.
      QHDBT=0.
************************************************************************
   start month loop:
************************************************************************
      MTOT=MEND-MSTART+1
      IF (MTOT.LE.0) MTOT=MTOT + 12
      DO 100 MRUN = 1, MTOT
       M=MSTART+MRUN-1
       IF (M.GT.12) M=M-12
       DO 101 IR = 1, NIR
************************************************************************
   determination of parameters for the given category
************************************************************************
          CAT=A : dwellings,   convective heating thermostat controlled by air te
          (10-19)              no extra vent. above 26 C, solar shading at
                               300 W/m2 level  (if present)


            10=A0:      unheated.
            11=A1:      masonry type, night set back
            12=A2       masonry type, continuous heating
            13=A3       wooden frame type, night set back
            14=A4       wooden frame type, continuous heating
      IF(KCAT(IR).EQ.10) THEN
       CN(IR)=0.
       CNWH(IR)=0.
       KK(IR)=0.
       DD(IR)=0.
      ENDIF
      IF(KCAT(IR).EQ.11) THEN
       CN(IR)=0.91
       CNWH(IR)=0.
       KK(IR)=1.36
       DD(IR)=0.29
      ENDIF
      IF(KCAT(IR).EQ.12) THEN
       CN(IR)=0.97
       CNWH(IR)=0.
       KK(IR)=1.35
       DD(IR)=0.27
      ENDIF
      IF(KCAT(IR).EQ.13) THEN
       CN(IR)=0.88
       CNWH(IR)=0.
       KK(IR)=1.22
       DD(IR)=0.13
      ENDIF
      IF(KCAT(IR).EQ.14) THEN
       CN(IR)=0.97
       CNWH(IR)=0.
       KK(IR)=1.19
       DD(IR)=0.00
      ENDIF
************************************************************************
   determination of parameters for the given category
************************************************************************
          CAT=B : dwellings,   radiator heating, thermostat on comfort temp.
          (20-29)              extra vent. above 26 C, solar shading at
                               500 W/m2 level  (if present)


            20=B0:      unheated.
            21=B1:      heavy mass, night set back
            22=B2       heavy mass, continuous heating
            23=B3       light weight mass, night set back
      IF(KCAT(IR).EQ.20) THEN
       CN(IR)=0.
```

```
          CNWH(IR)=0.
          KK(IR)=0.
          DD(IR)=0.
         ENDIF
         IF(KCAT(IR).EQ.21) THEN
          CN(IR)=0.90
          CNWH(IR)=0.
          KK(IR)=1.19
          DD(IR)=0.45
         ENDIF
         IF(KCAT(IR).EQ.22) THEN
          CN(IR)=1.00
          CNWH(IR)=0.
          KK(IR)=1.70
          DD(IR)=0.02
         ENDIF
         IF(KCAT(IR).EQ.23) THEN
          CN(IR)=0.92
          CNWH(IR)=0.
          KK(IR)=1.16
          DD(IR)=0.37
         ENDIF
```

```
*********************************************************************
 determination of parameters for the given category
*********************************************************************
          CAT=C : offices (not mechanically cooled)
                  convective heating thermostat controlled by air temp
          (30-39) no extra vent. above 26 C, solar shading at
                  300 W/m2 (only offices hours) level

              30=C0:      unheated
              31=C1:      heavy weight
              33=C3:      light weight
              35=C5:      extra heavy weight
         IF(KCAT(IR).EQ.30) THEN
          CN(IR) = 0.
          CNWH(IR)=0.
          KK(IR)= 0.
          DD(IR)= 0.
         ENDIF
         IF(KCAT(IR).EQ.31) THEN
          CN(IR)=0.
          CNWH(IR)=1.0
          KK(IR)=1.55
          DD(IR)=-0.16
         ENDIF
         IF(KCAT(IR).EQ.33) THEN
          CN(IR)=0.
          CNWH(IR)=1.0
          KK(IR)=1.14
          DD(IR)=-0.05
         ENDIF
         IF(KCAT(IR).EQ.35) THEN
          CN(IR)=0.
          CNWH(IR)=1.0
          KK(IR)=1.64
        . DD(IR)=-0.16
         ENDIF
```

