INTERNATIONAL ENERGY AGENCY
energy conservation in buildings and
community systems programme
Annex XII
Windows and fenestration

Step 4

Comparison of six simulation codes
DEROB
DYWON
PASSIM
DOE-2.1C
SERI-RES
HELIOS 1

January 1987

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Annex XII, WINDOWS AND FENESTRATION

Report from Step 4

COMPARISON OF SIX SIMULATION CODES
DEROB
DYWON
PASSIM
DOE-2.1C
SERI-RES
HELIOS1

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

Annex XII - Windows and Fenestration

Participants in Annex XII:

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

The complete list of representatives who have contributed to this report is given in Appendix G.

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CONTENT PAGE

Appendix

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 Cooparation 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 signifcant 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 programm energy conservation in buildings and community systems is maintained by and 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 glazings and combinations of glazings 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 to 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 manufactures.

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: Compare and analyse existing dynamic calculation methods dealing with the influence of window type, size and oriantation 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 focused on windows also complex systems 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 buldings (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.

Informations concerning the other reports from the project can be obtained from the operating agent:

H.A.L. van Dijk
TNO Institute of applied physics
P.O.Box 155
2600 AD Delft
The Netherlands

1. INTRODUCTION

Previous studies conducted within IEA (Annex I [Ref. 1] and Annex III [Ref. 2]) showed quite large differences in heating and cooling loads predicted by dynamic building energy simulation programs on hourly basis. The purpose of the study within Annex XII was to identify the problem areas responsible for those differences and to compare in more detail the calculation procedures connected to windows.

The chosen strategy within Annex XII was to perform a detailed code to code comparison based on a given standard test room and Geneva climatological data. In order to be able to analyse and compare the calculation results of the different simulation codes, a uniform, standardized output structure had to be defined. One important subject was to give a most detailed building heat balance on monthly or seasonal basis.

Table 1.1 gives an overlook of the program codes and participants, which have been involved in this part of the IEA-Project:

Program code	Participant
DEROB	Fraunhofer Institute of Building Physics Dir.: Prof.Dr.Ing.K.Gertis H.Erhorn,R.Stricker,M.Szerman Nobelstr.12 D-7000 Stuttgart 80 F R Germany
DYWON	TNO Institute of Applied Physics (TPD) H.A.L. van Dijk,K.Th.Knorr Stieltjesweg 1 2600 AD Delft The Netherlands
PASSIM	EPFL Solar Research Group,LESO J.B.Gay,N.Morel CH-1015 Lausanne Switzerland
DOE - 2.1C	Lawrence Berkeley Laboratory J.H.Klems 1,Cyclotron Road Berkeley,California 94720 U.S.A.
SERI - RES	EMPA Section Building Physics T.W.Püntener CH-8600 Dübendorf Switzerland
HELIOS - 1	EMPA Section Building Physics Th.Frank CH-8600 Dübendorf Switzerland

Table 1.1 Program codes and participants

Three different calculations have been performed:

- Simplified base case conditions in order to identify the problem areas
- Base case calculations over a short period of 10-days
- Calculation of seasonal heating demand.

The Swiss participants of the annex decided to complete the calculations with an additional validation procedure of the three Swiss simulation programs against measured data of a direct gain cell. For the validation study, a high mass building of the Federal Institute of Technology in Lausanne has been chosen, the LESO-building from the Solar Research Group GRES. The results have been published in a seperate report (see Ref. [3]).

Discussing the results of the program comparison and analysing the differences, a distinction of the possible reasons for deviations has to be made:

- effects caused by the input specifications
- effects caused by different models and simplifications
- effects causes by different control strategies of heating or cooling equipment (set points).

REFERENCES

[1] IEA Annex I
Comparison of Load Determination Methodologies for Building Energy Analysis Programs.
NTIS, 1981

[2] IEA Annex III
Calculation Methods to Predict Energy Savings in Residential Buildings.
Swedish Council for Building Research, 1983

[3] Th. Frank; T.W. Püntener; J.B. Gay; N. Morel
Comparison of three different simulation codes with measured data.
EMPA, 1985

[4] H. Erhorn; R. Stricker; M. Szerman
Sunspace Calculation Comparison
SUNCODE-DEROB
Working Document IEA Task VIII/ Annex XII, FhG-IBP, 1986

2. DESCRIPTION OF THE SIMULATION CODES

Six different simulation codes have been compared within this annex. The program types and methodologies are summerized in table 2.1.

NAME	TYPE	METHOD	HEAT TRANSFER SURFACE - ROOM AIR
DEROB	Multizone model	RC-network (finite differences)	detailed model
DYWON	Multizone model	RC-network (finite differences)	detailed model
PASSIM	Multizone model	RC-network (finite differences)	detailed model
DOE-2	Multizone model	Weighting factors (response factors)	detailed model
SERI-RES	Multizone model	RC-network (finite differences)	simplified model
HELIOS1	Single zone model	Response factors	simplified model

Table 2.1 Program codes and methodologies

a) Program Code DEROB

DEROB (Dynamic Energy Response of Buildings) is a dynamic thermal simulation program. It was developed originally by Prof. F.N. Arumi at the Numerical Simulation Laboratory at the University of Texas at Austin in 1979.

The program transfers a building description into an electrical network analogy and then proceeds to solve the network for hourly weather conditions.

For this solution the Gaussion method is used.

The program needs as input an exact description of the building and the boundary conditions (e.g. geometry, materials, building component structure, geographical data, internal heat sources, data about heating and cooling equipment, furniture, ventilation, hourly weather data etc.).

With these boundary conditions the program system DEROB, that consists of a suite of six programs, is enabled to predict the thermal behaviour of a complex building.

A pecularity of the program is the more or less sufficient treatment of the long- and short wave radiation and the dealing of these phenomena in- and outside of the building.

Moreover the convective heat transfer on surfaces in- and outside of a building is not constant, but temperature and air-velocity dependent.

This leads to a variable, radiation and convection dependent surface film coefficient onto the inner and outer building surface.

The heating model in the program system is ideal, without time delays. Thermostat setpoints for the required room temperature, switch on- and off times and the installed power of the heating system are input data.

In the same way the aspect of cooling is handled in DEROB.

The ventilation rate between the rooms of the building can be specified. Moreover the possibility of fan connections between the rooms is available. It is possible to define advection connections between rooms, that means ventilation between rooms only caused by the force of temperature-differences.

By need of temporary insulation it is possible to define them in the input.

The disadvantage of the program system is the relatively high needed calculation time and therefore computing costs. There is still demand for validation and verifying the algorithms and therefore the whole program.

The DEROB International User Association endeavours for improving the program system and deriving a common validated DEROB version.

b) Program code 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.

c) Program code PASSIM

PASSIM is a program developed at EPFL Lausanne to simulate dynamically any thermal nodal network (maximum 99 nodes). It was written originally to simulate passive solar systems, and so contains facilities such as a solar radiation generator, transmission functions for window, shadowing functions, and so on. But the program would also be usable to simulate simple active systems or any thermal system.

The nodes may be connected together by conducitive, radiation and/or convective couplings. The needed meteorological data (at least the outside air temperature and solar radiation on an horizontal plane) are introduced by an external tabulation file, the interval being any value (usually 30 minutes or 1 hour). Other data, for example temperatures assigned to certain nodes of the thermal network, may be introduced by the same way.

The program is implemented on a VAX 11/780, and is written in FORTRAN 77. The output may be:

- graphic representations (on Tektronix 4012 or compatible terminal) of temperatures or thermal powers or heat flows, versus time;
- energy balances;
- the whole simulation data may be saved on a file, to be retrieved later on by another program (for example DISPLAY to see data output or COMFORT to evaluate the comfort level in view of the Fanger's theory).

Functionnaly, the code solves the energy balances for every node in the thermal network. So, if the temperatures at time t are known, then one can compute the increments between t and t + Δt; the calculation uses the Crank-Nicholson method.

The program is interactive, but may of course also be used in batch mode for long simulations. The network configuration has to be input by a "configuration file", edited before by any text editor. On the other side, the tabulated data has to be on a "tabulation file", following the GRES format (whose description may be found in the program manual; a short program exists to convert any form of tabulated data to GRES format).

The program is rather flexible, it allows a decomposition of the considered building (or part of a building) in any thermal network with a maximum of 99 nodes. However this flexibilitiy may also be considered as a drawback, the user having to know how to build the optimal network. In the future the code could be completed in order to produce automatically the nodal network from the building raw data. Such an additional element would be a part of an expert system.

Recently the program has already been made more userfriendly by the addition of a conversation code named "SCREEN". This routine allows an easy interactive entry of the input thermal network, it includes facilities as a table of material properties and convenient editing possibilities.

d) Program code DOE-2

The computer program DOE-2, developed at LBL, Berkeley, provides a detailed simulation of the energy consumption of buildings of all sizes, ranging from simple detached residences to large commercial buildings with complex HVAC systems. It was designed for fast calculation in order to make detailed simulations as part of the building design process economically feasible, and concentrates on facilitating a systems approach to the building rather than obtaining extreme accuracy on any one subsystem.

The simulation is divided into three parts, LOADS, SYSTEMS and PLANT. In LOADS, the individual spaces (called zones) in the building are modeled and the hourly heating or cooling amounts necessary to keep each zone at a fixed reference air temperature are calculated. In SYSTEMS the interactions between different zones and between the zones and the HVAC system are modeled. The thermostat set points, ability of the HVAC system to deliver the demandes loads, interzone heat transfers, and actual hourly zone temperatures are calculated in this step. In PLANT the generation of the HVAC energy flows (hot air, chilled water, etc.) from primary energy inputs (gas, oil, electricity) are modeled and the building's primary energy demand computed. In this description we concentrate on the LOADS and some SYSTEMS calculations.

The key quantities of interest in a zone in DOE-2 are the heating and cooling loads necessary to maintain the zone air temperature at a given value. These loads, Q_i, (which are defined to be positive for cooling loads and negative for heating loads) must be related to the driving forces affecting the building thermal performance, namely exterior weather conditions, admitted solar gain through windows, and internal sources of heat from activities in the building. To do this, DOE-2 assumes a linearized form of the heat transfer equations (i.e., linearized radiative couplings and constant interior convective film coefficients) and treats the problem by superposition. Response factors are used to relate the surface temperatures and heat fluxes on the inward (to the zone) and outward side of each envelope element bounding the zone.

For solar gain, the user specifies the fraction of the solar gain absorbed at each surface, and these fractions are used to apportion the unit pulse. The ratios Q_i/q_i then define the weighting factors for conduction, solar gain, lights, people/equipment, etc., which are used in the hourly calculation to determine the manner in which radiant gains in the zone appear as heat flows into the air.

In addition, another calculation is done by following the time history of a unit temperature pulse through this network. The hourly values fo Q_i which result define the temperature weighting factors which are later (in SYSTEMS) used to relate changes in the zone temperature to deviations between the demandes loads and the heat actually supplied by the HVAC system.

In the hourly calculation, LOADS uses the hourly temperature values, solar gain, (scheduled) internal loads, etc., to determine the driving heat inputs or outputs of the zone. Wind and incident solar gain are used to determine the heat transfer to the exterior surfaces of walls, and the response factor, calculation transfer this into delayed heat fluxes at the interior wall surfaces. For a given hour, then, the heat fluxes conducted to the wall interior surfaces are known from the exterior surface heat transfers at that and previous hours. The fluxes are split into convective and radiative parts; the convecitve part contributes immedately to the Q_i for that surface, The radiative part is distributed as a uniform flux over the interior surfaces to form the q_i; these then mulitply the conductive weighting factor series to determine the contributions to the Q_i at that and subsequent hours. In the LOADS calculation windows are treated as walls with negligible thermal mass. Solar/optical radiation transmitted through the windows is treated separately; heat absorbed in the windows is treated as additional conducted flux to the extent that it is tranferred to the interior. Furniture or other thermal mass within the zone is treated as a wall with no connection to the exterior or other zones.

Transmitted solar radiation is first corrected for cavity back-reflection out the window and then distributed among the wall surfaces as specified by the user to form the q_i, which then multiply the solar weighting factor series to determine the load contributions Q_i at the current and subsequent hours. Internal loads are split into convecitve and radiative parts. The convective part contributes to the current hour Q_i and the radiative part is distributed among the internal surfaces and apportioned among the current and subsequent hourly Q_i using the internal load weigthing factors. Internal loads arising from different sources may have different scheduling but are otherwise treated identically, with the exception of lighting, where a portion of the load may be specified to appear in an adjacent plenum zone.

At the end of the LOADS calculation, the net loads Q_i for each wall element necessary to maintain the zone at the temperature T_z (the "demanded loads") have been computed for each hour. These and the weighting factors are then combined to form loads and weighting factors for the overall zone and are passed to the SYSTEMS section of the program.

In the SYSTEMS calculation, the zones of the building are linked together, the HVAC system is modeled, including the effects of thermostat setpoints for each zone, and the coupled equations for the actual zone hourly temperatures are solved, taking into account

(1) the dependence of each zone's demandes loads on that zone's temperature, as established through the temperature weighting factors for that zone (calculated in LOADS)

(2) the corrections to the zone demands due to interzone heat transfers

(3) the dependence of the HVAC system capacity on zone temperatures.

The result of this calculation is a set of hourly zone temperatures for which the heating or cooling supplied by the HVAC system equals the heating or cooling demandes in each zone.

The authors of DOE-2 attempted to model the important interactions in the thermal behaviour of convetional buildings of all degrees of complexity. A number of active and passive solar modeling capabilities have subsequently been added, as have daylight modeling capabilities with reduction of internal lighting loads in response to the availability of daylight. However, the approximations and solution methods chosen imply certain built-in limitations. One might expect DOE-2 modeling to be inadequate for cases where

- interior walls are massive and interzone heat conduction is both important and strongly time-dependent,
- direct solar gain is important, and sunlight may fall on surfaces with very different absorptivity and thermal mass at different hours of the day,
- solar gain transferred between zones is important, or
- heat transfer between specific locations either within a zone or between zones by natural convection is important.

In general, DOE-2 calculations on whole buildings appear to agree with measurements to about the 10 % level. The degree to which the above-mentioned circumstances may cause larger errors is unknown.

e) Program code SERI-RES

This program is a general purpose thermal analysis program for residential buildings. It was written by Larry Palmiter and Terry Wheeling of Ecotope Group, Seattle, WA, a non-profit corporation specializing in energy research and education. It is an outgrowth of a series of thermal analysis programs written by the authors over the past four years. One of these, SUNCAT 2.4, is in the Models Data Base at the Solar Energy Research Institute in Golden, CO. The present program is a major extension of the capabilities of these earlier efforts. It includes a large number of enhancements, and in many ways, is a totally new product.

The mathematical representation of the building is a thermal network with nonlinear, temperature dependent controls. The mathematical solution technique uses a combination of forward finite differences, Jacobian iteration, and constrained optimization.

The program has an interactive editor for creating building descriptions. While creating a building description the user is continuously prompted with headers that provide the names and units for each data entry. This allows for rapid and error free input. The editor also checks the validity of the input and reports errors as soon as possible. It also provides facilities for storing and referencing several types of building description files.

Like all thermal analysis programs, this one has many limitations. Some of the limitations stem from deliberate choice, while others were imposed by necessary compromises. Perhaps the major limitation is the lack of detailed treatment of equipment. This is primarily a building loads program. It is designed to simulate the dynamic performance of the building in great detail and report the amounts of energy and power that the heating and cooling equipment must supply in order to maintain comfort conditions. No attempt has been made to simulate the actual performance of particular heating and cooling units. This must be contrasted with programs for the analysis of large commercial buildings, where a majority of the effort is expended on equipment simulation and the building is treated somewhat cursorily. Such an approach is necessary for these buildings because the most pressing question frequently is which types and combinations of equipment will provide the best comfort or the lowest operating costs. In many cases, the building itself is a "given" in the analysis.

In contrast, the energy and power requirements for small buildings are dominated by the performance of the building. This is particularly true for structures designed to maximize solar benefits. The inclusion of performance characteristics for the many kinds of residential equipment would have greatly increased the size and complexity of the program. In addition, the required operating curves for residential equipment are not generally available. Also, in residential work, there is frequently no choice about equipment (for example, whether to use a gas furnace or electric resistance heat), or the choice is made on non-energetic grounds. For these, and other reasons, the authors have chosen to restrict the program to the modeling of building loads. It is not intended for situations where equipment choice is the primary interest.

A building is conceptualized as one or more zones. Each zone has independent solar inputs and independent heating, cooling, and ventilation equipment and controls. Each zone may also contain a rockbin. Zones may be connected by walls or pure thermal conductances. In addition, thermostatically controlled fans may connect zones.

The major simplification in the conceptual model of zones is the use of a single zone temperature node. The program does not allow for direct radiation heat transfer between walls of a zone with separate calculation of convective heat transfer to the zone air. Instead, the zone is represented by a single temperature node. All heat transfer paths are connected to this central node. Walls are connected by a constant heat transfer coefficient to the central zone node. This heat transfer coefficient includes both convective and radiative heat transfer. This simplification avoids the calculation of radiation view factors (which would also require a three-dimensional building description in the input) and the solution of a radiosity matrix at each time step.

The central zone temperature is not really the air temperature. It is a conductance-weighted average of the all temperatures which affect the zone. In the simple case where there are no pure resitances or fans in the zone, the zone temperature is a weighted average of the surface temperatures. In this case it is, in effect, a form of mean radiant temperature. In some circumstances, the central node temperature may differ significantly form the true "air" temperarue. It is shown that, with proper calculation of the combined surface coefficients, the resulting error in temperature is typically comparable to that produced by differences in radiation transfer resulting from the detailed modeling of furniture in the zone. For convenience, the central zone temperature is referred to as the zone "air" temperature in this program.

Walls are coupled to the zone air node by constant coefficients which include the combined effects of convection and radiation heat transfer. New node temperatures are determined in each wall independently, using explicit finite differences. Equipment operation is controlled on the basis of the zone air temperature node. However, only equipment loads are calculated, no attempt has been made to model the actual performance of the equipment.

f) Program code HELIOS-1

HELIOS-1 is a dynamic single zone model, based on the ASHRAE response factor technique.

The program has been developed at EMPA in 1980 in order to investigate the influence of short- and longwave radiation at the exteriour building envelope to the energy consumption. Therefore convective and radiative heat transfer at the outside surfaces is treated in more detail and infrared sky radiation input data are needed.

The simulation program has been extended up till now for different special problem areas like heating regulation strategies and heating delivery systems. The program can be adopted quite easy to new fields of simulation problems.

The input procedure has been improved by using a simplified input table system. The output format has been chosen in that way, that a check of all input data and the calculated heat balance is possible.

The program has been implemented on a CDC Cyber 174 and a VAX 750.

The major simplification in the model is the use of combined inside surface film coefficient and of one homogenious room airtemperature. This simplification avoids the complex calculation of radiation view factors which would require a three dimensional building input description. The calculated airtemperature may therefore in some cases differ from the true air temperature. For rooms with furniture and variable occupants, a correct calculation of the radiation heat exchange is not possible unless the real position of all radiative surfaces are known. Therefore the resulting error in airtemperature by using combined surface film coefficients is comparable to that produced by the uncertainty of the radiation exchange by furniture and occupants.

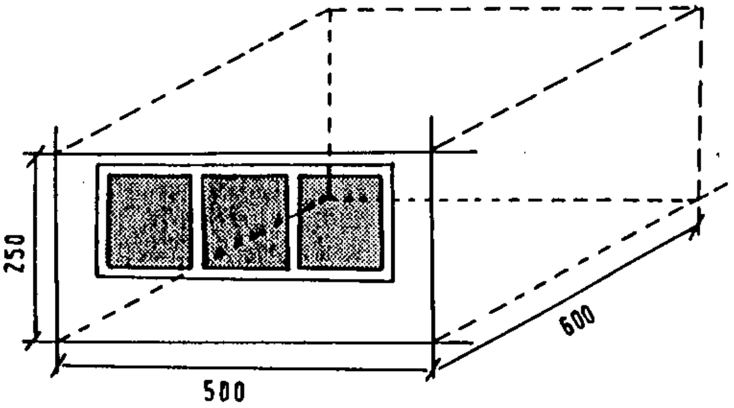
In order to meet a wide range of thermal boundary conditions, the calculation procedure (thermal balance matrix system) has been divided into three modules:
- initialization module to meet steady state starting conditions
- module to meet floating room airtemperature conditions for a given load situation
- module to meet constant room airtemperature.

The program is based on an explicit thermal balance method using the matrix inversion technique for solving the linear equation system.

3. SPECIFICATIONS OF THE STANDARD TEST ROOM

a) Introduction

For the comparison of the simulation codes, a standardized test room has been specified. This room is in the center of the building with similar adjacent rooms and has one external wall with a window. The specific heat loss rate of the room is very low (30 W/K) and therefore the room is very sensitive to solar gains.



Floorarea	A_F	=	30 m^2
Windowarea	A_W	=	3 - 9 m^2
Roomvolume	V	=	75 m^3
Air-change rate	n	=	0.50 Vh
Installed power	P	=	1000 W
Heating setpoint	t_i	=	20.0 °C (daytime)
	t_i	≥	15.0 °C (nighttime)

Figure 3.1 Specifications of the standard test room

b) Details of the standard test room

The details of the room are given in Figure 3.2 for the heavy weight construction and in Figure 3.3 for the light weight construction.

Two dimensional heat flows have not been treated by any program code.

