| 2.4 | **Calculation Branch** |
|-----|------------------------|

The calculation branch of WAEBRU is only accessible from the Main Menu, that is, once an input model (construction and grid files) has been completed for calculation and is currently loaded. The simplest procedure for executing calculation of base solutions consists of a brief sequence of options to be activated in the Main Menu:

1. **Selection** - press **Alt-A** (or **A** → **Enter**) to choose **All cases**.

2. Then press **Alt-B** (or **B** → **Enter**) to **Begin calculation**.

The calculation branch then runs automatically to completion (or termination) without any further input by the user.

The course of calculation, including the precision of results, can be influenced prior to execution through manipulation of various parameters. These possibilities are described in greater detail in the following sections on the individual options of the Main menu relevant to the calculation branch.

### 2.4.1                               Selecting Cases for Calculation

As described in the first part of this manual, the calculation branch of WAEBRU serves to determine the set of *base solutions* fundamentally describing a calculation model. The concept of a base solution can be thought of as the basic temperature distribution, which is assumed to set in when the "preferred" space (solution case) has an air temperature of 1 and all other model environments are at a theoretical 0 temperature.

*base solutions*

This theoretical concept is important to the user because of the inherent nature of such "preferred" spaces: since they are selected as cases for the calculation of base solutions, they can subsequently be treated independently of other spaces when assigning boundary conditions (air temperatures) in the evaluation branch of WAEBRU.

The same principle applies to any heat sources which may have been included in the input model. A heat source for which a base solution has been calculated is also treated as an independent case when assigning power conditions in the evaluation branch.

Which and how many base solutions need to be calculated to sufficiently describe a model is thus a question of the differentiation necessary for the purpose of evaluation. This must be judged by the user based on the nature of the problem to be analysed as well as the time to be invested in calculation.

The simplest calculation model consists of one "preferred" environment - typically the exterior - to which one air temperature is assigned. A single common air temperature is then prescribed for all the other (interior) spaces of the model.

*selection options*

Single "preferred" environments are selected with the menu options **Space case** (**Alt-S**) or **Heat source case** (**Alt-H**), whereupon an input field appears at the bottom of the screen for specifying case numbers. All potential cases existing are listed in messages at the top left of the Main Screen for reference.

Once individual selection is complete, the input field is closed by pressing **Esc** to return to the Main Menu.

If the possibility of assigning different air temperatures to all spaces bordering a building component needs to be maintained for evaluation, then the menu option **1- All spaces** (**Alt-1**) can be used. (This causes all the space cases to be calculated explicitly, including th otherwise superposable case.)

The second group option, **2- All heat sources** (**Alt-2**), functions analogously for selecting heat sources. (Heat source cases must all be calculated explicitly.)

The most complete calculation model is simply achieved by activating the first option: **All cases** (**Alt-A**). This automatically selects all the spaces and heat sources defined in the model for the calculation of individual base solutions.

*case status*

Once one or more cases have been selected, they are listed in the status field below the messages describing all potential cases, and shown as having been **selected**. The last case listed here is described as **superposable.** This is the one case which need not be solved in the calculation branch, since its base solution can be derived much more simply through superposition on the basis of the other solutions (the sum of all base solutions must equal 1). The superposable case - usually the exterior space 0 - is automatically determined in the evaluation branch.

## 2.4.2      Defining the Parameters of Iteration

Usually case selection is directly followed by starting calculation. If, however, the model is obviously too poorly conditioned for solution with the standard parameters used by WAEBRU in the iterative procedure, these can be adjusted prior to calculation with the menu option **Parameters of iter.(Alt-P)**.

The input window which then appears shows two parameters which can be editted:

- the termination condition (dT)

and

- the maximum number of iterations.

*precision*

The first of these parameters provides a measure of the precision to which a solution is calculated. When the deviation of results between iterations, $\Delta_{max}$, remains smaller than the limit defined here (dT) for a pre-set number of subsequent iterations, the calculation case is considered solved. If, in the course of evaluation, the error margins shown for the conductance matrix should prove to be too large (also apparent if the matrix is not reasonably symmetrical), it may be necessary to tighten the termination condition by decreasing the standard value of $10^{-6}$ and continue calculation. An increase in this value should be avoided.

The second parameter is the maximum number of iterations performed in a single calculation run. If this number of steps is reached before the results satisfy the termination condition, calculation is aborted and the case deemed **terminated**, but not solved, i.e. **calculated**, in the case status list.

*calculation time*

If it is foreseeable that a calculation model will require an unusually large number of iterations, the bothersome interruption of re-starting calculation can be avoided by increasing the standard value here (4000) prior to the first run.

Both parameters are specified in numeric input fields and confirmed with **Enter**, whereupon the parameters of iteration window is closed and the cursor returned to the Main Menu.

The numeric method of finite differences used by WAEBRU in the calculation branch is also guided by further parameters linked to the relaxation factor. For more information about such parameters, see **Numerical Solution** in section 1.2.2 - **Method of Analysis**. The standard values defined in the **WAEBRU.INI** file are acceptable for nearly all situations, and should therefore be manipulated only by very experienced WAEBRU users for exceptional cases.

### 2.4.3 Starting Calculation

Once the cases which shall be calculated have been defined as **selected**, the actual calculation procedure for attaining base solutions is started by activating the option **Begin calculation** (**Alt-B**). The parameters of iteration used by the program in calculation are either standard or previously specified by the user (see above).