```
*********************************************************************
 climate data for this month and category and zone
*********************************************************************
```

```
         IF(KCAT(IR).LT.30) THEN
          TE(IR)=TE1(M)
          DO 111 OR=1,9
           QS(OR,IR)=QS1(M,OR)
111      CONTINUE
  Warning: if offices and dwellings are mixed then the days do not match !!!
          D(IR)=D1(M)
          FTN(IR)=FTN1(M)
          FTEN(IR)=FTEN1(M)
          FWD(IR)=0.
          FTWH(IR)=0.
         ENDIF
         IF(KCAT(IR).GE.10.AND.KCAT(IR).LT.20) THEN
          DO 113 OR=1,9
           FQ(OR,IR)=FQ31(M,OR)
113      CONTINUE
         ENDIF
         IF(KCAT(IR).GE.20.AND.KCAT(IR).LT.30) THEN
          DO 115 OR=1,9
           FQ(OR,IR)=FQ51(M,OR)
115      CONTINUE
         ENDIF
         IF(KCAT(IR).GE.30.AND.KCAT(IR).LT.40) THEN
          TE(IR)=TE2(IR)
          D(IR)=D2(IR)
          FTN(IR)=0.
          FTEN(IR)=0.
          FWD(IR)=FWD2(M)
          FTWH(IR)=FTWH2(M)
          DO 117 OR=1,9
           QS(OR,IR)=QS2(M,OR)
           FQ(OR,IR)=FQ32(M,OR)
117      CONTINUE
         ENDIF
         DTFAC(IR)=D(IR)*24.*.0036
*******************************************************************
 determine night set back correction and initial guess for real indoor temp.
*******************************************************************
  only for heated zones:
         IF (KCAT(IR).GT.10.AND.KCAT(IR).LT.20) THEN
          TIMIN(IR)=CN(IR)*TISET(IR)+(1.-CN(IR))*TE(IR)
         ENDIF
         IF (KCAT(IR).GT.20.AND.KCAT(IR).LT.30) THEN
          TIMIN(IR)=CN(IR)*TISET(IR)+(1.-CN(IR))*TE(IR)
         ENDIF
         IF (KCAT(IR).GT.30.AND.KCAT(IR).LT.40) THEN
          TIMIN(IR)=(FTWH(IR)+(1.-FTWH(IR))*CNWH(IR))*TISET(IR)
    #              + (1.-FTWH(IR))*(1.-CNWH(IR))*TISNWH(IR)
         ENDIF
 initial guess for zone temp. and temp. under groundfloor:
         TI(IR)=TIMIN(IR)
         TG(IR)=TE(IR)
101   CONTINUE
*******************************************************************
 calculate sum of gains, per zone
*******************************************************************
      DO 201 IR=1,NIR
        QIS(IR)=0.
        HE=23.
        DO 121 OR=1,9
          QIS(IR)=QIS(IR)+(1.-(1.-Z(IR))*FQ(OR,IR))*
    #                          AW(OR,IR)*GW(IR)*QS(OR,IR)*DTFAC(IR)
          IF (OR.LE.8) THEN
 vertical facades:
          IF (UFAC(IR).NE.0.)
    #     QIS(IR)=QIS(IR)+(ABSF(IR)/(HE/UFAC(IR)-1.))*
```

