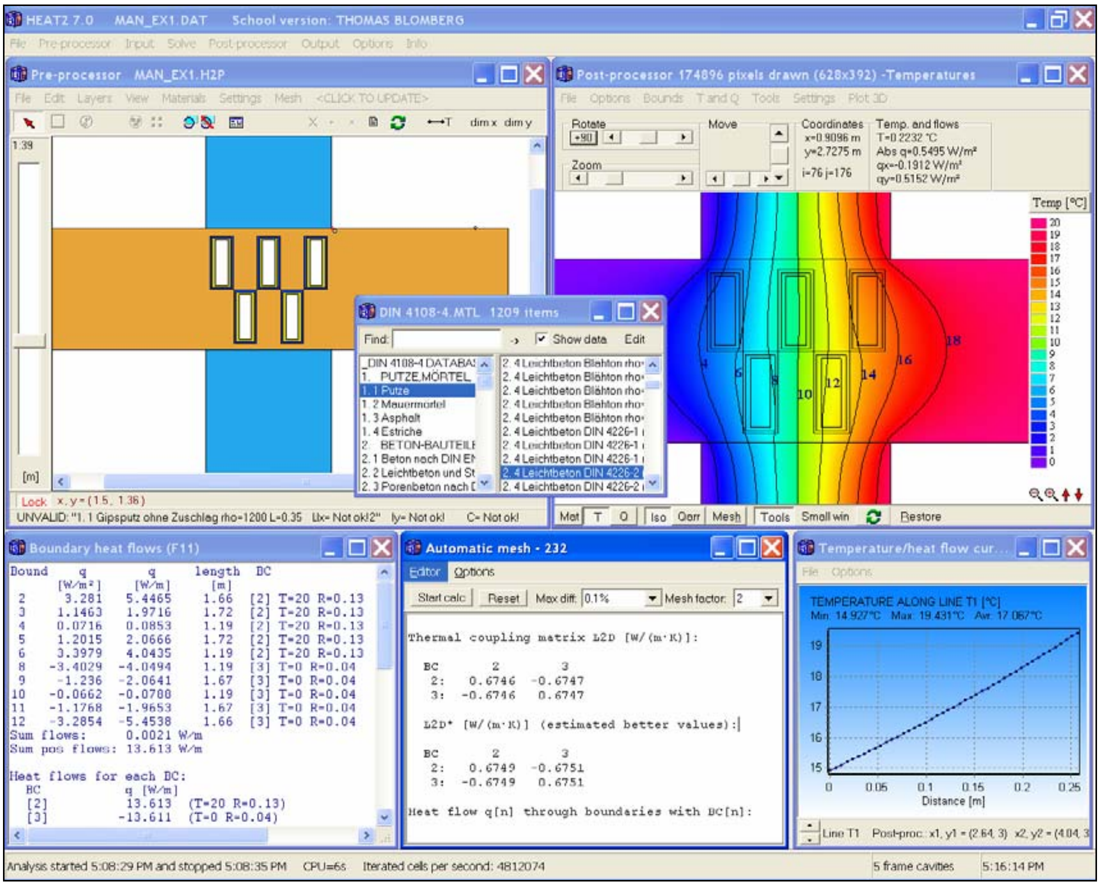
Software within building physics and ground heat storage

HEAT2 7.0

A PC-program for heat transfer in two dimensions

Update manual


HEAT2 7.0 MAN_EX1.DAT School version: THOMAS BLOMBERG
File Pre-processor Input Solve Post-processor Output Options Info
Pre-processor MAN_EX1.H2P
File Edit Layers View Materials Settings Mesh <CLICK TO UPDATE>
Lock x, y = (1.5, 1.36)
Post-processor 174896 pixels drawn (628x392) -Temperatures
File Options Bounds T and Q Tools Settings Plot 3D
Rotate
Move
Zoom
Temp [°C]
DIN 4108-4.MTL 1209 items
Find:
Show data
Edit
Mat T Q Iso Corr Mesh Tools Small win Restore
Temperature/heat flow cur...
TEMPERATURE ALONG LINE T1 [°C]
Min: 14.927°C Max: 19.431°C Avr: 17.067°C
Distance [m]
Line T1
Boundary heat flows (F11)
Automatic mesh - 232
Editor Options
Start calc
Reset
Max diff: 0.1%
Mesh factor: 2

Coordinates x=0.9096 m y=2.7275 m i=76 j=176

Temp. and flows T=0.2232 °C Abs q=0.5495 W/m² qx=-0.1912 W/m² qy=0.5152 W/m²

UNVALID: "1.1 Gipsputz ohne Zuschlag rho=1200 L=0.35 Lx= Not ok!2" ly= Not ok! C= Not ok!

```
Bound     q         q      length   BC
       [W/m²]     [W/m]     [m]
 2     3.281    5.4465     1.66   [2] T=20 R=0.13
 3    1.1463    1.9716     1.72   [2] T=20 R=0.13
 4    0.0716    0.0853     1.19   [2] T=20 R=0.13
 5    1.2015    2.0666     1.72   [2] T=20 R=0.13
 6    3.3979    4.0435     1.19   [2] T=20 R=0.13
 8   -3.4029   -4.0494     1.19   [3] T=0 R=0.04
 9    -1.236   -2.0641     1.67   [3] T=0 R=0.04
10   -0.0662   -0.0788     1.19   [3] T=0 R=0.04
11   -1.1768   -1.9653     1.67   [3] T=0 R=0.04
12   -3.2854   -5.4538     1.66   [3] T=0 R=0.04
Sum flows:      0.0021 W/m
Sum pos flows: 13.613 W/m

Heat flows for each BC:
  BC              q  [W/m]
  [2]             13.613   (T=20 R=0.13)
  [3]            -13.611   (T=0 R=0.04)
```

```
Thermal coupling matrix L2D [W/(m·K)]:

  BC        2         3
   2:    0.6746   -0.6747
   3:   -0.6746    0.6747

  L2D* [W/(m·K)] (estimated better values):

  BC        2         3
   2:    0.6749   -0.6751
   3:   -0.6749    0.6751

Heat flow q[n] through boundaries with BC[n]:
```

Post-proc: x1, y1 = (2.64, 3) x2, y2 = (4.04, 3

Analysis started 5:08:29 PM and stopped 5:08:35 PM CPU=6s Iterated cells per second: 4812074 5 frame cavities 5:16:14 PM

August 8, 2006

BLOCON

www.buildingphysics.com

Contents

1. What’s new in HEAT2 version 7

Blocon is proud to present a new version of HEAT2. Many new important features have been added. Up-to-date information is given on www.buildingphysics.com and www.buildingphysics.de (in German).

This update manual covers new features (see list below) that have been added since version 6. New users should also read the update manual for version 6 and the full manual for version 5 at

http://www.buildingphysics.com/manuals/Heat2_6_update.pdf

http://www.buildingphysics.com/manuals/HEAT2_5.pdf

1.1 Automatic mesh generation

HEAT2 can automatically perform steady-state calculations with gradually refined meshes. The user does not have to think about how to give a proper mesh - HEAT2 does this. The mesh criterion from EN ISO 10211 can be applied.

1.2 Thermal coupling coefficient analyses

HEAT2 automatically calculates the thermal coupling coefficient matrix (L^{2D}) according to EN ISO 10211 for a wide variety of problems involving thermal bridges.

1.3 Faster calculations

Most steady-state problems will now be solved 5-15 times (!) quicker due to optimization of the relaxation coefficient and the numerical scheme.

1.4 Batch jobs

Multiple consecutive simulations may be started externally via batch files.

1.5 Increased sizes for data fields

Many data fields have been increased in sizes. The maximum number of numerical nodes has been quadrupled from 122500 (350·350) to 490000 (700·700).

The maximum number of cavities with full radiation analyses has been extended from 20 to 50. The maximum number of radiation nodes in each cavity has been extended from 500 to 1000.

HEAT2 7.0 with 490000 nodes requires only about 30 MB RAM (a pc with 256 MB is recommended), and less than 5 MB hard disk space.