From this point on, the calculation branch of WAEBRU runs automatically, that is, without further input by the user. The time which the program needs to reach solution (or termination) is highly dependant on the size and complexity of the calculation model.

During the course of calculation, numerous program modules are run in stages (see also **Numerical Solution**, section 1.2.2). The progress of these stages is reported continuously on the screen in the form of calculation status messages. The start of each program module is announced with date and time of compilation, e.g. the program for estimating the "optimal" ω-value:

```
omegao.c FRI Oct 04 13:00:13 1991 Compiled: Oct 04 1991 13:19:19
```

*memory*

Prior to actual calculation, the program checks if enough memory is available for execution in normal DOS mode. If this is not the case, a "memory allocation error" message appears briefly (e.g. `malloc error Y`), and the DOS-extender is loaded automatically, accompanied by copyright information. The message

`os386: Kernel installed`

then shows that installation of the DOS-extender has been completed successfully.

In the event that the extended memory is still not sufficient for program execution, the `malloc error` message appears again and an alternate program (which manages memory differently but is otherwise equivalent to the original) is loaded. This substitute program accesses all memory available by utilising two auxiliary files on the hard disk. Since such an execution method is associated with considerable increases in calculation time and hard disk use, installation of the alternate program is accompanied by a brief warning message:

`Working with 2 files!`

*calc. model size*

In this case, the user must decide if the disadvantages of calculating with two files are acceptable. If not, the program can be interrupted with **Ctrl-C** and the model simplified in the input branch (coarser grid structure) before repeating calculation. Exceptionally large models may require a reduction of the fine grid even for calculation with the alternate two-file method.

The first step towards actual calculation is the mathematical definition of the model with a set of equations. The number of equations to be solved is a measure of the calculation time to be expected (from experience). Since this is identical to the number of cells in the calculation geometry, the determination of this number is accompanied by a message of the form

```
##################
#    10619 cells #
##################
```

*calculation progress*

In the course of calculating an optimal value for the relaxation factor, $\omega_0$, a running table is displayed on the screen, showing the progress of iteration results approximately every two seconds, e.g.

```
#2    omega=1.901582    time=2.2s
#5    omega=1.911694    time=2.2s
#8    omega=1.910265    time=2.3s
#11   omega=1.913212    time=2.2s
#14   omega=1.913089    time=2.3s
#17   omega=1.914165    time=2.2s
```

For further information pertaining to the convergence behaviour of the relaxation factor - and what can be done in the rare event that this value should diverge in calculation - see **Numerical Solution** in section 1.2.2 (**Method of Evaluation**) as well as Appendix A, **Configuration Data**.

The second stage of calculation is the numerical solution of the system of equations, i.e. base solutions, with a continually varying $\omega$; this is also accompanied by progress messages aproximately every two seconds, e.g:

```
#326   maxdiff=2.582806e-006   mean=3.362618e-006   omega=1.971298 (2.2s)
#329   maxdiff=3.330340e-006   mean=3.184474e-006   omega=1.976637 (2.1s)
#332   maxdiff=1.875263e-006   mean=2.989768e-006   omega=1.901338 (2.1s)
#335   maxdiff=1.646420e-006   mean=2.590418e-006   omega=1.919698 (2.2s)
#338   maxdiff=1.479699e-006   mean=2.259959e-006   omega=1.934627 (2.1s)
```

The first column shows iteration numbers associated by line with current results data. The maximum difference (deviation) in results between iterations, $\Delta_{max}$, is given in the second column, and is compared with a continually actualised mean value as shown in the third column.

The corresponding relaxation factor, $\omega$, is the last of the three values which - combined - provide information about the speed with which the relaxation method is converging, that is, nearing solution.

The final column of the display shows computation time between messages. For the example illustrated above (with 10619 cells), this corresponds to approximately 0.7 seconds per iteration.

## 2.4.4          Continuing Calculation

If a calculation case has been terminated before reaching solution (either by interruption with **Ctrl-C** or by running the maximum number of iterations defined with **Parameters of iter.**), calculation can be continued "from where it left off" simply by re-starting the option **Begin calculation** (**Alt-B**).

Cases which have already been "solved" (thus termed **calculated** in the case status list), but do not meet precision requirements in the evaluation branch, must first undergo a change in status before calculation can be resumed. This is done by activating the menu option **Continue case calc.** (**Alt-C**), whereupon the user is asked to specify the number(s) of the case(s) to be re-defined as **terminated**.

The termination condition for calculation must also be tightened using the option **Parameters of iter.** (**Alt-P**). Then calculation can be continued as described above.

| 2.5 | Evaluation Branch |
|-----|-------------------|

The evaluation branch of WAEBRU is executed by activating the option **Evaluation** in the **Output** section of the Main Menu. Evaluation is, of course, only applicable when calculation of the base solution for at least one calculation case has already been completed successfully. In the event that insufficient base data is available for evaluation, the following message appears before the program automatically returns to the Main Menu screen:

**Too few cases calculated! No evaluation possible.**

The evaluation screen, once activated, initially shows only the input fields for defining the conditions of evaluation in the upper left-hand region of the screen. As soon as these conditions have been entered, an Evaluation Menu listing options available for evaluating the calculation model appears in the lower right-hand region of the screen.

If only results which are independent of boundary conditions are sought (i.e. strictly the conductance matrix and heat source distribution factors for the model), the evaluation menu can be accessed directly - without entering any conditions - by pressing either **F9** or **Alt-W**.

