ISO 10211:2007 validation of HEAT2 7.0/HEAT3 5.0

Results for test case 1 (HEAT2+HEAT3)

ISO 10211 states that the difference between the temperatures may not exceed 0,1 °C. HEAT2 and HEAT3 give the same results as the standard. See results further down.

Results for test case 2 (HEAT2+HEAT3)

	ISO 10211	HEAT2	HEAT3
Case	***Q*** W/m	***Q*** W/m	***Q*** W/m
2	9,5	9,490 44 000 nodes	9,489 25 000 nodes

Temp (°C)	A	B	C	D	E	F	G	H	I
ISO 10211	7,1	0,8	7,9	6,3	0,8	16,4	16,3	16,8	18,3
HEAT2	7,06	0,76	7,90	6,27	0,83	16,40	16,33	16,77	18,33
HEAT3	7,06	0,76	7,89	6,29	0,83	16,40	16,33	16,77	18,33

EN ISO 10211 states that the difference of heat flow should not be more than 0,1 W/m. The temperature difference may not exceed 0,1 °C. HEAT2 and HEAT3 give the same results as the standard.

Results for test case 3 (HEAT3)

ISO 10211 states that the difference between the heat flows may not exceed 1%. HEAT3 gives a maximum difference of 0,03%. ISO 10211 states that the difference between the temperatures should not exceed 0,1 °C. HEAT3 gives a maximum difference of 0,02 °C. See results further down.

Results for test case 4 (HEAT3)

	ISO 10211	HEAT3	Nodes	CPU		ISO 10211	HEAT3	
Case	***Q*** W	***Q*** W			Diff	T °C	T °C	Diff
4	0,540	0,5394 (0,5398)	840000 (guessed)	6min (8min)	0,1% (0%)	0,805	0,8047	0%
		0,5398 (0,5399)	15 million (guessed)	4,5h (7h)	0% (0%)			

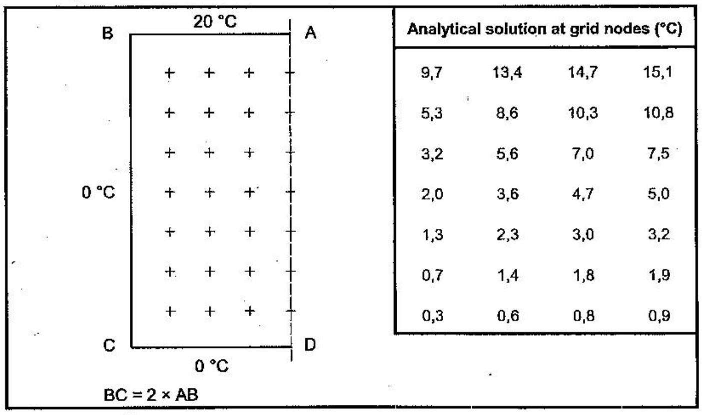
EN ISO 10211 states that the difference of heat flow should not be more than 1%. The temperature difference may not exceed 0,005 °C. HEAT2 gives a maximum difference of 0,1% for the heat flow and 0,0003 °C for the temperature.

- “CPU” is the calculation time on a Intel Core 2 Duo 2,4 GHz.
- Values within parenthesis are estimated values based on results from different meshes.
- Values in blue are calculated using a special version of HEAT3 with 50 million nodes.

A short description of the input with some comments is given below.

Test case 1 (HEAT2)

The heat transfer through half a square column, with known surface temperatures, can be calculated analytically, see figure below. The analytical solution at 28 points of an equidistant grid is given in the same figure. The difference between the temperatures calculated by the method being validated and the temperatures listed, shall not exceed 0,1 °C.



To make these calculations do as follows:

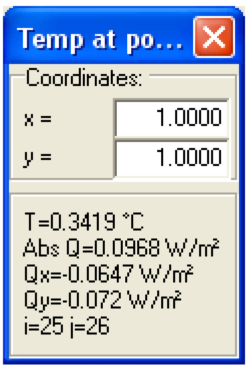
1. Start HEAT2 standard version

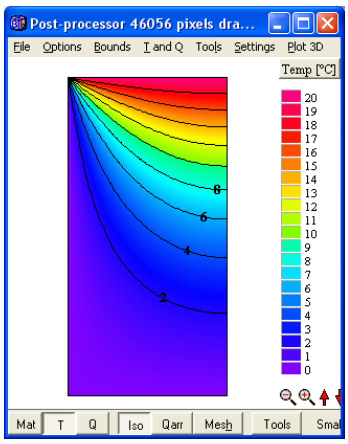
2. Open ISO10211_CASE1.dat

3. Press Start Steady-state calculation (F9)

A calculation with 20 000 nodes takes a second on an Intel Core 2 Duo 2,4 GHz. Results for temperatures are as follows (Open menu item **Output/Temp at point**):

9,66	13,38	14,73	15,09
5,25	8,64	10,32	10,81
3,19	5,61	7,01	7,47
2,01	3,64	4,66	5,00
1,26	2,31	2,99	3,22
0,74	1,36	1,77	1,91
0,34	0,63	0,82	0,89





Test case 1 (HEAT3)

To make these calculations do as follows:

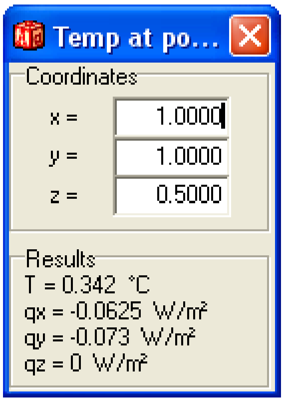
1. Start HEAT3 standard version

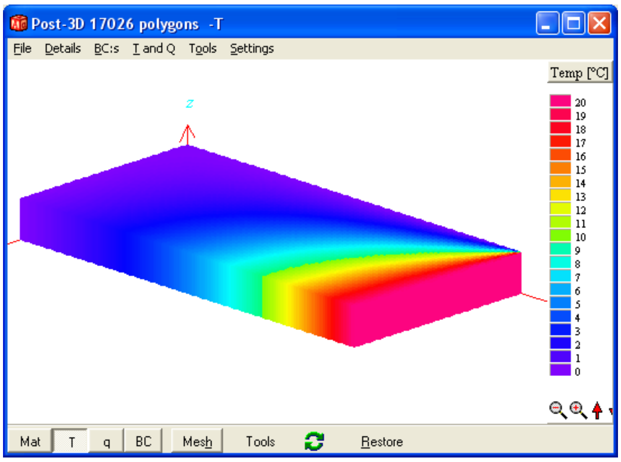
2. Open ISO10211_CASE1.h3p

3. Press Start Steady-state calculation (F9)

A calculation with 20 000 nodes takes a second on an Intel Core 2 Duo 2,4 GHz. Results for temperatures are as follows (see menu item **Output/Temp at point**):

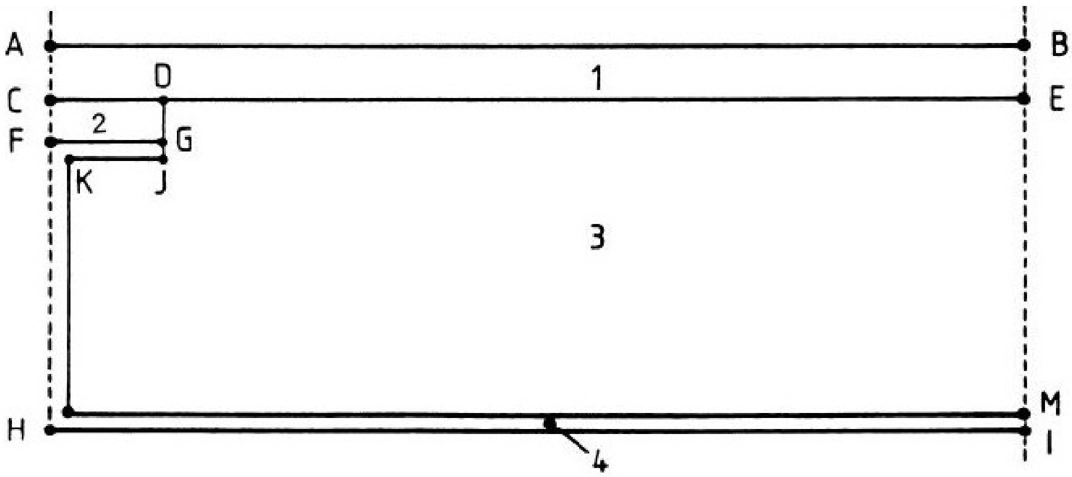
9,66	13,38	14,73	15,09
5,25	8,64	10,31	10,81
3,19	5,61	7,01	7,46
2,01	3,64	4,66	5,00
1,26	2,31	2,98	3,22
0,74	1,36	1,77	1,91
0,34	0,63	0,82	0,89





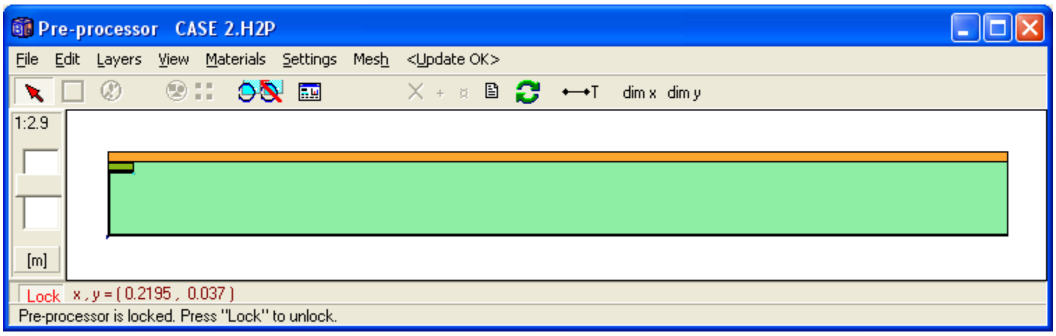
Test case 2 (HEAT2)

This is an example of two-dimensional heat transfer, see figure below.