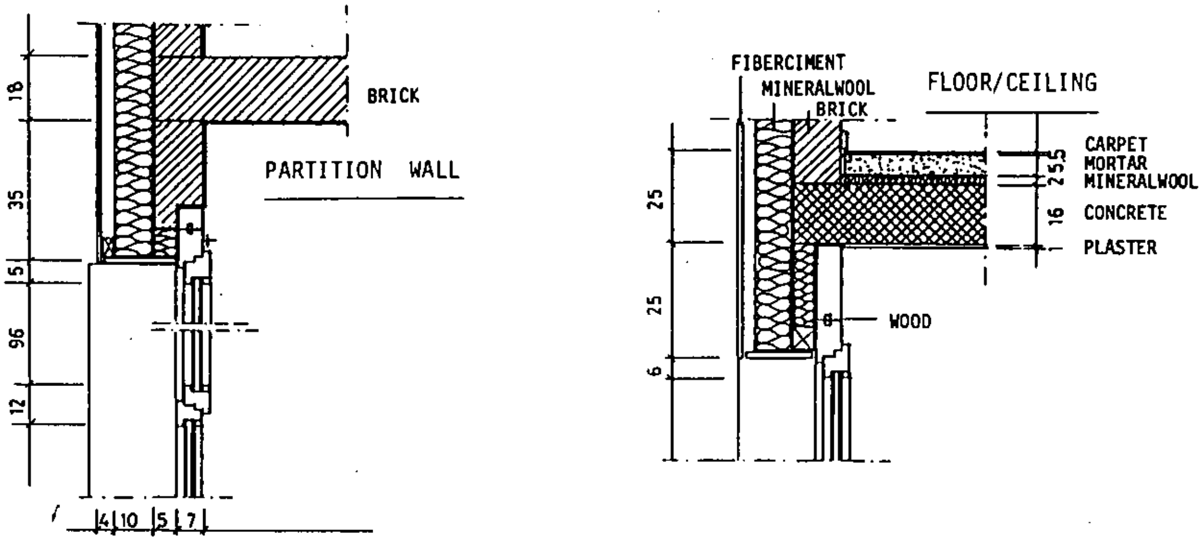


Figure 3.2 Details of the standard heavy weight test room

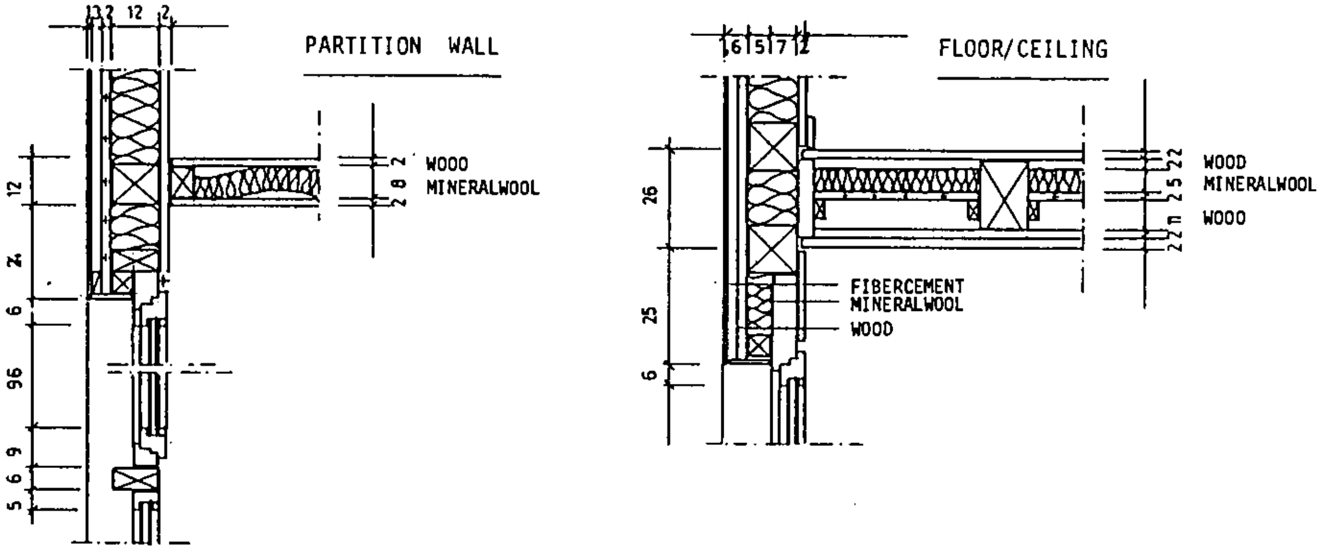


Figure 3.3 Details of the standard light weight test room

c) Construction data of the standard test room

Element	Area $[m^2]$	Material	d [m]	λ [W/mK]	ρ $[kg/m^3]$	c [J/kgK]
Partition		Plaster	0,005	0,60	1300	940
wall		Brick	0,180	0,44	1100	940
Side walls	15	Plaster	0,005	0,60	1300	940
Rear Wall	12,5					
External		Fibercement	0,010	0,48	1800	865
Wall	6,5	Air space	0,030	R = 0,17 $[m^2\ K/W]$		
		Mineralwool	0,100	0,033	40	600
		Brick	0,120	0,44	1100	940
		Plaster	0,005	0,60	1300	940
Floor and		Carpet	0,005	0,10	500	1470
Ceiling	30	Mortar	0,050	1,40	2200	1100
		Mineralwool	0,020	0,036	80	600
		Concrete	0,160	1,80	2400	1100
		Plaster	0,010	0,52	1300	840

Table 3.1 Construction data: heavy weight test room

Element	Area $[m^2]$	Material	d [m]	λ [W/mK]	ρ $[kg/m^3]$	c [J/kgK]
Partition		Wood	0,020	0,14	500	2100
wall		Mineralwool	0,050	0,040	80	600
Side walls	15	Wood	0,020	0,14	500	2100
Rear wall	12.5		1 joist 50 x 80 mm^2 each 80 cm			
External		Fibercement	0,010	0,48	1800	865
wall	6,5	Air space	0,030	R = 0,17 $[m^2\ K/W]$		
		Wood	0,020	0,14	500	2100
		Mineralwool	0,120	0,040	40	600
		Wood	0,020	0,14	500	2100
Floor and	30	Wood	0,020	0,14	500	2100
Ceiling		Air Space	0,020	R = 0,17 $[m^2\ K/W]$		
		Mineralwool	0,050	0,040	80	600
		Wood	0,020	0,14	500	2100
		Air space	0,110	R = 0,17 $[m^2\ K/W]$		
		Particle boards	0,040	0,17	800	2700
			1 joist 100 x 200 mm^2 each 60 cm			

Table 3.2 Construction data: light weight test room

d: Thickness

λ: Thermal conductivity

ρ: Specific weight

c: Specific heat

d) Fixed parameters of the standard test room

Windows (nominal values)

	Area $[m^2]$	U $[W/m^2 K]$	g [-]	ε [-]
Glazing (4/12/4)	4,9	2,8	0,77	0,82
Frame (Wood)	1,1	2,0	-	-

U	Window heat transfer coefficient
g	Solar factor for normal incident radiation (see DIN 67507)
ε	Emittance outside, in between and inside

The window area is 20 % of the floor area; 18,5 % is frame, 81,5 % is glazed area (double glazing).

No night protection, no corrections for wall connections, no solar protection for normal cases.

Internal gains

By inhabitants, lighting and equipments . . . .

- from 6 p.m. till 10 p.m.	200 [W]
- otherwise	50 [W]

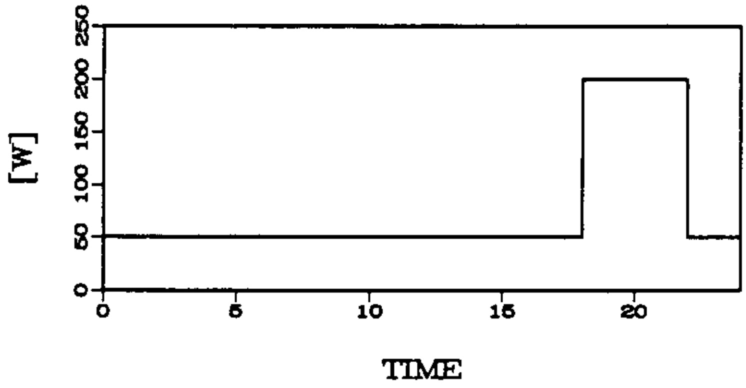


Figure 3.4 Schedule of internal gains

Infiltration rate

0,5 air changes per hour, constant day and night.

Repartition of the solar radiation

30 % convective

70 % radiative (homogeneously distributed over all surfaces, excl. glazing area).

e) Variable parameters (for base case calculations)

Code	Parameter
	Thermal mass
HE:	heavy weight construction
LI:	light weight construction
	Orientation of the external wall
SO:	south
NO:	north
	Heating system Convective heating system, controlled by a thermostat according to the zone temperature.
RE:	Setpoint 21°C day and night
NA:	Without heating at all
NI:	Setpoint 21°C from 6 a.m. - 10 p.m. from 10 p.m. - 6 a.m. heating system off.
	Adjacent rooms: Temperature conditions on five surfaces, the room is enclosed by adjacent rooms.
A:	All adjacent rooms are at the same temperature as the standard test room (Adjabatic conditions for the walls between test room and adjacent rooms).
B:	All adjacent rooms are at fixed temperature 21°C.
	Solar shading:
BL:	In cases with moveable solar shading devices it is assumed that the shading is active as soon as the incident solar radiation on the outside of the surface exceeds 300 W/m^2. The solar factor of the window system with closed internal blinds: $SF = 0,48$ [-] $U_{tot} = 2,62$ [W/m^2 K]

4. SIMPLIFIED BASE CASE CALCULATIONS

In order to identify the problem areas, where the simulation codes may produce significantly different results, a check using steady state boundary conditions has been performed for following questions:

- Initial steady state starting conditions
- Cooling rate of the room after turning off the heating system.
- Thermal response due to 1000 W internal gain over 5 hours.
- Thermal response due to one day of solar gains.

The specifications of these simplified base case calculations are tabulated in table 4.1.

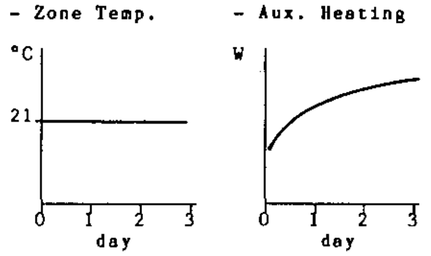
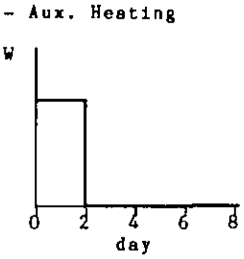
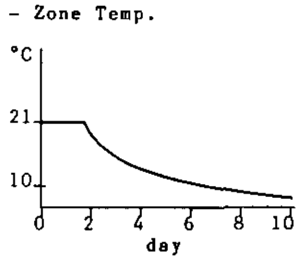
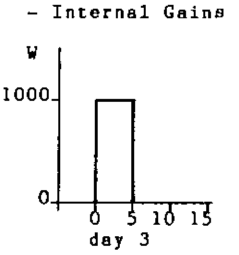
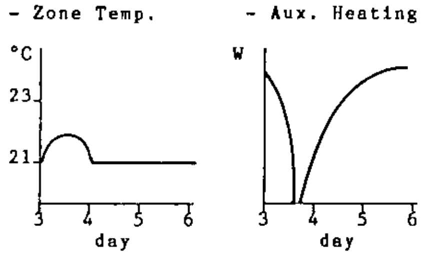
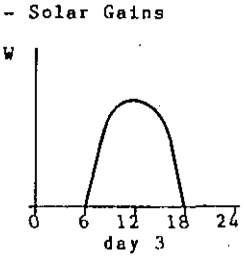
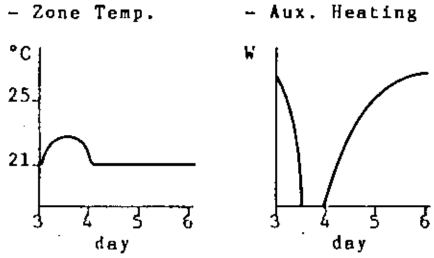
Case	Thermal Inputs	Thermal Response
Initial steady state conditions	- constant ambient air temperature (0 °C) - no solar or internal gains - Heating System on	
Cooling rate (Heating off) HESOREA1	- constant ambient air temperature - no solar or internal gains - Heating System on over 48 hours 	
Response from internal gain pulse HESOREA2	- constant ambient air temperature - no solar gains - Heating System on - Internal gains hours 1-5, day 3 	
Response from solar gain pulse HESOREA3	- constant ambient air temperature - no internal gains - Heating System on - Solar gains day 3 	

Table 4.1 Specifications of simplified base case calculations

a) Initial steady state conditions

The results of the calculations are summarized as follows:

Figure 4.1 shows the calculated heating load, table 4.2a the components of the heating load and table 4.2b the thermal properties of the glazing.

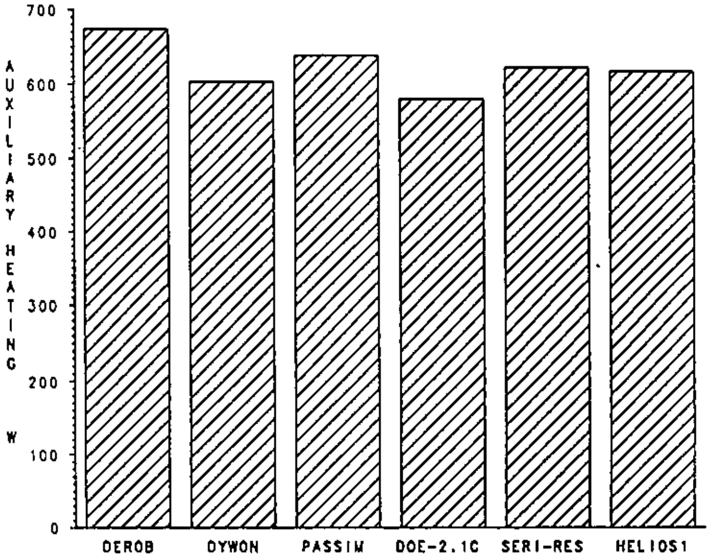


Figure 4.1 Auxiliary heating load for steady state conditions

INITIAL STEADY STATE CONDITIONS (VALUES IN [W])

	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
EXTERNAL WALL	37	35	35	71	37	37
WINDOW FRAME	50	43	50		47	46
PARTITION WALLS	0	0	0		0	0
CEILING	0	-1	0		0	0
FLOOR	0	0	0		0	0
GLAZING AREA	323	263	292	259	289	289
TOTAL TRANSMISSION	410	339	377	330	373	372
VENTILATION LOSSES	264	265	262	251	250	246
AUXILIARY HEATING	674	604	639	581	623	618

Table 4.2a Load components for initial steady state starting conditions

Figure 4.2 shows that some simulation codes (DEROB, DYWON and SERI-RES) need several days for reaching steady state conditions, due to the definition of the initial node temperatures. Comparing short running periods, this effect may cause some difficulties in comparing the results.

Program-Code	Conductance of glazing Λ_G [W/m*K]	Exterior Film Coefficient		Interior Film Coefficient		Overall U-Value [W/m*K]
		$h_{e,Radiation}$	$h_{e,Convection}$	$h_{i,Radiation}$	$h_{i,Convection}$	
DEROB	5.30 (fixed)	19.0 (variable)		12.5 (variable)		3.1
DYWON	5.29 (fixed)	23.0 (fixed)		4.58 (variable)	2.41 (variable)	2.7
PASSIM	5.71 (variable)	23.0 (fixed)		4.27 (variable)	3.15 (variable)	2.8
DOE-2.1C	5.30 (fixed)	10.7 (variable)		8.3 (fixed)		2.5
SERI-RES	5.30 (fixed)	23.0 (fixed)		8.3 (fixed)		2.8
HELIOS1	5.30 (fixed)	11.5 (variable)	5.6 (variable)	8.0 (fixed)		2.7

Table 4.2b Thermal properties of the glazing (4/12/4) for steady state starting conditions: t_i = 21 °C, t_e = 0 °C, v_{wind} = 1.8 m/s, $I_{longwave}$ = 285 W/m^2 (incoming longwave radiation)

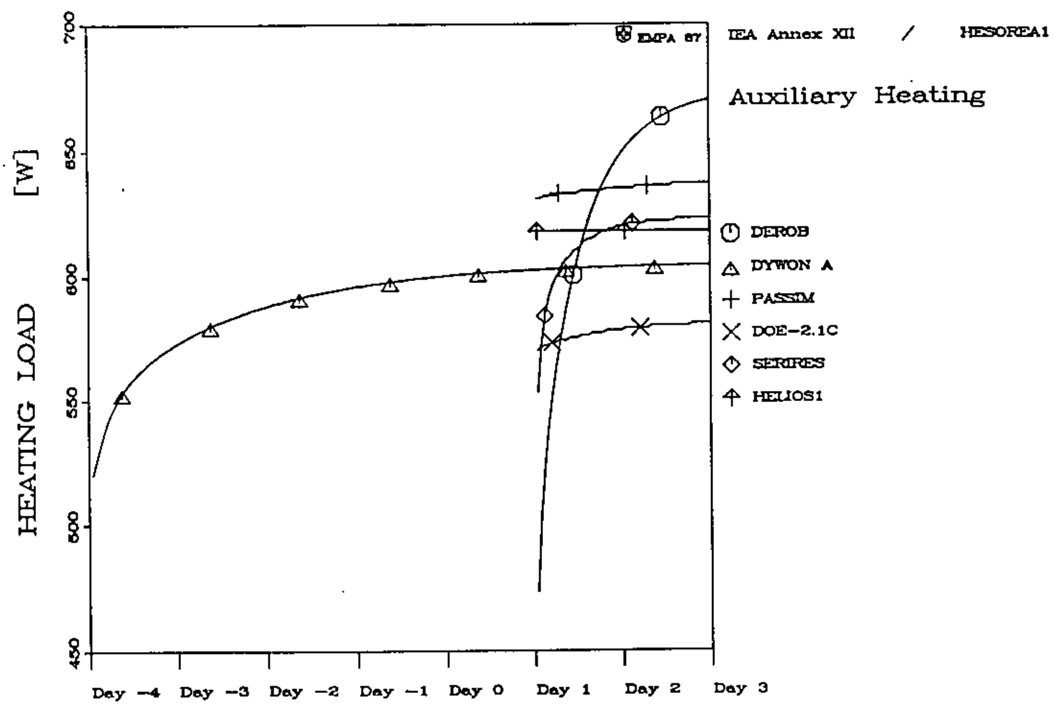


Figure 4.2 Auxiliary heating load for reaching the steady state

Conclusions

The deviations of the steady state conditions are small. The problem of comparing short running periods is obvious, since some programms need several days to reach steady state conditions.

The differences in heat losses (table 4.2) are likely due to differences in

- heat transfer coefficient simplifications (see Appendix D)
- actual heat transfer coefficient values in models where these are considered dependent on actual conditions.
- heat capacitiy ($\rho * c_p$) of the room air and therefore different ventilation losses.

b) Cooling rate

The goal of this calculation run was to compare the cooling rate behaviour of the test room after switching off the heating system. Figure 4.3 shows that there is a significant difference in temperature drop for the first hour, but a similar slope of all temperature curves.

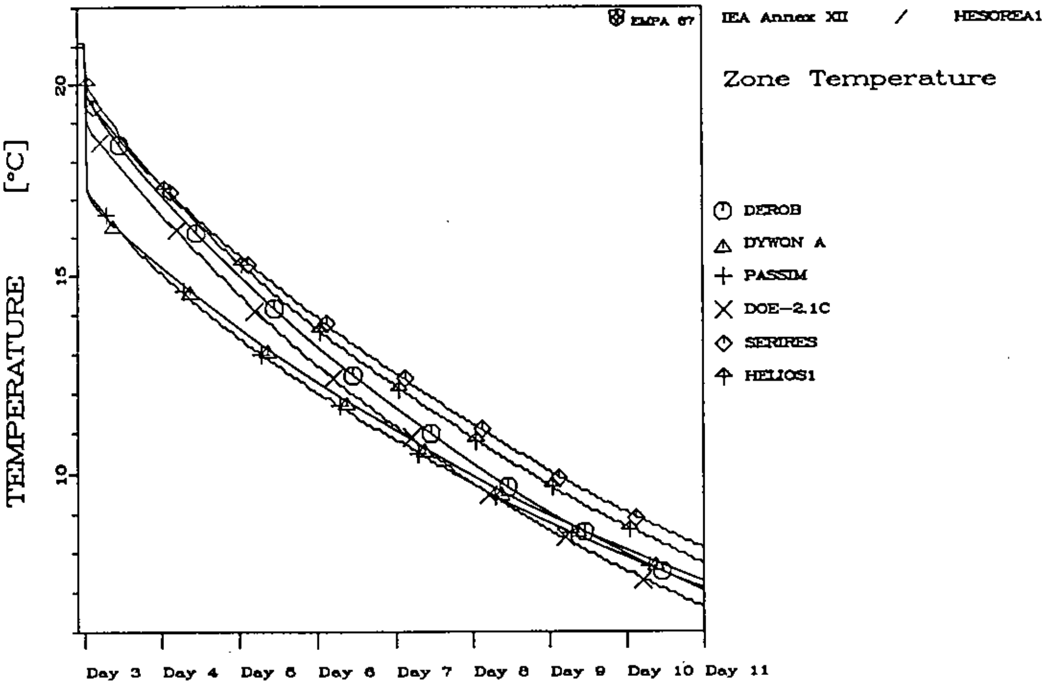


Figure 4.3 Zone temperature after switching off the heating system

The first six hours are illustrated in more detail in figure 4.4 .

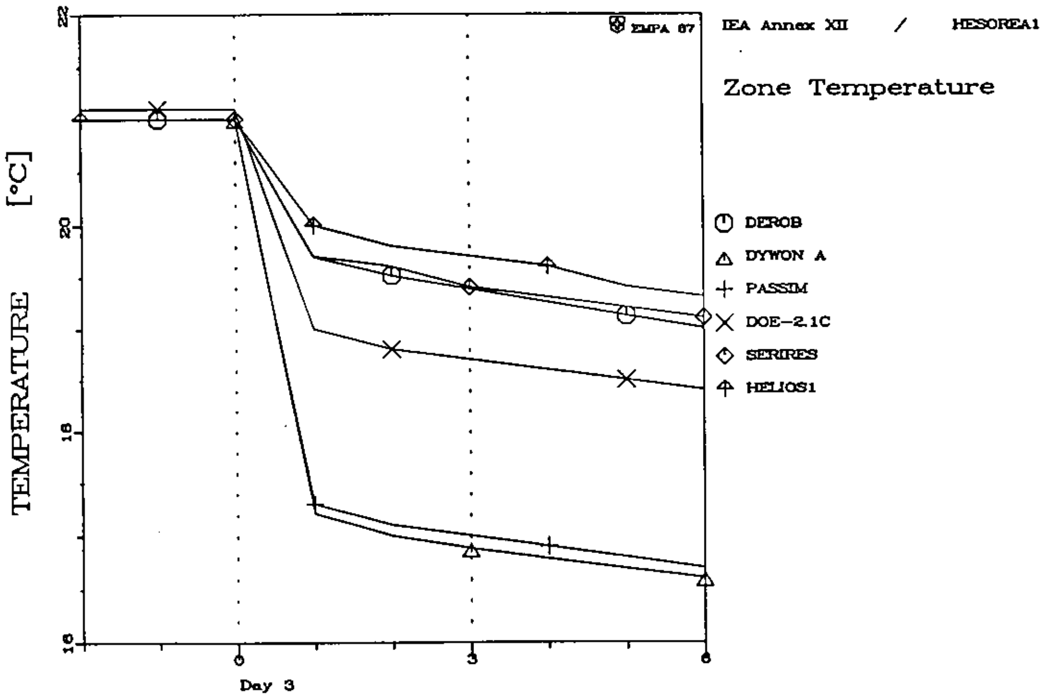


Figure 4.4 Detailed analysis of the first 6 hours of zone temperature

DYWON and PASSIM, both program codes with splitted internal film coefficients, show a very high temperature drop of 4 K within the first hour.