**Evaluation Menu**

The options listed in the evaluation menu are divided into three sections, of which the first and the last sections apply to any type of model to be evaluated. These include the options for reading a file, defining conditions, as well as printing numeric output.

The functions available for graphic output, listed in the middle section of the evaluation menu, depend on the dimensions of the model (two- or three-dimensional) and on whether or not an emanating heat source has been assumed (power not equal to zero).

```
   Read file
   Boundary conditions

   Surface temperature
   False color graph
   Isotherms
   Heat flow

   ==== Printouts ====
   Conductance matrix
   Evaluation results
```

The menu illustrated to the left appears when evaluating a two-dimensional model in which no power has been assigned to a potential heat source (the most common situation). It shows options for generating surface temperature graphs, as well as false (pseudo-) colour graphs, isotherms, and heat flow diagrams. In the event that one or more heat sources have been included and activated in the model, the heat flow option is not included in the list.

When a three-dimensional model is to be considered, the evaluation menu appears as illustrated in the second figure to the left. In this case, the temperature along an edge can be plotted instead of the surface temperature in two dimensions. The pseudo-colour and isotherm graphs are the same as above.

Due to the intrinsically three-dimensional nature of heat flow in such a model, a representation in the form of two-dimensional sections would provide no meaningful information; therefore this output is not included as an option here.

```
Read file
Boundary conditions

Temp. along an edge
False color graph
Isotherms

==== Printouts ====
Conductance matrix
Evaluation results
```

All of the functions listed in the evaluation menu are described in separate sections further on in this chapter. The evaluation branch of WAEBRU can be closed at any time by pressing **F10** to return to the Main Menu screen.

**2.5.1**                          **Reading Aggregate Files**

Upon activating the option `Read file` (**Alt-R**) in the Evaluation Menu, the file survey screen appears for selecting a *filename* in the same manner as described in previous sections of this manual (see **File Survey**, Chapter 2.1).

This option allows the user to evaluate and compare various calculation models while working in the evaluation branch, without having to return to the Main Menu to load a new set of files. A change in the dimensional mode of operation is also possible in the usual manner using the file survey screen. Once a set of files (calculation model) has thus been selected, the appropriate evaluation menu appears automatically.

**2.5.2**                          **Specifying Boundary Conditions**

Information pertaining to the scope of the calculation model, i.e. the calculated cases ready for evaluation, is described in the top left region of the evaluation screen in the form of status messages:

`Following space numbers exist:`
`0(...)`

and, if applicable,

`Following heat source numbers exist:`
`0 (...)`

The nature of each of these space and/or heat source numbers must be known to the user based on previous model documentation.

Input fields for defining evaluation conditions are located directly below the status messages and can be accessed for editing with the menu option `Boundary conditions` (**Alt-B**).

*temperature*

In theory, the term "boundary conditions" pertains - strictly speaking - only to the set of input fields for assigning temperatures ( in °C) to the various existing air-filled spaces of the model. Here it should be noted that the spaces for which individual base solutions have been calculated are listed first (1, 2, etc.). These are usually assumed to be interior spaces of differing room temperatures. The last space listed is the superposable case of number 0, which is typically assigned to the exterior environment and therefore requires input of a standard exterior temperature (see the section on **Selecting cases for calculation**, Chapter 2.4).

*power*

If heat source elements have been included in the model, a second set of input fields for specifying the power output of these (in Watts) also appears directly below the space temperature list. In two-dimensional models, power output is assumed per meter (normal to the section); in three-dimensional models, power is assigned per entire heat source. These values can thus be treated like boundary conditions within the evaluation branch, that is, they can be modified, or even eliminated (power set equal to 0), for the purpose of comparison using the option `Boundary conditions`.

## 2.5.3

## Numeric Results

The numeric results of evaluation are divided into two characteristic types:

- inherent to the calculation model (independent of boundary conditions) - such are thermal conductances, as well as heat source distribution and weighting factors.

- dependant on the conditions of evaluation - such are surface temperature extremes and dewpoints.

Corresponding more or less to these types, the Evaluation Menu offers two separate options for printing numeric output within the evaluation branch of WAEBRU (see also the section on **Environmental Factors**, Chapter 1.2). Both **Printouts** are headed by general licensing information, date and time of execution, as well as the project description text which was specified in the input branch for the model under consideration.

### Conductance Matrix

Each calculation model is thermally characterised by a matrix of conductances - derived from the previously determined set of base solutions - by selecting the option **Conductance matrix** (**Alt-C**) in the evaluation menu. The conductance matrix, including the necessary information about the precision of the results, then appears on the screen with a message asking the user whether or not these results shall be printed.

*close-up error*

A theoretically exact method of calculation would necessarily satisfy the condition that the sum of heat entering a component exactly equals the sum leaving the same - for any set of base solutions. The inherent nature of a numeric method, however, will always result in a marginal difference in the evaluated energy balance. This is referred to in WAEBRU as the *close-up error* of a base solution.

Dividing the close-up error by the sum of the conductances associated with the respective base solution provides a measure of the precision of calculation: the conductance-related error. If this value exceeds $10^{-5}$, a continuation of calculation based on more stringent parameters for more precise base solutions should be considered before proceeding with further evaluation (see Chapter 2.4 - **Calculation Branch**).