```
   #                             AOP(OR,IR)*QS(OR,IR)*DTFAC(IR)
         ELSE
horizontal roofs:
often, horizontal will be a sufficiently accurate approximation also
  for tilted roofs, because the value is relatively small.
         IF (UROOF(IR).NE.0.)
   #     QIS(IR)=QIS(IR)+(ABSR(IR)/(HE/UROOF(IR)-1.))*
   #                             AOP(OR,IR)*QS(OR,IR)*DTFAC(IR)
         ENDIF
121      CONTINUE
         IF(KCAT(IR).LT.30) THEN
           QG(IR)=QII(IR)*DTFAC(IR)+QIS(IR)
         ENDIF
         IF(KCAT(IR).GT.30.AND.KCAT(IR).LT.40) THEN
 for offices:
           QG(IR)=QII(IR)*FWD(IR)*(10./24.)*DTFAC(IR)+QIS(IR)
         ENDIF
HL is in fact equal to the value of HL*dt in the report
***************************************************************************
 calculate specific heat loss coefficient, per zone (MJ/K)
***************************************************************************
         HL(IR)=0.
         DO 131 OR=1,9
           IF (KCAT(IR).LT.30) THEN
             HL(IR)=HL(IR)+ (1.-(1.-R(IR))*FTEN(IR))*
   #                     AW(OR,IR)*UW(IR)*DTFAC(IR)
           ENDIF
           IF (KCAT(IR).GE.30.AND.KCAT(IR).LT.40) THEN
 for offices: no 'night' insulation implemented:
             HL(IR)=HL(IR)+
   #                     AW(OR,IR)*UW(IR)*DTFAC(IR)
           ENDIF
           IF (OR.LE.8) THEN
             HL(IR)=HL(IR)+AOP(OR,IR)*UFAC(IR)*DTFAC(IR)
           ELSE
             HL(IR)=HL(IR)+AOP(OR,IR)*UROOF(IR)*DTFAC(IR)
           ENDIF
131      CONTINUE
         DO 132 J=1,NIR
           HL(IR)=HL(IR)+UAADJ(IR,J)*DTFAC(IR)
132      CONTINUE
         HL(IR)=HL(IR)+AFL(IR)*UFL(IR)*DTFAC(IR)
         DO 133 J=1,10
           HL(IR)=HL(IR)+.336*V(IR,J)*DTFAC(IR)
   for offices :
           HL(IR)=HL(IR)+.336*VM(IR,J)*FTWH(IR)*DTFAC(IR)
133      CONTINUE

 PRO MEMORIA: correction for cold surfaces in case of combination
   HERE        convective heating and air temp. control (see also
               however comments under "Limitations" above).
201  CONTINUE
***************************************************************************
 iteration loop start
***************************************************************************
     DO 300 ITER=1,NITER
 set switch for balance check and save previously guessed values:
     KBAL=1
     DO 251 IR=1,NIR
       TIOLD(IR)=TI(IR)
251  CONTINUE
     DO 301  IR=1,NIR
***************************************************************************
 calculate mean ambient temperature, per zone
***************************************************************************
         TA(IR)=0.
```

```
            DO 141 OR=1,9
            IF (KCAT(IR).LT.30) THEN
            TA(IR)=TA(IR)+ (1.-(1.-R(IR))*FTEN(IR))*
    #                      AW(OR,IR)*UW(IR)*DTFAC(IR)*TE(IR)
            ENDIF
            IF (KCAT(IR).GE.30.AND.KCAT(IR).LT.40) THEN
 offices: no 'night' insulation implementd yet:
            TA(IR)=TA(IR)+
    #                      AW(OR,IR)*UW(IR)*DTFAC(IR)*TE(IR)
            ENDIF
            IF (OR.LE.8) THEN
            TA(IR)=TA(IR)+AOP(OR,IR)*UFAC(IR)*DTFAC(IR)*TE(IR)
            ELSE
            TA(IR)=TA(IR)+AOP(OR,IR)*UROOF(IR)*DTFAC(IR)*TE(IR)
            ENDIF
141     CONTINUE
            DO 142 J=1,NIR
            TA(IR)=TA(IR)+UAADJ(IR,J)*DTFAC(IR)*TI(J)
142     CONTINUE
            TA(IR)=TA(IR)+AFL(IR)*UFL(IR)*DTFAC(IR)*TG(IR)
            TI(10)=TE(IR)
            DO 143 J=1,10
            TA(IR)=TA(IR)+.336*V(IR,J)*DTFAC(IR)*TI(J)
  offices:
            TA(IR)=TA(IR)+.336*VM(IR,J)*FTWH(IR)*DTFAC(IR)*TI(J)
143     CONTINUE