Conclusion

The mass storage effect is strongly influenced by the thermal model used for coupling the surfaces with the room air temperature. The definition of the room air temperature may therefore not be equal in each program. The problem of modeling the interior heat exchange in a room and how to define a "zone temperature" will be discussed in more detail in Appendix D.

c) Response from internal gain pulse

Internal heat gain sources may be convective or radiative. The convective gain immediately influences the heating or cooling load and the room air temperature, where the radiative heat gain, distributed over all surfaces, shows a clear time lag. For the calculations a convective heat gain source of 1000 W over 5 hours has been assumed.

Figure 4.5 shows the thermal response due to this internal heat gain pulse, over the first 24 hours.

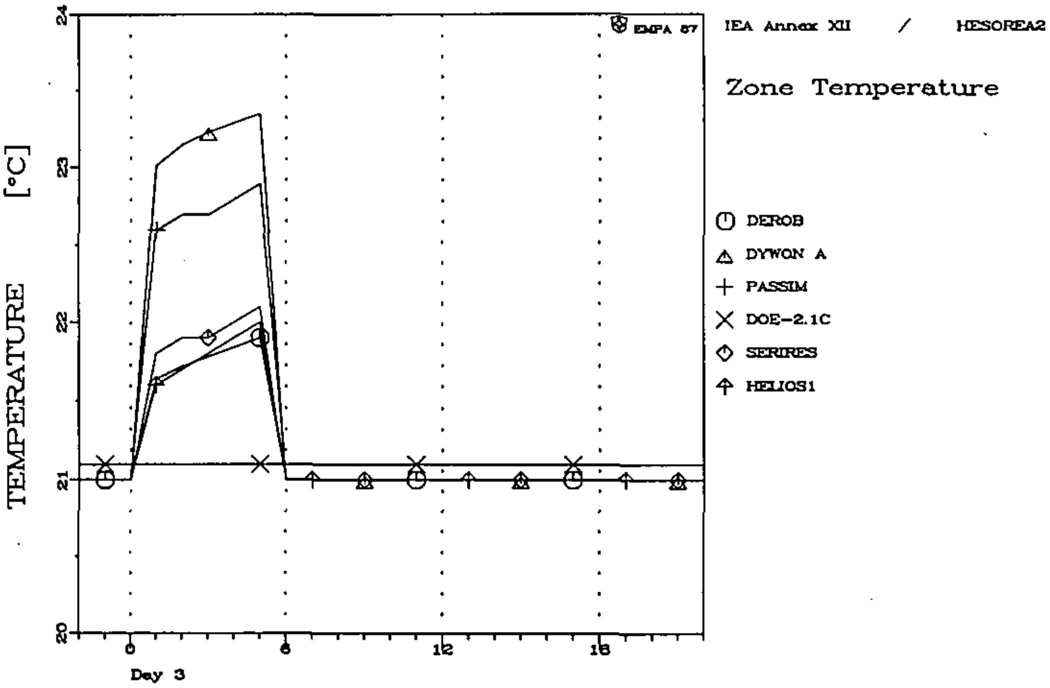


Figure 4.5 Zone temperature response from internal gain pulse

* DOE-2.1 doesn't fullfill the assumption of 100 % convective internal gains. A fixed split of 60 % radiative and 40 % convective component has been used.

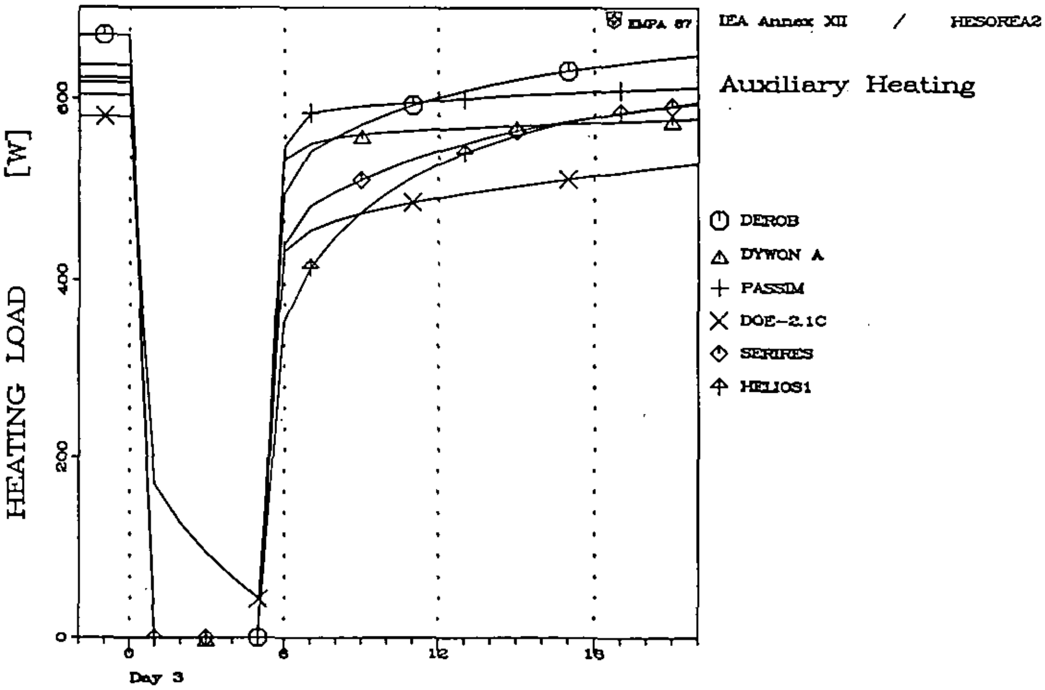


Figure 4.6 Heating load response from internal gain pulse

In Table 4.3 the relative daily auxiliary heating demand over the whole 8 day period is tabulated.

DAY	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
3	71.3	74.3	74.3	71.5	70.1	68.5
4	98.5	97.1	97.4	95.5	98.2	98.9
5	99.7	98.5	98.7	98.7	99.5	99.7
6	99.9	99.3	99.4	99.6	99.9	99.8
7	100.0	99.6	99.7	99.8	100.0	99.8
8	100.0	99.8	99.9	100.0	100.0	99.9
9	100.0	99.9	100.0	100.0	100.0	100.0
10	100.0	100.0	100.0	100.0	100.0	100.0
TOTAL	96.2	96.1	96.2	95.6	96.0	95.8

Table 4.3 Relative daily auxiliary heating demand

d) Response to solar heat gain pulse

Solar radiation, penetrating the glas surfaces may be absorbed or reflected on the interior surfaces or may be converted into a convective heat gain component when falling on ligthweight surfaces like furniture.
The different simulation codes handle the distribution of solar gains very differently. Therefore a given split has been assumed for the solar radiation distribution:

- 20 % convective (air node)
- 30 % floor area
- 50 % all remaining surfaces.

The calculated temperature and heating load responses to a solar gain pulse of one day are illustrated in figures 4.7 and 4.8 .

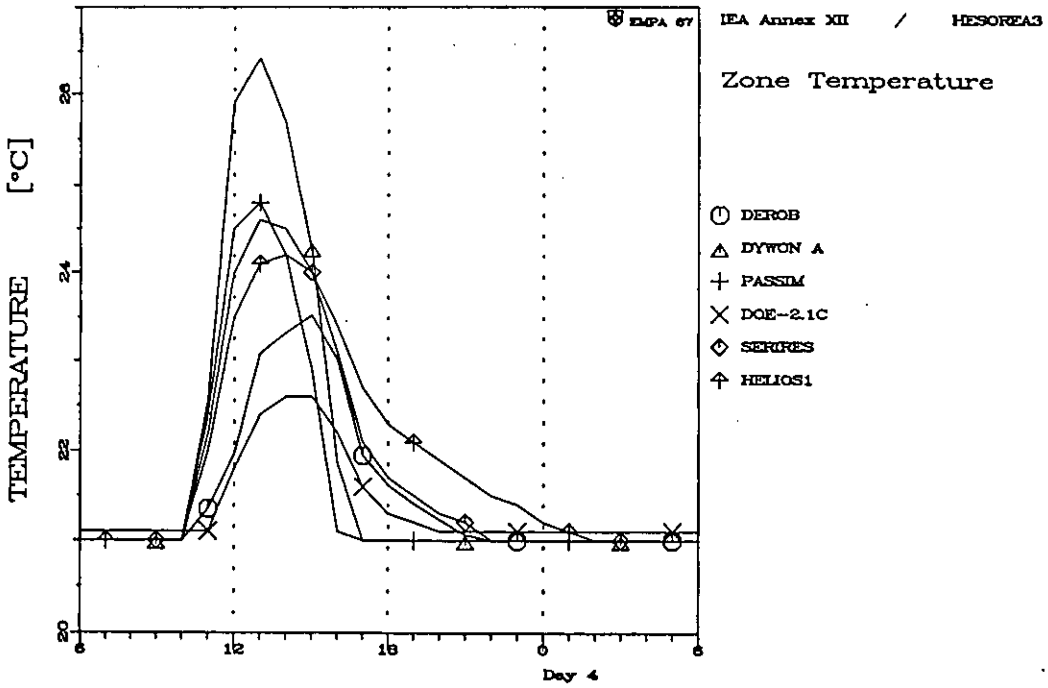


Figure 4.7 Zone temperature response to solar heat gain pulse (first 24-hour period)

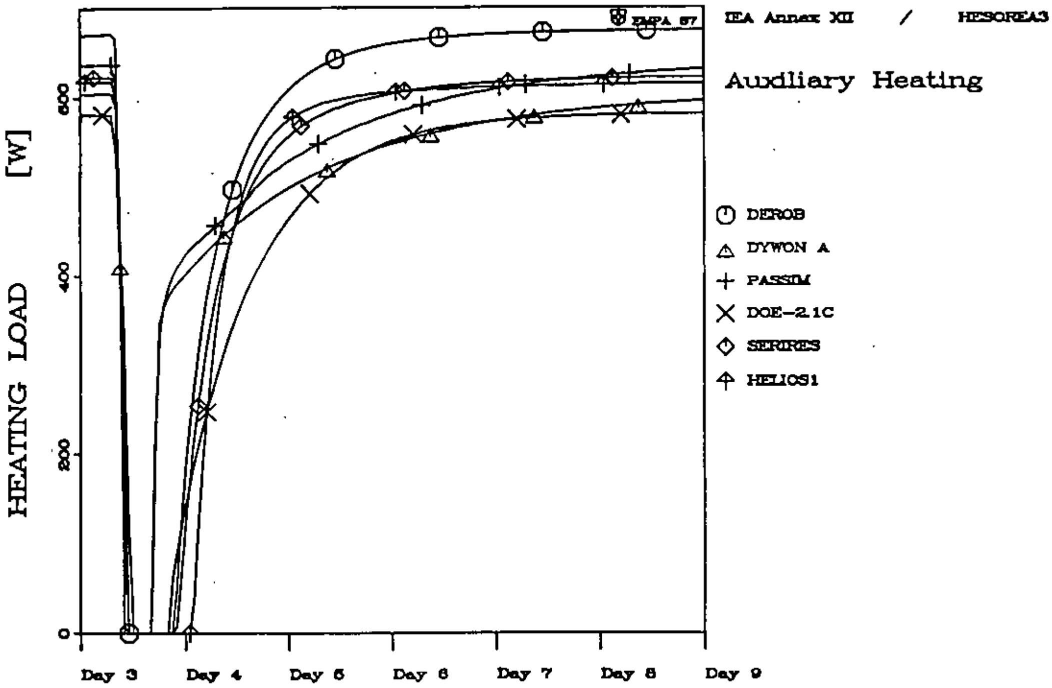


Figure 4.8 Heating load response to solar heat gain pulse
(6 day period)

The relative daily auxiliary heating demand ist tabulated in table 4.4 over the whole 8 day period.

DAY	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
3	39.4	56.9	57.1	42.4	37.1	35.8
4	71.9	76.3	75.7	59.2	69.6	66.4
5	95.2	87.6	87.9	89.1	94.3	96.7
6	98.8	93.5	93.9	97.1	98.2	98.8
7	99.6	96.6	97.0	99.2	99.4	99.4
8	99.9	98.5	98.7	99.8	99.8	99.7
9	100.0	99.5	99.5	99.9	99.9	99.9
10	100.0	100.0	100.0	100.0	100.0	100.0

TOTAL	88.1	88.6	88.7	85.8	87.3	87.1

Table 4.4 Relative auxiliary heating demand

Conclusions

The differences in peak zone temperatures are quite significant (4 K). The way how solar gains are distributed and what thermal coupling model between surfaces and room air has been used are responsible for the deviations (see also Appendix C and D).

5. BASE CASE CALCULATIONS (10 DAY WINTER PERIOD)

This part of the comparison of the different simulations codes deals with calculations over a 10-day winter period (8. - 17. February 1981, Geneva weather data).

The calculations for the base case studies follow the scheme in Table 5.1.

Identification code	Building type	Orien-tation	Heating system	Solar shading	Temperature adj. rooms
HESORE-A	HE	SO	RE	-	A
HESONA-A	HE	SO	NA	-	A
HESORE-B	HE	SO	RE	-	B
HESONA-B	HE	SO	NA	-	B
HENORE-A	HE	NO	RE	-	A
LISORE -A	LI	SO	RE	-	A
LISONA -A	LI	SO	NA	-	A
LISORE -B	LI	SO	RE	-	B
LISONA -B	LI	SO	NA	-	B
LINORE -A	LI	NO	RE	-	A
LINONA -A	LI	NO	NA	-	A
LISOBL -A	LI	SO	RE	BL	A
HENONI -A	HE	NO	NI	-	A

Table 5.1 Calculation scheme for the base case calculations

Building type:	HE	heavy weight construction
	LI	light weight construction
Orientation:	SO	south
	NO	north
Heating system:	RE	Set point 21°C day and night
	NA	without heating at all
	NI	Night heating system off
Solar shading:	-	no solar shading
	BL	internal venetian blinds
Temp.adj.rooms:	A	adiabatic walls
	B	adjacent rooms 21°C

a) Solar gain simulator

In Table 5.2, the results for the solar gain calculations are shown for the south and the north facade.

- Solar radiation before and after glazing
- Solar transmissivity
- Solar absorptivity inner pane

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Incident Radiation [MJ/m^2]						
Direct	70.1	74.5	76.4	66.9	72.5	71.6
Diffuse	20.4	22.3	20.4	29.3	26.1	26.4
Total	90.5	96.8	96.8	96.2	98.6	98.0
Transmitted Radiation [MJ/m^2]						
Direct	49.9	49.9	53.3	47.8	50.5	50.4
Diffuse	14.6	14.9	12.0	18.8	16.3	17.0
Total	64.5	64.8	65.3	66.6	66.9	67.4
Solar Transmissivity [-]						
Direct	0.71	0.67	0.70	0.71	0.70	0.70
Diffuse	0.71	0.67	0.59	0.64	0.63	0.64
Total	0.71	0.67	0.67	0.69	0.68	0.69
Solar absorptivity of inner pane [–]						
Direct	0.074	0.070	0.054		0.057	0.043

a) South facade

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Incident Radiation [MJ/m^2]						
Direct	0.0	0.3	0.6	0.0	0.0	0.0
Diffuse	15.1	18.8	18.5	14.4	19.1	19.7
Total	15.1	19.1	19.1	14.4	19.1	19.7
Transmitted Radiation [MJ/m^2]						
Direct	0.0	0.2	0.0	0.0	0.0	0.0
Diffuse	10.7	12.6	10.9	9.2	11.9	12.7
Total	10.7	12.8	10.9	9.2	11.9	12.7
Solar Transmissivity [-]						
Direct	0.71	0.67	0.00	0.00	0.00	0.00
Diffuse	0.71	0.67	0.59	0.64	0.63	0.64
Total	0.71	0.67	0.57	0.64	0.63	0.64

b) North facade

Table 5.2: Comparison of solar gain calculations

b) Analysis of heat flux balance and temperature behaviour

In Tables 5.3 - 5.15 are given for the thirteen base case calculations heat fluxes and information about the temperature behaviour of the room.

TEMPERATURES [°C]   Period: 8. 2. - 17. 2.1981   Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Mean Indoor Air	21.5	22.1	21.8	22.0	22.0	22.0
Minimum Indoor Air	21.0	21.0	21.0	21.1	21.0	21.0
Maximum Indoor Air	23.9	28.9	26.9	25.0	26.1	25.5
Mean Outdoor Air	1.9	1.9	1.9	1.8	1.9	1.9
Mean Glaz. Surf. In.	17.1	15.3	15.8		16.0	15.9
Mean Glaz. Surf. Out		4.7	5.4			5.8
Mean Ceiling Surface	21.7	22.4	21.9		22.3	22.3
Mean Floor Surface	21.8	22.0	21.9		22.5	22.3

HEAT FLOWS [MJ]   Period: 8. 2. - 17. 2.1981   Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Glazing Area	245	238	241	190	240	229
Window Frames	32	34	31	25	32	32
External Walls	26	28	27	23	24	28
Ceiling	14	1	29		13	2
Floor	11	0	6		1	12
Partition Walls	3	0	11		1	0
Total	331	301	369	230	311	303
Air Infiltration	213	220	215	217	208	209
Total Heat Losses	545	522	581	455	519	512
Solar Gains	320	352	347	296	357	352
Internal Heat Gains	65	65	65	65	65	65
Total Heat Gains	385	417	412	361	421	417
Auxiliary Heating	160	105	149	94	97	95
Heating Peak Load W	548	413	440	479	532	565

Table 5.3 Heat flux balance and temperature behaviour
Base case HESORE-A

TEMPERATURES [°C]   Period: 8. 2. - 17. 2.1981   Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Mean Indoor Air	10.6	18.6	18.5	19.2	19.8	19.8
Minimum Indoor Air	7.5	15.3	15.9	15.9	16.8	16.9
Maximum Indoor Air	14.9	25.9	24.5	23.0	23.8	23.2
Mean Outdoor Air	1.9	1.9	1.9	1.8	1.9	1.9
Mean Glaz. Surf. In.	8.7	13.2	12.8		14.5	14.4
Mean Glaz. Surf. Out		4.3	4.5			5.2
Mean Ceiling Surface	10.5	19.3	19.4		20.2	20.1
Mean Floor Surface	10.8	19.3	19.5		20.3	20.2

HEAT FLOWS [MJ]   Period: 8. 2. - 17. 2.1981   Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Glazing Area	99	200	202	152	213	206
Window Frames	9	28	25	20	28	28
External Walls	12	23	20	19	19	24
Ceiling	57	-6	-2		-10	-11
Floor	79	-2	-26		-6	-8
Partition Walls	36	-5	6		-7	-8
Total	290	237	224	191	237	231
Air Infiltration	95	183	175	170	185	186
Total Heat Losses	384	420	414	361	421	417
Solar Gains	320	352	347	296	357	352
Internal Heat Gains	65	65	65	65	65	65
Total Heat Gains	385	417	412	361	421	417
Auxiliary Heating	0	0	0	0	0	0

Table 5.4 Heat flux balance and temperature behavior
Base case HESONA-A

TEMPERATURES [°C]   Period: 8. 2. - 17. 2.1981   Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Mean Indoor Air	21.2	21.8			21.6	21.6
Minimum Indoor Air	21.0	21.0			21.0	21.0
Maximum Indoor Air	23.2	28.0			25.8	24.6
Mean Outdoor Air	1.9	1.9			1.9	1.9
Mean Glaz. Surf. In.	16.8	14.9			15.7	15.6
Mean Glaz. Surf. Out		4.7				5.7
Mean Ceiling Surface	21.0	21.5			21.8	21.7
Mean Floor Surface	21.4	21.6			21.9	21.8

HEAT FLOWS [MJ]   Period: 8. 2. - 17. 2.1981   Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Glazing Area	240	231			235	224
Window Frames	31	33			31	32
External Walls	26	27			24	27
Ceiling	36	28			27	25
Floor	92	19			26	24
Partition Walls	124	37			50	47
Total	549	375			393	379
Air Infiltration	210	217			204	204
Total Heat Losses	760	592			597	583
Solar Gains	320	352			357	352
Internal Heat Gains	65	65			65	65
Total Heat Gains	385	417			421	417
Auxiliary Heating	375	176			175	166
Heating Peak Load W	757	446			535	570

Table 5.5 Heat flux balance and temperature behaviour

Base case HESORE-B

TEMPERATURES [°C] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Mean Indoor Air	18.2	19.9			20.4	20.5
Minimum Indoor Air	16.1	17.4			18.5	18.7
Maximum Indoor Air	21.4	27.5			25.0	23.9
Mean Outdoor Air	1.9	1.9			1.9	1.9
Mean Glaz. Surf. In.	14.6	14.1			14.9	14.8
Mean Glaz. Surf. Out		4.5				5.4
Mean Ceiling Surface	18.4	20.6			20.8	20.8
Mean Floor Surface	18.8	20.6			20.9	20.8

HEAT FLOWS [MJ] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Glazing Area	202	215			220	213
Window Frames	25	30			29	29
External Walls	22	25			20	25
Ceiling	-40	-13			-15	-16
Floor	27	-11			-7	-10
Partition Walls	-30	-25			-18	-17
Total	207	222			230	224
Air Infiltration	178	196			191	193
Total Heat Losses	385	418			421	417
Solar Gains	320	352			357	352
Internal Heat Gains	65	65			65	65
Total Heat Gains	385	417			421	417
Auxiliary Heating	0	0			0	0

Table 5.6 Heat flux balance and temperature behaviour
Base case HESONA-B

TEMPERATURES [°C] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Mean Indoor Air	21.0	21.0	21.0	21.1	21.0	21.0
Minimum Indoor Air	21.0	21.0	21.0	21.1	21.0	21.0
Maximum Indoor Air	21.0	21.0	21.0	21.1	21.0	21.0
Mean Outdoor Air	1.9	1.9	1.9	1.8	1.9	1.9
Mean Glaz. Surf. In.	16.4	13.4	14.2		14.7	14.5
Mean Glaz. Surf. Out		4.1	4.9			4.5
Mean Ceiling Surface	20.9	20.0	20.3		21.1	21.0
Mean Floor Surface	20.9	20.0	20.3		21.1	21.1

HEAT FLOWS [MJ] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Glazing Area	246	210	226	194	228	225
Window Frames	38	33	38	29	35	37
External Walls	28	27	31	27	27	32
Ceiling	1	0	-10		1	0
Floor	1	0	-15		0	0
Partition Walls	0	0	-19		0	0
Total	314	270	251	250	291	294
Air Infiltration	208	208	207	203	198	199
Total Heat Losses	522	479	454	453	488	493
Solar Gains	52	69	58	40	64	66
Internal Heat Gains	65	65	65	65	65	65
Total Heat Gains	117	134	123	105	129	131
Auxiliary Heating	406	344	335	348	359	362
Heating Peak Load W	548	637	619	588	713	729