An immediate indicator of the precision of the solutions is the conductance matrix itself - if it is not reasonbly symmetrical, then further calculation may be necessary.

### Temperature Data

Temperature extremes, dew points, and weighting factors (g-values) for a given model under the currently defined conditions can be obtained as a separate printout by selecting the menu option **Evaluation results** (**Alt-E**). In this case, the program must run further calculations to generate a temperature distribution. This process requires a certain length of time; just how long depends on the complexity of the model. The results here do not appear on the screen before being sent to the output device.

Minimum and maximum temperatures are given for each space in °C, with an associated dewpoint in %. Weighting factors are printed as a matrix of the coldest surface points, which are furthermore defined by x and y coordinates (in mm) in the last block of data printed.

Sample numeric data printouts are illustrated in part three - the **Tutorial** - of this manual.

### 2.5.4            Graphic Results

The various graphs and diagrams which can be produced with the options available in the Evaluation Menu require further definition by the user; procedures specific to each type of graphic output are described separately in the following sections.

Two operations are generally applicable:

- the procedure for generating a plot file (for later use in the output branch).

- the possibility of "dumping" the screen display of a graph onto an output device (directly from the evaluation branch).

*plot files*

Once input of the parameters defining a particular graph has been completed, the graph is automatically generated upon pressing **Enter** from the last input field or with **F9**. A message then appears asking the user whether or not the results shall be written onto a plot file:

**Write output onto plotfile? 'Y' -YES;'N' or <CR> or <ESC> -NO :**

Since such files can require relatively large amounts of memory, the question should only be answered with yes (**y** → **Enter**) if the user intends to plot results in the high resolution mode provided in the graphic output branch of WAEBRU (see **Output Branch**, Chapter 2.6).

*graph dump*

For preliminary documentation of evaluation results, any graph or diagram drawn on the screen can be printed directly as displayed by pressing **Alt-P**. The possibilities for manipulating screen display (view) depend on the type of graph generated; input windows which may still be visible on the screen are generally eliminated from the graphic data sent to the output device automatically.
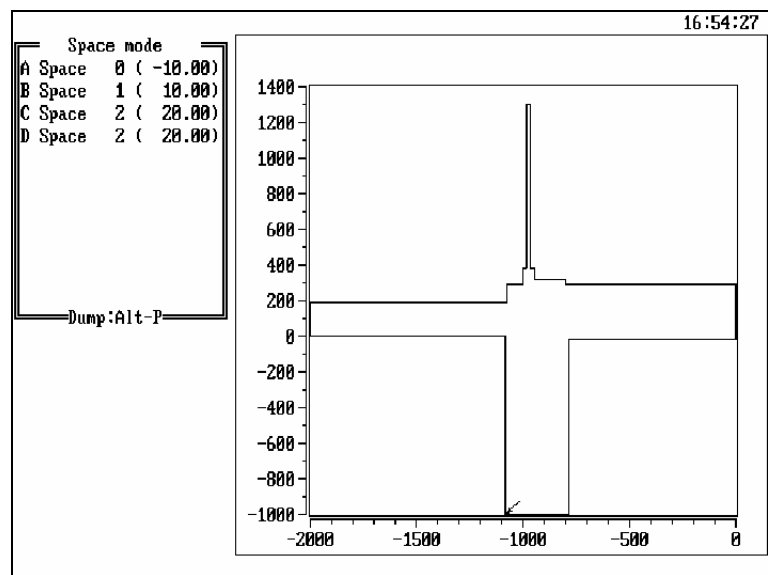
**Surface Temperature**

The option **Surface temperature** (**Alt-S**) is only available when evaluating a two-dimensional model. Upon execution of this function, the Evaluation Menu screen is replaced by a list of spaces bordering the building component and an accompanying graph showing an outline of the material surface.

The list is used to select a space with the cursor (and page) keys; press **Enter** to confirm. The component surface bordering the selected space is then marked in the control graph by pressing **F2**, whereupon the surface to be evaluated is delineated with a different colour.

An arrow also appears at one end of the delineation to show the beginning (0-point) of the temperature plot which will be generated. To change the graph plot orientation, press **Alt-I** (for 'invert') and then **F2** again; the arrow is then moved to the other end of the selected surface.
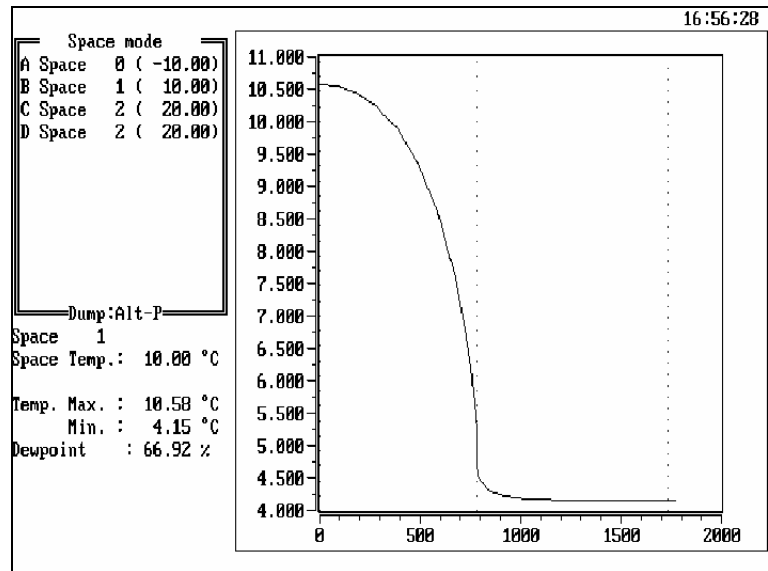
*surface selection - 2D*



The surface temperature graph is generated by confirming the control graph display with **Enter**. As described above, a message asking if a plot file shall also be generated appears before output is plotted on the screen.