  PRO MEMORIA: correction for cold surfaces in case of combination
    HERE          convective heating and air temp. control (see "Limitations")

            TA(IR)=TA(IR)/HL(IR)
301  CONTINUE
****************************************************************************
  calculate QL,GLR,CG,DT,TI for each heated zone
        and TI for unheated zones
****************************************************************************
        DO 401 IR=1,NIR
            IF (KCAT(IR).NE.10.AND.KCAT(IR).NE.20.AND.KCAT(IR).NE.30) THEN
 heated zones:
            QL(IR)=HL(IR)*(TIMIN(IR)-TA(IR))
            GLR(IR)=QG(IR)/QL(IR)
 relation for utilization factor:
            IF((GLR(IR)-DD(IR)).GT..1) THEN
              CG(IR)=1.-EXP(-KK(IR)/(GLR(IR)-DD(IR)))
              IF((CG(IR)-1./GLR(IR)).GT.0.) CG(IR)=1./GLR(IR)
            ELSE
              IF (GLR(IR).GE.0.) THEN
              CG(IR)=1
              ELSE
 in case GLR negative during iteration, due to negative QL, then heat
 demand is certainly zero; let CG and DT be zero and calculate Ti directly.
              CG(IR)=0.
              ENDIF
            ENDIF
 calculation of the overheating with new value of GLR (and thus of CG) :
            IF (GLR(IR).GE.0.) THEN
            DTR(IR)=1.+(1.-CG(IR))*GLR(IR)
            TI(IR)=(TIMIN(IR)-TA(IR))*DTR(IR) + TA(IR)
            DTA(IR)=TI(IR)-TIMIN(IR)
            ELSE
            for negative QL, calculate as in case of unheated zone:
            TI(IR)=QG(IR)/HL(IR)+TA(IR)
            DTR(IR)=0.
            DTA(IR)=TI(IR)-TIMIN(IR)
            ENDIF
            ELSE
```

```
unheated zones:
        TI(IR)=QG(IR)/HL(IR)+TA(IR)
        DTR(IR)=0.
        DTA(IR)=0.
        ENDIF
        QLREAL(IR)=HL(IR)*(TI(IR)-TA(IR))
        QHD(IR)=QLREAL(IR)-QG(IR)
 temp. under ground floor need to be calculated:
        IF(AFL(IR).GT..01) THEN
         TG(IR)=UFL(IR)*TI(IR)+YGRC(IR)*TGR(IR)+YGRE(IR)*TE(IR)
         TG(IR)=TG(IR)/(UFL(IR)+YGRC(IR)+YGRE(IR))
        ENDIF
401  CONTINUE
*******************************************************************************
 output during iteration for error detection
*******************************************************************************
        IF (KOUT.EQ.1) THEN
        WRITE(LFNU,1350)M,ITER,(TI(I),I=1,9)
1350    FORMAT(' ',2I5,9F8.3)
        ENDIF
*******************************************************************************
 convergence check
*******************************************************************************
 set switch on off in case one or more zones aren't yet in balance:
     IF (ITER.NE.1) THEN
       DO 501 IR=1,NIR
         XHE=ABS(TIOLD(IR)-TI(IR))
         IF(XHE.GT.BALCRI) KBAL=0
501  CONTINUE
       ELSE
        KBAL=0
       ENDIF
       IF (KBAL.EQ.1) THEN
 sufficient convergence reached
*******************************************************************************
 summation over all zones (B= building)
*******************************************************************************
        QLB(M)=0.
        QLRLB(M)=0.
        QGB(M)=0.
        QHDB(M)=0.
        DO 551 IR=1,NIR
         QLB(M)=QLB(M)+QL(IR)
         QLRLB(M)=QLRLB(M)+QLREAL(IR)
         QGB(M)=QGB(M)+QG(IR)
         QHDB(M)=QHDB(M)+QHD(IR)
551     CONTINUE
*******************************************************************************
 addition to total values over all periods
*******************************************************************************
        DO 601 IR=1,NIR
         QLT(IR)=QLT(IR)+QL(IR)
         QLRLT(IR)=QLRLT(IR)+QLREAL(IR)
         QGT(IR)=QGT(IR)+QG(IR)
         QHDT(IR)=QHDT(IR)+QHD(IR)
 601    CONTINUE
        QLBT=QLBT+QLB(M)
        QLRLBT=QLRLBT+QLRLB(M)
        QGBT=QGBT+QGB(M)
        QHDBT=QHDBT+QHDB(M)