Table 5.7 <u>Heat flux balance and temperature behaviour</u>

Base case HENORE-A

TEMPERATURES [°C] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Mean Indoor Air	22.4	23.0	22.5	23.5	23.8	23.8
Minimum Indoor Air	21.0	21.0	21.0	21.1	21.0	21.0
Maximum Indoor Air	29.4	34.7	29.2	32.1	34.0	33.5
Mean Outdoor Air	1.9	1.9	1.9	1.8	1.9	1.9
Mean Glaz. Surf. In.	17.8	15.9	16.3		17.2	17.2
Mean Glaz. Surf. Out		4.8	6.1			6.2
Mean Ceiling Surface	22.6	23.1	22.9		24.1	24.1
Mean Floor Surface	22.8	23.2	22.8		24.3	24.2

HEAT FLOWS [MJ] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Glazing Area	258	248	251	204	261	247
Window Frames	34	36	33	22	35	36
External Walls	28	29	28	25	28	31
Ceiling	7	3	9		1	0
Floor	7	1	-5		0	0
Partition Walls	0	0	5		0	0
Total	334	317	321	256	325	314
Air Infiltration	223	230	223	228	226	228
Total Heat Losses	557	548	544	484	551	542
Solar Gains	320	352	347	310	357	352
Internal Heat Gains	65	65	65	65	65	65
Total Heat Gains	385	417	412	375	421	417
Auxiliary Heating	173	133	134	109	129	125
Heating Peak Load W	549	500	497	479	563	607

Table 5.8 Heat flux balance and temperature behaviour

Base case LISORE-A

TEMPERATURES [°C] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Mean Indoor Air	11.9	18.7	18.0	19.6	19.6	19.5
Minimum Indoor Air	4.4	11.7	12.2	11.8	11.9	11.5
Maximum Indoor Air	22.4	28.5	25.4	30.0	30.3	29.4
Mean Outdoor Air	1.9	1.9	1.9	1.8	1.9	1.9
Mean Glaz. Surf. In.	9.7	13.3	13.2		14.4	14.2
Mean Glaz. Surf. Out		4.3	4.9			5.2
Mean Ceiling Surface	11.9	19.3	18.8		20.0	19.9
Mean Floor Surface	12.2	19.3	18.9		20.1	19.9

HEAT FLOWS [MJ] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Glazing Area	118	200	202	159	211	203
Window Frames	12	28	24	21	27	28
External Walls	13	22	22	20	21	24
Ceiling	39	-7	15		-12	-12
Floor	76	-3	-8		-3	-4
Partition Walls	15	-3	9		-5	-5
Total	274	237	263	200	238	234
Air Infiltration	110	183	174	178	183	183
Total Heat Losses	384	420	437	378	421	417
Solar Gains	320	352	347	310	357	352
Internal Heat Gains	65	65	65	65	65	65
Total Heat Gains	385	417	412	375	421	417
Auxiliary Heating	0	0	0	0	0	0

Table 5.9 Heat flux balance and temperature behaviour

Base case LISONA-A

TEMPERATURES [°C] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Mean Indoor Air	22.0	22.4			22.7	22.6
Minimum Indoor Air	21.0	21.0			21.0	21.0
Maximum Indoor Air	28.4	30.6			31.5	30.8
Mean Outdoor Air	1.9	1.9			1.9	1.9
Mean Glaz. Surf. In.	17.4	15.4			16.5	16.3
Mean Glaz. Surf. Out		4.7				5.9
Mean Ceiling Surface	22.0	22.2			22.9	22.8
Mean Floor Surface	22.3	22.3			23.0	22.8

HEAT FLOWS [MJ] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Glazing Area	251	239			248	235
Window Frames	33	34			33	33
External Walls	27	28			26	29
Ceiling	25	16			24	23
Floor	53	15			25	23
Partition Walls	62	30			44	43
Total	451	361			400	386
Air Infiltration	219	224			215	216
Total Heat Losses	670	585			615	602
Solar Gains	320	352			357	352
Internal Heat Gains	65	65			65	65
Total Heat Gains	385	417			421	417
Auxiliary Heating	286	171			193	185
Heating Peak Load W	634	523			648	678

Table 5.10 Heat flux balance and temperature behaviour

Base case LISORE-B

TEMPERATURES [°C]   Period: 8. 2. - 17. 2.1981   Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Mean Indoor Air	17.7	19.7			20.2	20.2
Minimum Indoor Air	13.3	15.3			15.9	16.1
Maximum Indoor Air	26.0	29.6			30.1	29.0
Mean Outdoor Air	1.9	1.9			1.9	1.9
Mean Glaz. Surf. In.	14.2	13.9			14.8	14.6
Mean Glaz. Surf. Out		4.5				5.3
Mean Ceiling Surface	18.0	20.4			20.6	20.5
Mean Floor Surface	18.3	20.4			20.7	20.6

HEAT FLOWS [MJ]   Period: 8. 2. - 17. 2.1981   Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Glazing Area	195	213			218	210
Window Frames	24	30			28	29
External Walls	21	24			22	25
Ceiling	-22	-14			-15	-15
Floor	15	-9			-7	-8
Partition Walls	-21	-17			-14	-14
Total	212	227			233	227
Air Infiltration	172	194			189	190
Total Heat Losses	385	421			422	417
Solar Gains	320	352			357	352
Internal Heat Gains	65	65			65	65
Total Heat Gains	385	417			421	417
Auxiliary Heating	0	0			0	0

Table 5.11   Heat flux balance and temperature behaviour
Base case LISONA-B

TEMPERATURES [°C] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Mean Indoor Air	21.0	21.0	21.0	21.1	21.0	21.0
Minimum Indoor Air	21.0	21.0	21.0	21.1	21.0	21.0
Maximum Indoor Air	21.0	21.0	21.0	21.1	21.0	21.0
Mean Outdoor Air	1.9	1.9	1.9	1.9	1.9	1.9
Mean Glaz. Surf. In.	16.4	13.4	14.1		14.7	14.5
Mean Glaz. Surf. Out		4.1	4.9			4.5
Mean Ceiling Surface	20.9	20.0	20.2		21.1	21.0
Mean Floor Surface	20.9	20.0	20.1		21.1	21.0

HEAT FLOWS [MJ] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Glazing Area	246	210	225	197	228	225
Window Frames	38	33	38	29	35	37
External Walls	29	27	31	27	28	32
Ceiling	0	0	-5		0	0
Floor	0	0	-8		0	0
Partition Walls	0	0	-10		0	0
Total	313	271	270	253	291	294
Air Infiltration	208	208	207	201	198	198
Total Heat Losses	521	479	477	454	488	492
Solar Gains	52	69	58	43	64	66
Internal Heat Gains	65	65	65	65	65	65
Total Heat Gains	117	134	122	108	129	131
Auxiliary Heating	405	345	353	346	359	361
Heating Peak Load W	549	673	667	639	732	748

Table 5.12 Heat flux balance and temperature behaviour

Base case LINORE-A

TEMPERATURES [°C] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Mean Indoor Air		10.1		9.6	9.9	8.9
Minimum Indoor Air		5.0		4.5	4.9	3.2
Maximum Indoor Air		17.9		18.9	20.1	19.8
Mean Outdoor Air		1.9		1.9	1.9	1.9
Mean Glaz. Surf. In.		7.0			7.4	6.0
Mean Glaz. Surf. Out		2.9				1.6
Mean Ceiling Surface		10.5			10.3	9.1
Mean Floor Surface		10.4			10.1	9.0

HEAT FLOWS [MJ] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Glazing Area		93		47	96	101
Window Frames		14		7	14	15
External Walls		9		6	9	11
Ceiling		-39			-49	-43
Floor		-14			-10	-11
Partition Walls		-13			-14	-15
Total		51		60	46	58
Air Infiltration		90		48	83	73
Total Heat Losses		141		108	129	131
Solar Gains		69		43	64	66
Internal Heat Gains		65		65	65	65
Total Heat Gains		134		108	129	131
Auxiliary Heating		0		0	0	0

Table 5.13 Heat flux balance and temperature behaviour
Base case LINONA-A

TEMPERATURES [°C] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Mean Indoor Air		22.2	21.6	22.2	22.3	22.1
Minimum Indoor Air		21.0	21.0	21.1	21.0	21.0
Maximum Indoor Air		29.3	25.7	27.5	28.6	27.7
Mean Outdoor Air		1.9	1.9	1.8	1.9	1.9
Mean Glaz. Surf. In.		15.1	15.5		16.2	15.7
Mean Glaz. Surf. Out		4.8	5.8			5.4
Mean Ceiling Surface		22.1	21.7		22.5	22.3
Mean Floor Surface		22.1	21.6		22.6	22.3

HEAT FLOWS [MJ] Period: 8. 2. - 17. 2.1981 Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Glazing Area			238	150	243	232
Window Frames		33	31	18	32	32
External Walls		27	26	16	25	28
Ceiling		2	3		1	0
Floor		1	-4		0	0
Partition Walls		0	0		0	0
Total			295	184	301	292
Air Infiltration		221	214	145	211	210
Total Heat Losses			509	329	512	502
Solar Gains			255	94	254	242
Internal Heat Gains		65	65	65	65	65
Total Heat Gains			320	159	319	307
Auxiliary Heating		163	189	170	193	195
Heating Peak Load W		539	509	550	662	706

Table 5.14 Heat flux balance and temperature behaviour

Base case LISOBL-A

TEMPERATURES [°C]   Period: 8. 2. - 17. 2.1981   Geneva

PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Mean Indoor Air		19.8		20.3	20.5	20.5
Minimum Indoor Air		16.1		17.9	18.5	18.7
Maximum Indoor Air		21.0		21.1	21.0	21.0
Mean Outdoor Air		1.9		1.8	1.9	1.9
Mean Glaz. Surf. In.		12.8			14.3	14.2
Mean Glaz. Surf. Out		4.0				4.4
Mean Ceiling Surface		19.2			20.6	20.6
Mean Floor Surface		19.1			20.6	20.6

HEAT FLOWS [MJ]   Period: 8. 2. - 17. 2.1981   Geneva

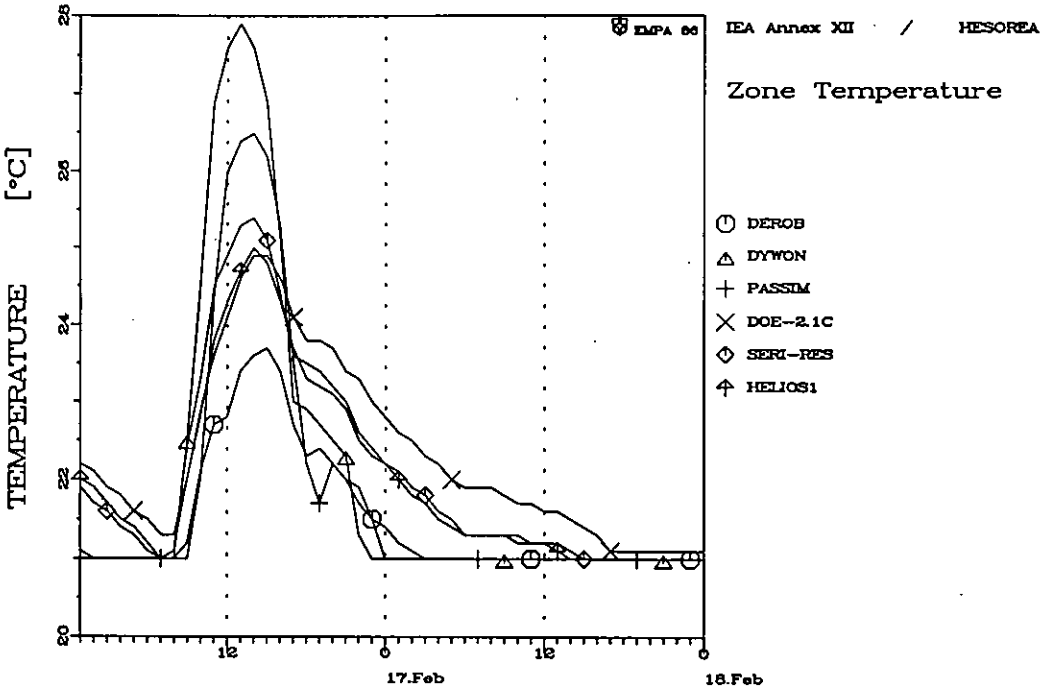
PROGRAM	DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
Glazing Area		198		187	221	220
Window Frames		32		28	34	36
External Walls		25		26	25	31
Ceiling		-10			-6	-2
Floor		-4			-2	-4
Partition Walls		-3			-2	-2
Total		237		241	270	279
Air Infiltration		195		194	192	194
Total Heat Losses		433		435	462	473
Solar Gains		69		40	64	66
Internal Heat Gains		65		65	65	65
Total Heat Gains		134		105	129	131
Auxiliary Heating		287		330	333	342
Heating Peak Load W		886		897	1268	1500

Table 5.15 <u>Heat flux balance and temperature behaviour</u>

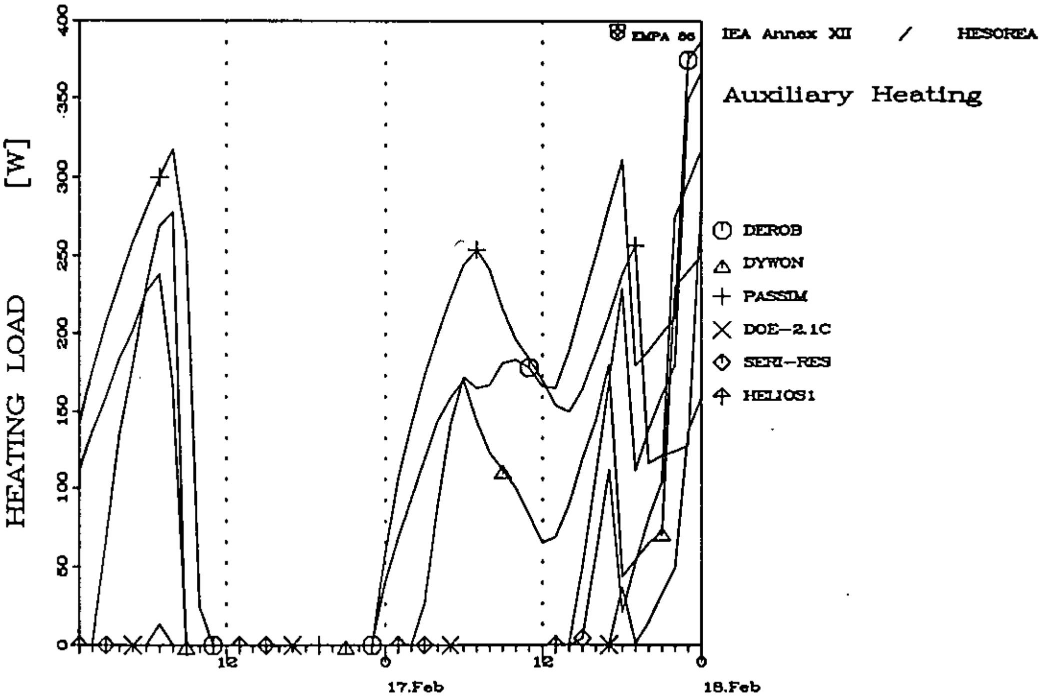
Base case HENONI-A

c) Zone temperature and auxiliary heating demand

In Figures 5.1 - 5.3, the zone temperature and the auxiliary heating demand are hourly plotted for day 9 und 10 (16. + 17. February) for three cases (HESORE-A, HENORE-A, LISORE-A).

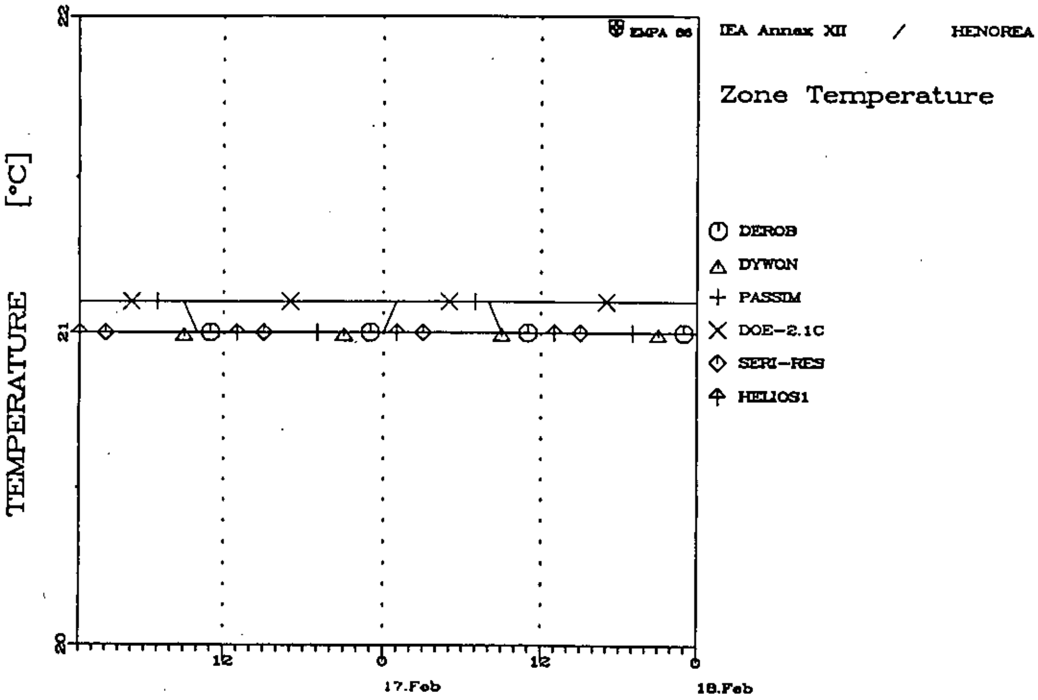


a) Zone temperature

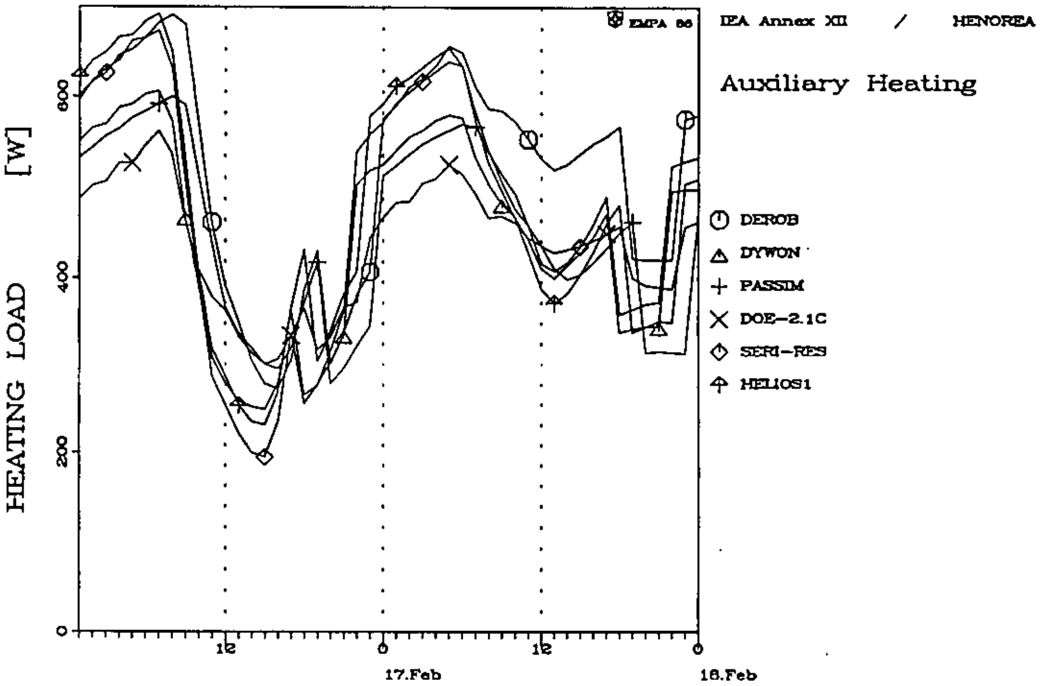


b) Auxiliary heating demand

Figure 5.1 Base case calculations: HESORE-A

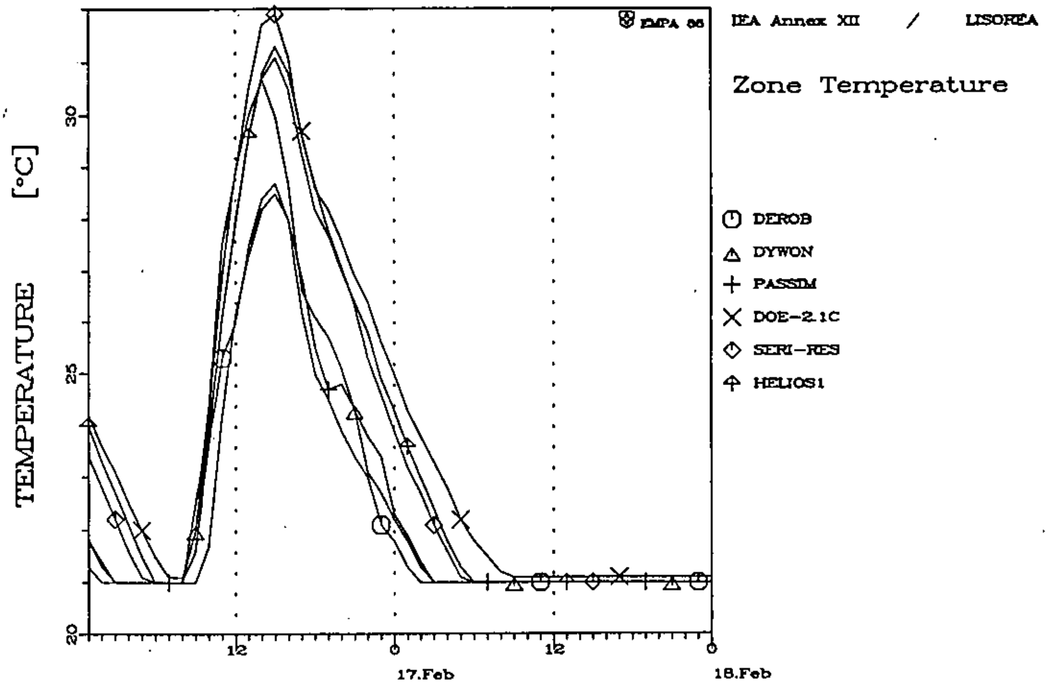


a) Zone temperature

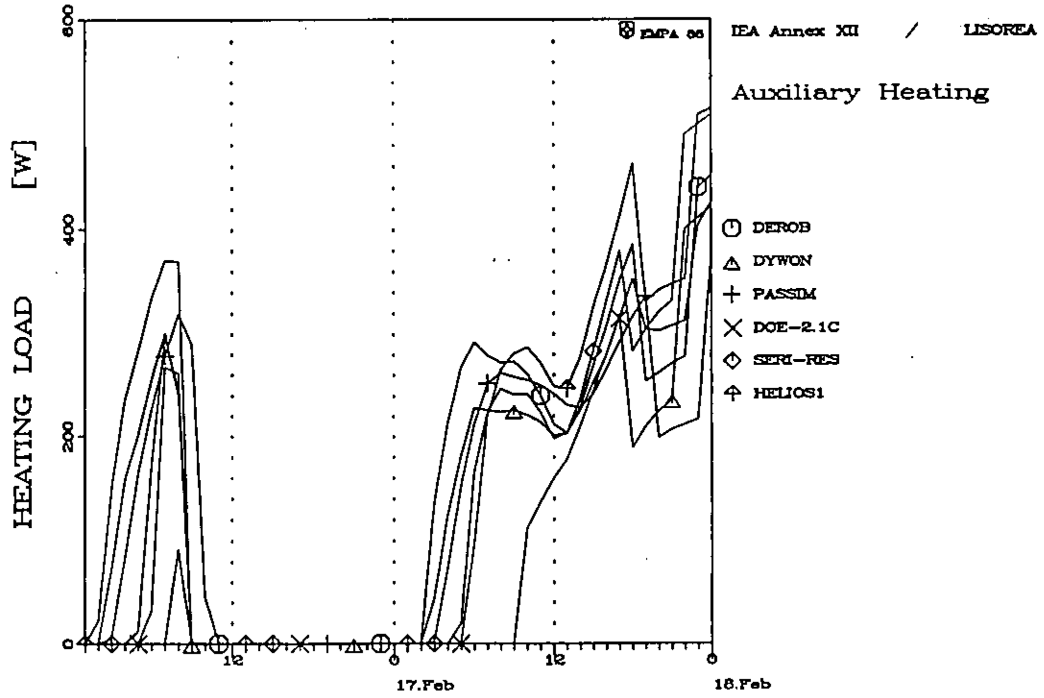


b) Auxiliary heating demand

Figure 5.2 Base case calculations: HENORE-A



a) Zone temperature



b) Auxiliary heating demand

Figure 5.3 Base case calculations: LISORE-A

d) Conclusions

From the calculation runs over a 10 day period it appeared, that the starting conditions may have a significant influence since different initial mass temperatures may occur according to the chosen heat exchange model in the room. Beside these problems the following conclusions may be drawn from the calculation runs:

- All solar radiation models, used by the different programs, show a good agreement of the results for the total incident radiation but quite obvious differences in the split into direct and diffuse components.
- HELIOS 1, SERIRES and DOE 2.1C, programs with different simplifications treating internal heat exchange in the room, show quite similar results for the auxiliary heating demand as well as for the zone temperature.
- DYWON, PASSIM and DEROB, programs with complex internal coupling models (split into convective and radiative heat exchange) show quite large differences in auxiliary heating demand and room airtemperature.