1.6 Other changes

Hundreds of minor improvements are made. The most important are shown below:

- The emissivity in frame cavities may now be changed
- The temperature field T(i,j) can now be saved/read to/from a file
- Enhancements in pre-processor
- Desktop (placement and sizes of windows) may be saved/read (menu item *Options*)
- Toggling from HEAT2 6.0 to another program and back again would sometimes close down several windows in HEAT2. This is now fixed.
- The chart window for the recorder can now show multiple graph lines in the same chart

- The summarized boundary flows for boundaries that have the same boundary condition type are now shown (F11)
- For users using old-style text input: the given mesh (length, number of cells, expansion coefficient in each mesh segment) is not overwritten if description of boundaries changes

Enhancements in post-processing:

- Window content may be zoomed to a much higher limit than before
- Faster drawing/updating
- The numerical cell that determines the smallest time-step can be visually shown

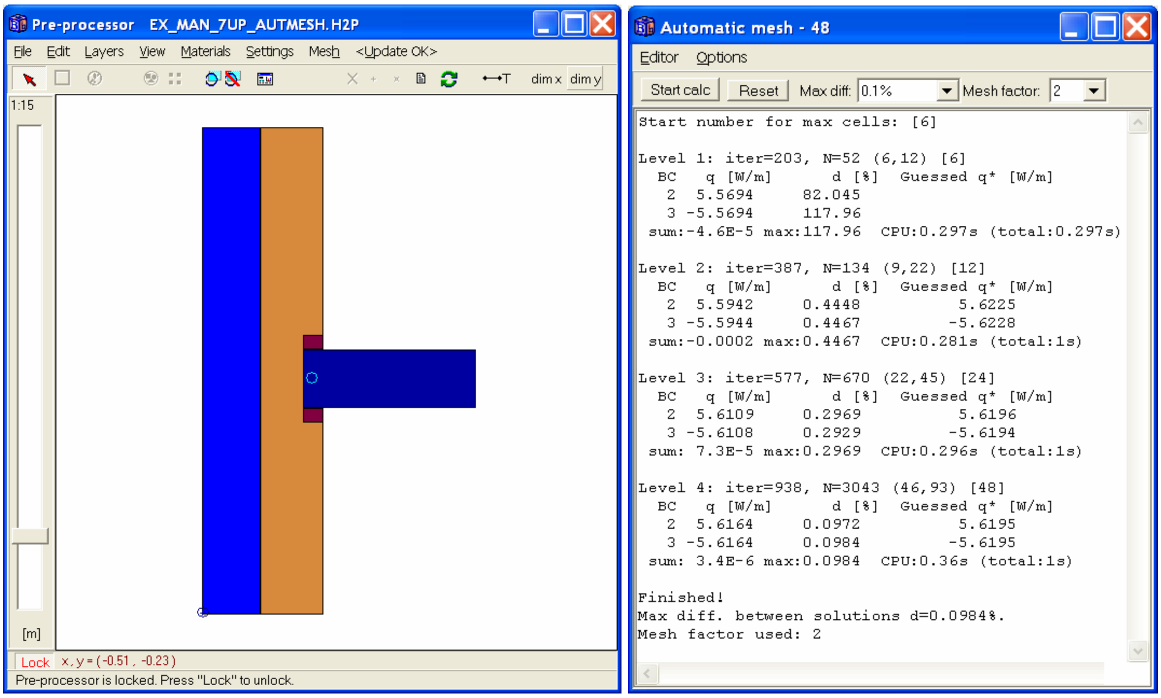
2. Automatic mesh generation

2.1 Introduction

There is a numerical error due to the mesh. A finer mesh grid with small cells gives more accurate results compared to a coarse grid with large cells. HEAT2 can automatically perform steady-state calculations with gradually refined meshes. The following mesh criterion from EN ISO 10211 can be applied: *The sum of the absolute values of all heat flows entering the object is calculated twice, for n cells and for 2n cells. The relative difference between the flows must be smaller than 2%, otherwise a new mesh division is required*. (This criterion will probably be changed to 1% later on).

2.2 Mesh factor for finer grids

Consider the example *Ex_man_7up_autmesh.dat*. Menu item *Solve/Automatic mesh and L2D* brings up the **Automatic mesh window**, see Figure 2.1. The mesh factor describes how much the number of cells should increase in each direction for the new finer grid. The default value for this factor is 2 in HEAT2. Figure 2.1 shows an example with calculations for four levels of refined meshes.



Lock x,y=(-0.51, -0.23)
Pre-processor is locked. Press "Lock" to unlock.

Max diff: 0.1%
Mesh factor: 2

```
Start number for max cells: [6]

Level 1: iter=203, N=52 (6,12) [6]
  BC    q [W/m]       d [%]  Guessed q* [W/m]
   2  5.5694      82.045
   3 -5.5694      117.96
 sum:-4.6E-5 max:117.96  CPU:0.297s (total:0.297s)

Level 2: iter=387, N=134 (9,22) [12]
  BC    q [W/m]       d [%]  Guessed q* [W/m]
   2  5.5942      0.4448          5.6225
   3 -5.5944      0.4467         -5.6228
 sum:-0.0002 max:0.4467  CPU:0.281s (total:1s)

Level 3: iter=577, N=670 (22,45) [24]
  BC    q [W/m]       d [%]  Guessed q* [W/m]
   2  5.6109      0.2969          5.6196
   3 -5.6108      0.2929         -5.6194
 sum: 7.3E-5 max:0.2969  CPU:0.296s (total:1s)

Level 4: iter=938, N=3043 (46,93) [48]
  BC    q [W/m]       d [%]  Guessed q* [W/m]
   2  5.6164      0.0972          5.6195
   3 -5.6164      0.0984         -5.6195
 sum: 3.4E-6 max:0.0984  CPU:0.36s (total:1s)

Finished!
Max diff. between solutions d=0.0984%.
Mesh factor used: 2
```

Figure 2.1: An example and the automatic mesh window with calculated results.

Press button *Start calc* to begin the analyses. Consider e.g. level 3 that has 22·45 cells (the total number of cells is here N=670). The next level has 46·93 (N=3043) cells. Due to irregular geometry the resulting mesh increase value is not exact.

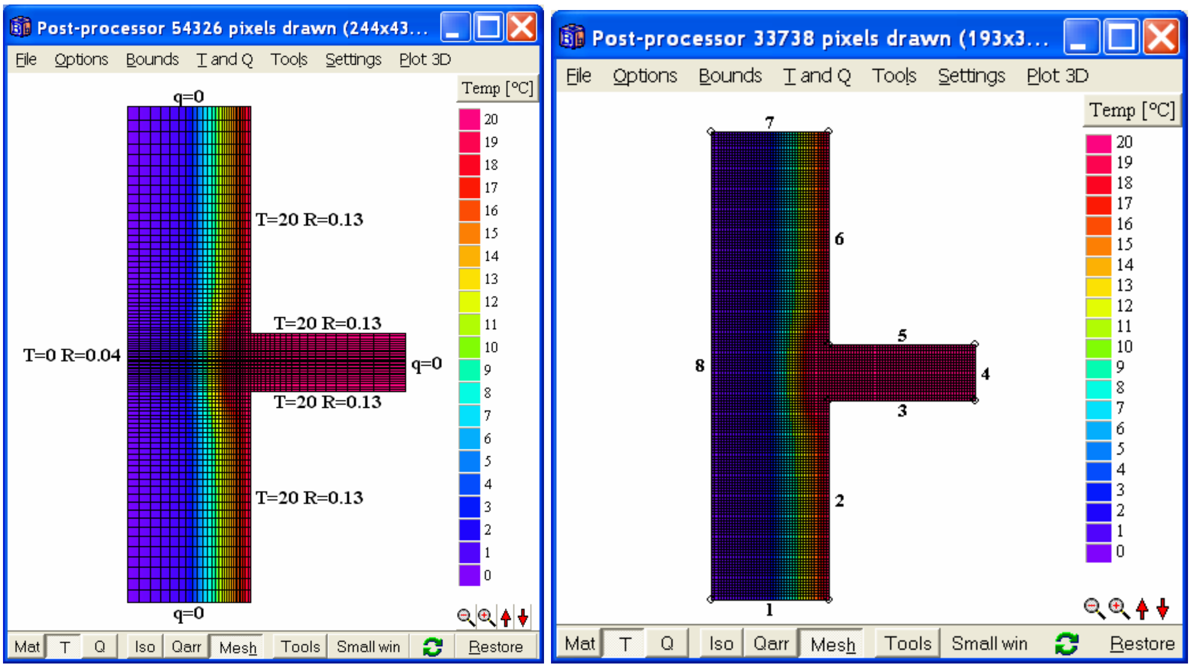
The division into finer grids will continue until the maximum difference of the heat flow through the boundaries between consecutive solutions becomes smaller than a specified value *d* (*Max diff*). This value is by default 0.1% (the EN ISO 10211 criterion is 2% but this value may not be sufficient, a value of 1% is now proposed).

Consider once again level 3 and 4. The heat flow through all surfaces with boundary condition number 2 is 5.6109 W/m for level 3 and 5.6164 W/m for level 4. The difference is 1-5.6109/5.6164= 0.098%. The guessed heat flow Q^* is explained in chapter 3.

The last level fulfills the 0.1% difference criterion. The total simulation time on a Pentium 4 (2.7 MHz) was for all levels about two seconds.