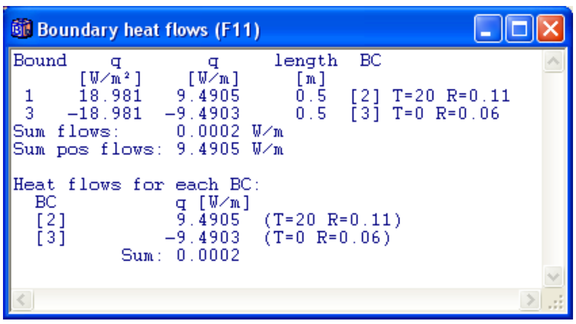


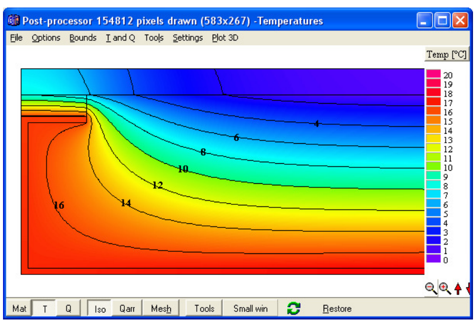
Dimensions	Thermal cond.	Boundary conditions
(mm)	W/(m·K)	
AB = 500	1: 1,15	AB: 0 °C with R_{se} = 0,06 m²·K/W
AC = 6	2: 0,12	HI: 20 °C with R_{si} = 0,11 m²·K/W
CD = 15	3: 0,029	
CF = 5	4: 230	
EM = 40		
GJ = 1,5		
IM = 1,5		
FG - KJ = 1,5		

Input in pre-processor:



A calculation with 44 000 nodes takes about 12 seconds and gives the following result:



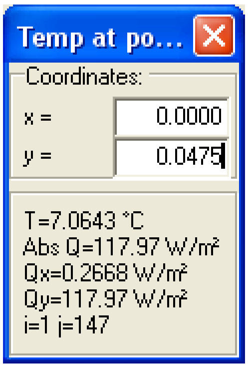


To make these calculations do as follows:

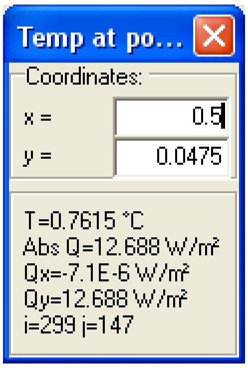
1. Start HEAT2 standard version
2. Open ISO10211_CASE2.dat
3. Press **Start Steady-state calculation** (F9)

Temperatures are as follows (Open menu item **Output/Temp at point**):

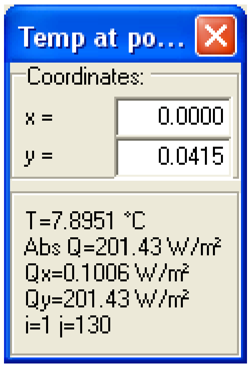
A:



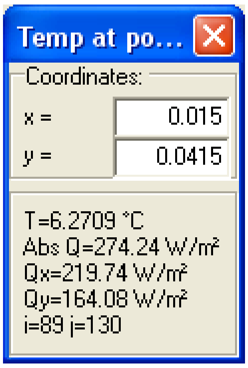
B:



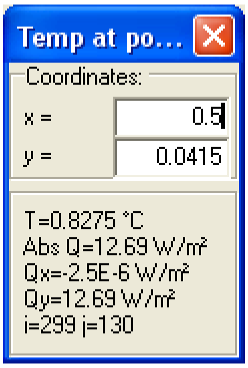
C:



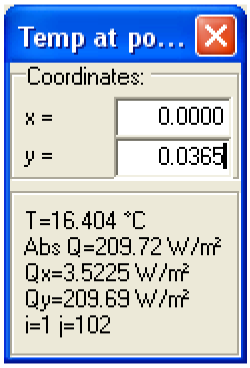
D:



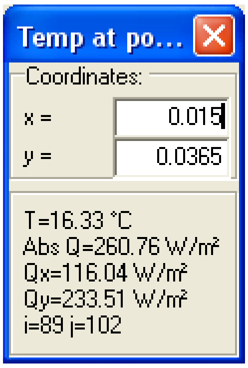
E:



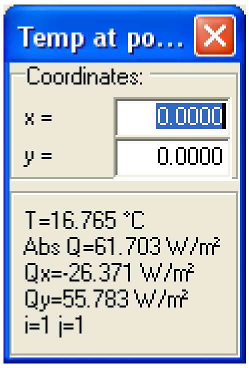
F:



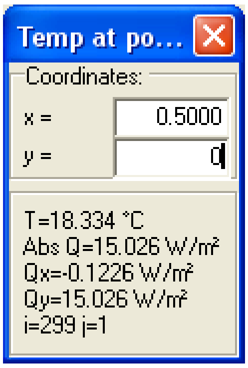
G:



H:



I:



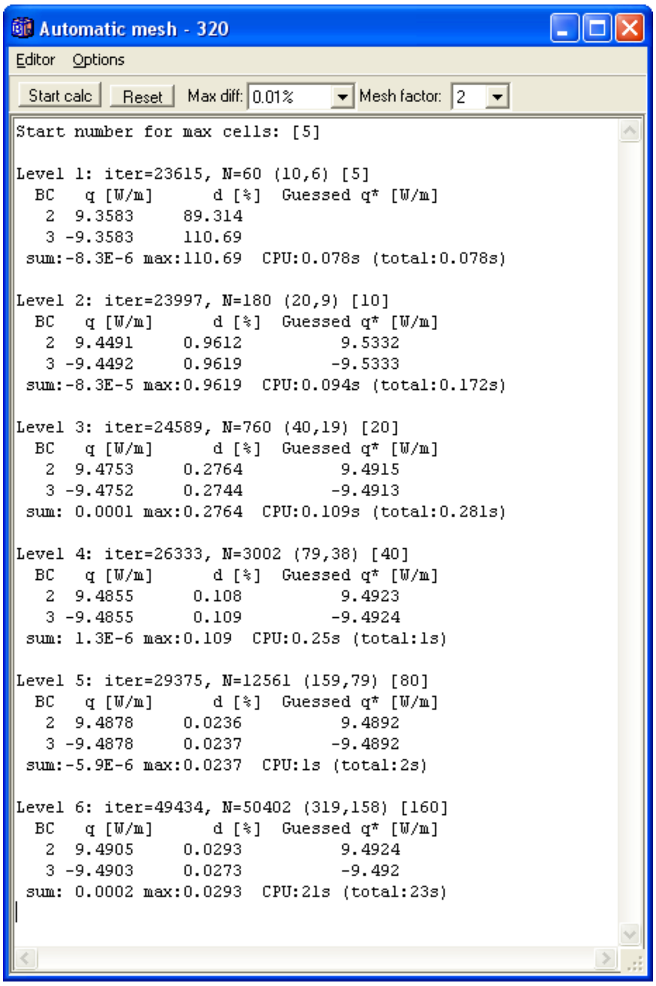
We can also use the automatic mesh feature and combine results for different meshes in order to guess a more exact heat flow. This will give q=9,492 W/m and take about 23 seconds in total. To make these calculations do as follows:

1. Start HEAT2 standard version
2. Open ISO10211_CASE2.dat
3. Go to menu **Solve/Automatic mesh and L2D window**

5. Set the drop down list box **Max diff:** to **All Levels**

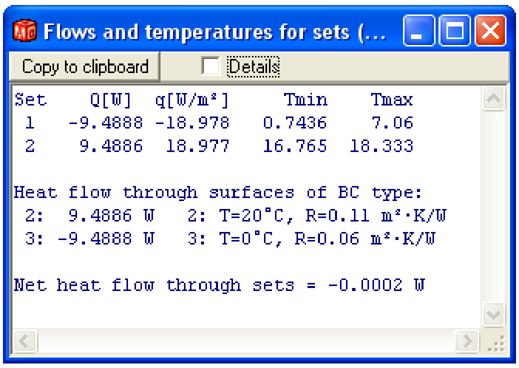
6. Press **Start Calc**

Result window:



Test case 2 (HEAT3)

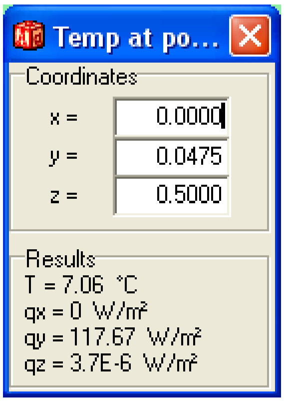
A calculation with 25 000 nodes gives a heat flow of 9,489:

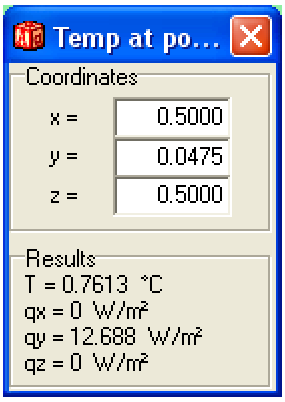


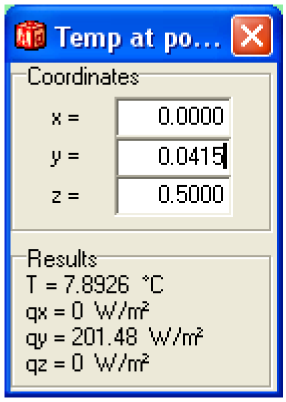
To make these calculations do as follows:

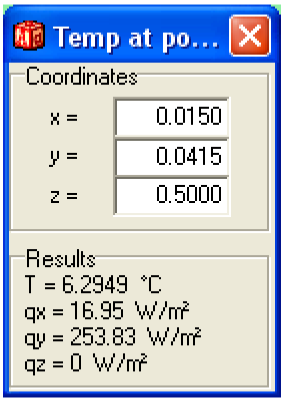
1. Start HEAT3 standard version
2. Open ISO10211_CASE2.h3p
3. Press **Start Steady-state calculation** (F9)

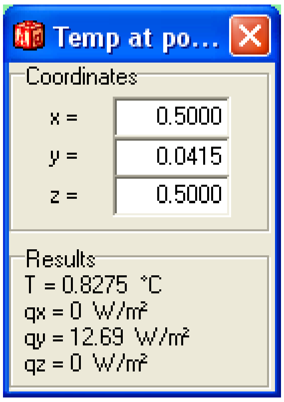
Temperatures are as follows (Open menu item **Output/Temp at point**):

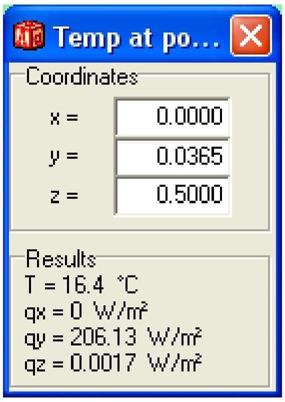
A:


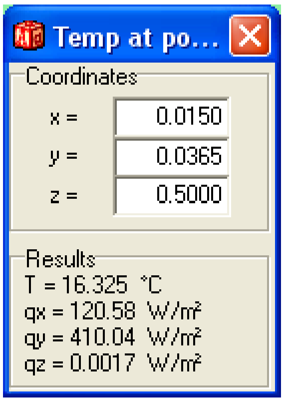
B:


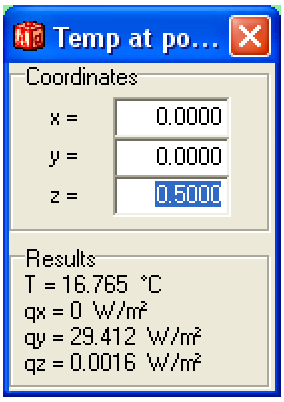
C:


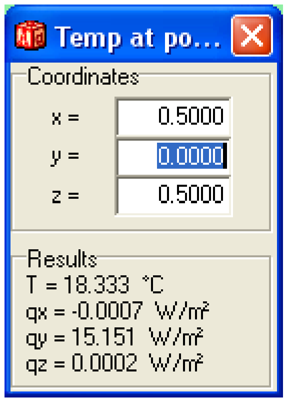
D:


E:


F:


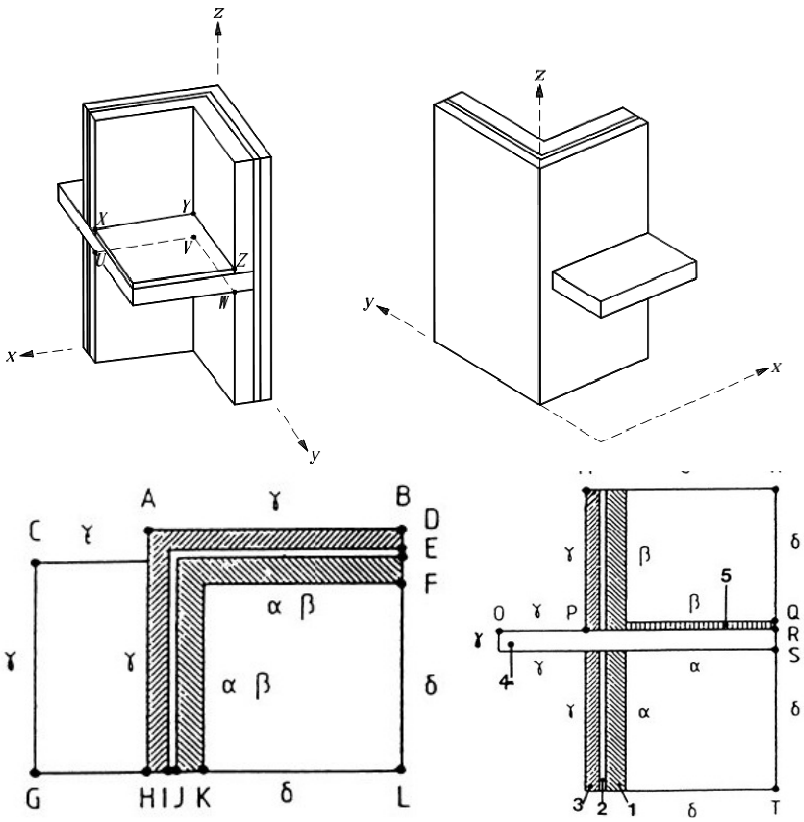
G:


H:


I:


Test case 3 (HEAT3)

There are two walls that meet in a corner, and a floor element, see figures below.



Label	Boundary condition
α	*T*=20 ºC, *R*=0.2 m²·K/W
β	*T*=15 ºC, *R*=0.2 m²·K/W
γ	*T*=0 ºC, *R*=0.05 m²·K/W
δ	*Q*=0 (adiabatic)

Thermal coupling coefficients

Thermal coupling coefficients (W/K) according to ISO 10211:

ISO 10211	γ	α	β
γ	-	1,781	1,624
α	1,781	-	2,094
β	1,624	2,094	-

Thermal coupling coefficients (W/K) according to HEAT3, number of nodes N = 370000:

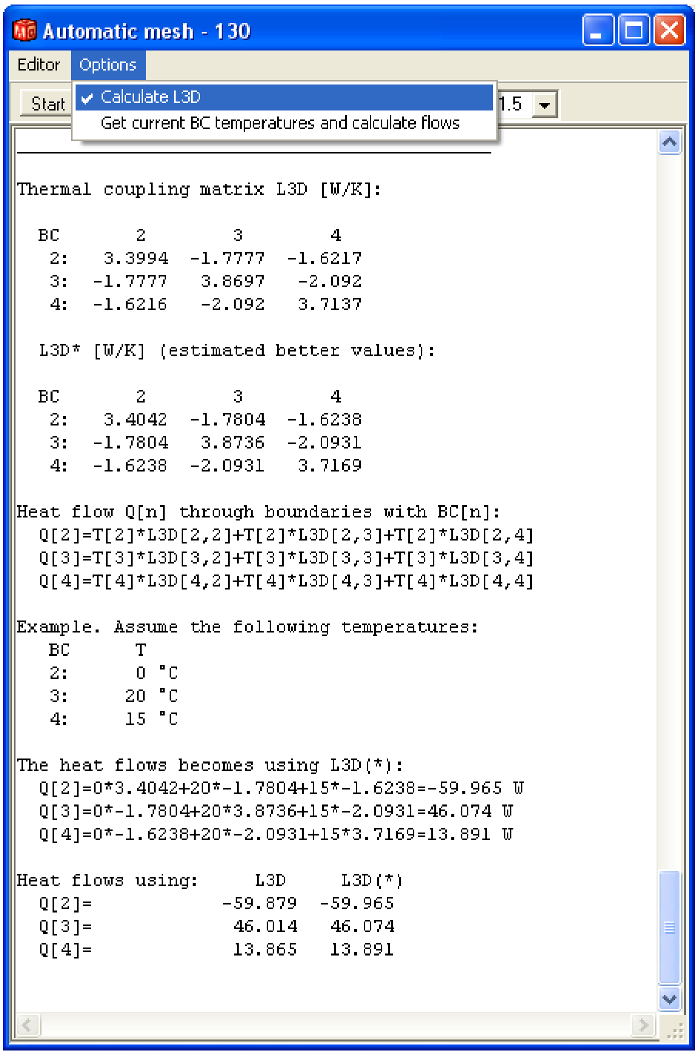
HEAT3	γ	α	β
γ	-	1,7804	1,6238
α	1,7804	-	2,0931
β	1,6238	2,0931	-