6. TEST CASE CALCULATIONS (SEASONAL AUXILIARY HEATING DEMAND)

a) Test case specifications

In order to investigate the deviation in predicting seasonal auxiliary heating demand the following test case specifications have been used (Table 6.1). Case A corresponds to free temperature control (no shading and extra-ventilation), case B to a venting set point of 26 °C and solar shading strategy.

In Figures 6.1 and 6.2, the seasonal auxiliary heating demands are compared.

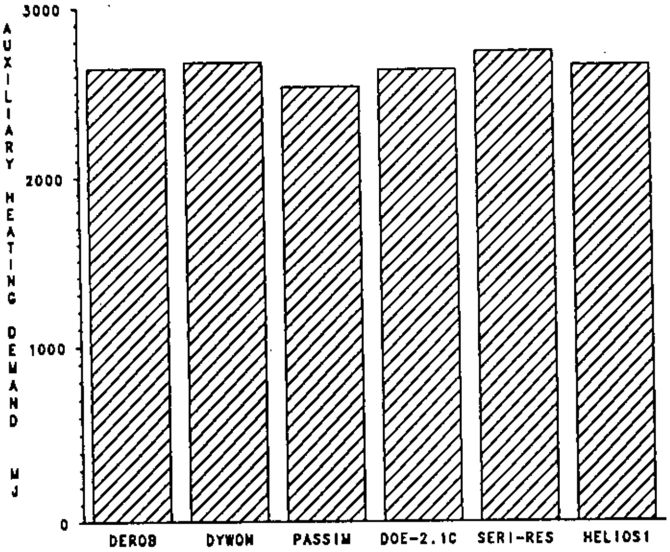


Figure 6.1 Auxiliary heating demand Test case A

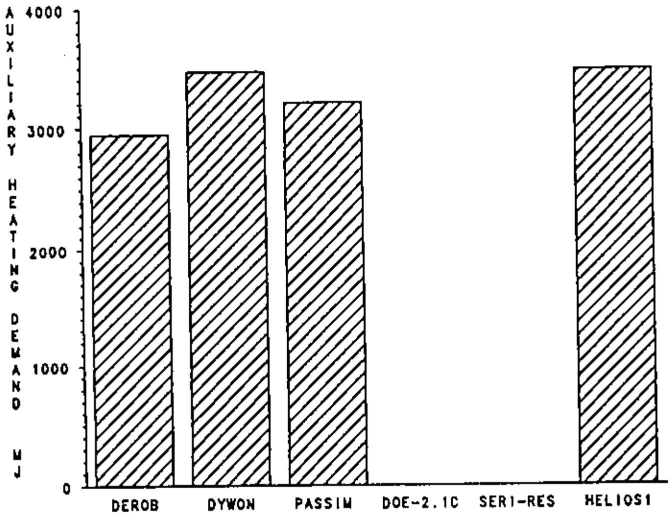


Figure 6.2 Auxiliary heating demand Test case B

Building mass:	Heavy
Room orientation:	South
Room location:	Center of the building
Boundary conditions:	Adiabatic
Window area:	A_g = 4.5 m^2 (glazing) A_f = 1.5 m^2 (frame)
Glazing type: (nominal values)	Double glazing (4/12/4) U_g = 3,1 W/m^2 K g = 0,75 (solar factor)
Frame type:	Wood, U_f = 2.0 W/m^2 K
External wall:	A = 6,5 m^2 U = 0,3 W/m^2 K
Partition walls:	A = 42,5 m^2
Ceiling:	A = 30,0 m^2
Floor:	A = 30,0 m^2
Temperature control:	t_{set} = 20,0 °C Case A: t_{max} = free Case B: t_{ven} = 26 °C (venting set point)
Internal gains:	8 a.m. - 6 p.m. 100 W 6 p.m. - 10 p.m. 400 W 10 p.m. - 8 a.m. 0 W
Ventilation:	n = 0,6 1/h (constant) Case B: Increased ventilation n = 10 1/h if indoor zone temperature exceeds 26 °C.
Solar protection:	Case A: no shading devices Case B: external shading device, reducing the solar factor by 0,3 if incident radiation on window surface exceeds 500 W/m^2
Climate:	Geneva, 1. October - 30. April 1981
Initialisation:	21. Sept. to 30. Sept. 80
Heating delivery:	Convector system
Heating regulation:	Indoor air temperature
Heating mode:	Continuous heating

Table 6.1 Test case specifications
(nominal values)

b) Zone temperature and auxiliary heating demand

In Tables 6.2 and 6.3, monthly and heating period summaries for the different simulation codes are compared, Table 6.2 for Test case A and Table 6.3 for Test case B.

		DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
October	Q_{Loss} [MJ]	-1340	-1423	-1280	-1142	-1262	-1247
	Q_{Gains} [MJ]	1332	1404	1269	1109	1253	1240
	$Q_{Aux.}$ [MJ]	5	13	4	33	9	8
	t_i [°C]	28.8	26.3	28.3	25.1	26.7	26.1
	$t_{i,max}$ [°C]	44.0	36.8	41.6	34.2	36.2	34.2
November	Q_{Loss} [MJ]	-1368	-1261	-1159	-1175	-1219	-1177
	Q_{Gains} [MJ]	990	934	866	792	870	852
	$Q_{Aux.}$ [MJ]	378	324	288	383	349	325
	t_i [°C]	21.8	21.4	21.9	21.4	21.7	21.6
	$t_{i,max}$ [°C]	28.7	28.2	30.8	27.0	27.8	27.2
December	Q_{Loss} [MJ]	-1728	-1644	-1552	-1517	-1614	-1577
	Q_{Gains} [MJ]	999	864	805	736	808	792
	$Q_{Aux.}$ [MJ]	729	779	746	781	806	785
	t_i [°C]	20.3	20.1	20.3	20.2	20.2	20.2
	$t_{i,max}$ [°C]	23.8	23.3	25.3	22.0	22.9	22.4
January	Q_{Loss} [MJ]	-1783	-1713	-1599	-1561	-1681	-1634
	Q_{Gains} [MJ]	935	833	774	735	783	763
	$Q_{Aux.}$ [MJ]	847	879	825	826	898	871
	t_i [°C]	20.2	20.1	20.2	20.2	20.1	20.1
	$t_{i,max}$ [°C]	23.4	22.4	25.4	22.2	23.2	22.6
February	Q_{Loss} [MJ]	-1546	-1537	-1432	-1372	-1453	-1427
	Q_{Gains} [MJ]	983	987	900	880	904	889
	$Q_{Aux.}$ [MJ]	562	548	532	492	549	539
	t_i [°C]	20.4	20.3	20.6	20.4	20.4	20.4
	$t_{i,max}$ [°C]	23.4	23.9	26.0	23.1	23.7	23.2
March	Q_{Loss} [MJ]	-1521	-1378	-1206	-1184	-1218	-1209
	Q_{Gains} [MJ]	1397	1237	1072	1067	1092	1083
	$Q_{Aux.}$ [MJ]	124	137	138	117	126	126
	t_i [°C]	24.3	22.8	22.8	23.0	22.7	22.7
	$t_{i,max}$ [°C]	36.0	31.1	31.5	30.7	29.9	29.3
April	Q_{Loss} [MJ]	-2116	-1602	-1311	-1330	-1352	-1339
	Q_{Gains} [MJ]	2115	1597	1312	1330	-1352	1339
	$Q_{Aux.}$ [MJ]	0	0	0	0	0	0
	t_i [°C]	34.9	29.1	28.2	29.2	28.9	28.6
	$t_{i,max}$ [°C]	44.1	35.9	36.0	35.3	34.6	34.1
TOTAL	Q_{Loss} [MJ]	-11404	-10559	-9538	-9279	-9799	-9610
	Q_{Gains} [MJ]	8753	7857	6997	6647	7062	6957
	$Q_{Aux.}$ [MJ]	2645	2680	2533	2632	2737	2654
	t_i [°C]	24.4	22.9	23.2	22.8	23.0	22.8
	$t_{i,max}$ [°C]	44.1	36.8	41.6	35.3	36.2	34.2

Table 6.2 Zone temperatures and auxiliary heating demand
Test case A

		DEROB	DYWON	PASSIM	DOE-2.1C	SERI-RES	HELIOS1
October	Q_{Loss} [MJ]	-1293	-1024	-988			-909
	Q_{Gains} [MJ]	1230	892	875			811
	$Q_{Aux.}$ [MJ]	62	130	82			97
	t_i [°C]	22.7	21.7	22.3			21.8
	$t_{i,max}$ [°C]	28.2	27.3	26.0			25.9
November	Q_{Loss} [MJ]	-1347	-1178	-1128			-1166
	Q_{Gains} [MJ]	915	628	627			589
	$Q_{Aux.}$ [MJ]	431	548	500			577
	t_i [°C]	21.0	20.3	20.5			20.2
	$t_{i,max}$ [°C]	28.1	23.3	24.7			21.9
December	Q_{Loss} [MJ]	-1719	-1595	-1545			-1569
	Q_{Gains} [MJ]	915	698	705			649
	$Q_{Aux.}$ [MJ]	804	895	840			920
	t_i [°C]	20.2	20.0	20.1			20.0
	$t_{i,max}$ [°C]	23.0	20.9	22.4			21.0
January	Q_{Loss} [MJ]	-1775	-1666	-1577			-1623
	Q_{Gains} [MJ]	876	695	672			644
	$Q_{Aux.}$ [MJ]	899	969	905			978
	t_i [°C]	20.1	20.0	20.1			20.0
	$t_{i,max}$ [°C]	22.8	20.5	22.1			20.8
February	Q_{Loss} [MJ]	-1540	-1443	-1394			-1407
	Q_{Gains} [MJ]	922	734	715			686
	$Q_{Aux.}$ [MJ]	618	707	679			721
	t_i [°C]	20.3	20.0	20.2			20.1
	$t_{i,max}$ [°C]	22.8	20.9	22.1			21.1
March	Q_{Loss} [MJ]	-1464	-1144	-1044			-1021
	Q_{Gains} [MJ]	1331	948	846			842
	$Q_{Aux.}$ [MJ]	132	192	197			180
	t_i [°C]	22.5	21.4	21.5			21.2
	$t_{i,max}$ [°C]	29.7	26.5	25.9			24.9
April	Q_{Loss} [MJ]	-2000	-1235	-1063			-1026
	Q_{Gains} [MJ]	1999	1205	1027			1026
	$Q_{Aux.}$ [MJ]	0	27	1			0
	t_i [°C]	24.7	23.4	23.6			23.7
	$t_{i,max}$ [°C]	29.7	28.3	26.4			26.3
TOTAL	Q_{Loss} [MJ]	-11138	-9284	-8738			-8721
	Q_{Gains} [MJ]	8188	5802	5465			5248
	$Q_{Aux.}$ [MJ]	2946	3468	3205			3473
	t_i [°C]	21.7	21.0	21.2			21.0
	$t_{i,max}$ [°C]	29.7	28.3	26.4			26.3

Table 6.3: <u>Zone temperatures and auxiliary heating demand</u>

Test case B

c) Conclusions

The calculation results of the seasonal auxiliary heating demand for test case A (no shading and venting strategy) varies within a deviation band of ± 5 %. The calculated mean zone temperatures range from 22.8 to 23.0°C except for DEROB which obtained a much higher value of 24.4°C.

The high solar gains in DEROB are due to the simplifications in the solar model.

For the test case B (including shading and extra ventilation) the results in auxiliary heating demand, calculated by DYWON, HELIOS 1, and PASSIM agree within 4 %, DEROB shows a deviation of -17 %.

The calculated examples demonstrate very clearly, that the chosen boundary conditions have an important influence on the auxiliary heating demand. Test case B (with some realistic assumptions of inhabitants behaviour) shows an increase of the heating demand of +30 %.

As general conclusion of the validity of building simulation codes, all programs predicted the same auxiliary heating demand within ± 5 % deviation band, but the components of the heat balance may differ in a larger deviation band.

7. CONCLUSIONS

The work performed within step 4 has shown the following problems which have to be considered for a program comparison:

- Different levels of input / output documentation of the programs. Each program should have the same level of data documentation. At least a detailed building heat balance and information on zone temperatures should be available in order to check and analyse the results. The participants agreed to establish a standardized output data structure for each code.
- Since each program code has its own algorithms and key parameters, the possibilities of changing input parameters are limited from code to code different. Often some parameters cannot be altered by the program user without changing the source code. Therefore the user of the program needs to know the algorithms and simplifications of his program in detail. In order to meet input data requirements it was necessary to adapt the source codes by the participants. A total agreement of all parameters was not possible since the complexity of the used algorithms were different.
- The procedure used within this step has been chosen so, that the main problem areas can be identified. Therefore three different levels of calculation runs have been performed:
  - steady state conditions and given thermal response situations
  - short period calculations with real weather data
  - seasonal calculations based on real weather data

The investigations showed very clearly, that due to the number of parameters involved in the simulation and the simplification levels of the algorithms, the analyses of the results implies a detailed knowledge of the program code. The following conclusions may be drawn from the work which has been performed:

. Deviation in seasonal auxiliary heating demand is small (± 5 %).

. Deviations in hourly peak loads and floating zone temperatures are much bigger.

These differences are mainly due to the differences in approach for treating heat transfer between surfaces and room air (see appendix D).

The following factors have a significant influence on the results:

- Distribution of solar gains in the room (absorbed component, convective component due to furniture).
- Type of internal loads (convective and/or radiative).
- Thermal coupling between room air and internal surfaces.
- Additional heat exchange surfaces in a room, which influence the zone temperature (furniture, people, curtains, ...)

The simulation of the thermal behaviour of a building is very complex from the point of view of the input parameters, which may not be defined clearly enough. Therefore the complexity level of the simulationcode selected should match to the level of uncertainty present in the building description and weather data.. The program user has to unterstand the different simplifications of his program algorithms in order to make a correct input, corresponding with the description of the building.

While overall agreement in the average heat use calculations between all the programs was good (within 5%), detailed behaviours were found to differ in areas related to the transient response of the room. These differences were traced to differences in calculational algorithms which implicitly include different physical assumptions about the manner in which the room control systems (that is, thermostat and heating equipment) behave and in which the room responds to solar gain.

The transient behaviour of the room may affect the manner in which windows are utilized, because the need to avoid local overheating will control the extent to which solar gain is tolerable and daylighting is utilizable.

It can be seen, therefore, that even when sophisticated models with carefully matched input assumptions are chosen and when the resultant heating demand calculations agree, there remain differences in physical assumptions which may importantly affect the window performance calculation. To insure that these calculations are correct, it is therefore necessary to choose a model which correctly represents these details of room behaviour for the type of space being studied. In general, however, the detailed physical behaviour of rooms is not known sufficiently; this should be subject for future research.

Annex A

Effect of selected timestep and number of nodes in a finite difference network model

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1. INTRODUCTION

Many unsteady state computer models use the concept of finite differences to simulate the thermal responses within building elements.
For the modelling of walls, floor or other constructions with a finite thermal conductivity and thermal capacity the depth of the construction can be divided into one or a number of layers. The higher the chosen number of nodes the more accurate the calculated response, at the cost of higher computation time.

The accuracy and computation time is also influenced by the chosen size of the timestep.
The comparative calculations in Step 4, e.g. the simplified base cases show large deviations in the hourly results between the different computer codes.
One of the possible sources could be the choice of number of nodes and timestep size.
In the following the effect of number of nodes and timestep size is illustrated by comparing analytical solutions of heat penetration into a wall with thermal node networks.
The examples are valid for an implicit solution technique.

2. SELECTED EXAMPLES

Wall type:

As typical example a wall has been selected with the following properties:

depth 0.20 m;
conductivity 1.7 W/mK;
mass density 2500 kg/m^3
thermal capacity 840 J/kgK.

Selected wall models:

The wall has been modelled by a single node (figure 1a) and a four nodes network (figure 1b).

Selected timestep sizes:

Three different timestep sizes have been selected for the calculations: $\Delta t1$ = 1 min.

$\Delta t2$ = 15 min.

$\Delta t3$ = 1 hr.

Calculations:

Two calculation cases have been selected. For both cases the thermal response can also be calculated by solving the differential equations analytically.

The comparison with the analytical solutions illustrates the effect of selected wall model and timestep on the accuracy of the results.

The selected calculations are:

Boundary conditions:

Initial wall temperature: 20° C; steady state situation. The conditions at both surfaces of the wall are considered adiabatic.

Case 1:

At time t = 0 the **surface temperature**, Θ_1, is step-wise increased from $\Theta_1 = 20\ ^\circ C$ to $\Theta_1 = 30\ ^\circ C$. This results in a penetration of heat, q_1, into the wall and a gradual increase of the temperatures inside the wall.

Case 2:

At time = 0 a **heat flux**, $q_1 = 100\ W/m^2$ is imposed on the wall surface 1. This results in an immediate temperature rise of Θ_1 and a gradual increase of the temperatures inside the wall.

3. RESULTS

For case 1, the results are presented as the amount of heat penetrated into the wall since time zero, $Q_1(t)$. See figure 2.

For case 2, figure 3 presents the calculated surface temperature Θ_1.

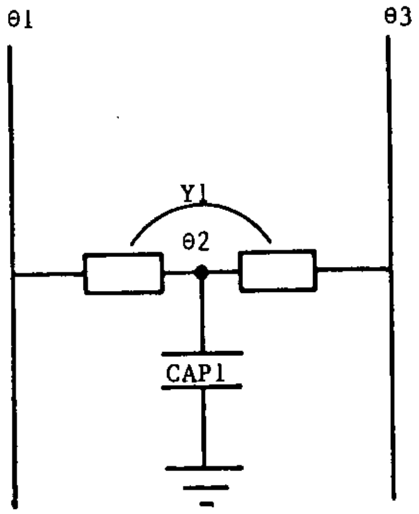

Figure 1a: Single node representation.

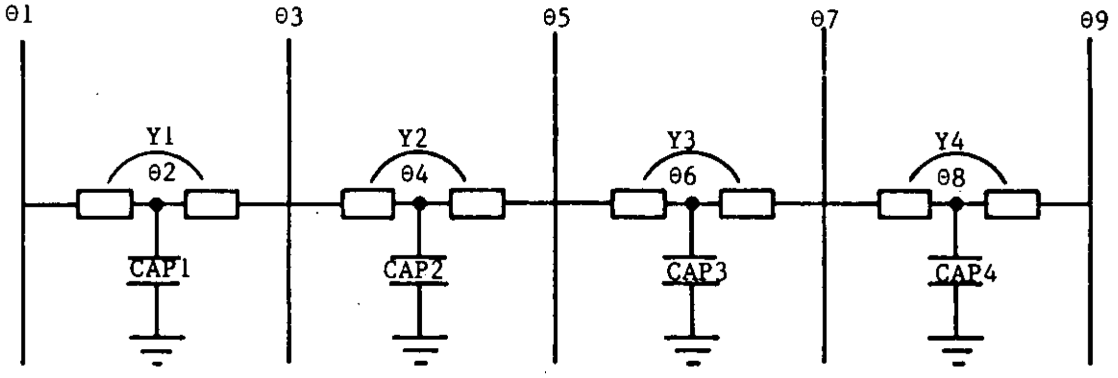

Figure 1b: Four nodes representation.

$\theta_{1,..,n}$: wall temperature at successive locations inside the wall (°C)

θ_1 , θ_n : wall surface temperatures (°C)

$y_{1,...,4}$: thermal conductance of layers 1,..,4 (W/m^2K)

$cap_{1,..,4}$: thermal capacity of layer 1,..,4 (J/m^2K)

Figure 1: Selected finite difference models for the wall.