The output displayed here consists of both numeric and graphic data. Air temperature, surface temperature extremes, as well as dew point (i.e. relative humidity at which surface condensation will occur) are displayed under the space list. The control graph shows a temperature curve with vertical dotted lines at the coordinates of temperature extremes and surface corners - often these points are identical.

*temperature curve - 2D*

Control graph display can be switched back and forth between surface selection and temperature curve (output) by pressing **F2** and **Enter**. Pressing **Esc** leads back to the Evaluation Menu.

Weighting factors, i.e. g-values, for a given space can also be plotted using the **Surface temperature** function by assigning an air temperature of 1 °C to the "preferred" space and 0 °C to all other environments (press **Alt-B** for the function **Boundary conditions** - see above).

If the input model has been so structured that regions of special interest have been defined as sub-spaces, corresponding surface regions can be selected for specific evaluation by switching the space list into **Sub-space mode** with **F4** (the initial setting is **Space mode**).

**Temperature Along an Edge**

The three-dimensional equivalent to **Surface temperature** is the menu option **Temperature along an edge** (**Alt-T**), which allows temperatures to be plotted along a line defined parallel to coordinate axes.

The screen which appears when this function is activated includes an input window for specifying the geometric data of a line along which the temperature shall be evaluated, i.e.

- a reference direction (x, y, or z) and coordinates defining beginning and end of the evaluation stretch in this direction

as well as

- the coordinate position of the stretch in the plane normal to the reference direction (y+z, x+z, or x+y coordinates, respectively).

The input data must describe a line which lies at least partly within or along the surface of the building component. To facilitate coordinate specification, a list showing all grid coordinates in the direction of the current input field can be accessed for selection by pressing **F2**. Coordinate values can be marked and entered from this list in the usual manner (with cursor keys or first letter, then **Enter**).

*surface selection - 3D*

```
                                                                          17:05:49
    Y=          305.000                    ┌═Grid coordinates :X═══════┐
    Z=          510.000               A    -1080.000 mat. space
 from X=          0.000               B              layer center
 to  X=          0.000               C    -1000.000 mat. space
                                      D              layer center
                                      E    -985.000 space
                                      F              layer center
                                      G    -965.000 space
                                      H              layer center
                                      I    -955.000
                                      J              layer center
                                      K    -945.000 space
                                      L              layer center
                                      M    -872.500
                                      N              layer center
                                      O    -800.000 mat. space
                                      P              layer center
                                      Q    -705.000 space
                                      R              layer center
                                      S    -685.000
                                      T              layer center
                                      U    -505.000
```
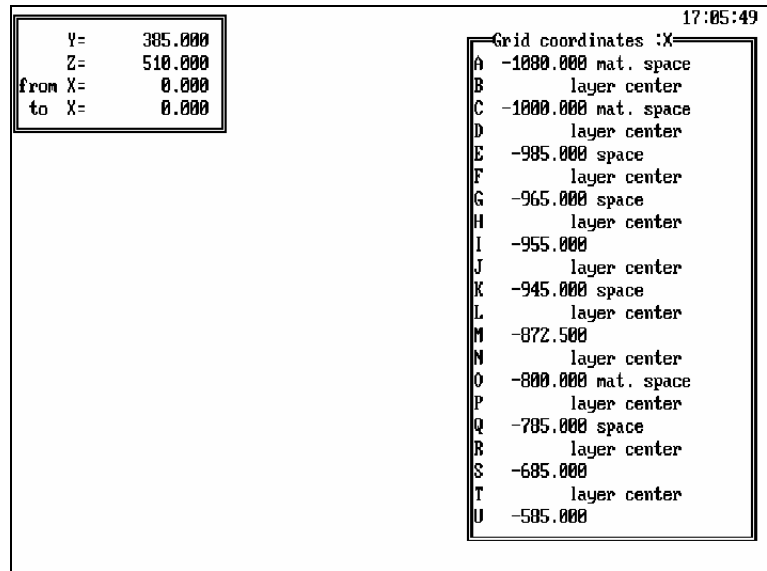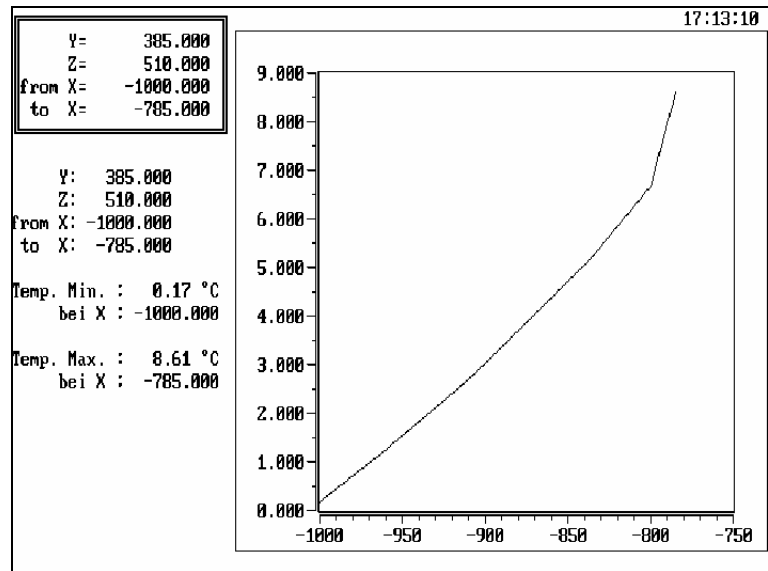
The initially displayed input window is for the reference direction x. To evaluate a stretch running parallel to the y or z axis, the direction for input can be changed with **Alt-Y** or **Alt-Z**, respectively.