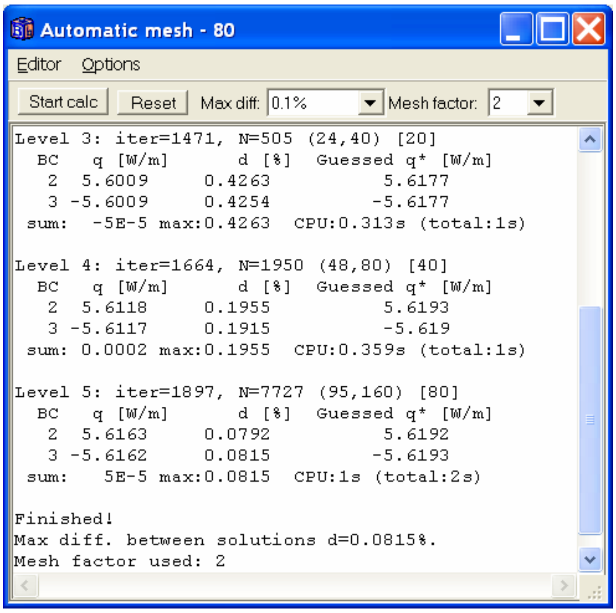
Note that the calculation for each level is finished when the steady-state stop criterion for boundary flows is fulfilled, see Figure 6.2. The sum of all heat flows (positive and negative) entering the boundary surfaces Q_b, divided by the sum of the absolute values of all these heat flows, must be less than a given value F (by default 0.01% in HEAT2).

The automatic mesh dividing works well with both expansive meshes (where an expansion point is put in the pre-processor) as well with equidistant meshes. Figure 2.2 shows the final mesh that gives a numerical error of less than 0.1%. (left: expansive mesh with N=3043, right: equidistant mesh with N=7727 cells). Figure 2.3 shows the last mesh levels in the equidistant mesh case.



Post-processor 54326 pixels drawn (244x43...
File Options Bounds T and Q Tools Settings Plot 3D
Temp [°C]
q=0
T=20 R=0.13
T=20 R=0.13
T=0 R=0.04
q=0
T=20 R=0.13
T=20 R=0.13
q=0
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Mat T Q Iso Qarr Mesh Tools Small win Restore
Post-processor 33738 pixels drawn (193x3...
File Options Bounds T and Q Tools Settings Plot 3D
Temp [°C]
7
6
5
8
4
3
2
1
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Mat T Q Iso Qarr Mesh Tools Small win Restore

Figure 2.2: The expansive and equidistant meshes that gives an error of less than 0.1%.



Max diff: 0.1%
Mesh factor: 2

```
Level 3: iter=1471, N=505 (24,40) [20]
  BC    q [W/m]       d [%]  Guessed q* [W/m]
   2  5.6009      0.4263           5.6177
   3 -5.6009      0.4254          -5.6177
 sum:  -5E-5 max:0.4263  CPU:0.313s (total:1s)

Level 4: iter=1664, N=1950 (48,80) [40]
  BC    q [W/m]       d [%]  Guessed q* [W/m]
   2  5.6118      0.1955           5.6193
   3 -5.6117      0.1915          -5.619
 sum: 0.0002 max:0.1955  CPU:0.359s (total:1s)

Level 5: iter=1897, N=7727 (95,160) [80]
  BC    q [W/m]       d [%]  Guessed q* [W/m]
   2  5.6163      0.0792           5.6192
   3 -5.6162      0.0815          -5.6193
 sum:    5E-5 max:0.0815  CPU:1s (total:2s)

Finished!
Max diff. between solutions d=0.0815%.
Mesh factor used: 2
```

Figure 2.3: The last mesh levels in the equidistant mesh case.

3. Estimation of more accurate heat flows

More accurate heat flows can be obtained by combining results from two or three solutions with different meshes. For more information about this topic, please see chapter 4.2 in the thesis by Blomberg “Heat conduction in two and three dimensions” at

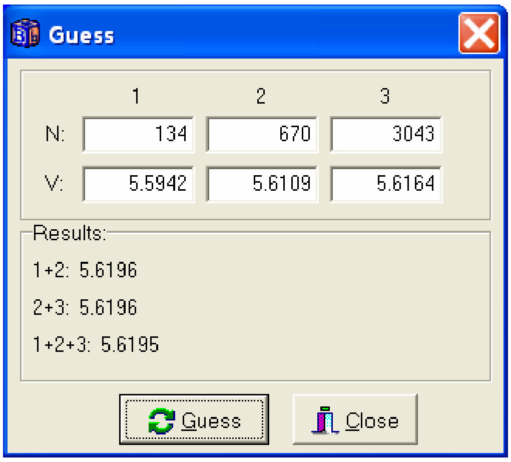
http://www.buildingphysics.com/manuals/avh_TB.pdf

Figure 2.1 in Chapter 2 shows the guessed heat flow Q^* that is calculated by combining results from the two last simulations.

Consider e.g. the heat flow for boundary condition BC=2 for level 2 which fulfills the 1% max diff criterion. The calculated value is 5.5942 W/m and the estimated better value is 5.6225. The calculated “true” heat flow with an infinite number of cells is actually 5.619 W/m. This gives a numerical error for the calculated value 5.5942 of 0.4%, and 0.07% for the guessed value 5.6225.

At least two numerical calculations are needed to check the 2% criterion in the EN ISO 10211 standard mentioned in Chapter 2. It is therefore a good idea to use results from two or three simulations to obtain more accurate heat flows.

There is also an option to make such an estimation by hand in HEAT2. Figure 3.1 shows a dialogue for guessing better heat flows by combining different meshes, see menu item *Output/Guess heat flow/temperature*. Here data is entered for levels 3, 4 and 5, see Figure 2.1. Using the two last results [2+3] gives a guessed heat flow of 5.6196, using all three results [1+2+3] gives a heat flow of 5.6195 (a 0.01% error compared to the true result 5.619).



	1	2	3
N:	134	670	3043
V:	5.5942	5.6109	5.6164

Results:

1+2: 5.6196

2+3: 5.6196

1+2+3: 5.6195

Figure 3.1: Dialog for guessing better heat flows/temperatures by combining results from different meshes.

Note that for some cases, a solution for three levels may not be found.

Estimations of more accurate temperatures can be done in the same way as with heat flows by substituting the heat flows (*V1, V2, V3*) with temperatures.

4. Thermal coupling coefficients (L^{2D})

4.1 Introduction

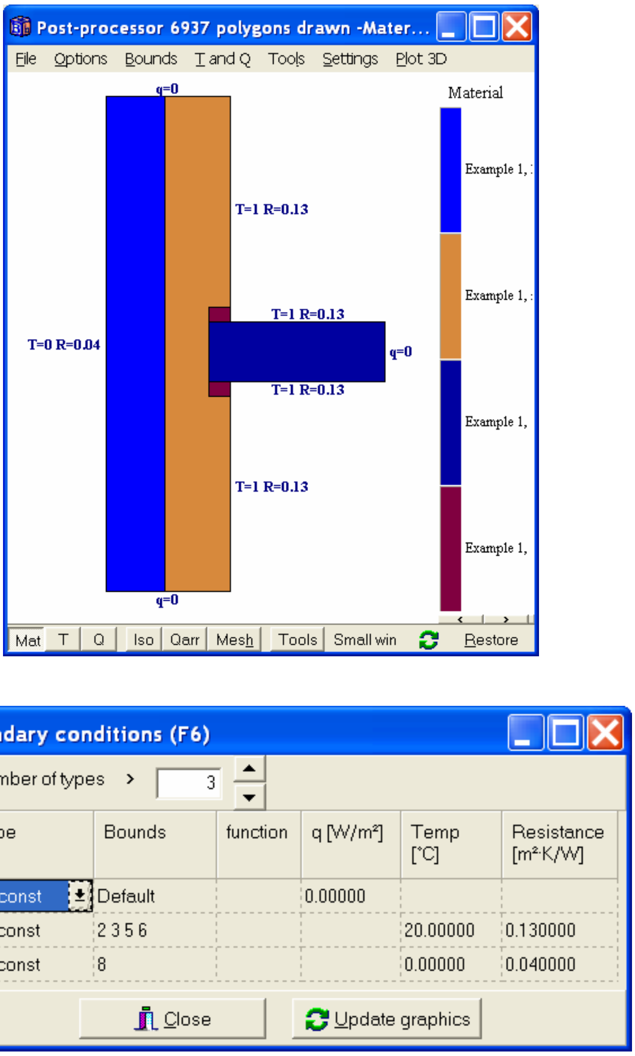
HEAT2 automatically calculates the thermal coupling coefficients (L^{2D}) according to EN ISO 10211 for a wide variety of problems involving thermal bridges. To calculate the L^{2D} matrix, check the menu item *Options/Calculate L2D* in the automatic mesh window, see Figure 2.1 in Chapter 2.

The thermal coupling coefficient matrix will have $n·n$ number of columns and rows where n is the number of different boundary conditions with a specified temperature. HEAT2 will automatically make n calculations. There may be up to 20 different boundary temperature conditions (giving a 20·20 L^{2D} matrix).

The thermal transmittance (ψ) can be obtained directly for simpler geometry, see the update manual for version 6.

4.2 Example

Consider the example in Chapter 2 that has two different boundary temperatures, see Figure 4.1.