*******************************************************************************
 output for this month
*******************************************************************************
```

```
   heading for output per month:
      WRITE(LFNU,1501)CODEB, CODEC
1501 FORMAT('0',A10,' ',A10,//,
   #        ' month zone Temp. Tamb   Te   GLR  CG   DTR  DTA ',
   #        '    QL     QLreal      QG        QHD',/,
   #        ' or period  C    C      C    -    -    -    C  ',
   #        '    MJ        MJ        MJ        MJ')
      DO 701 IR=1,NIR
       WRITE(LFNU,1505) M,IR,TI(IR),TA(IR),TE(IR),
   #        GLR(IR),CG(IR),DTR(IR),DTA(IR),QL(IR),QLREAL(IR),
   #        QG(IR),QHD(IR)
1505     FORMAT(' ',
   #               2I5,3F6.1,4F5.2,4F10.0)
701      CONTINUE
         WRITE(LFNU,1510)QLB(M),QLRLB(M),QGB(M),QHDB(M),ITER
1510     FORMAT('0',5X,'total:',37X,4F10.0,/,
   #           ' number of iterations needed:',I5)
      GOTO 95
      ELSE
 continue with the iteration loop "300"
      IF(ITER.EQ.NITER) THEN
      WRITE(LFNU,1900) NITER
1900     FORMAT('0','WARNING: iteration stopped by maximum =',I5,/,
   #     ' convergence not reached; results can not be trusted!!')
      ENDIF
      ENDIF
300   CONTINUE
 95   CONTINUE
100   CONTINUE
***********************************************************************
 output total values for all periods
***********************************************************************
 heading:
      WRITE(LFNU,1620)
1620 FORMAT('0','total values all periods:',/,
   #        '                                                    ',
   #        '            QL     QLreal      QG        QHD',/,
   #        '                                                    ',
   #        '            MJ        MJ        MJ        MJ')
      DO 801 IR=1,NIR
       WRITE(LFNU,1630)IR,QLT(IR),QLRLT(IR),QGT(IR),QHDT(IR)
1630   FORMAT(' ',5X,I5,38X,4F10.0)
801  CONTINUE
      WRITE(LFNU,1640)QLBT,QLRLBT,QGBT,QHDBT
1640 FORMAT(' ',5X,'total:',37X,4F10.0)
 99  CONTINUE
     END
```

```
21, 10,  4
100, .001, 0
'T.VAR01 NW', 5
1, 21, 19.06,  0.0, 3
1,  5.5, 11.3
3,  0.0, 21.8
5,  3.0,  6.8
46, .40, .80, .20, .50
40.2, .308, .33, 10., .50
0.0, 31.9, 49.8, 33.8, 0.0,  0.0,  0.0,  0.0,  0.0
230.8
0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, 49.6
0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0
2, 21, 19.06,  0.0, 1
5,  2.5,  4.5
46, .40, .80, .20, .50
7.8, .308, .33, 10., .50
31.9,  0.0,  0.0, 16.0,  0.0,  0.0,  0.0,  0.0,  0.0
210.0
24.0,  0.0,  8.0, 14.4, 28.8,  0.0,  0.0,  0.0,  0.0, 22.4
0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0
3, 21, 18.0, 0., 2
1,  3.5, 12.1
3,  0.0, 10.1
46, .40, .80, .20, .50
0.0,  0.0,  0.0,  0.0,  0.0
49.8,  0.0,  0.0, 31.5, 49.8,  0.0,  0.0, 0.0,  0.0
46.67
11.2,  0.0,  0.0,  8.0, 14.4,  0.0,  0.0,  0.0,  0.0, 36.8
0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0
4, 21, 18.0, 0., 2
3,  0.0, 10.1
5,  3.5, 12.1
46, .40, .80, .20, .50
0.0,  0.0,  0.0,  0.0,  0.0
33.8, 16.0, 31.5,  0.0, 49.8,  0.0, 0.0,  0.0,  0.0
23.33
0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, 30.4
0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0
5, 20 ,  0.0,  0.0, 2
3,  0.0, 10.7
9,  0.0, 58.6
46, .40, .80, .20, .50
0.0,  0.0,  0.0,  0.0,  0.0
0.0,  0.0, 49.8, 49.8,  0.0,  0.0,  0.0,  0.0,  0.0
0.0
0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, 62.4
0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0
```