The maximum difference between the results for HEAT3 and ISO 10211 is less than 0.05%. HEAT3 automatically calculates all the above values within 60 seconds (Intel Core 2 Duo 2,4 GHz). To make these calculations do as follows:

Copy the material file **DEFAULT_ISO_TESTCASES.MTL** to the same folder where HEAT3.exe is.

1. Start HEAT3 standard version
2. Open ISO10211_CASE3.H3P
3. Go to menu **Solve/Automatic mesh and L3D window**
4. Check item **Options/Calculate L3D** (see figure below)
5. Set the drop down list box **Max diff:** to **All Levels**
6. Press **Start Calc**

Result window:



Assume the following temperatures:

BC	**T**	
2:	0 °C	(γ)
3:	20 °C	(α)
4:	15 °C	(β)

The heat flows becomes using L3D(*), see result window above:

Q[2]=0*3.4042+20*-1.7804+15*-1.6238=-59.965 W (γ)
Q[3]=0*-1.7804+20*3.8736+15*-2.0931=46.074 W (α)
Q[4]=0*-1.6238+20*-2.0931+15*3.7169=13.891 W (β)

Heat flow between pairs of environment:

(β) and (γ) : 1.6238*(15-0)=24.357 W	[ISO 10211: 24.36]	diff: 0.0%
(β) and (α) : 2.0931*(20-15)=10.467 W	[ISO 10211: 10.47]	diff: 0.0%
(α) and (γ) : 1.7804*(20-0)=35.608 W	[ISO 10211: 35.62]	diff: <0.03%

Heat flow from internal to external environment:

59,965 W	[ISO 10211: 59.98]	diff <0.03%

ISO 10211 states that the difference between the heat flows should not exceed 1%. OK!

Surface temperature factors

Surface temperature factors according to ISO 10211:

ISO 10211	**gγ**	**gα**	**gβ**
gγ	1,000	0,000	0,000
gα	0,378	0,399	0,223
gβ	0,331	0,214	0,455

Surface temperature factors according to HEAT3 standard version, number of nodes (N)=1100000:

HEAT3	**gγ**	**gα**	**gβ**
γ	1,000	0,000	0,000
α	0,3770	0,4003	0,2221
β	0,3311	0,2146	0,4545

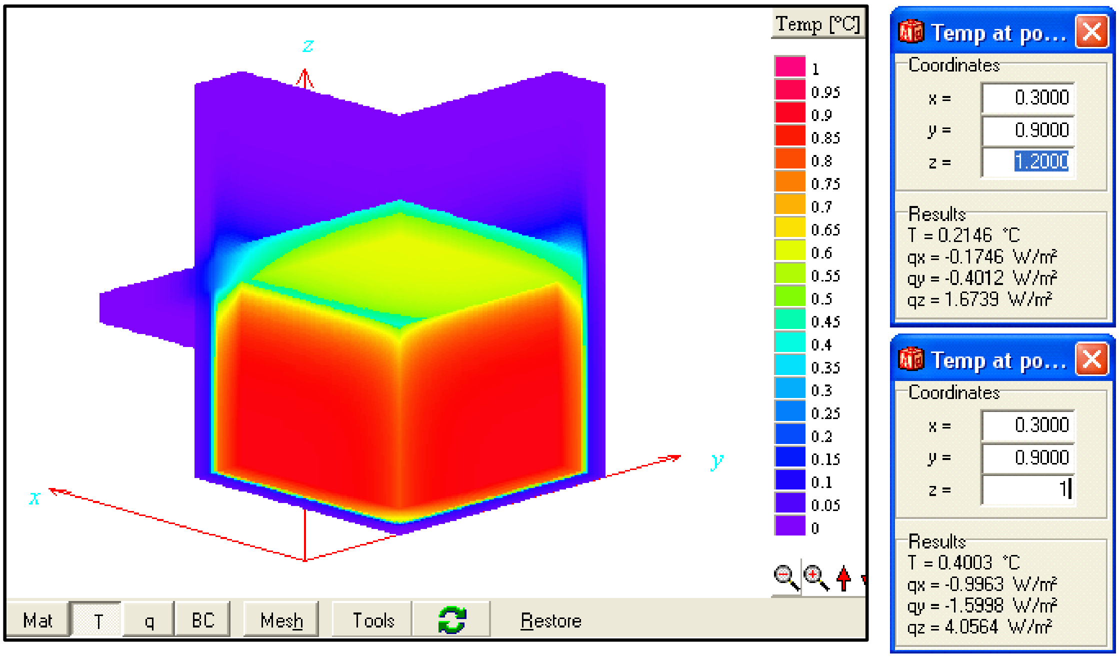
We need to make three calculations. The first one is for the boundary conditions

(α) T=1 (β) T=0 (γ) T=0

The temperature at point V is the factor (α, gα). The temperature at point Y is the factor (β, gα).