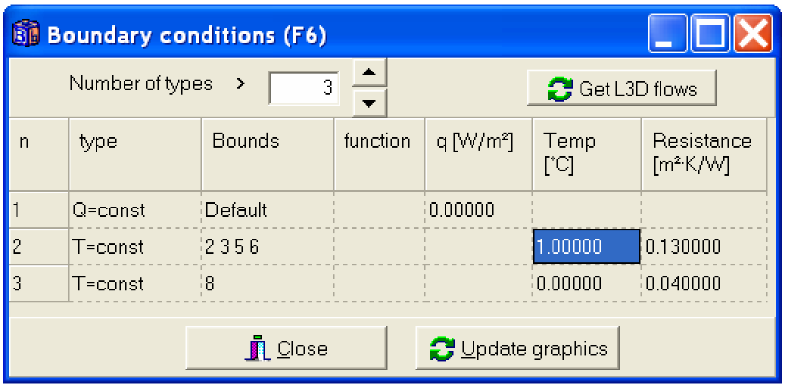


Number of types > 3

n	type	Bounds	function	q [W/m²]	Temp [°C]	Resistance [m²K/W]
1	Q=const	Default		0.00000		
2	T=const	2 3 5 6			20.00000	0.130000
3	T=const	8			0.00000	0.040000

Figure 4.1: Original boundary temperatures.

Press button *Start calc* (see Figure 2.1) to begin the analyses. The first calculation will give the first row (which is the same as the first column by symmetry) of the L^{2D} matrix. Here the boundary temperatures of type 2 will be substituted automatically with T=1. All other boundary conditions temperature types will have T=0, see Figure 4.2.



Number of types > 3

n	type	Bounds	function	q [W/m²]	Temp [°C]	Resistance [m²·K/W]
1	Q=const	Default		0.00000		
2	T=const	2 3 5 6			1.00000	0.130000
3	T=const	8			0.00000	0.040000

Figure 4.2: The first calculation gives the first row of the L^{2D} matrix.

Due to symmetry, the simulation for T=1 for BC number 3 does not have to be made.

The following output results will be presented in the automatic mesh window. Each case will be simulated with different meshes according to Chapter 2 to obtain a satisfactory numerical accuracy. Comments are shown in bold-face.

```
CALCULATION OF L2D FOR BC 2
```

(levels 1-4 not shown here)

```
.
Level 5: iter=3588, N=6937 (77,125) [96]
   BC    q [W/m]       d [%]   Guessed q* [W/m]
    2   0.2809      0.0601           0.281
    3 -0.2809       0.049           -0.281
  sum: 3.4E-5 max:0.0601  CPU:0.469s (total:2s)

Finished!
Max diff. between solutions d=0.0601%.
Mesh factor used: 2

Thermal coupling coefficients
for BC number 2:
   2:2  0.2809    0.281(*)
   2:3 -0.2809   -0.281(*)
(*) estimated better values
```

```
CALCULATION OF L2D FOR BC 3

Thermal coupling coefficients (symmetry)
for BC number 3:
   3:2  0.2809    0.281(*)
   3:3 -0.2809   -0.281(*)
(*) estimated better values
```

```
Thermal coupling matrix L2D [W/(m·K)]:

  BC       2        3
   2:   0.2809  -0.2809
   3:  -0.2809   0.2809
```

The final thermal coupling coefficient (L^{2D}) is shown above (W/m·K). Note the symmetry.

A matrix (L^{2D*}) with estimated more accurate heat flows (see chapter 3) is also presented:

```
  L2D* [W/(m·K)] (estimated better values):
```

```
  BC       2        3
   2:    0.281   -0.281
   3:   -0.281    0.281
```

Boundary heat flows can now be calculated for any arbitrary temperatures. An example with the original boundary conditions (see Figure 4.1) is shown in the output result:

```
Heat flow q[n] through boundaries with BC[n]:
  q[2]=T[2]*L2D[2,2]+T[2]*L2D[2,3]
  q[3]=T[3]*L2D[3,2]+T[3]*L2D[3,3]

Example. Assume the following temperatures:
   BC      T
   2:     20 °C
   3:      0 °C

The heat flows becomes using L2D(*):
  q[2]=20*0.281+0*-0.281=5.6201 W/m
  q[3]=20*-0.281+0*0.281=-5.6201 W/m

Heat flows using:     L2D     L2D(*)
  q[2]=              5.618   5.6201
  q[3]=             -5.618  -5.6201
```

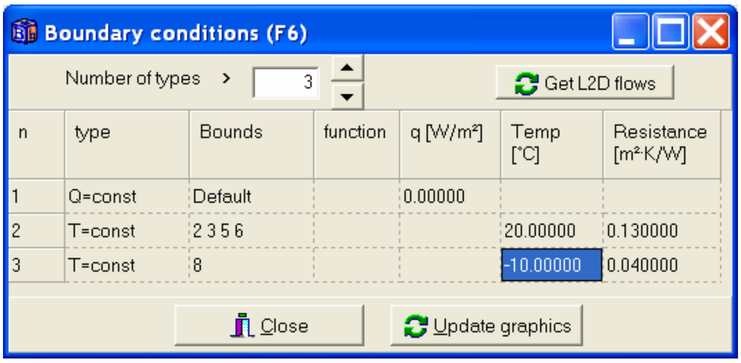
These values are about the same as the full calculation results in Figure 2.1.

Note that HEAT2 also will provide the thermal transmittance (ψ) for simpler geometry, see the update manual for version 6. The following results will be shown in the “Boundary Flows” window (menu item “Calculate thermal bridges (EN ISO 10211-2” under “Output” should be enabled):

```
Bound    q        q     length  BC
      [W/m²]    [W/m]     [m]
 2     3.003    2.042    0.68  [2] T=20 R=0.13
 3    1.3719   0.6859     0.5  [2] T=20 R=0.13
 5    1.3719   0.6859     0.5  [2] T=20 R=0.13
 6    3.0171   2.2025    0.73  [2] T=20 R=0.13
 8   -3.5102  -5.6163     1.6  [3] T=0 R=0.04
Sum flows:     3.6E-5 W/m
Sum pos flows: 5.6164 W/m

Heat flows for each BC:
  BC           q [W/m]
  [2]          5.6164  (T=20 R=0.13)
  [3]         -5.6163  (T=0 R=0.04)
          Sum: 3.6E-5

THERMAL BRIDGES ACCORDING TO EN ISO 10211:

Thermal coupling coefficient:
  L^2D=q_in/dT=5.6164/20= 0.2808 W/(m·K)

The distance between cut-off plane and central element should
normally be at least 1 m according to EN ISO 10211.
However, the max error between exact and calculated one-dimensional
U-values at cut-off planes is zero so results should be OK.

Thermal transmittance coefficient:
  Psi=L^2D-U_1D*L=0.2808-0.1604*1.6= 0.0241 W/(m·K)

Average U-value for section:
  U_avr=U_1D+Psi/L=0.1755 W/(m²·K)

Horizontal cut-off planes found.

One-dimensional U-values at cut-off planes [W/(m²·K)]:
                   exact    calc    error(%)
  lower boundary:  0.1604   0.161    <0.5
  upper boundary:  0.1604  0.1608    <0.5

Extreme temperatures and temperature factor f_Rsi:
  Indoor  Min: 19.504°C f_Rsi=f_0.13=0.9752 at (x, y)=(0.4, 0.87)
          Max: 19.932°C
  Outdoor Min: 0.1402°C
          Max: 0.1639°C
  Indoor boundaries : 2 3 4 5 6
  Outdoor boundaries: 8
```

4.3 Calculation of heat flows using the L^{2D} matrix

When the L^{2D} matrix has been calculated it is possible to get the heat flows for arbitrary temperatures in the boundary conditions input window (short-cut **F6**). Press the menu item *Options/Get current BC temperatures and calculate flows* in the automatic mesh window or press (F6), see Figure 4.3.



Number of types > 3

n	type	Bounds	function	q [W/m²]	Temp [°C]	Resistance [m²·K/W]
1	Q=const	Default		0.00000		
2	T=const	2 3 5 6			20.00000	0.130000
3	T=const	8			-10.00000	0.040000

Figure 4.3: Press *Get L2D flows* to obtain the flows directly using the L^{2D} matrix .