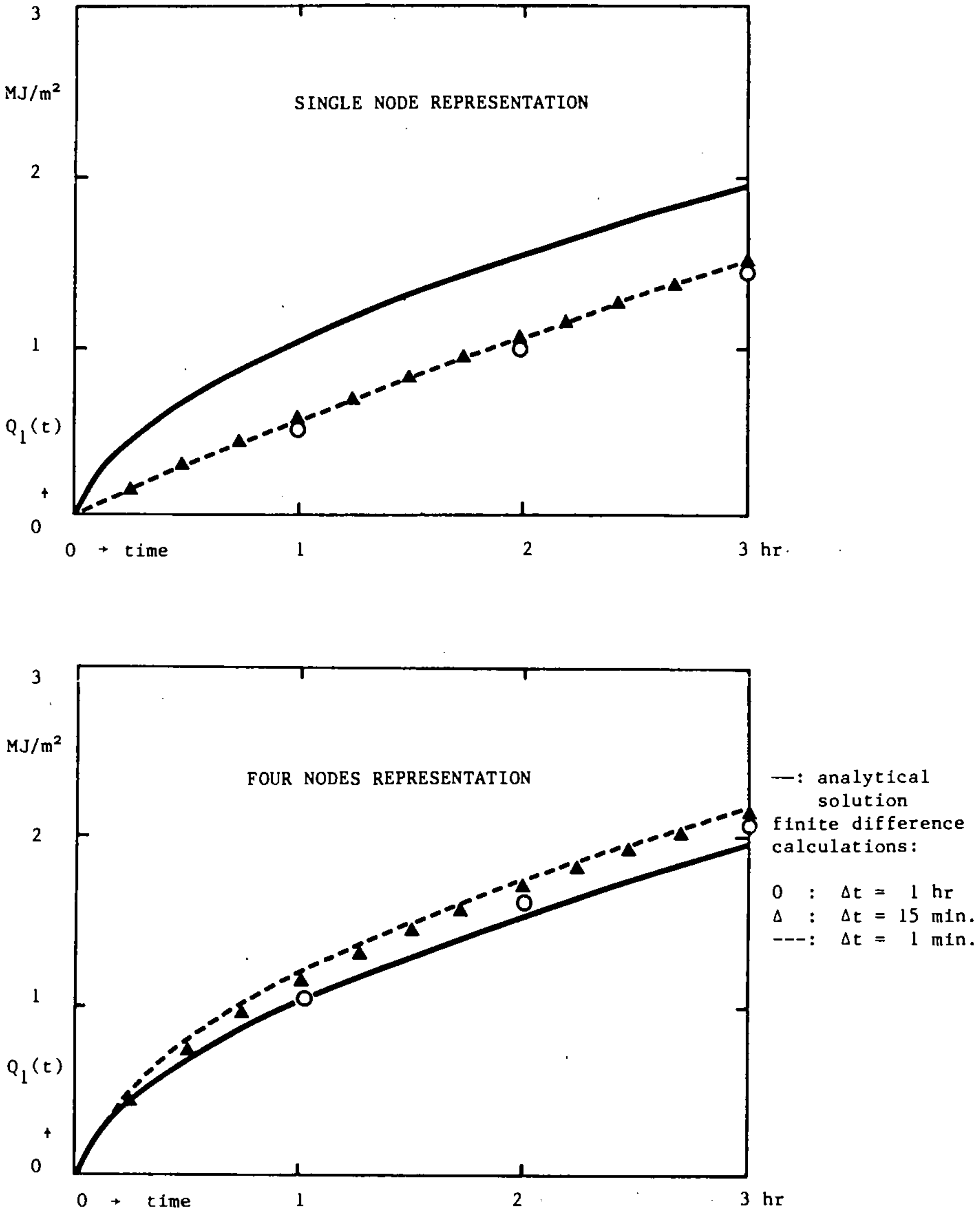

Figure 2: Heat penetrated into the wall as a result of a surface temperature step of 10 K at time zero.

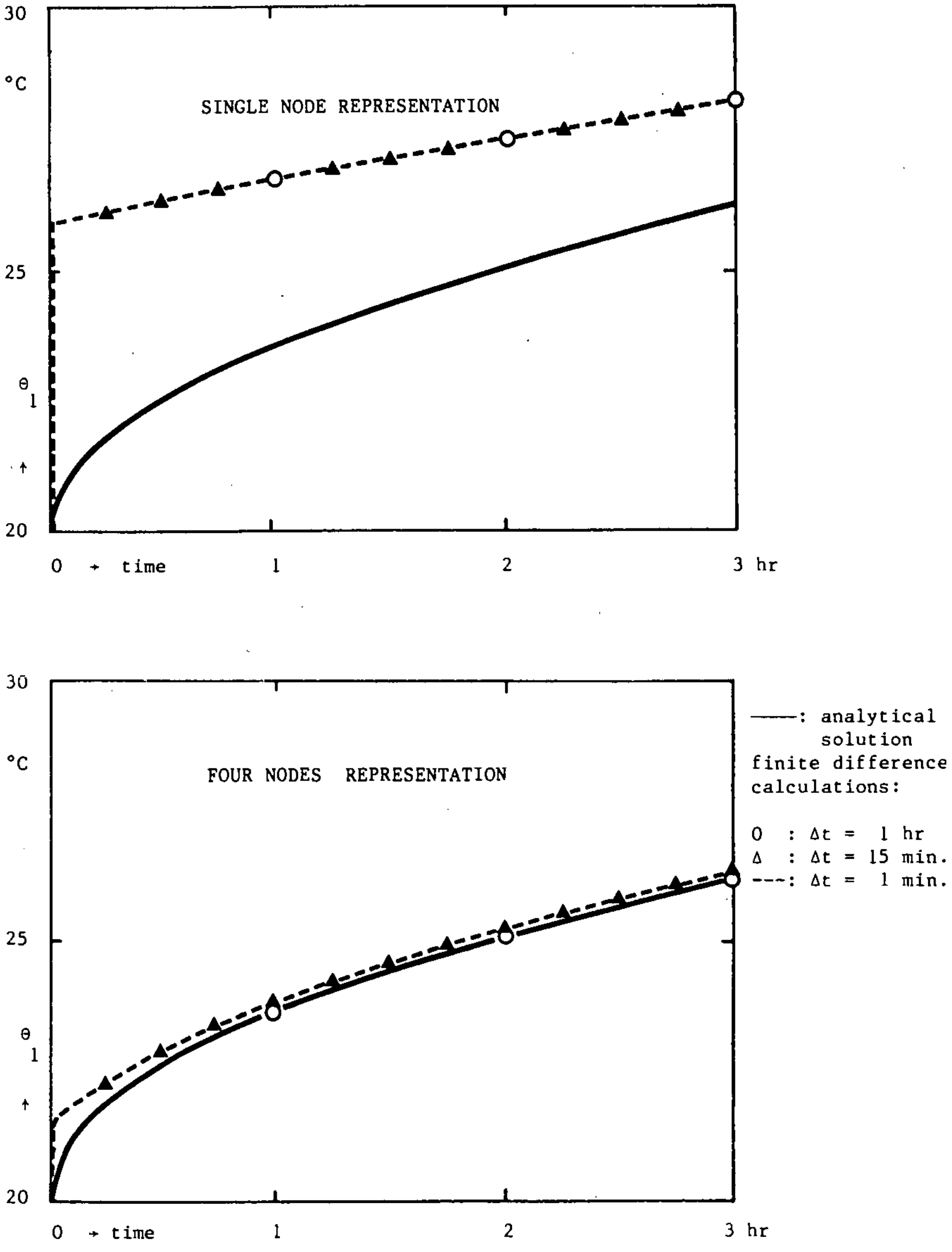

Figure 3: Surface temperature of the wall as result of an imposed heat flux q_1 = 100 W/m² from time zero.

4. DISCUSSION OF RESULTS

The results presented in figures 2 and 3 lead to the following observations:

Penetrated heat as result of temperature step (figure 2):

With a single node representation the amount of heat penetrated into the wall is underestimated seriously.
This is caused by the fact that the surface temperature step in this model is confronted with the thermal resistance from surface to mid-wall. In reality (analytical solution) the relevant depth for the heat penetration is much smaller.

The single node model misses the initial peak in the penetrating heat, irrespective of the chosen timestep size.

With the four nodes representation the amount of heat penetrated into the wall is calculated correctly for the first timestep, irrespective of the timestep size. For the next timesteps the penetrated heat is somewhat overestimated.

Surface temperature as result of imposed heat flux (figure 3):

With the single node representation the calculated surface temperature at the end of each timestep is much too high, irrespective of the chosen timestep size.

With the four nodes representation the calculated surface temperature at the end of each timestep is correct in case of **large** timestep, but overestimated in case of **small** timestep sizes.
This seems surprising, but it can again be explained by the difficulty of the finite difference model to simulate a high frequency change with penetration depths significantly smaller than the layer depth in the model.

The choice of a small timestep size has no positive effect. On the contrary, in case of an implicit solution technique a quasi steady state situation is assumed at each end of a timestep. For too small timesteps, in relation to the time constant of the nodes, this condition is violated. The time constant of the single node is roughly 15 hours; for the four nodes the "RC-time" per node is roughly 1 hour.

5. CONCLUSIONS

Examples have been presented of results obtained with a finite difference network with an implicit solution technique.
For the selected examples of heat penetration into a heavy weight wall the single node representation leads to serious deviations from the real transient thermal behaviour, irrespective of the selected timestep size.
The four nodes representation leads to correct results, except in case of small timesteps compared to the time constant of the nodes.

In general one can conclude that a correct transient thermal response can only be reached if the number of nodes is sufficiently large to get time constants per node less than or equal to the time step of the calculation.
This implies, that when the time step size is decreased, the number of nodes should be increased accordingly, in order to avoid erroneous results.

In the DYWON-calculations in Step 4 all building elements have been modelled as four nodes networks and for the timestep size 1 hour was chosen.

Technisch Physische Dienst TNO-TH
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Ir. H.A.L. van Dijk

Annex B

Influence of indoor air mass and thermal couplings between indoor air and inside surfaces

GRES EPF Lausanne, CH

SOME MODELIZATION TESTS USING "PASSIM4"

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INTRODUCTION :

In order to check the sensitivity of the results to the simulation procedure, we have performed some validations using the computer code PASSIM - 4.

The selected case was HESORE - A
with :
- double glazing (4.92 m^2)
- continuous auxiliary heating without night set back
- no blinds or solar protection
- simulation period : 8 - 17.2.81.

1. Influence of the simulation timestep :

In the base case calculation, the simulation timestep was 10 minutes, we have repeated the calculations with timesteps going from one minute to one hour.

Table 1 presents the main results, one notices that neither the heat balances nor the temperatures are affected by these variations.

Simulation timestep (min)	1	2	5	10	30	60
Number of nodes for each wall or slab	4	4	4	4	4	4
Coupling between inside air and indoor surfaces(1)	C + R	C + R	C + R	C + R	C + R	C + R
Indoor thermal mass (kJ/K)	86	86	86	86	86	86
Total heat losses (MJ)	533.3	533.3	533.6	534.1	534.6	534.7
Required aux. heating (MJ)	148.0	148.0	148.2	148.8	149.2	148.0
Indoor air temp.						
°C Minimum	21.0	21.0	21.0	21.0	21.0	21.0
Average	21.8	21.8	21.8	21.8	21.8	21.8
Maximum	26.9	26.9	26.9	26.9	27.0	27.1

(1) Convection and radiation separated

Table 1 : Influence of the simulation timestep on the results.

2. Influence of the number of nodes :

The base case calculation was characterised by 4 nodes for each wall or slab : 2 on both surfaces and 2 in the thermal mass in-between. We have changed this last number from 1 to 4 using 3 to 6 nodes for each wall or slab.

The table 2 gives the results of such an exercice. Once more no significant change is observed.

Simulation timestep (min)		10	10	10
Number of nodes for each wall or slab		3	4	6
Coupling between inside air and indoor surfaces (1)		C + R	C + R	C + R
Indoor thermal mass (kJ/K)		86	86	86
Total heat losses (MJ)		534.9	534.1	533.8
Required aux. heating (MJ)		149.6	148.8	148.5
Indoor air temp. °C	Minimum	21.0	21.0	21.0
	Average	21.7	21.8	21.8
	Maximum	26.7	26.9	26.8

(1) Convection and radiation separated

Table 2 : Influence of the number of nodes on the results.

3. Influence of the couplings between indoor air and inside surfaces :

The base case calculation included a detailed calculation using separate convection and radiation couplings. The convective part (between the air and the inside surfaces) was calculated for each step using the Grasshof and Nusselt numbers. The radiative part (directly between the inside surfaces) required a detailed calculation of the different form factors.

We tried to replace this procedure by using an equivalent coupling between the surfaces and the indoor air. The following constant values were adopted :

$h = 6$ $[W/m^2K]$ for horizontal surfaces

$h = 8$ $[W/m^2K]$ for vertical surfaces

The simulation results are presented in the tables 3 and 4 : despite the heat balance are not significantly affected one notices a change in the indoor temperature (the maximum temperatures being lower by 1.7 °C).

This is quite understandable, because the base case detailed modelization involves a much lower coupling from the air to the surfaces, as the radiative parts take place between surfaces only.

Simulation timestep (min)		10	10	10	10
Number of nodes for each wall or slab		4	4	4	4
Coupling between inside air and indoor surfaces(1)		C + R	fixed values (6(W/m^2K)for horizontal, 8(W/m^2K)for vertical)		
Indoor thermal mass (kJ/K)		86	86	258 (x3)	2580 (x30)
Total heat losses (MJ)		534.1	529.2	528.9	525.8
Required aux. heating (MJ)		148.8	143.2	142.9	139.8
Indoor air temp.					
°C	Minimum	21.0	21.0	21.0	21.0
	Average	21.8	21.7	21.7	21.6
	Maximum	26.9	25.2	25.1	24.2

(1) Convection and radiation separated

Table 3 : Influence of the coupling between indoor air and inside surfaces and of the indoor air thermal capacity.

4. Influence of the indoor thermal mass :

Finally, using the constant indoor coefficient hypothesis, we increased the air thermal capacitance in order to simulate the effect of furniture. Starting from the base case we used 258 [kJ/K] (3 times the air thermal mass) and 2580 [kJ/K] (30 times the air thermal mass).

The effect of such a modification can be observed in the table 3. Multiplying the air thermal mass by a factor 30 reduced the maximum indoor air temperature by about 1 °C.

Additional test, on a yearly basis, are presented in reference (1).

CONCLUSION:

Among the studied parameters, the only one which influences significantly the results is the way couplings between indoor air and inside surfaces are treated.

Reference 1 moreover has shown that two factors plays an important role:

a) the heat losses to the sky, which may represents up to 35% change in the total auxiliary heating requirements,

b) the effective solar transmission through the glazing panes.

REFERENCE:

(1) N. Morel, Ch. Eriksson and J.-B. Gay
Problèmes liés à la modélisation du comportement thermique dynamique des fenêtres.
5ème Symposium sur la recherche et le développement en énergie solaire. EPFL (octobre 1985) p.83

Annex C

Influence of distribution of internal and solar gains to floating zone temperature

EMPA Dübendorf, CH

Influence of solar radiation split

Solar and internal gains may be split into a radiative and a convective component. The way how the split is done has an influence to the calculated peak zone temperature. The following table shows the order of magnitude for models with combined inside heat transfer coefficients (HELIOS1) and such with split ones (DYWON).
The effect of additional furniture in the room is illustrated by the results from DYWON-F:

Split	HELIOS1	DYWON		DYWON-F	
	$t_{i,max}$	$t_{air,max}$	$t_{com,max}$	$t_{air,max}$	$t_{com,max}$
30 % air (convective) 20 % floor 50 % walls and ceiling	24.2 °C	26.4 °C	25.0 °C	26.2 °C	25.1 °C
0 % air (convective) 40 % floor 60 % walls and ceiling	23.5 °C	22.8 °C	23.7 °C	23.5 °C	24.1 °C
100 % air (convective) 0 % floor 0 % walls and ceiling	26.2 °C	–	–	–	–

$$t_{com,max} = t_{air,max} * 0.4 + \bar{t}_{surfaces} * 0.6$$

Table : Influence of solar radiation split (HESOREA-3)

t_i : Zone temperature
t_{air} : Air temperature
t_{com} : Comfort temperature

Annex D

Comparison of room air temperature and comfort index temperature

GRES EPF Lausanne, CH
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COMPARISON OF ROOM AIR TEMPERATURE AND COMFORT INDEX TEMPERATURE, DEPENDING ON THE AIR SURFACES COUPLING MODELS

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The model used to describe the coupling between the indoor air and the surfaces has a direct effect on the air - and comfort temperatures. The different codes, considered in this study, use one of the following models.

1. Detailed heat transfer model

In figure 1 the air node is coupled by convection to the room surfaces, between surface 1 (window or wall) and surface 2 (wall) a radiative heat exchange takes place. Therefore the calculated zone-node temperature **corresponds exactly** to the real room air temperature. Other heat exchange surface (like furniture) has to be treated like an additional wall or floor element.

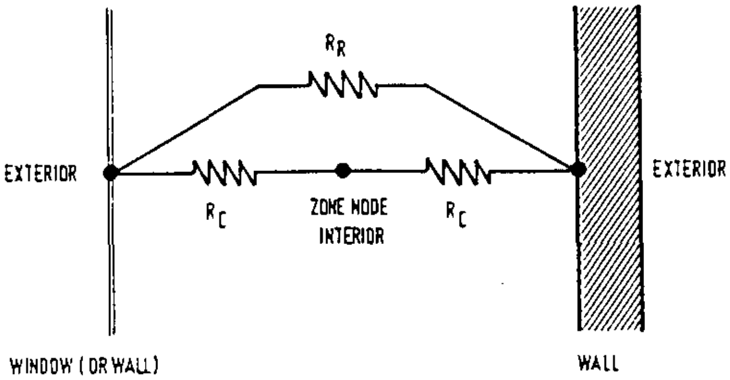


Figure 1 Detailed heat transfer model

with: R_C = convective film resistance
R_R = radiative equivalent resistance

2. Simplified heat transfer model

In figure 2, all surfaces are coupled to the zone node **by an equivalent resistance.** Since air is transparent for longwave radiation, it is assumed that the walls see surfaces which are on zone-node temperature. The calculated zone-nodes temperature therefore does not always correspond to the real room air temperature.

For rooms with no additional surfaces (furniture) which are on room air temperature, the calculated node-temperature corresponds to a surface weighted temperature which could be compared with an index temperature.

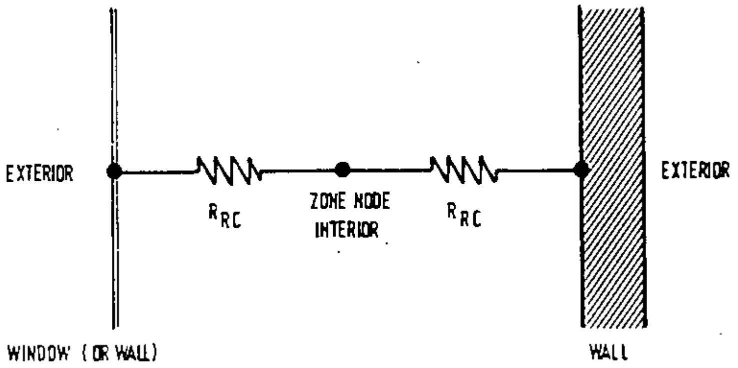


Figure 2 : Simplified heat transfer model

with: R_{RC} = combined film resistance

3. Calculation results

In order to compare the two approaches,a calculation comparison has been performed using the program PASSIM,once with a detailed split film resistance and once with a simplified,combined one.

The cases b),c) and d) already used in the simplified base case calculations of chapter 4 have been considered.In each case and for both approaches,the auxiliary heating has been regulated according to the zone temperature.Figures 3 to 5 present the evolution of the zone and index temperature.The index temperature has been introduced by P.O.Fanger [1] , it is close to the effective temperature feeled by an human body sitting in the middle of the room.

$$T_{index} = 0.5 * (T_{air} + T_{surfaces})$$

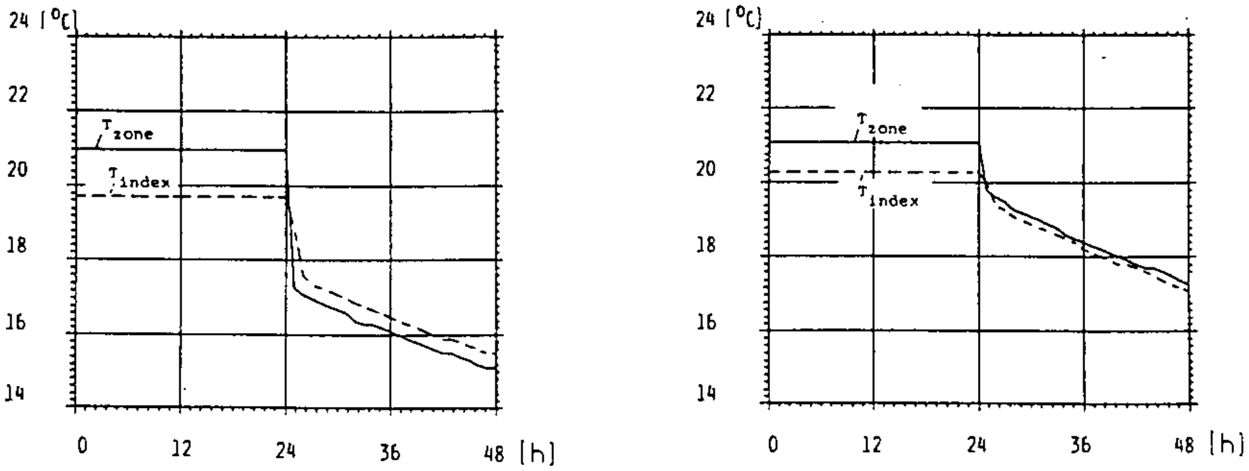
with : $T_{surfaces} = T_{glazing} * a + (1 - a)\left(\frac{T_{ceiling} + T_{floor} + T_{walls}}{3}\right)$

$a = 0.1$ for $A_{glazing} = 3\ m^2$

$= 0.2$ for $A_{glazing} = 6\ m^2$

$= 0.3$ for $A_{glazing} = 9\ m^2$

a) Cooling rate :

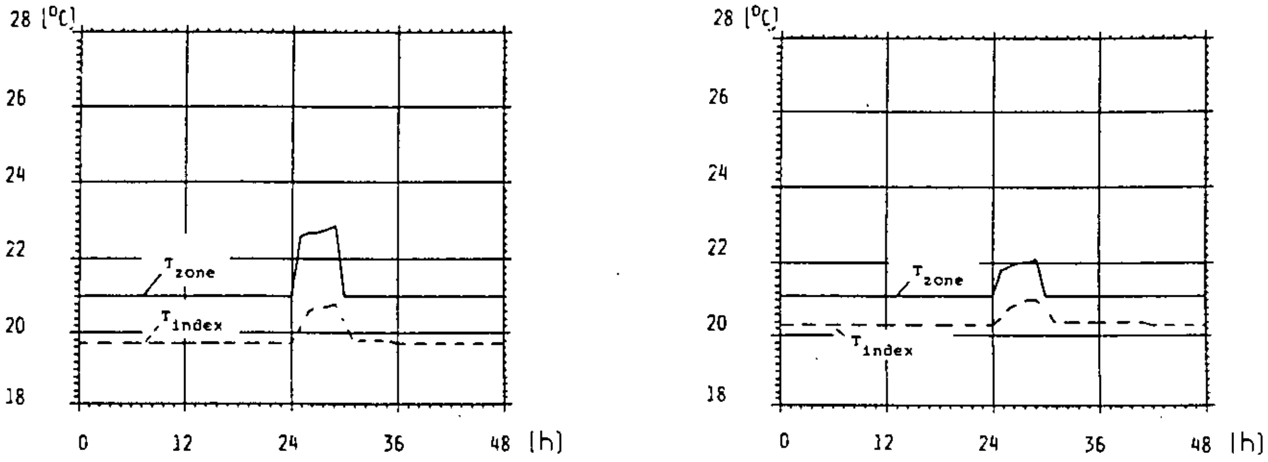


(a) detailed model (b) simplified model

Figure 3 : Response to switching off the auxiliary heating after 24 h.