1. Start HEAT3 standard version
2. Open ISO10211_CASE3_ALPHA.H3P
3. Press **Start Steady-state calculation** (F9)
4. Open menu item **Output/Temp at point** and read the temperatures at point Y (x=0.3, y=0.9, z=1.2), and point V (x=0.3, y=0.9, z=1.0).

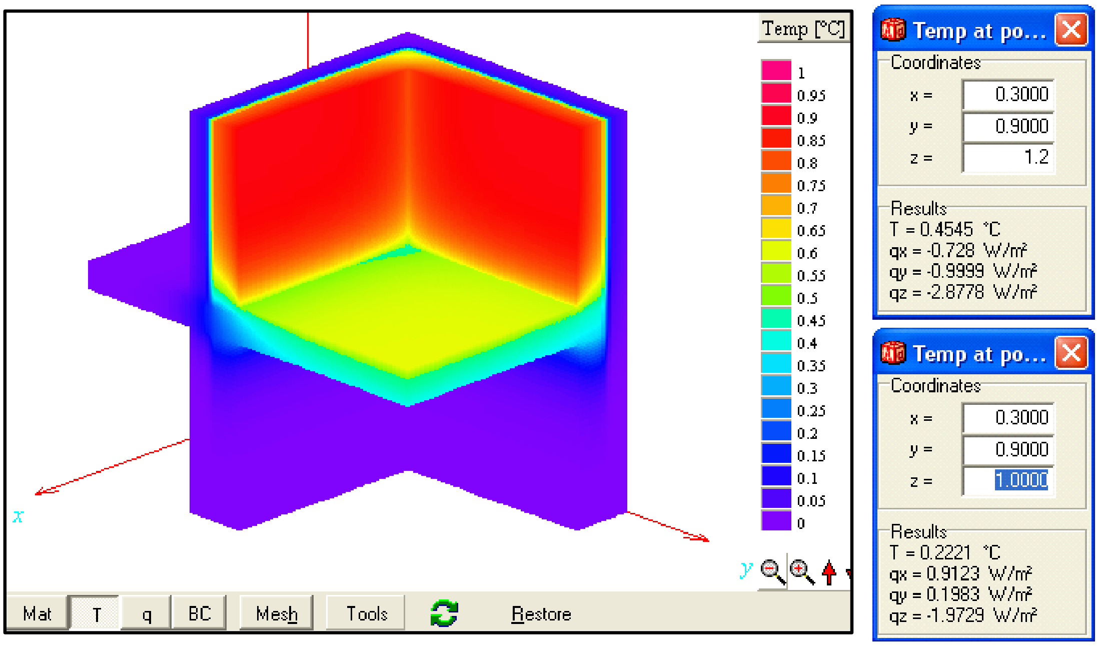
This calculation with 1,1 million nodes takes about 80 seconds (Intel Core 2 Duo 2,4 GHz).



The second calculations is made for

(α): T=0 (β): T=1 (γ): T=0 See file ISO10211_CASE3_BETA.H3P

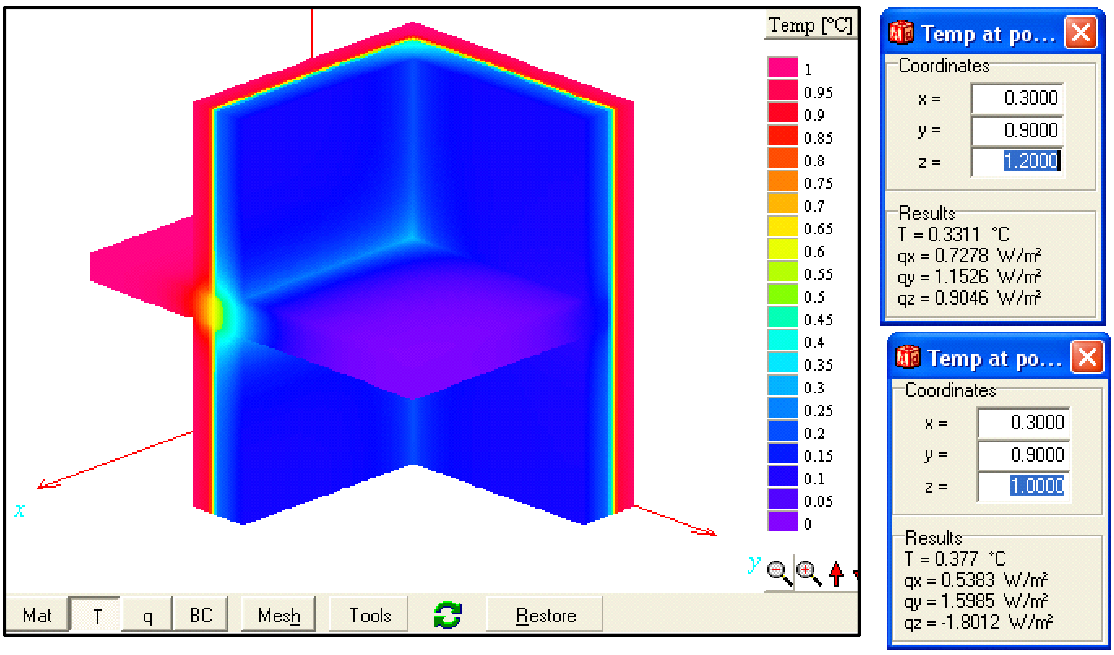
The temperature at point V is the factor (α, gβ). The temperature at point Y is the factor (β, gβ).