Since the coordinate selection lists include all grid plane coordinates with position characteristics, they also serve as a valuable orientation aid. Planes characterised by the term **space** are located at a transition between component material and space elements; **mat.** stands for a border plane between elements of different materials. Both of these plane types are of the minimal grid.

Beyond the actual grid structure, coordinates located mid-way between two fine grid planes - **layer center** - are also offered for selection in this list.

The corresponding coordinate value is automatically entered in the currently active field of the input window (and the list closed as soon as a selection is confirmed). Once the position of the evaluation stretch is completely defined, the temperature curve is plotted either directly upon entering the last input data or by pressing **F9**. Here again, the message about plot files appears before results are generated on the screen.

*temperature curve -3D*

```
                                                                    17:13:10
   Y=      385.000
   Z=      510.000      9.000
from X=   -1000.000
 to  X=    -785.000      8.000

                         7.000

    Y:   385.000         6.000
    Z:   510.000
from X: -1000.000         5.000
 to  X:  -785.000
                         4.000
Temp. Min. :   0.17 °C
      bei X : -1000.000   3.000

Temp. Max. :   8.61 °C    2.000
      bei X :  -785.000
                         1.000

                         0.000
                               -1000  -950  -900  -850  -800  -750
```

**Isotherms and Pseudo-colour Graph**

Beyond the linear plot of a temperature curve, temperature distributions can also be described in planar form, that is, as a two-dimensional rendering of temperature regions within a planar section of the building component.

Two different conventions for rendering this kind of data exist:

- the pseudo-colour graph - in which the distribution continuum is gradated into temperature ranges by colour.

- isotherms - in which points of the same temperature are connected in lines for a prescribed set of temperature intervals.

In either case, a section plane must be specified for evaluation. For two-dimensional models, this is always the x/y plane (z coordinate constant). Three-dimensional models can be evaluated in any of the three coordinate reference directions (x, y, or z constant).

The Evaluation Menu offers two functions for generating graphs corresponding to these conventions. Though similar in content and operation, both options serve different purposes in WAEBRU, as shall be described in the following.

*pseudo-colour graph*     The first option, **False color graph** (**Alt-F**), is for generating a pseudo-colour screen display with a standard temperature/colour gradation (defined in the **WAEBRU.INI** file). The relatively coarsely stepped boundaries between colour regions here correspond to highly simplified isotherms.

Given a two-dimensional model, the graph is automatically generated as soon as the option is activated (**Alt-F** or **F** → **Enter**). Initially it is displayed in "affine" distortion, i.e. x and y axes are scaled separately to maximise screen view of the building component. This type of distortion can be removed by pressing **Alt-A** (for 'affine'), whereupon both graph axes are displayed in the same scale. Pressing **Alt-A** again returns display to the initial view.

The colour scale (legend) displayed next to the graph can also be removed to allow more screen space for the graph itself. This is done by pressing **Ctrl-F**. Repeating **Ctrl-F** brings the legend back onto the screen.

When `False color graph` is activated for a three-dimensional model, a list of possible section planes appears above the menu first, headed by a line of the form:

$$\text{\texttt{Section plane: +X+Y Z axis}}$$

This example heads a list of z coordinates (constant) describing possible positions of section planes parallel to the x/y plane. The **+** signs signify the positive orientation of each coordinate direction: to the right for the first (in this case x), and upward for the second axis mentioned in this line (here y).

A reference direction (x, y, or z constant) can be selected with **Alt-X**, **Alt-Y**, or **Alt-Z**, respectively. Furthermore, the desired orientation of coordinate axes can be specified at this point. To invert first and second axes of the section plane, press **F4**. The positive orientation of each axis is reversed with **Alt-1** (for the first) and **Alt-2** (for the second).

Once the desired selection list has been thus set up, a constant coordinate is chosen for input in the same manner as in the list of planes for temperature along an edge (see above).

The pseudo-colour graph is generated as soon as selection is confirmed with **Enter**. The functions described for manipulating display in two-dimensional evaluations (**Alt-A** and **Alt-F**) are applicable here as well. Press any key to return to the Evaluation Menu.

*isotherms*

A considerably more precise picture of the temperature distribution in a building component can be achieved with the menu option `Isotherms` (**Alt-I**). All of the functions and procedures described in connection with pseudo-colour graphs also apply to isotherms in two as well as three dimensions. The generation of an isotherm diagram, however, requires additional data.