Assume new boundary temperatures according to Figure 4.3. Press the button *Get L2D flows* to obtain the boundary flows directly using the L^{2D} matrix. The following will be written to the automatic mesh editor:

```
Thermal coupling matrix L2D [W/(m·K)]:

  BC        2         3
   2:    0.2809  -0.2809
   3:   -0.2809   0.2809

  L2D* [W/(m·K)] (estimated better values):

  BC        2         3
   2:     0.281    -0.281
   3:    -0.281     0.281

Heat flow q[n] through boundaries with BC[n]:
  q[2]=T[2]*L2D[2,2]+T[2]*L2D[2,3]
  q[3]=T[3]*L2D[3,2]+T[3]*L2D[3,3]

Example. Assume the following temperatures:
   BC       T
   2:      20 °C
   3:     -10 °C

The heat flows becomes using L2D(*):
  q[2]=20*0.281+-10*-0.281=8.4297 W/m
  q[3]=20*-0.281+-10*0.281=-8.4297 W/m

Heat flows using:      L2D      L2D(*)
  q[2]=              8.4267    8.4297
  q[3]=             -8.4267   -8.4297
```

4.4 Calculation of the L^{2D} matrix with high precision

The L^{2D} matrix can be calculated with the highest number of available numerical nodes (see last row **All levels** in the column for "Max diff" *d*). This will use up to 700·700 nodes in the standard version. The output results become:

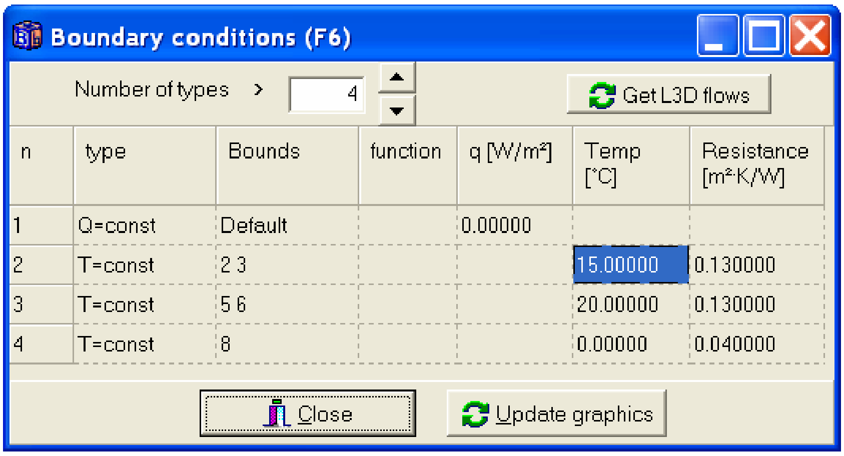
```
Thermal coupling matrix L2D [W/(m·K)]:

  BC        2        3
   2:     0.281  -0.2809
   3:    -0.281   0.2809

  L2D* [W/(m·K)] (estimated better values):

  BC        2        3
   2:    0.2811  -0.2809
   3:   -0.2811   0.2809

Heat flow q[n] through boundaries with BC[n]:
  q[2]=T[2]*L2D[2,2]+T[2]*L2D[2,3]
  q[3]=T[3]*L2D[3,2]+T[3]*L2D[3,3]

Example. Assume the following temperatures:
   BC       T
   2:      20 °C
   3:       0 °C

The heat flows becomes using L2D(*):
  q[2]=20*0.2811+0*-0.2809=5.6217 W/m
  q[3]=20*-0.2811+0*0.2809=-5.6217 W/m

Heat flows using:      L2D     L2D(*)
  q[2]=              5.6196   5.6217
  q[3]=             -5.6196  -5.6217
```

4.5 Coupling between groups of different boundary condition types

Note that the coupling is made between groups belonging to different boundary condition types that have a prescribed constant boundary temperature. Figure 4.4 shows three types (2, 3, 4) that have prescribed boundary temperatures.

Consider

Figure 4.5, where we want to have separate couplings for the upper internal space (boundaries 5+6) and for the lower internal space (boundaries 2+3). The separate coupling will allow us to calculate heat flows using the L2D matrix in cases where the temperature in the upper internal space is not the same as the temperature in the lower internal space.



Number of types > 4

n	type	Bounds	function	q [W/m²]	Temp [°C]	Resistance [m²K/W]
1	Q=const	Default		0.00000		
2	T=const	2 3			15.00000	0.130000
3	T=const	5 6			20.00000	0.130000
4	T=const	8			0.00000	0.040000

Figure 4.4: Coupling is made between the three groups with different boundary condition types (that is of type "T=const").

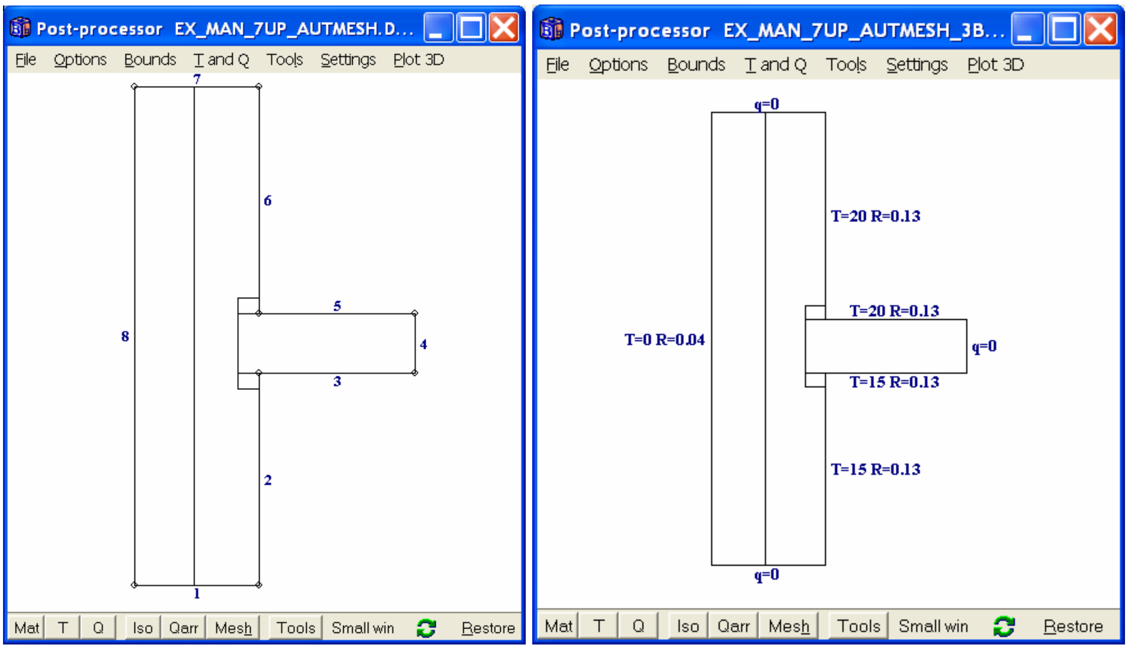
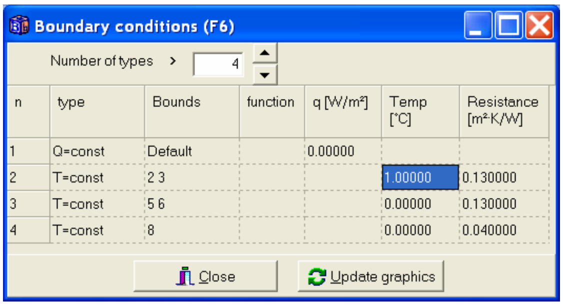
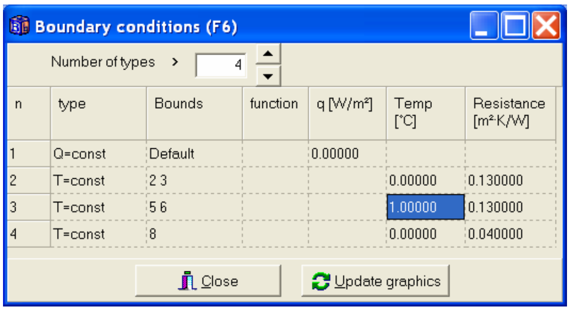

Post-processor EX_MAN_7UP_AUTMESH.D...
File Options Bounds T and Q Tools Settings Plot 3D
7
6
5
8
4
3
2
1
Mat T Q Iso Qarr Mesh Tools Small win Restore
Post-processor EX_MAN_7UP_AUTMESH_3B...
File Options Bounds T and Q Tools Settings Plot 3D
q=0
T=20 R=0.13
T=20 R=0.13
T=0 R=0.04
q=0
T=15 R=0.13
T=15 R=0.13
q=0
Mat T Q Iso Qarr Mesh Tools Small win Restore

Figure 4.5: Boundary numbers and an example with different internal temperatures.