Immediately after the heating switches off,the zone temperature behaves very differently : due to the smaller coupling between the air and the surfaces,the zone temperature drops more strongly for the detailed model as for the simplified one.As it could be expected,such a fast drop is not observed for the index temperature.For the detailed model,the zone temperature corresponds to the room air temperature while for the simplified model,the zone temperature already has the signification of a air and surface weighted temperature.The zone and index temperature of the simplified model lie therefore close together.A comparison with the detailed model is better on the basis of the index temperature than for the zone temperature.

b) Internal gain pulse :

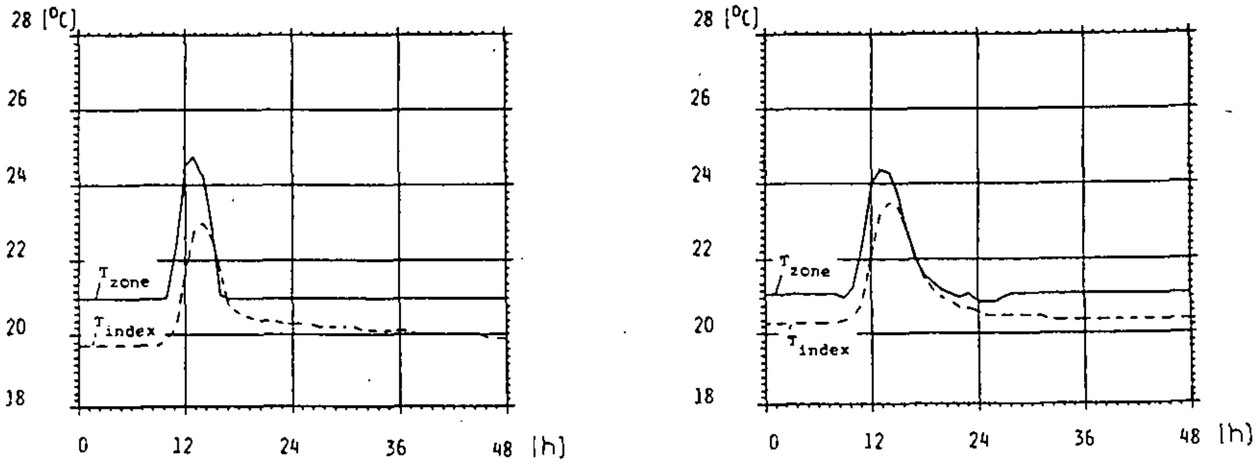


(a) detailed model (b) simplified model

Figure 4 : response to internal gain pulse (1000 W from 24 to 29 h)

Same tendency is observed when an internal gain pulse is applied to the zone node : in the detailed model a smaller power may be transferred to the surfaces, resulting in a larger increase of the zone temperature.

c) Solar gain pulse



(a) detailed model (b) simplified model

Figure 5 : response to solar gain pulse during the first day, (20 % of heat to air, 30 % to floor, 50 % to remaining surfaces)

Once more a stronger increase of the zone temperature is observed with the detailed model, but due to the direct transfer of only 20 % of solar gain to the air, the difference between the two models is much smaller than in case (b).

4. Conclusions

Many simulation codes use a simplified model in order to describe the coupling between the indoor air and the sufaces;the equivalent combined film conductances lie usually between 6 and 9 $[W/m^2K]$ depending on the surface position.In that case,the calculated zone temperature is not the room air temperature but more close to a weighted mean value between the air and the surface temperatures,corresponding to the definition of a kind of index temperature.This may induce deviations to a detailed model concerning the used heating set point temperature and the calculated ventilation heat loss.
However one should notice,that the above test cases have not included any influence of furniture in the room,which may have a relevant influence to the radiative heat exchange.The addition of such elements would reduce the differences between detailed and simplified calculation models (see Annex C ,DYWON versus DYWON-F).

Reference: [1] P.O. Fanger Thermal comfort
Krieger publishing company (1982)

Annex E

Meteo data for the simplified base case calculations

EMPA Dübendorf, CH

Meteo data

For HESOREA-1 and HESOREA-2

Global/Diffuse Radiation	0 [W/m^2]
IR-Radiation horizontal	254 [W/m^2]
vertical	285 [W/m^2]
Ambient air temperature	0.0 [°C]
Wind speed	1.8 [m/s]
Wind direction frequency (S/W/N/E)	10/70/10/10 [%]

For HESOREA-3

Global/Diffuse radiationfor 10.2.1981 (Day 3), Geneva

I(H) : Global radiation horizontal |
I(S) : Global radiation vertical south > [W/m^2]
D(H) : Diffuse radiation horizontal |

Hour	I(H)	I(S)	D(H)
8	26	10	24
9	112	118	94
10	217	292	155
11	344	515	147
12	501	854	114
13	509	829	106
14	444	689	109
15	330	510	90
16	174	267	66
17	43	71	23

IR-Radiation, Ambient air temperature, wind speed and wind direction frequency: as for HESOREA-1 and HESOREA-2.

Annex F

Meteo data for the base case calculations

10-day period, Geneva 1981

EMPA Dübendorf, CH

VARIABLES		UNIT
YR	Year	
DNR	Day-Number	
DAY	Day	
MO	Month	
HR	Hour	
I(H)	Global radiation horizontal	[W/m^2]
I(E)	Global radiation vertical east	[W/m^2]
I(S)	Global radiation vertical south	[W/m^2]
I(W)	Global radiation vertical west	[W/m^2]
I(N)	Global radiation vertical north	[W/m^2]
I(D)	Diffuse radiation horizontal	[W/m^2]
IR(H)	Infrared radiation horizontal	[W/m^2]
IR(V)	Infrared radiation vertical	[W/m^2]
TL	Ambient air temperature	[°C]
RH	Relative humidity ambient air	[%]
VW	Wind velocity	[m/s]
E(H)	Sky emmisivity horizontal	[-]
E(V)	Sky emmisivity vertical	[-]
WR1	Wind direction frequency south	[%]
WR2	Wind direction frequency west	[%]
WR3	Wind direction frequency north	[%]
WR4	Wind direction frequency east	[%]

YR	DNR	DAY	MO	HR	I(H)	I(E)	I(S)	I(W)	I(N)	I(D)	IR(H)	IR(V)	TL	RH	VV	E(H)	E(V)	VR1	VR2	VR3	VR4
1981	39	8	2	1	0.	0.	0.	0.	0.	0.	265.	295.	1.8	91.0	.6	.82	.91	10.	10.	10.	70.
1981	39	8	2	2	0.	0.	0.	0.	0.	0.	283.	307.	1.4	93.0	.6	.88	.95	10.	10.	10.	70.
1981	39	8	2	3	0.	0.	0.	0.	0.	0.	295.	315.	1.3	93.0	.3	.92	.98	10.	10.	10.	70.
1981	39	8	2	4	0.	0.	0.	0.	0.	0.	305.	322.	1.5	93.0	.7	.94	1.00	10.	10.	70.	10.
1981	39	8	2	5	0.	0.	0.	0.	0.	0.	306.	323.	1.8	94.0	.6	.94	1.00	10.	10.	10.	70.
1981	39	8	2	6	0.	0.	0.	0.	0.	0.	305.	322.	1.4	95.0	.8	.95	1.00	10.	10.	10.	70.
1981	39	8	2	7	0.	0.	0.	0.	0.	0.	304.	322.	1.3	95.0	.6	.95	1.00	10.	10.	70.	10.
1981	39	8	2	8	11.	4.	4.	3.	4.	9.	306.	324.	1.8	95.0	.3	.94	1.00	10.	10.	10.	70.
1981	39	8	2	9	50.	23.	24.	23.	24.	48.	310.	327.	2.3	95.0	.6	.95	1.00	10.	10.	70.	10.
1981	39	8	2	10	85.	38.	40.	39.	39.	83.	312.	329.	2.7	93.0	.4	.95	1.00	10.	10.	10.	70.
1981	39	8	2	11	93.	40.	45.	43.	41.	91.	313.	331.	3.6	91.0	.3	.94	.99	10.	10.	70.	10.
1981	39	8	2	12	76.	34.	35.	34.	35.	74.	313.	332.	4.0	90.0	.3	.93	.99	10.	10.	70.	10.
1981	39	8	2	13	80.	36.	36.	35.	38.	78.	314.	333.	4.4	89.0	.4	.93	.99	10.	10.	70.	10.
1981	39	8	2	14	68.	31.	32.	31.	31.	66.	313.	333.	4.6	88.0	.2	.93	.99	10.	10.	70.	10.
1981	39	8	2	15	51.	21.	24.	23.	23.	50.	315.	335.	4.7	89.0	.4	.93	.99	10.	10.	10.	70.
1981	39	8	2	16	26.	10.	11.	10.	11.	24.	316.	335.	4.5	90.0	.6	.94	.99	10.	10.	10.	70.
1981	39	8	2	17	5.	1.	2.	1.	2.	3.	319.	337.	4.4	90.0	.4	.95	1.00	10.	10.	70.	10.
1981	39	8	2	18	0.	0.	0.	0.	0.	0.	317.	335.	4.1	92.0	.6	.95	1.00	70.	10.	10.	10.
1981	39	8	2	19	0.	0.	0.	0.	0.	0.	317.	334.	3.8	93.0	.7	.95	1.00	10.	70.	10.	10.
1981	39	8	2	20	0.	0.	0.	0.	0.	0.	316.	333.	3.7	92.0	.5	.95	1.00	10.	10.	70.	10.
1981	39	8	2	21	0.	0.	0.	0.	0.	0.	315.	332.	3.5	92.0	.6	.95	1.00	10.	10.	70.	10.
1981	39	8	2	22	0.	0.	0.	0.	0.	0.	313.	330.	3.1	92.0	.8	.95	1.00	10.	70.	10.	10.
1981	39	8	2	23	0.	0.	0.	0.	0.	0.	311.	328.	2.7	92.0	.7	.95	1.00	10.	70.	10.	10.
1981	39	8	2	24	0.	0.	0.	0.	0.	0.	310.	327.	2.5	93.0	.4	.95	1.00	10.	10.	70.	10.
1981	40	9	2	1	0.	0.	0.	0.	0.	0.	306.	324.	2.1	92.0	1.0	.94	1.00	10.	10.	10.	70.
1981	40	9	2	2	0.	0.	0.	0.	0.	0.	304.	322.	1.5	92.0	.9	.94	1.00	10.	10.	10.	70.
1981	40	9	2	3	0.	0.	0.	0.	0.	0.	305.	322.	1.5	93.0	.7	.94	1.00	10.	10.	10.	70.
1981	40	9	2	4	0.	0.	0.	0.	0.	0.	306.	324.	1.9	92.0	.6	.94	1.00	10.	10.	10.	70.
1981	40	9	2	5	0.	0.	0.	0.	0.	0.	308.	325.	2.0	92.0	.7	.95	1.00	10.	10.	70.	10.
1981	40	9	2	6	0.	0.	0.	0.	0.	0.	308.	325.	2.0	91.0	.8	.95	1.00	10.	10.	70.	10.
1981	40	9	2	7	0.	0.	0.	0.	0.	0.	308.	325.	2.1	90.0	.5	.94	1.00	10.	10.	70.	10.
1981	40	9	2	8	9.	3.	3.	1.	3.	7.	307.	325.	2.0	89.0	.6	.94	1.00	10.	10.	70.	10.
1981	40	9	2	9	32.	13.	14.	12.	13.	31.	307.	325.	2.0	88.0	.6	.94	1.00	10.	10.	70.	10.
1981	40	9	2	10	57.	24.	25.	24.	25.	55.	309.	326.	2.2	88.0	.5	.95	1.00	10.	10.	70.	10.
1981	40	9	2	11	81.	35.	36.	33.	35.	79.	310.	328.	2.8	87.0	.6	.94	1.00	10.	10.	10.	70.
1981	40	9	2	12	126.	55.	62.	53.	52.	124.	309.	328.	3.3	85.0	.6	.93	.99	10.	10.	70.	10.

YR	DNR	DAY	MO	HR	I(H)	I(E)	I(S)	I(W)	I(N)	I(D)	IR(H)	IR(V)	TL	RH	VW	E(H)	E(V)	WR1	WR2	WR3	WR4
1981	40	9	2	13	236.	88.	193.	131.	78.	194.	305.	326.	4.0	83.0	.9	.91	.98	10.	10.	70.	10.
1981	40	9	2	14	331.	75.	508.	366.	68.	119.	296.	326.	6.9	76.0	.7	.85	.93	10.	10.	70.	10.
1981	40	9	2	15	298.	81.	331.	362.	77.	175.	309.	340.	10.3	71.0	1.7	.84	.93	10.	10.	10.	70.
1981	40	9	2	16	91.	33.	73.	96.	35.	76.	315.	342.	9.2	75.0	.7	.87	.95	10.	10.	10.	70.
1981	40	9	2	17	17.	7.	21.	38.	8.	13.	284.	320.	9.0	75.0	1.0	.79	.89	10.	10.	10.	70.
1981	40	9	2	18	0.	0.	0.	0.	0.	0.	272.	312.	8.7	77.0	1.0	.76	.87	10.	10.	70.	10.
1981	40	9	2	19	0.	0.	0.	0.	0.	0.	270.	309.	8.3	78.0	.8	.76	.87	10.	10.	70.	10.
1981	40	9	2	20	0.	0.	0.	0.	0.	0.	273.	313.	9.0	76.0	2.8	.76	.87	10.	10.	70.	10.
1981	40	9	2	21	0.	0.	0.	0.	0.	0.	282.	319.	8.9	77.0	2.9	.78	.89	10.	10.	70.	10.
1981	40	9	2	22	0.	0.	0.	0.	0.	0.	303.	333.	8.8	78.0	2.8	.85	.93	10.	10.	70.	10.
1981	40	9	2	23	0.	0.	0.	0.	0.	0.	325.	349.	8.8	79.0	3.3	.91	.97	10.	10.	70.	10.
1981	40	9	2	24	0.	0.	0.	0.	0.	0.	332.	353.	8.8	78.0	3.4	.93	.99	10.	10.	70.	10.
1981	41	10	2	1	0.	0.	0.	0.	0.	0.	334.	355.	9.1	76.0	3.2	.93	.99	10.	10.	70.	10.
1981	41	10	2	2	0.	0.	0.	0.	0.	0.	334.	355.	8.8	78.0	2.1	.93	.99	10.	10.	70.	10.
1981	41	10	2	3	0.	0.	0.	0.	0.	0.	329.	351.	8.3	80.0	1.6	.92	.98	10.	10.	70.	10.
1981	41	10	2	4	0.	0.	0.	0.	0.	0.	326.	348.	8.2	80.0	1.8	.92	.98	10.	10.	70.	10.
1981	41	10	2	5	0.	0.	0.	0.	0.	0.	325.	347.	8.0	80.0	2.2	.92	.98	10.	10.	70.	10.
1981	41	10	2	6	0.	0.	0.	0.	0.	0.	325.	346.	7.3	87.0	1.7	.93	.99	10.	10.	70.	10.
1981	41	10	2	7	0.	0.	0.	0.	0.	0.	326.	346.	7.3	84.0	2.1	.93	.99	10.	10.	10.	70.
1981	41	10	2	8	15.	5.	4.	4.	8.	13.	326.	347.	7.4	85.0	2.5	.93	.99	10.	10.	10.	70.
1981	41	10	2	9	53.	22.	22.	21.	22.	50.	321.	344.	7.5	82.0	2.8	.91	.98	10.	10.	70.	10.
1981	41	10	2	10	68.	29.	29.	28.	31.	66.	321.	343.	7.5	81.0	2.8	.91	.98	10.	10.	70.	10.
1981	41	10	2	11	68.	29.	31.	28.	30.	67.	319.	341.	6.9	72.0	2.3	.91	.98	10.	10.	70.	10.
1981	41	10	2	12	53.	24.	21.	25.	31.	51.	317.	339.	6.1	71.0	1.0	.92	.98	10.	10.	70.	10.
1981	41	10	2	13	109.	50.	41.	65.	74.	107.	315.	337.	6.3	66.0	1.1	.91	.97	10.	10.	70.	10.
1981	41	10	2	14	190.	76.	117.	126.	82.	180.	286.	318.	6.6	63.0	1.5	.82	.92	10.	70.	10.	10.
1981	41	10	2	15	182.	65.	149.	189.	63.	154.	285.	317.	6.8	62.0	1.2	.82	.91	10.	70.	10.	10.
1981	41	10	2	16	120.	44.	181.	319.	43.	69.	259.	300.	6.8	60.0	1.7	.74	.86	10.	70.	10.	10.
1981	41	10	2	17	50.	18.	106.	239.	17.	22.	244.	288.	6.5	61.0	2.3	.70	.83	10.	70.	10.	10.
1981	41	10	2	18	0.	0.	0.	0.	0.	0.	248.	288.	4.9	62.0	2.2	.73	.85	10.	70.	10.	10.
1981	41	10	2	19	0.	0.	0.	0.	0.	0.	274.	305.	4.0	60.0	1.2	.82	.91	10.	10.	70.	10.
1981	41	10	2	20	0.	0.	0.	0.	0.	0.	292.	317.	4.0	59.0	1.9	.87	.95	10.	70.	10.	10.
1981	41	10	2	21	0.	0.	0.	0.	0.	0.	261.	296.	4.0	59.0	2.1	.78	.88	10.	70.	10.	10.
1981	41	10	2	22	0.	0.	0.	0.	0.	0.	236.	278.	3.5	63.0	1.6	.71	.84	10.	70.	10.	10.
1981	41	10	2	23	0.	0.	0.	0.	0.	0.	231.	274.	3.0	60.0	2.0	.70	.83	10.	70.	10.	10.
1981	41	10	2	24	0.	0.	0.	0.	0.	0.	230.	273.	2.8	61.0	1.7	.70	.83	10.	70.	10.	10.

YR	DNR	DAY	MO	HR	I(H)	I(E)	I(S)	I(W)	I(N)	I(D)	IR(H)	IR(V)	TL	RH	VW	E(H)	E(V)	WR1	WR2	WR3	WR4
1981	42	11	2	1	0.	0.	0.	0.	0.	0.	229.	271.	2.4	61.0	1.0	.70	.83	10.	70.	10.	10.
1981	42	11	2	2	0.	0.	0.	0.	0.	0.	229.	271.	2.2	66.0	1.2	.70	.83	70.	10.	10.	10.
1981	42	11	2	3	0.	0.	0.	0.	0.	0.	227.	270.	2.1	66.0	2.1	.70	.83	10.	70.	10.	10.
1981	42	11	2	4	0.	0.	0.	0.	0.	0.	226.	268.	1.8	66.0	1.6	.70	.83	10.	70.	10.	10.
1981	42	11	2	5	0.	0.	0.	0.	0.	0.	226.	268.	1.5	66.0	1.0	.70	.83	10.	10.	70.	10.
1981	42	11	2	6	0.	0.	0.	0.	0.	0.	221.	262.	0.0	25.0	.6	.70	.83	10.	10.	10.	70.
1981	42	11	2	7	0.	0.	0.	0.	0.	0.	222.	262.	-.1	27.0	.7	.70	.83	10.	10.	10.	70.
1981	42	11	2	8	45.	245.	219.	17.	22.	20.	228.	269.	1.6	67.0	1.4	.70	.83	10.	70.	10.	10.
1981	42	11	2	9	185.	433.	521.	50.	53.	52.	233.	275.	2.5	67.0	1.4	.71	.84	10.	70.	10.	10.
1981	42	11	2	10	343.	428.	750.	70.	73.	72.	237.	280.	3.8	65.0	2.0	.71	.84	10.	70.	10.	10.
1981	42	11	2	11	366.	249.	695.	81.	87.	120.	239.	282.	4.6	62.0	2.5	.71	.84	10.	70.	10.	10.
1981	42	11	2	12	450.	126.	780.	144.	98.	113.	236.	281.	5.3	59.0	3.0	.69	.82	10.	70.	10.	10.
1981	42	11	2	13	381.	93.	617.	254.	86.	109.	233.	280.	6.0	57.0	3.5	.68	.81	10.	70.	10.	10.
1981	42	11	2	14	397.	103.	615.	462.	84.	122.	243.	287.	6.0	55.0	3.8	.70	.83	10.	70.	10.	10.
1981	42	11	2	15	319.	79.	500.	564.	70.	76.	236.	283.	6.6	52.0	3.8	.68	.81	10.	70.	10.	10.
1981	42	11	2	16	184.	52.	324.	548.	52.	53.	234.	281.	6.3	51.0	3.3	.68	.81	10.	70.	10.	10.
1981	42	11	2	17	41.	16.	75.	178.	18.	22.	245.	287.	5.3	52.0	4.0	.72	.84	10.	70.	10.	10.
1981	42	11	2	18	0.	0.	0.	0.	0.	0.	244.	285.	4.3	56.0	3.1	.73	.85	10.	10.	70.	10.
1981	42	11	2	19	0.	0.	0.	0.	0.	0.	266.	299.	3.7	60.0	2.8	.80	.90	10.	70.	10.	10.
1981	42	11	2	20	0.	0.	0.	0.	0.	0.	246.	284.	3.0	54.0	1.9	.75	.86	10.	10.	70.	10.
1981	42	11	2	21	0.	0.	0.	0.	0.	0.	251.	287.	2.6	56.0	2.4	.76	.87	10.	70.	10.	10.
1981	42	11	2	22	0.	0.	0.	0.	0.	0.	237.	277.	2.3	60.0	1.8	.73	.85	10.	10.	70.	10.
1981	42	11	2	23	0.	0.	0.	0.	0.	0.	249.	284.	2.0	62.0	2.0	.76	.87	10.	70.	10.	10.
1981	42	11	2	24	0.	0.	0.	0.	0.	0.	262.	293.	2.0	63.0	2.5	.81	.90	10.	70.	10.	10.
1981	43	12	2	1	0.	0.	0.	0.	0.	0.	241.	279.	1.7	63.0	2.9	.75	.86	70.	10.	10.	10.
1981	43	12	2	2	0.	0.	0.	0.	0.	0.	237.	275.	1.6	63.0	3.3	.73	.85	10.	70.	10.	10.
1981	43	12	2	3	0.	0.	0.	0.	0.	0.	240.	278.	1.5	64.0	3.1	.74	.86	10.	10.	70.	10.
1981	43	12	2	4	0.	0.	0.	0.	0.	0.	279.	304.	1.3	64.0	2.8	.87	.95	10.	70.	10.	10.
1981	43	12	2	5	0.	0.	0.	0.	0.	0.	286.	309.	1.3	62.0	2.8	.89	.96	10.	70.	10.	10.
1981	43	12	2	6	0.	0.	0.	0.	0.	0.	281.	305.	.9	62.0	3.1	.88	.95	10.	70.	10.	10.
1981	43	12	2	7	0.	0.	0.	0.	0.	0.	278.	303.	.8	60.0	2.4	.87	.95	10.	70.	10.	10.
1981	43	12	2	8	26.	12.	10.	9.	12.	24.	281.	304.	.7	59.0	1.8	.88	.95	10.	70.	10.	10.
1981	43	12	2	9	112.	93.	118.	48.	50.	94.	256.	287.	.7	59.0	1.6	.80	.90	10.	70.	10.	10.
1981	43	12	2	10	217.	193.	292.	79.	77.	155.	256.	289.	1.5	60.0	1.4	.79	.89	10.	70.	10.	10.
1981	43	12	2	11	344.	177.	515.	98.	88.	147.	226.	269.	2.1	60.0	1.4	.70	.83	10.	70.	10.	10.
1981	43	12	2	12	501.	127.	854.	158.	106.	114.	219.	266.	3.3	56.0	2.3	.66	.80	10.	70.	10.	10.