After selecting a section plane in the manner already described, the next step is to define temperatures for the individual isotherms. This is done by intervals according to data specified by the user in an input window appearing in the form:

```
Total range:(T_min)
            :(T_max)
Eval. range:(T_1)    :(T_2)
Interval   :
No. of int.:
```

The term `Total range` is followed by the values of the minimum and maximum temperatures occurring in the building component (these are automatically defined by the program). The next line, `Eval. range`, is for specifying the range which shall be delineated in isotherms. Initially, the values of the total range are displayed here as outer limits; any input values editted in these two numeric fields must lie within this range.

How the evaluation range is to be gradated is then determined in either one of two possible ways:

- by specifying a temperature difference between isotherms, that is, the **Interval** (e.g. **2** °C), and setting the **No. of int.** equal to **0**,

or

- by prescribing an integer by which the temperature range shall be divided equally, that is, the number of intervals (**No. of int.** - a positive value here overrides the **Interval** field above).

The cursor can be moved through the input fields with the cursor keys or by confirming changes with **Enter**. Once input is complete, pressing either **Enter** from the last line or **F9** closes the input window and executes graph generation. Here also, screen contents can be "dumped" by pressing **Alt-P** and/or a plot file written for higher resolution output.

The input window, which covers a small portion of the graph, is automatically editted out of the graph dump. It can also be removed from the screen display with **Alt-V** (for 'view'). The input window is brought back into view by pressing any key.

The generation of isotherms can be interrupted in order to change input parameters by pressing **Esc**. Once a diagram has been completed, the **Esc** key leads back to the Evaluation Menu.

Finally, the **Isotherm** function can also be used to illustrate the distribution of g-values in a particular section plane. As described in the section on **Surface Temperature**, weighting factors are attained by defining appropriate boundary conditions with **Alt-B** (temperature of 1 in preferred space and 0 in all others).

*isotherms - graph dump*



Section: +X+Y Z Coor.=500 (center)   Temp. min.=-9.996574, max.=18.72355
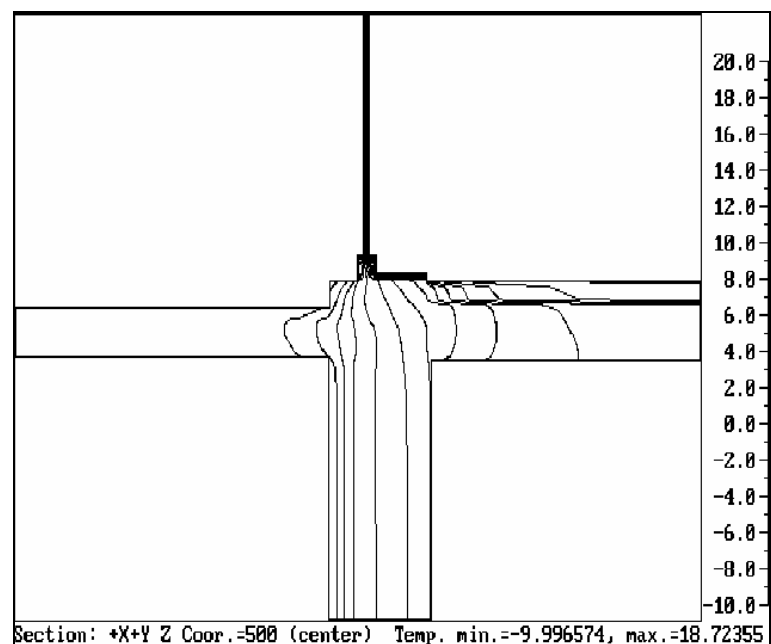
**Heat Flow**

The menu option for generating a heat flow diagram is only available for two-dimensional models (which furthermore include no active heat source).

Upon activating the line `Heat flow` (**Alt-H**), an outline of the building component appears, accompanied by an input window which lists existing spaces and surface regions, e.g.:

|     | Space | Reg± | Int |
|-----|-------|------|-----|
| A-  | 0     | 1 +  | 10  |
| B-  | 0     | 2 +  | 10  |
| C-  | 2     | 1 -  | 10  |
| D-  | 1     | 1 +  | 10  |
| E-  | 1     | 2 -  | 10  |

The contents of this window require further explanation. The normal component of heat flow can change directions (positive or negative) along the boundaries of a space adjacent to component surfaces. In other words, heat can flow into a single space through certain segments of the overall component while simultaneously flowing out through others - depending on the relative air temperatures of neighbouring spaces.

*region*

A continuous segment with heat flow in the same direction is designated here as a region characterised by its flow direction - positive (**+**) or negative (**-**). The sign is always relative to the associated space, i.e. negative heat flow from one space must be accounted for as positive flow into another.

*interval*

The heat flowing through each such region can be sub-divided into a number of intervals, as specified in the last column of the window. A single line, starting at the corresponding surface, represents one interval in the heat flow diagram to be generated. Since heat flow lines are drawn from all surfaces for which an interval has been set (greater than 0), the regions to be evaluated should be explicitly selected in order to avoid redundant plotting.

To edit an interval value (initially 10 for all regions), the input field for a particular region is activated by marking the line with the cursor keys and then pressing **Enter**. The field is de-activated once input of an integer value (or 0) is confirmed, again with **Enter**.

To aid input, a region currently marked in the list can be identified in the control graph by pressing **F2**, whereupon the corresponding stretch of the component outline is shown in a different colour.

*diagram generation*

Heat flow lines are generated for the entire component - according to the parameters defined in the input window - by pressing **F9**. If an input field is currently active (blinking cursor) when **F9** is pressed, then flow lines only from the corresponding region are drawn. Since previously generated lines are not deleted when **F9** is executed again, a diagram can thus be generated in stages.