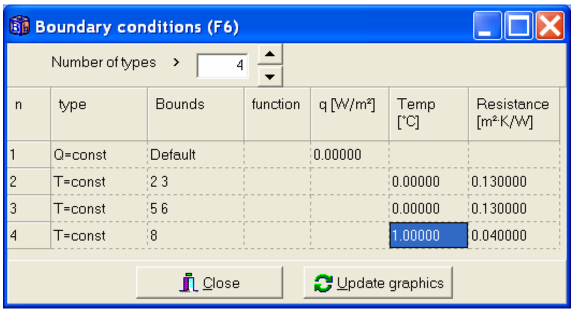
The automatic three calculations give the L^{2D} matrix, see Figure 4.6.



n	type	Bounds	function	q [W/m²]	Temp [°C]	Resistance [m²K/W]
1	Q=const	Default		0.00000		
2	T=const	2 3			1.00000	0.130000
3	T=const	5 6			0.00000	0.130000
4	T=const	8			0.00000	0.040000



n	type	Bounds	function	q [W/m²]	Temp [°C]	Resistance [m²K/W]
1	Q=const	Default		0.00000		
2	T=const	2 3			0.00000	0.130000
3	T=const	5 6			1.00000	0.130000
4	T=const	8			0.00000	0.040000



n	type	Bounds	function	q [W/m²]	Temp [°C]	Resistance [m²K/W]
1	Q=const	Default		0.00000		
2	T=const	2 3			0.00000	0.130000
3	T=const	5 6			0.00000	0.130000
4	T=const	8			1.00000	0.040000

Figure 4.6: The three automatic calculations give the L^{2D} matrix.

```
CALCULATION OF L2D FOR BC 2
. . .
Level 6: iter=53668, N=26413 (158,253) [192]
  BC   q [W/m]      d [%]  Guessed q* [W/m]
   2  1.7308      0.063          1.7315
   3  -1.594     0.0295         -1.5943
   4 -0.1364     0.0236         -0.1365
 sum: 0.0003 max:0.063  CPU:2s (total:4s)

Finished!
Max diff. between solutions d=0.063%.
Mesh factor used: 2

Thermal coupling coefficients
for BC number 2:
   2:2  1.7308   1.7315(*)
   2:3  -1.594  -1.5943(*)
   2:4 -0.1364  -0.1365(*)
(*) estimated better values

____________________________________________

CALCULATION OF L2D FOR BC 3
Start number for max cells: [6]
. . .
Level 6: iter=55246, N=26413 (158,253) [192]
  BC   q [W/m]      d [%]  Guessed q* [W/m]
   2 -1.5943     0.0539         -1.5948
   3  1.7387     0.0502          1.7393
   4 -0.1444     0.0177         -0.1444
 sum:   2E-5 max:0.0539  CPU:1s (total:3s)

Finished!
Max diff. between solutions d=0.0539%.
Mesh factor used: 2

Thermal coupling coefficients
for BC number 3:
   3:2 -1.5943  -1.5948(*)
   3:3  1.7387   1.7393(*)
   3:4 -0.1444  -0.1444(*)
(*) estimated better values

____________________________________________

CALCULATION OF L2D FOR BC 4
Start number for max cells: [6]
. . .
Level 5: iter=56670, N=6937 (77,125) [96]
  BC   q [W/m]      d [%]  Guessed q* [W/m]
   2 -0.1364     0.0581         -0.1365
   3 -0.1444     0.0478         -0.1445
   4  0.2809     0.0507           0.281
 sum:-9.6E-6 max:0.0581  CPU:1s (total:2s)

Finished!
Max diff. between solutions d=0.0581%.
Mesh factor used: 2

Thermal coupling coefficients
for BC number 4:
   4:2 -0.1364  -0.1365(*)
   4:3 -0.1444  -0.1445(*)
   4:4  0.2809    0.281(*)
(*) estimated better values

____________________________________________

Thermal coupling matrix L2D [W/(m·K)]:

  BC       2        3        4
   2:   1.7308   -1.594  -0.1364
   3:  -1.5943   1.7387  -0.1444
   4:  -0.1364  -0.1444   0.2809

  L2D* [W/(m·K)] (estimated better values):

  BC       2        3        4
   2:   1.7315  -1.5943  -0.1365
   3:  -1.5948   1.7393  -0.1444
   4:  -0.1365  -0.1445    0.281

Heat flow q[n] through boundaries with BC[n]:
  q[2]=T[2]*L2D[2,2]+T[2]*L2D[2,3]+T[2]*L2D[2,4]
  q[3]=T[3]*L2D[3,2]+T[3]*L2D[3,3]+T[3]*L2D[3,4]
  q[4]=T[4]*L2D[4,2]+T[4]*L2D[4,3]+T[4]*L2D[4,4]

Example. Assume the following temperatures:
   BC      T
   2:     15 °C
   3:     20 °C
   4:      0 °C

The heat flows becomes using L2D(*):
  q[2]=15*1.7315+20*-1.5943+0*-0.1365=-5.9135 W/m
  q[3]=15*-1.5948+20*1.7393+0*-0.1444=10.863 W/m
  q[4]=15*-0.1365+20*-0.1445+0*0.281=-4.9369 W/m

Heat flows using:     L2D     L2D(*)
  q[2]=             -5.9183  -5.9135
  q[3]=               10.86   10.863
  q[4]=             -4.9354  -4.9369
```

Using the L^{2D} matrix to obtain the heat flows for e.g. the temperatures below gives the following:

```
Example. Assume the following temperatures:
   BC      T
   2:     20 °C
   3:     20 °C
   4:      0 °C

The heat flows becomes using L2D(*):
  q[2]=20*1.7315+20*-1.5943+0*-0.1365=2.7442 W/m
  q[3]=20*-1.5948+20*1.7393+0*-0.1444=2.8892 W/m
  q[4]=20*-0.1365+20*-0.1445+0*0.281=-5.6194 W/m

Heat flows using:     L2D     L2D(*)
  q[2]=              2.7355   2.7442
  q[3]=              2.8889   2.8892
  q[4]=             -5.6175  -5.6194
```

Here, the heat flow through the internal upper boundaries (BC type=3, see boundaries 5+6 in Figure 4.5) is 2.8889 W/m using the L^{2D} matrix. A full calculation gives q=0.6857+2.203=2.8887 W/m.

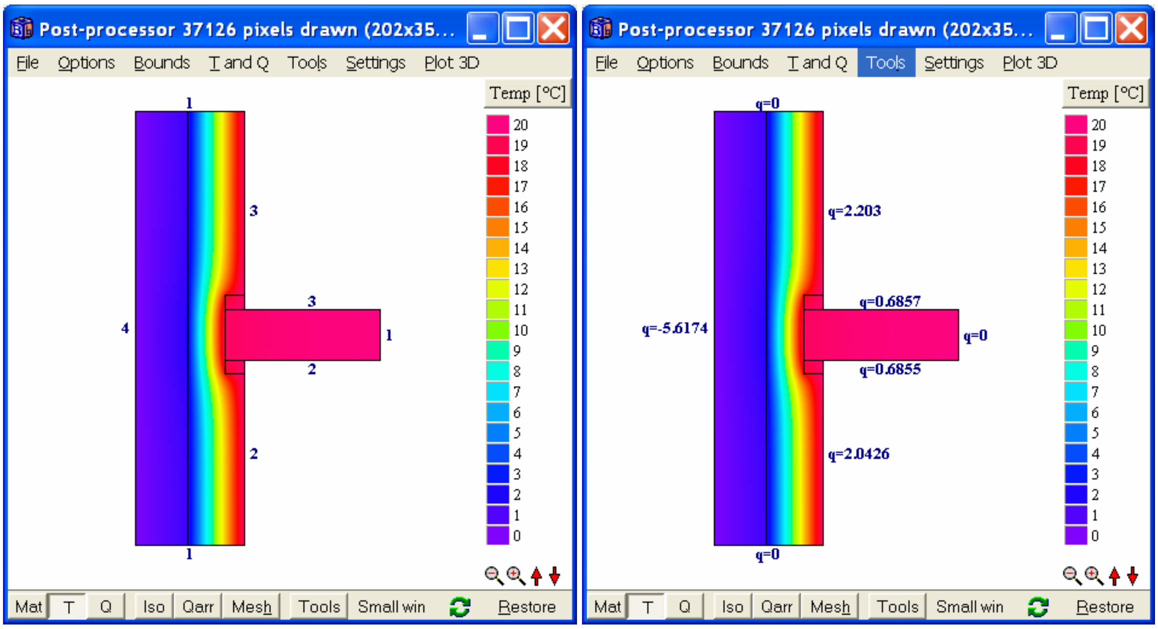

Post-processor 37126 pixels drawn (202x35...
File Options Bounds T and Q Tools Settings Plot 3D
Temp [°C]
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1
3
3
4
1
2
2
1
Mat T Q Iso Qarr Mesh Tools Small win Restore
Post-processor 37126 pixels drawn (202x35...
File Options Bounds T and Q Tools Settings Plot 3D
Temp [°C]
q=0
q=2.203
q=0.6857
q=-5.6174
q=0
q=0.6855
q=2.0426
q=0
Mat T Q Iso Qarr Mesh Tools Small win Restore

Figure 4.7: Heat flows through boundaries after full calculation.

4.6 Tips

The L^{2D} matrix is not saved automatically. It is possible to copy the editor content and save it in another program, such as Word.

Automatic mesh calculation works for both expansive meshes (i.e. an expansion point has been drawn in the pre-processor) and for equidistant ones.