```
general category:   21
first month     :   10
last            :    4

TCM.TRY.DW
month   :      1      2      3      4      5      6      7      8      9     10     11     12
Te      :     2.5    2.7    5.6    8.0    0.0    0.0    0.0    0.0    0.0   11.2    6.0    3.4
Qs (or.):    34.4   52.1   94.9  117.8    0.0    0.0    0.0    0.0    0.0   74.4   44.8   29.6
Qs (or.):    28.4   43.5   85.4  109.4    0.0    0.0    0.0    0.0    0.0   61.0   35.6   21.8
Qs (or.):    17.2   29.1   63.2   89.2    0.0    0.0    0.0    0.0    0.0   40.6   20.1   12.4
Qs (or.):    12.6   22.3   45.1   66.1    0.0    0.0    0.0    0.0    0.0   30.0   14.4    9.9
Qs (or.):    12.5   21.8   40.8   56.1    0.0    0.0    0.0    0.0    0.0   28.9   14.2    9.8
Qs (or.):    12.6   22.4   43.9   70.0    0.0    0.0    0.0    0.0    0.0   30.5   14.4    9.9
Qs (or.):    16.5   29.4   58.7   95.6    0.0    0.0    0.0    0.0    0.0   42.5   20.5   15.3
Qs (or.):    27.4   43.9   80.3  114.4    0.0    0.0    0.0    0.0    0.0   63.2   36.2   25.9
Qs (or.):    25.2   46.9   98.3  146.1    0.0    0.0    0.0    0.0    0.0   65.5   31.0   19.9
Fq5(or.):    0.34   0.40   0.46   0.44   0.00   0.00   0.00   0.00   0.00   0.41   0.33   0.33
Fq5(or.):    0.19   0.26   0.40   0.41   0.00   0.00   0.00   0.00   0.00   0.29   0.10   0.00
Fq5(or.):    0.00   0.00   0.13   0.30   0.00   0.00   0.00   0.00   0.00   0.02   0.00   0.00
Fq5(or.):    0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
Fq5(or.):    0.00   0.00   0.00   0.01   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
Fq5(or.):    0.00   0.00   0.13   0.31   0.00   0.00   0.00   0.00   0.00   0.02   0.00   0.00
Fq5(or.):    0.26   0.24   0.38   0.42   0.00   0.00   0.00   0.00   0.00   0.31   0.15   0.20
Fq5(or.):    0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
Fq3(or.):    0.58   0.61   0.69   0.65   0.00   0.00   0.00   0.00   0.00   0.66   0.67   0.55
Fq3(or.):    0.48   0.53   0.62   0.63   0.00   0.00   0.00   0.00   0.00   0.57   0.53   0.31
Fq3(or.):    0.07   0.20   0.39   0.46   0.00   0.00   0.00   0.00   0.00   0.22   0.04   0.00
Fq3(or.):    0.00   0.00   0.01   0.11   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
Fq3(or.):    0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
Fq3(or.):    0.00   0.00   0.02   0.16   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
Fq3(or.):    0.11   0.15   0.31   0.48   0.00   0.00   0.00   0.00   0.00   0.21   0.04   0.00
Fq3(or.):    0.47   0.51   0.59   0.62   0.00   0.00   0.00   0.00   0.00   0.57   0.57   0.48
Fq3(or.):    0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
D       :    31.0   28.0   31.0   30.0    0.0    0.0    0.0    0.0    0.0   31.0   30.0   31.0
FTn     :    0.34   0.36   0.39   0.41   0.00   0.00   0.00   0.00   0.00   0.40   0.35   0.34
FTen    :    0.57   0.56   0.56   0.55   0.00   0.00   0.00   0.00   0.00   0.62   0.60   0.59