The possibility of partial diagram generation can also be used to verify and, if necessary, adjust input parameters before producing a complete diagram for documentation. Heat flow lines already generated can be erased from the diagram by pressing **Alt-C** (for 'clear').

*heat flow - graph dump*
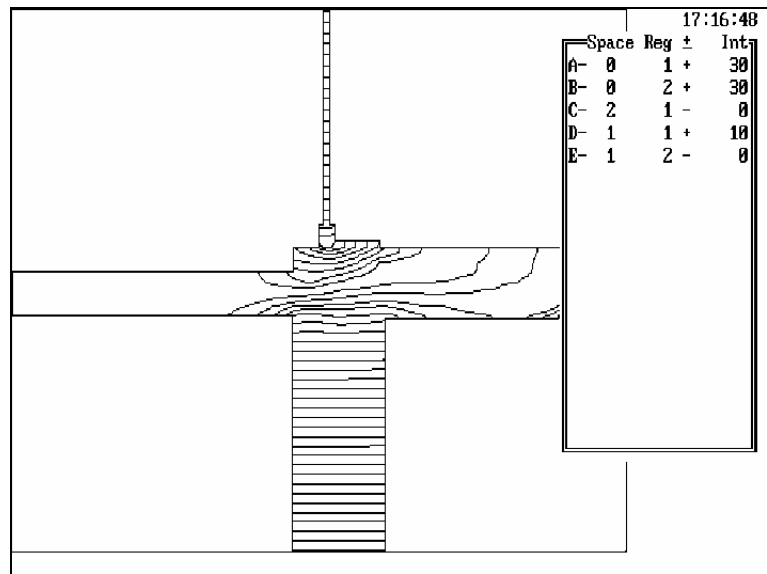


The graphic display can be manipulated with the already familiar functions for toggling affine distortion (**Alt-A**) and colour legend (**Ctrl-F**). Graph dumps (**Alt-P**) and plot files are also generated in the usual manner.

To return to the Evaluation Menu, press **Esc**.

| 2.6 | **Output Branch** |
|-----|-------------------|

The output branch of WAEBRU is the last stage of the program for high resolution output of graphic results. All of the functions here are for managing plot files already generated for a given model during execution of the evaluation branch. For information on the generation of plot files, see section 2.5.4 - **Graphic results**, Chapter 2.5.

Once such files exist for a currently loaded model (*filename*.**2GR** or *filename*.**3GR**), the output branch can be accessed from the Main Menu with the option **Graphic output** (**Alt-G**).

The first section of this chapter describes the parameters which must be set in the **WAEBRU.INI** file in order to attain high quality graphic output. Individual functions of the output branch are then explained in the second section titled **Operation**.

### 2.6.1 Program Preparation for Output

A number of parameters are used by WAEBRU for determining whether plot files shall be generated and how they are to be managed in the output branch (waebout). The names of these parameters are easily identified in the **WAEBRU.INI** file - they all start with the word **PLOT**.

Whether or not a plot file is generated at all during evaluation of graphic results depends on which of three primary plot parameters has been set in the appropriate line:

- **PLOT** - the most common setting - causes a message to appear asking the user if results shall be written onto a plot file each time a graph is generated during evaluation.

- **PLOT_ALL** automatically writes every graph onto a plot file, without explicit direction by the user.

- **PLOT_OFF** means that no plot files can be generated in the evaluation branch.

In the event that an inconveniently slow pen-plotter is in use, the type font used in connection with output graphs can be simplified by including the entry **PLOT_SIMPLEFONT**. The single-line lettering of this "simple font" is considerably less time-consuming to plot than that of the standard font.

All of the other plot parameters pertain to the standard configuration of the output device(s) to be used, and are therefore usually defined only once by the user during installation. These **WAEBRU.INI** plot/print parameters are described individually in the section on **Peripheral Parameters** of Appendix A - **Configuration Data**.

### 2.6.2 Operation

The option **Graphic output** can only be activated (**Alt-G**) if a plot file exists for the model under consideration. The output screen, which then appears, shows a list of all of the graphs stored in the currently loaded plot file - in the order that they were generated.

The graphs listed are labelled by type (**ISOTHERMS**, **HEAT FLOW**, etc.) and are available for selection. For this purpose they have also been assigned identification numbers.

Under the graph list, a line describing command options is displayed with an input field for entering a single character. The functions available here always pertain to a single, complete graph:

- help - **?**

- selection - **S**

- preview - **V**

- output onto printer or plotter - **P**

- deletion - **D**

- return to Main Menu - **E** (or **F10**)

Both the options **S** and **D** are followed by an input field requesting entry of a graph sequence number (to be selected or deleted from the list). The deletion operation often proves to be very time-consuming, and should therefore be avoided if not absolutely necessary.

Once a graph has been chosen, it can be sent directly to an output device by entering **P**. After a brief display of the complete graph, the screen shows data as it is transferred to output (this process can require a long waiting period under circumstances).

A selected graph can also be generated solely on the screen (rotated by 90°) - with **V** - for preview before actual hard copy output. Pressing any key causes the graph display to disappear and returns to the output screen.

To end the output branch and return to the Main Menu, type **E**, or the already familiar function key **F10**. Work with WAEBRU can then be continued through the Main Menu, or the program ended by pressing **F10** again.