Note that the sum of each row (and column) for the L^{2D} matrix should be zero (and that the matrix is symmetric) for the same numerical mesh. This is a good test of that a sufficiently low value for the steady-state stop criterion for boundary flows has been used, see Figure 6.2.

5. Batch jobs

5.1 Batch job options

HEAT2 can be started using the parameters given in Table 5.1.

parameter	description	followed by
Filename	The first parameter should be the input file name (with or without extension .dat). Note that empty spaces is not allowed in the file name ("my_file" is ok but not "my file") .	
s	steady-state analysis	
t	transient analysis	string (stop time e.g. "1d3h")
w	relaxation coefficient (use with the "noopt" parameter)	real number (e.g. "1.93")
x	read temperature field file (will be used for initial temperature field)	string (e.g. "temp.ijk")
y	write output temperature field file (calculated temperature field will be saved to this file)	string (e.g. "temp.ijk")
r	recorder output file name (recorder should be enabled in the h3p input file)	string (e.g. "recfile.rec")
min	minimize HEAT2 when started	
nowait	HEAT2 will by default wait 10 seconds after a batch job to allow the user to interrupt a new batch job. The "nowait" parameter makes HEAT2 continue to the next batch job without waiting.	
noopt	no optimization of the relaxation coefficient. (The relaxation coefficient specified by parameter "w" will be used, if this is missing the one given in the H3P-file will be used.)	
cen	Calculates the thermal transmittance value (ψ) according to EN ISO 10211. Values will be written to BatchLog.txt.	
aut	Uses automatic mesh generation according to Chapter 2	
l2d	Calculates the thermal coupling coefficient matrix according to Chapter 4. Values will be written to BatchLog.txt.	

Table 5.1: HEAT2 start parameters.

At least on blank space should be put between the parameters. An example is

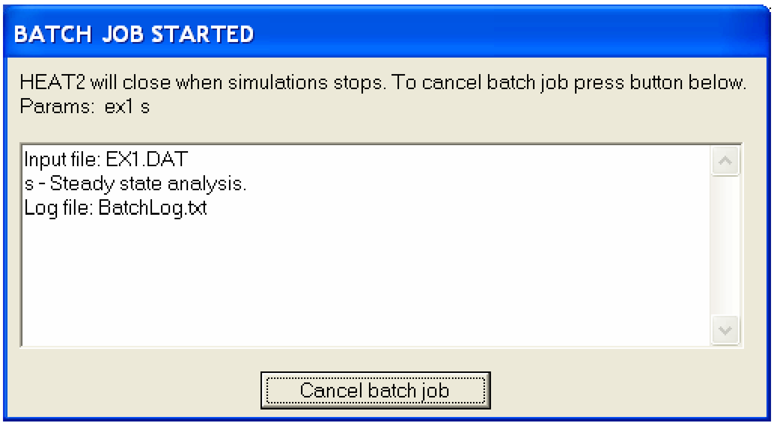
"HEAT2 ex1 s"

This will run a steady-state calculation of ex1.dat and then shut down HEAT2. A log file named **BatchLog.txt** will always be written with the calculated heat flows and the start and end time:

```
EX1 S
    Calculation started at 1:12:27 PM, 7/16/2006
     Bound     q         q      length  BC
           [W/m²]     [W/m]      [m]
       2    11.888   6.6572    0.56   [2] T=20 R=0.13
       3    4.0698   1.4651    0.36   [2] T=20 R=0.13
       4    0.5243   0.0629    0.12   [2] T=20 R=0.13
       5    4.0699   1.4651    0.36   [2] T=20 R=0.13
       6     11.88   6.7718    0.57   [2] T=20 R=0.13
       8   -12.048  -6.8676    0.57   [3] T=0 R=0.04
       9   -3.4936  -1.3974     0.4   [3] T=0 R=0.04
      10   -0.0526  -0.0063    0.12   [3] T=0 R=0.04
     11   -3.4934  -1.3974     0.4  [3] T=0 R=0.04
     12   -12.059  -6.7533    0.56  [3] T=0 R=0.04
     Sum flows:     0.0002 W/m
     Sum pos flows: 16.422 W/m

     Heat flows for each BC:
       BC           q [W/m]
       [2]          16.422
       [3]         -16.422
               Sum: 0.0002
    Calculation stopped at 1:12:27 PM, CPU time=0.172s  ICPS=334302 (iterated cells
    per second) Iter=125
```

If the file BatchLog.txt already exists, the output results will be appended (written) to the end of the file.

HEAT2 displays a window with the batch job parameters, see Figure 5.1. To interrupt a batch job press the cancel button.


BATCH JOB STARTED

HEAT2 will close when simulations stops. To cancel batch job press button below.
Params: ex1 s

Input file: EX1.DAT
s - Steady state analysis.
Log file: BatchLog.txt

Figure 5.1: Window shown in HEAT2 during batch mode.

5.2 Running multiple batch jobs

Multiple batch jobs can be started using a bat-file. This can be created with a simple editor such as *Notepad* or *WordPad*. The file name should have the extension “bat” (e.g. *mybat.bat*) or “cmd”. An example of such a file is shown below.

```
HEAT2 ex1 s                     //steady-state
HEAT2 ex1 s noopt w 1.99        //steady-state, use fixed relaxation 1.99
HEAT2 ex2 t 1d y tfile.ijk      //transient 1 day, writes temperature field
HEAT2 ex2 t 2d x tfile.ijk      //transient 2 days, reads temperature field
HEAT2 ex3 t 1d r test           //transient, recorder file test.rec will be saved
HEAT2 ex1 s noopt w 1.93        //steady-state, use fixed relaxation coeff. w=1.93
HEAT2 Ex_man_7up_autmesh.dat l2d  //calculates L2D matrix, forces automatic mesh
```

The batch file can be started by clicking on it. A line can be ignored by putting a letter before it, e.g “xHEAT2 ex1 s”.

To cancel multiple batch jobs during simulation, close the batch window (e.g. *mybat.bat*) and then stop the simulation in HEAT2.

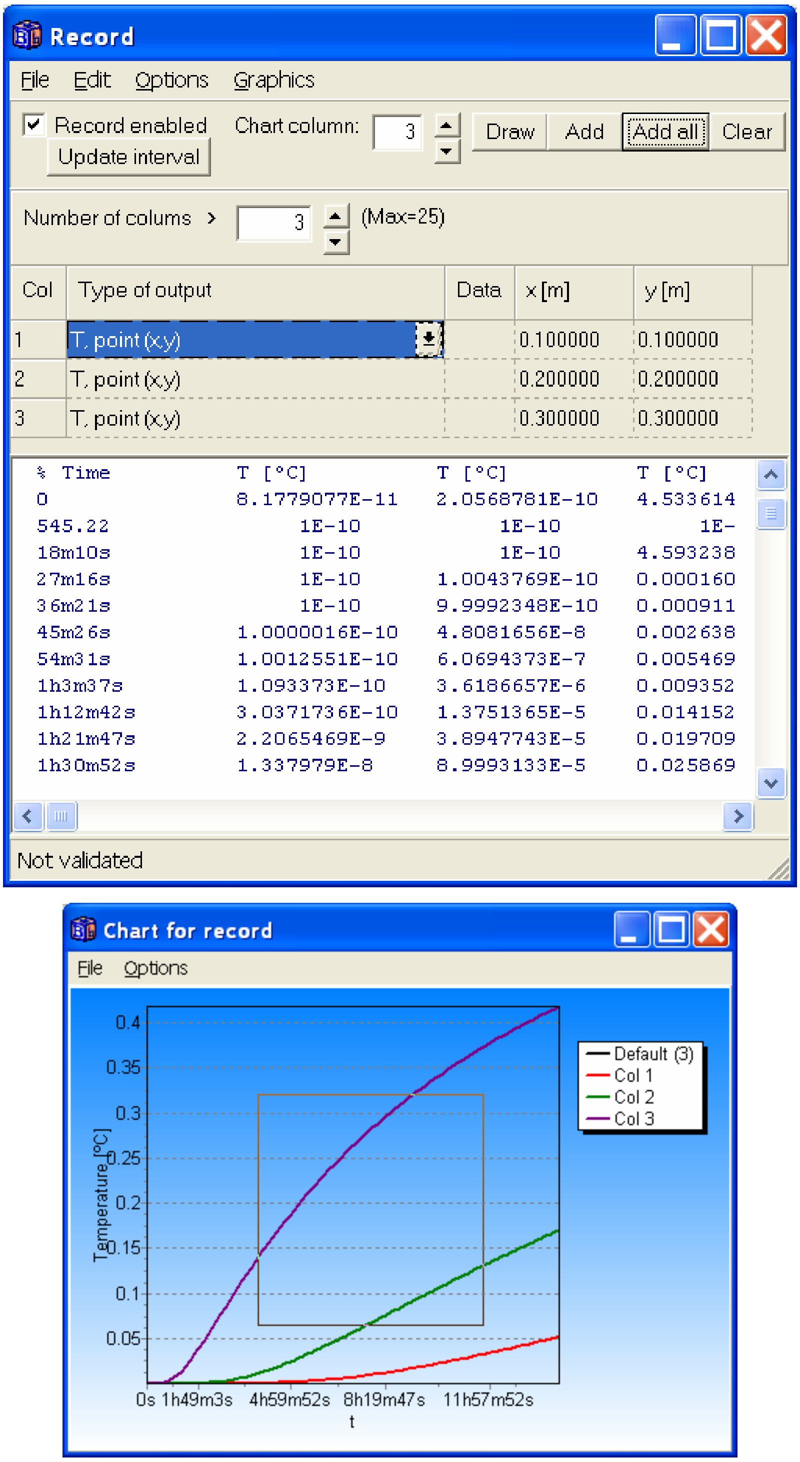
A batch file (Batch_test.bat) is installed with the program. To run it, just click on this file.

```
HEAT2 examples/Ex_man_7up_autmesh.dat l2d
HEAT2 examples/Ex_man_7up_autmesh.dat t 1d y test.tij
HEAT2 examples/Ex_man_7up_autmesh.dat t 2d x test.tij
```