Output main thermal characteristics, per zone:
     Sum of nominal heat loss coefficients (W/K)
     Nominal: no correction for night insulation
              no weighting with temp. adjac.zone,a.s.
        to outdoor:       gr.floor:  to other zones:
Zone Transmiss.  Vent. Transm.    Transm.Vent.   Total
     Wind. Opaq.       floor

  1  24.7 16.0 16.7 12.4    155.7   0.0   225.4
  2   7.3  1.8  7.5  2.4     55.7  25.3    99.9
  3  10.2  8.9 12.4  0.0    131.1  11.3   173.8
  4  10.2  8.9 10.2  0.0    131.1   0.0   160.3
  5   0.0 16.0 21.0  0.0     99.6   0.0   136.6
------------------------------------------------
total 52.2 51.5 67.7 14.8    573.2  36.6   796.0

T.VAR01 NW   TCM.TRY.DW

month zone Temp. Tamb   Te   GLR   CG   DTR   DTA     QL    QLreal    QG    QHD
or period   C    C     C    -     -     -     C     MJ     MJ      MJ    MJ
  10   1  18.9 15.7 11.2 1.21 0.79 1.26 0.66  1253.   1573.   1520.   53.
  10   2  19.6 16.7 11.2 1.87 0.53 1.87 1.34   375.    703.    703.    0.
  10   3  17.6 16.3 11.2 1.30 0.75 1.32 0.32   460.    608.    599.    9.
  10   4  17.3 16.5 11.2 0.76 0.98 1.02 0.01   368.    374.    281.   93.
  10   5  16.0 15.8 11.2 0.00 0.00 0.00 0.00     0.     62.     62.    0.

     total:                                   2456.   3319.   3164.  155.
```

```
number of iterations needed:    9

T.VAR01 NW   TCM.TRY.DW
```

month zone		Temp.	Tamb	Te	GLR	CG	DTR	DTA	QL	QLreal	QG	QHD
or period		C	C	C	-	-	-	C	MJ	MJ	MJ	MJ
11	1	17.8	13.4	6.0	0.54	1.00	1.00	0.00	2075.	2075.	1114.	961.
11	2	17.9	14.9	6.0	0.91	0.93	1.07	0.19	675.	720.	611.	109.
11	3	16.8	14.3	6.0	0.36	1.00	1.00	0.00	1111.	1111.	403.	709.
11	4	16.8	14.3	6.0	0.16	1.00	1.00	0.00	1017.	1017.	164.	853.
11	5	14.0	13.9	6.0	0.00	0.00	0.00	0.00	0.	29.	29.	0.
total:									4879.	4952.	2320.	2631.

```
number of iterations needed:    3

T.VAR01 NW   TCM.TRY.DW
```

month zone		Temp.	Tamb	Te	GLR	CG	DTR	DTA	QL	QLreal	QG	QHD
or period		C	C	C	-	-	-	C	MJ	MJ	MJ	MJ
12	1	17.5	12.3	3.4	0.38	1.00	1.00	0.00	2529.	2529.	972.	1557.
12	2	17.5	14.1	3.4	0.74	0.98	1.01	0.04	820.	830.	610.	220.
12	3	16.5	13.4	3.4	0.22	1.00	1.00	0.00	1435.	1435.	317.	1118.
12	4	16.5	13.4	3.4	0.10	1.00	1.00	0.00	1321.	1321.	136.	1185.
12	5	13.0	13.0	3.4	0.00	0.00	0.00	0.00	0.	19.	19.	0.
total:									6104.	6134.	2054.	4080.