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  YR DNR DAY  MO  HR  I(H)  I(E)  I(S)  I(W)  I(N)  I(D) IR(H) IR(V)    TL    RH   VW E(H) E(V) WR1 WR2 WR3 WR4
----------------------------------------------------------------------------------------------------------------
1981  43  12   2  13  509.   92.  829.  346.   97.  106.  218.  266.   4.0  54.0  2.8  .65  .79 70. 10. 10. 10.
1981  43  12   2  14  444.   93.  689.  512.   84.  109.  221.  270.   4.8  53.0  2.8  .65  .80 10. 10. 70. 10.
1981  43  12   2  15  330.   77.  510.  602.   71.   90.  223.  271.   5.1  52.0  2.6  .65  .80 10. 10. 70. 10.
1981  43  12   2  16  174.   48.  267.  470.   51.   66.  224.  272.   4.8  53.0  2.4  .66  .80 10. 70. 10. 10.
1981  43  12   2  17   43.   17.   71.  171.   19.   23.  228.  273.   3.7  53.0  2.9  .68  .82 10. 70. 10. 10.
1981  43  12   2  18    0.    0.    0.    0.    0.    0.  228.  270.   2.5  51.0  2.8  .69  .83 10. 70. 10. 10.
1981  43  12   2  19    0.    0.    0.    0.    0.    0.  225.  267.   1.7  49.0  2.3  .69  .83 10. 10. 70. 10.
1981  43  12   2  20    0.    0.    0.    0.    0.    0.  223.  265.   1.3  47.0  2.5  .69  .82 10. 10. 70. 10.
1981  43  12   2  21    0.    0.    0.    0.    0.    0.  222.  264.    .9  46.0  2.4  .69  .82 10. 70. 10. 10.
1981  43  12   2  22    0.    0.    0.    0.    0.    0.  219.  262.    .6  43.0  2.0  .69  .82 10. 70. 10. 10.
1981  43  12   2  23    0.    0.    0.    0.    0.    0.  218.  260.    .3  38.0  1.4  .69  .82 10. 70. 10. 10.
1981  43  12   2  24    0.    0.    0.    0.    0.    0.  217.  259.    .1  33.0  1.8  .69  .82 10. 70. 10. 10.
1981  44  13   2   1    0.    0.    0.    0.    0.    0.  215.  257.   -.3  90.0  1.5  .68  .82 10. 70. 10. 10.
1981  44  13   2   2    0.    0.    0.    0.    0.    0.  214.  256.   -.6  90.0  1.4  .68  .82 10. 70. 10. 10.
1981  44  13   2   3    0.    0.    0.    0.    0.    0.  222.  261.   -.8  90.0  1.1  .71  .84 10. 70. 10. 10.
1981  44  13   2   4    0.    0.    0.    0.    0.    0.  249.  279.  -1.0  90.0  1.2  .80  .90 10. 70. 10. 10.
1981  44  13   2   5    0.    0.    0.    0.    0.    0.  264.  290.  -1.0  90.0  1.5  .85  .93 10. 70. 10. 10.
1981  44  13   2   6    0.    0.    0.    0.    0.    0.  271.  295.  -1.2  90.0  1.7  .87  .95 10. 70. 10. 10.
1981  44  13   2   7    0.    0.    0.    0.    0.    0.  275.  297.  -1.0  90.0  2.3  .88  .96 10. 70. 10. 10.
1981  44  13   2   8   16.    6.    6.    5.    7.   14.  275.  298.  -1.1  90.0  2.7  .89  .96 10. 70. 10. 10.
1981  44  13   2   9   68.   31.   32.   27.   29.   66.  275.  298.  -1.0  90.0  2.0  .88  .96 10. 70. 10. 10.
1981  44  13   2  10  130.   61.   63.   61.   61.  128.  274.  297.   -.9  90.0  1.8  .88  .95 10. 70. 10. 10.
1981  44  13   2  11  267.  132.  201.  106.  101.  236.  263.  291.   -.3  13.0  2.0  .84  .92 10. 70. 10. 10.
1981  44  13   2  12  475.  132.  720.  173.  107.  178.  218.  261.    .8  76.0  1.9  .68  .82 10. 70. 10. 10.
1981  44  13   2  13  514.   95.  812.  351.   98.  125.  210.  257.   2.0  87.0  1.9  .64  .79 10. 70. 10. 10.
1981  44  13   2  14  449.   91.  687.  521.   84.  103.  210.  259.   3.0  92.0  2.1  .64  .78 10. 70. 10. 10.
1981  44  13   2  15  342.   79.  518.  617.   73.   91.  211.  260.   3.4  96.0  1.8  .63  .78 10. 10. 70. 10.
1981  44  13   2  16  190.   51.  303.  550.   54.   64.  213.  262.   3.3  57.0  1.6  .64  .79 10. 70. 10. 10.
1981  44  13   2  17   45.   18.   78.  184.   19.   23.  218.  264.   2.4  88.0  2.0  .67  .81 10. 70. 10. 10.
1981  44  13   2  18    0.    0.    0.    0.    0.    0.  223.  265.   1.3  97.0  1.1  .69  .82 10. 70. 10. 10.
1981  44  13   2  19    0.    0.    0.    0.    0.    0.  223.  265.    .8  97.0   .8  .70  .83 10. 10. 10. 70.
1981  44  13   2  20    0.    0.    0.    0.    0.    0.  222.  263.    .4  97.0   .7  .70  .83 10. 10. 70. 10.
1981  44  13   2  21    0.    0.    0.    0.    0.    0.  218.  260.   -.3  17.0   .6  .69  .83 10. 10. 70. 10.
1981  44  13   2  22    0.    0.    0.    0.    0.    0.  215.  256.  -1.2  90.0   .8  .69  .82 10. 10. 70. 10.
1981  44  13   2  23    0.    0.    0.    0.    0.    0.  213.  254.  -1.8  90.0   .7  .69  .82 10. 10. 10. 70.
1981  44  13   2  24    0.    0.    0.    0.    0.    0.  211.  252.  -2.3  90.0   .9  .69  .82 10. 10. 70. 10.
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YR	DNR	DAY	MO	HR	I(H)	I(E)	I(S)	I(W)	I(N)	I(D)	IR(H)	IR(V)	TL	RH	VW	E(H)	E(V)	WR1	WR2	WR3	WR4
1981	45	14	2	1	0.	0.	0.	0.	0.	0.	210.	249.	-3.0	90.0	.9	.69	.83	10.	10.	70.	10.
1981	45	14	2	2	0.	0.	0.	0.	0.	0.	209.	249.	-3.3	90.0	.6	.70	.83	10.	10.	70.	10.
1981	45	14	2	3	0.	0.	0.	0.	0.	0.	209.	248.	-3.4	90.0	.8	.69	.83	10.	10.	70.	10.
1981	45	14	2	4	0.	0.	0.	0.	0.	0.	207.	246.	-3.8	90.0	.8	.69	.82	10.	10.	70.	10.
1981	45	14	2	5	0.	0.	0.	0.	0.	0.	208.	247.	-4.1	90.0	.8	.70	.83	10.	10.	70.	10.
1981	45	14	2	6	0.	0.	0.	0.	0.	0.	222.	256.	-4.2	90.0	.6	.75	.86	10.	10.	70.	10.
1981	45	14	2	7	0.	0.	0.	0.	0.	0.	234.	265.	-3.5	90.0	.6	.78	.88	10.	10.	70.	10.
1981	45	14	2	8	39.	44.	39.	14.	16.	33.	244.	274.	-2.4	90.0	.7	.80	.90	10.	70.	10.	10.
1981	45	14	2	9	69.	36.	35.	30.	31.	67.	264.	288.	-1.8	90.0	1.1	.86	.94	10.	70.	10.	10.
1981	45	14	2	10	158.	110.	111.	58.	66.	153.	273.	297.	-.8	90.0	1.6	.87	.95	10.	10.	70.	10.
1981	45	14	2	11	273.	129.	259.	111.	102.	218.	254.	285.	0.0	31.0	1.8	.81	.90	10.	70.	10.	10.
1981	45	14	2	12	346.	127.	435.	161.	100.	228.	254.	286.	.8	97.0	1.7	.79	.89	10.	10.	70.	10.
1981	45	14	2	13	484.	99.	731.	328.	95.	153.	255.	289.	2.0	97.0	1.7	.78	.89	10.	70.	10.	10.
1981	45	14	2	14	442.	92.	664.	508.	83.	113.	255.	291.	3.1	75.0	1.9	.77	.88	10.	70.	10.	10.
1981	45	14	2	15	336.	78.	498.	598.	71.	93.	255.	292.	3.9	49.0	1.7	.76	.87	10.	70.	10.	10.
1981	45	14	2	16	194.	51.	302.	551.	55.	65.	255.	292.	3.8	47.0	1.6	.76	.87	10.	70.	10.	10.
1981	45	14	2	17	47.	19.	78.	184.	20.	23.	255.	290.	2.8	49.0	1.4	.78	.88	10.	10.	70.	10.
1981	45	14	2	18	0.	0.	0.	0.	0.	0.	255.	288.	1.7	51.0	.8	.79	.89	10.	10.	70.	10.
1981	45	14	2	19	0.	0.	0.	0.	0.	0.	255.	287.	.7	61.0	.8	.80	.90	10.	10.	10.	70.
1981	45	14	2	20	0.	0.	0.	0.	0.	0.	255.	285.	-.1	21.0	.5	.81	.90	10.	10.	10.	70.
1981	45	14	2	21	0.	0.	0.	0.	0.	0.	255.	284.	-.9	90.0	.7	.82	.91	10.	10.	70.	10.
1981	45	14	2	22	0.	0.	0.	0.	0.	0.	255.	283.	-1.7	90.0	.8	.83	.92	10.	10.	10.	70.
1981	45	14	2	23	0.	0.	0.	0.	0.	0.	255.	282.	-2.3	90.0	1.0	.84	.92	10.	10.	70.	10.
1981	45	14	2	24	0.	0.	0.	0.	0.	0.	218.	255.	-2.8	90.0	.8	.72	.84	10.	10.	70.	10.
1981	46	15	2	1	0.	0.	0.	0.	0.	0.	209.	249.	-3.2	90.0	.8	.69	.82	10.	10.	70.	10.
1981	46	15	2	2	0.	0.	0.	0.	0.	0.	207.	247.	-3.7	90.0	.8	.69	.82	10.	10.	70.	10.
1981	46	15	2	3	0.	0.	0.	0.	0.	0.	205.	245.	-4.0	90.0	.7	.69	.82	10.	10.	70.	10.
1981	46	15	2	4	0.	0.	0.	0.	0.	0.	204.	243.	-4.3	90.0	.6	.69	.82	10.	10.	10.	70.
1981	46	15	2	5	0.	0.	0.	0.	0.	0.	202.	241.	-4.7	90.0	.8	.69	.82	10.	10.	10.	70.
1981	46	15	2	6	0.	0.	0.	0.	0.	0.	202.	241.	-5.0	90.0	.7	.69	.82	10.	10.	70.	10.
1981	46	15	2	7	0.	0.	0.	0.	0.	0.	200.	239.	-5.6	90.0	.5	.69	.82	10.	10.	10.	70.
1981	46	15	2	8	50.	103.	84.	16.	18.	26.	203.	241.	-5.1	90.0	.7	.69	.82	10.	10.	10.	70.
1981	46	15	2	9	206.	335.	340.	56.	55.	90.	210.	249.	-3.1	90.0	.7	.69	.83	10.	10.	70.	10.
1981	46	15	2	10	327.	281.	470.	80.	75.	161.	219.	259.	-1.0	1.0	.7	.70	.83	10.	10.	70.	10.
1981	46	15	2	11	407.	206.	607.	114.	96.	202.	208.	254.	.5	75.0	.7	.65	.80	10.	10.	70.	10.
1981	46	15	2	12	494.	141.	762.	182.	111.	186.	208.	256.	1.8	97.0	1.0	.64	.79	10.	70.	10.	10.

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  YR DNR DAY  MO  HR  I(H)  I(E)  I(S)  I(W)  I(N)  I(D) IR(H) IR(V)    TL    RH    VW E(H) E(V) WR1 WR2 WR3 WR4
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1981  46  15   2  13  480.  105.  711.  328.  103.  174.  210.  259.   3.0  93.0   1.4  .64  .79 10. 10. 70. 10.
1981  46  15   2  14  446.  100.  642.  500.   92.  144.  213.  263.   4.1  49.0   1.5  .64  .79 10. 10. 70. 10.
1981  46  15   2  15  342.   82.  500.  600.   76.   99.  213.  265.   4.9  46.0   1.8  .63  .78 70. 10. 10. 10.
1981  46  15   2  16  196.   53.  297.  547.   57.   67.  216.  266.   5.0  46.0   1.2  .63  .78 10. 70. 10. 10.
1981  46  15   2  17   46.   20.   70.  169.   22.   25.  222.  269.   4.1  51.0   1.1  .66  .80 10. 70. 10. 10.
1981  46  15   2  18    0.    0.    0.    0.    0.    0.  231.  273.   2.8  57.0    .6  .70  .83 10. 10. 10. 70.
1981  46  15   2  19    0.    0.    0.    0.    0.    0.  229.  270.   1.8  60.0    .4  .71  .83 10. 10. 10. 70.
1981  46  15   2  20    0.    0.    0.    0.    0.    0.  226.  267.    .8  66.0    .5  .71  .83 10. 10. 70. 10.
1981  46  15   2  21    0.    0.    0.    0.    0.    0.  224.  263.   -.2  21.0    .6  .71  .84 10. 10. 10. 70.
1981  46  15   2  22    0.    0.    0.    0.    0.    0.  222.  261.   -.8  90.0    .7  .71  .84 10. 10. 10. 70.
1981  46  15   2  23    0.    0.    0.    0.    0.    0.  220.  259.  -1.5  90.0    .7  .71  .84 10. 10. 10. 70.
1981  46  15   2  24    0.    0.    0.    0.    0.    0.  219.  258.  -1.7  90.0    .6  .71  .84 10. 10. 70. 10.
1981  47  16   2   1    0.    0.    0.    0.    0.    0.  216.  255.  -2.3  90.0    .7  .71  .83 10. 10. 10. 70.
1981  47  16   2   2    0.    0.    0.    0.    0.    0.  213.  252.  -2.7  90.0    .6  .70  .83 10. 10. 70. 10.
1981  47  16   2   3    0.    0.    0.    0.    0.    0.  212.  251.  -2.9  90.0    .6  .70  .83 10. 10. 70. 10.
1981  47  16   2   4    0.    0.    0.    0.    0.    0.  211.  250.  -3.5  90.0    .8  .70  .83 10. 10. 70. 10.
1981  47  16   2   5    0.    0.    0.    0.    0.    0.  211.  250.  -3.6  90.0    .6  .71  .83 10. 10. 10. 70.
1981  47  16   2   6    0.    0.    0.    0.    0.    0.  210.  248.  -4.0  90.0    .8  .71  .83 10. 10. 70. 10.
1981  47  16   2   7    0.    0.    0.    0.    0.    0.  209.  247.  -4.2  90.0    .8  .70  .83 10. 10. 70. 10.
1981  47  16   2   8   39.   58.   50.   16.   17.   31.  210.  249.  -3.8  90.0    .7  .70  .83 10. 10. 70. 10.
1981  47  16   2   9  192.  283.  297.   53.   53.   97.  219.  257.  -1.9  90.0    .7  .71  .84 10. 10. 70. 10.
1981  47  16   2  10  335.  276.  472.   79.   73.  158.  227.  267.    .5  65.0    .6  .71  .84 10. 10. 70. 10.
1981  47  16   2  11  443.  230.  675.  118.  102.  199.  216.  262.   1.9  95.0   1.1  .67  .81 10. 70. 10. 10.
1981  47  16   2  12  450.  136.  663.  172.  103.  195.  213.  261.   2.5  97.0    .9  .65  .80 10. 10. 70. 10.
1981  47  16   2  13  447.   99.  632.  304.   98.  181.  219.  266.   3.6  92.0    .7  .66  .80 10. 70. 10. 10.
1981  47  16   2  14  413.   96.  572.  455.   91.  161.  218.  268.   4.6  49.0   1.1  .65  .79 10. 10. 70. 10.
1981  47  16   2  15  325.   81.  428.  516.   81.  142.  222.  271.   5.2  48.0   1.1  .65  .80 10. 70. 10. 10.
1981  47  16   2  16  182.   51.  232.  415.   59.   96.  224.  273.   5.1  49.0   1.0  .66  .80 10. 70. 10. 10.
1981  47  16   2  17   39.   14.   42.  101.   19.   27.  229.  275.   4.2  50.0   1.1  .68  .82 10. 70. 10. 10.
1981  47  16   2  18    0.    0.    0.    0.    0.    0.  235.  277.   3.3  54.0   1.2  .71  .84 10. 10. 70. 10.
1981  47  16   2  19    0.    0.    0.    0.    0.    0.  235.  276.   2.8  58.0    .8  .71  .84 10. 10. 70. 10.
1981  47  16   2  20    0.    0.    0.    0.    0.    0.  233.  273.   1.6  59.0    .7  .72  .84 10. 10. 10. 70.
1981  47  16   2  21    0.    0.    0.    0.    0.    0.  230.  269.    .2  40.0    .8  .73  .85 10. 10. 70. 10.
1981  47  16   2  22    0.    0.    0.    0.    0.    0.  228.  265.   -.6  90.0    .7  .73  .85 10. 10. 10. 70.
1981  47  16   2  23    0.    0.    0.    0.    0.    0.  225.  263.  -1.1  90.0    .7  .73  .85 10. 10. 70. 10.
1981  47  16   2  24    0.    0.    0.    0.    0.    0.  224.  262.  -1.4  90.0    .8  .72  .85 10. 10. 70. 10.
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  YR DNR DAY  MO  HR  I(H)  I(E)  I(S)  I(W)  I(N)  I(D) IR(H) IR(V)    TL    RH    VW E(H) E(V) WR1 WR2 WR3 WR4
-----------------------------------------------------------------------------------------------------------------
1981  48  17   2   1    0.    0.    0.    0.    0.    0.  222.  259.  -2.0  90.0    .9  .72  .85 10. 10. 70. 10.
1981  48  17   2   2    0.    0.    0.    0.    0.    0.  220.  258.  -2.3  90.0    .7  .72  .84 10. 10. 10. 70.
1981  48  17   2   3    0.    0.    0.    0.    0.    0.  219.  257.  -2.6  90.0    .8  .72  .84 10. 10. 10. 70.
1981  48  17   2   4    0.    0.    0.    0.    0.    0.  222.  258.  -2.9  90.0    .8  .73  .85 10. 10. 70. 10.
1981  48  17   2   5    0.    0.    0.    0.    0.    0.  222.  257.  -3.2  90.0    .8  .74  .85 10. 10. 70. 10.
1981  48  17   2   6    0.    0.    0.    0.    0.    0.  245.  274.  -2.9  90.0    .6  .81  .91 10. 10. 70. 10.
1981  48  17   2   7    0.    0.    0.    0.    0.    0.  267.  292.   -.9  90.0   1.2  .86  .94 10. 70. 10. 10.
1981  48  17   2   8   15.    5.    5.    4.    6.   13.  283.  306.    .3  79.0   1.8  .89  .96 10. 10. 70. 10.
1981  48  17   2   9   36.   18.   18.   13.   16.   34.  286.  308.    .4  87.0   2.5  .90  .97 10. 70. 10. 10.
1981  48  17   2  10   55.   28.   29.   21.   23.   53.  287.  309.    .6  61.0   2.3  .90  .97 10. 70. 10. 10.
1981  48  17   2  11   81.   41.   40.   32.   35.   79.  288.  310.    .9  54.0   2.3  .90  .97 10. 70. 10. 10.
1981  48  17   2  12  107.   53.   52.   46.   50.  105.  288.  310.   1.2  54.0   2.1  .90  .96 70. 10. 10. 10.
1981  48  17   2  13  108.   54.   53.   46.   50.  106.  287.  310.   1.3  59.0   1.7  .89  .96 10. 70. 10. 10.
1981  48  17   2  14   90.   44.   44.   39.   42.   88.  286.  309.   1.3  62.0   2.0  .89  .96 10. 70. 10. 10.
1981  48  17   2  15   65.   31.   31.   27.   32.   63.  288.  310.   1.3  68.0   2.3  .89  .96 70. 10. 10. 10.
1981  48  17   2  16   42.   19.   19.   17.   20.   40.  287.  310.   1.2  77.0   2.3  .89  .96 10. 70. 10. 10.
1981  48  17   2  17   13.    3.    4.    3.    5.   10.  288.  310.   1.2  85.0   2.1  .90  .96 70. 10. 10. 10.
1981  48  17   2  18    0.    0.    0.    0.    0.    0.  286.  308.   1.1  91.0   2.7  .89  .96 10. 70. 10. 10.
1981  48  17   2  19    0.    0.    0.    0.    0.    0.  285.  308.   1.0  94.0   2.6  .89  .96 10. 70. 10. 10.
1981  48  17   2  20    0.    0.    0.    0.    0.    0.  283.  306.    .9  94.0   1.7  .88  .96 10. 70. 10. 10.
1981  48  17   2  21    0.    0.    0.    0.    0.    0.  284.  307.    .9  95.0   1.6  .89  .96 10. 10. 70. 10.
1981  48  17   2  22    0.    0.    0.    0.    0.    0.  284.  307.    .9  96.0   1.5  .89  .96 10. 10. 10. 70.
1981  48  17   2  23    0.    0.    0.    0.    0.    0.  283.  306.    .8  96.0   1.7  .89  .96 10. 70. 10. 10.
1981  48  17   2  24    0.    0.    0.    0.    0.    0.  281.  305.    .7  96.0   1.7  .88  .96 10. 70. 10. 10.
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