6. Miscellaneous new features and changes

6.1 Recorder

The chart window for the recorder can now show multiple graph lines in the same chart. Use the buttons *Draw*, *Add*, *Add* all and *Clear* in the Recorder window, see Figure 6.1.



☑ Record enabled

Chart column: 3

Number of colums > 3 (Max=25)

Col	Type of output	Data	x [m]	y [m]
1	T, point (x,y)		0.100000	0.100000
2	T, point (x,y)		0.200000	0.200000
3	T, point (x,y)		0.300000	0.300000

```
% Time          T [°C]          T [°C]          T [°C]
0               8.1779077E-11   2.0568781E-10   4.533614
545.22               1E-10           1E-10          1E-
18m10s               1E-10           1E-10      4.593238
27m16s               1E-10      1.0043769E-10   0.000160
36m21s               1E-10      9.9992348E-10   0.000911
45m26s          1.0000016E-10   4.8081656E-8    0.002638
54m31s          1.0012551E-10   6.0694373E-7    0.005469
1h3m37s         1.093373E-10    3.6186657E-6    0.009352
1h12m42s        3.0371736E-10   1.3751365E-5    0.014152
1h21m47s        2.2065469E-9    3.8947743E-5    0.019709
1h30m52s        1.337979E-8     8.9993133E-5    0.025869
```

Not validated

Figure 6.1: Use buttons *Draw*, *Add*, *Add* all and *Clear* to add lines to the chart. A zoom window is shown here.

6.2 Optimization of numerical solution

Most steady-state problems will now be solved 5-15 times (!) quicker due to optimization of the relaxation coefficient and of the numerical scheme.

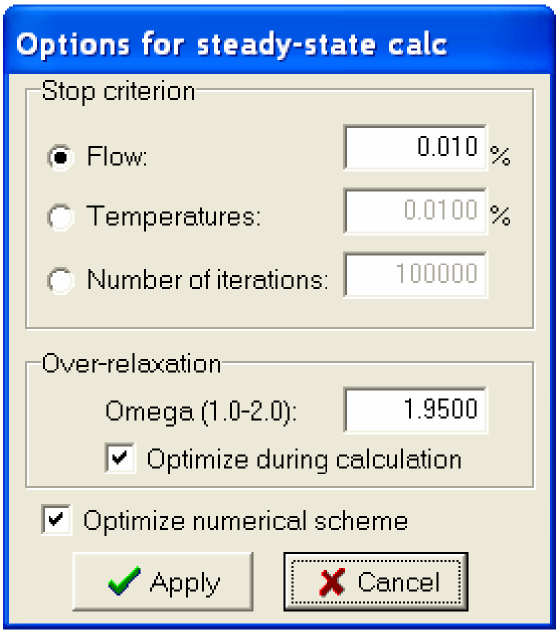
6.2.1 Optimization of the relaxation coefficient

The relaxation coefficient is now optimized during the calculation which may give considerably shorter calculation times. As an extreme example, the EN ISO 10211 test problem (see Section 8.3 in the HEAT2 5 manual) with 21 000 nodes took 5 seconds to solve with optimization on a Pentium 4 2.7 MHz. Without optimization this calculation needed 85 seconds when the default value for the relaxation coefficient of 1.95 was used. The difference is a factor 17! (Note that a simulation using automatic mesh and the EN ISO 1% criterion according to Chapter 2 only takes about second for this case).

The optimization is made by default but can be turned off (menu item *Solve/Options for steady-state*), see Figure 6.2.

6.2.2 Optimization of the numerical scheme

Different numerical schemes are now optimized for each steady-state calculation. This can improve calculation speed of up to 25%. The option is turned on by default, see Figure 6.2. To view more details, open the *debug window* under the menu item *Output*. Some complex problems, e.g. those with internal modifications, will not utilize optimization of the numerical scheme.



Options for steady-state calc

Stop criterion

● Flow: 0.010 %

○ Temperatures: 0.0100 %

○ Number of iterations: 100000

Over-relaxation

Omega (1.0-2.0): 1.9500

☑ Optimize during calculation

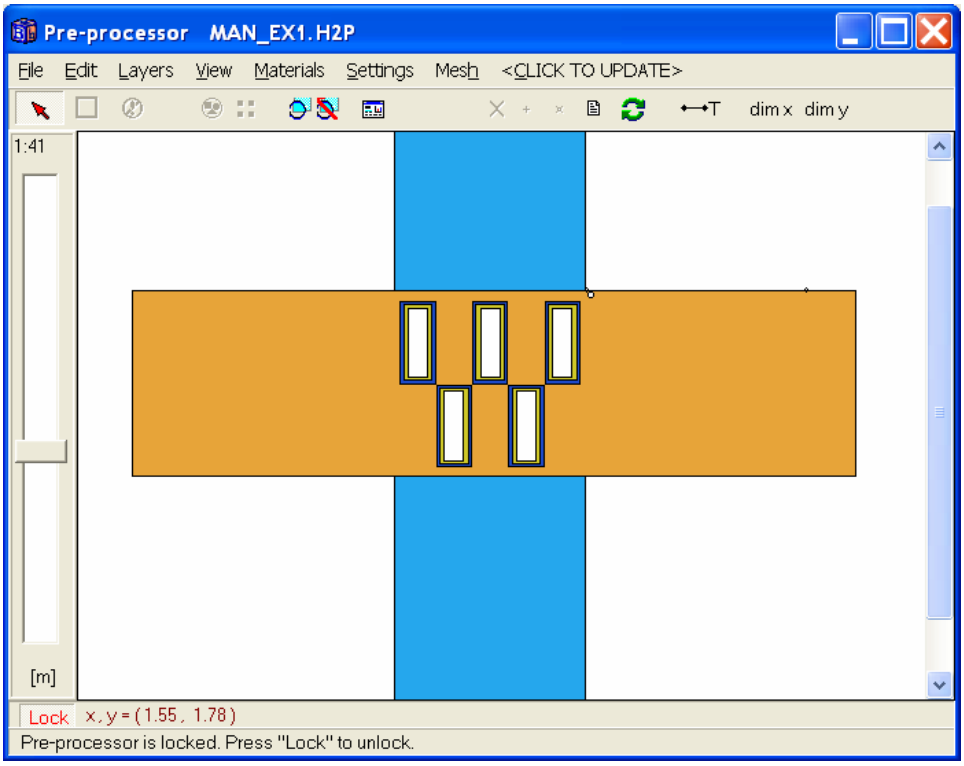
☑ Optimize numerical scheme

Figure 6.2: Optimizations of the relaxation coefficient and the numerical scheme are turned on by default.

6.3 Enhancements in pre-processor

Figure 6.3 shows the new lay-out for the pre-processor. The row at the bottom will display information such as material properties.

The pre-processor is now locked after a simulation is made. This is to avoid unintentional changes. Many items are disabled in locked mode but the tool for e.g. *temperature lines* is still enabled. To unlock the pre-processor click on the **Lock** button (lower left).



x,y=(1.55, 1.78)

Pre-processor is locked. Press "Lock" to unlock.

Figure 6.3: New lay-out for pre-processor.

6.4 Saving desktop state

The desktop state with placement and sizes of windows may be saved/read (menu item *Options)* to a file (*.dsk). Most, but not all, windows are included.

Optionally, a default desktop file “HEAT2.DSK” may be read/saved every time HEAT2 is started/closed.

6.5 Option to save/read temperature field

The temperature field T(i,j) can now be saved/read to/from a textfile. This makes it possible for two different problems with different material properties (but with the same geometry and mesh dividing) to use the other problems’ temperature field in e.g. a transient calculation. It is of course also possible to edit this file.

6.6 Change text font for labels in post-processor

The font for the labels in the right panel in the post-processor (affecting material names, temperature and heat flows) can now be change in menu item *Settings/Text font in right panel*.