```
number of iterations needed:    3

T.VAR01 NW   TCM.TRY.DW
```

month zone		Temp.	Tamb	Te	GLR	CG	DTR	DTA	QL	QLreal	QG	QHD
or period		C	C	C	-	-	-	C	MJ	MJ	MJ	MJ
1	1	17.4	11.9	2.5	0.39	1.00	1.00	0.00	2662.	2662.	1037.	1625.
1	2	17.4	13.9	2.5	0.72	0.99	1.01	0.03	862.	870.	623.	247.
1	3	16.5	13.1	2.5	0.23	1.00	1.00	0.00	1531.	1531.	349.	1183.
1	4	16.5	13.1	2.5	0.11	1.00	1.00	0.00	1411.	1411.	157.	1254.
1	5	12.7	12.7	2.5	0.00	0.00	0.00	0.00	0.	24.	24.	0.
total:									6467.	6499.	2190.	4310.

```
number of iterations needed:    3

T.VAR01 NW   TCM.TRY.DW
```

month zone		Temp.	Tamb	Te	GLR	CG	DTR	DTA	QL	QLreal	QG	QHD
or period		C	C	C	-	-	-	C	MJ	MJ	MJ	MJ
2	1	17.4	12.0	2.7	0.48	1.00	1.00	0.00	2377.	2377.	1139.	1238.
2	2	17.5	13.9	2.7	0.78	0.97	1.02	0.08	770.	787.	604.	183.
2	3	16.5	13.2	2.7	0.30	1.00	1.00	0.00	1357.	1357.	414.	943.
2	4	16.5	13.2	2.7	0.16	1.00	1.00	0.00	1249.	1249.	205.	1044.
2	5	12.9	12.7	2.7	0.00	0.00	0.00	0.00	0.	40.	40.	0.
total:									5753.	5810.	2401.	3409.

```
number of iterations needed:    3

T.VAR01 NW   TCM.TRY.DW
```

month zone		Temp.	Tamb	Te	GLR	CG	DTR	DTA	QL	QLreal	QG	QHD
or period		C	C	C	-	-	-	C	MJ	MJ	MJ	MJ
3	1	17.9	13.2	5.6	0.82	0.96	1.03	0.15	2181.	2252.	1786.	466.
3	2	18.2	14.9	5.6	1.09	0.84	1.17	0.49	698.	816.	761.	56.
3	3	16.8	14.3	5.6	0.63	1.00	1.00	0.00	1148.	1149.	724.	425.
3	4	16.8	14.3	5.6	0.36	1.00	1.00	0.00	1044.	1044.	373.	671.
3	5	14.0	13.7	5.6	0.00	0.00	0.00	0.00	0.	93.	93.	0.
total:									5071.	5355.	3737.	1618.

```
number of iterations needed:    5
```

T.VAR01 NW TCM.TRY.DW

month zone or period		Temp. C	Tamb C	Te C	GLR -	CG -	DTR -	DTA C	QL MJ	QLreal MJ	QG MJ	QHD MJ
4	1	18.9	14.5	8.0	1.25	0.77	1.28	0.98	1641.	2102.	2048.	54.
4	2	19.4	16.0	8.0	1.73	0.58	1.73	1.44	468.	808.	808.	0.
4	3	17.4	15.4	8.0	1.21	0.79	1.25	0.40	703.	879.	849.	30.
4	4	17.0	15.5	8.0	0.79	0.97	1.02	0.04	599.	614.	475.	139.
4	5	15.1	14.7	8.0	0.00	0.00	0.00	0.00	0.	132.	132.	0.
total:									3411.	4536.	4312.	223.

number of iterations needed: 9

total values all periods:

	QL MJ	QLreal MJ	QG MJ	QHD MJ
1	14718.	15569.	9615.	5954.
2	4668.	5534.	4720.	815.
3	7745.	8071.	3654.	4417.
4	7010.	7031.	1791.	5240.
5	0.	399.	399.	0.
total:	34141.	36605.	20178.	16427.

.