The third calculations is made for

(α): T=0 (β): T=0 (γ): T=1 See file ISO10211_CASE3_GAMMA.H3P

The temperature at point V is the factor (α, gγ). The temperature at point Y is the factor (β, gγ).



Assume the following temperatures:

BC	**T**	
2:	0 °C	(γ)
3:	20 °C	(α)
4:	15 °C	(β)

Lowest surface temperatures:

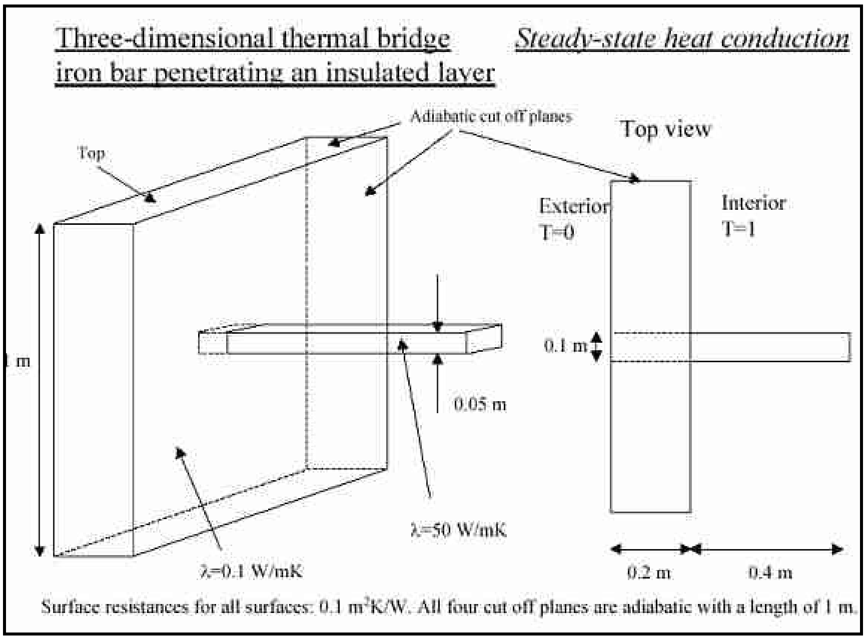
(α) : 0.4003x20+0.2221x15=11.337 [ISO 10211: 11.32] diff: 0.02 °C

(β) : 0.2146x20+0.4545x15=11.110 [ISO 10211: 11.11] diff: 0.0 °C

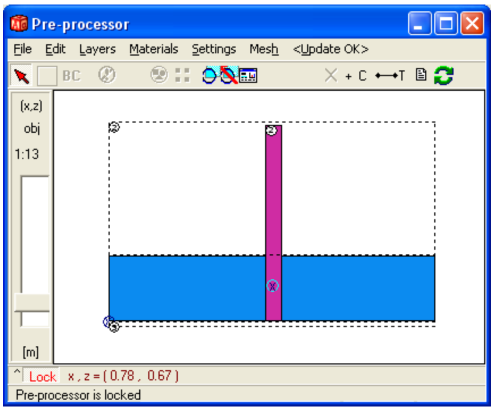
ISO 10211 states that the difference between the temperatures should not exceed 0,1 °C. OK!

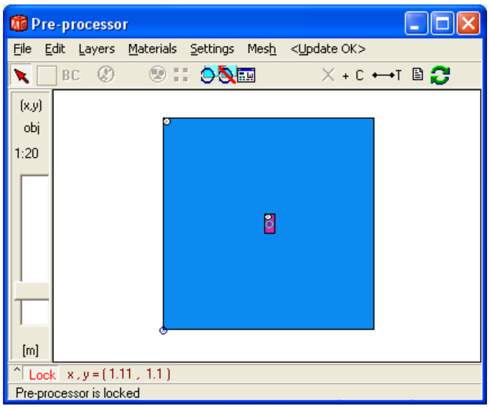
Test case 4 (HEAT3)

Case 4 is a three-dimensional thermal bridge consisting of an iron bar penetrating an insulation layer, see figure below.

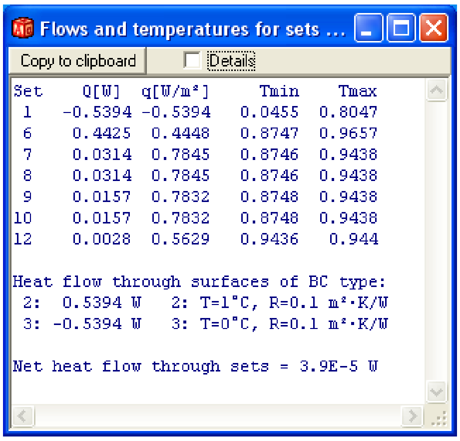


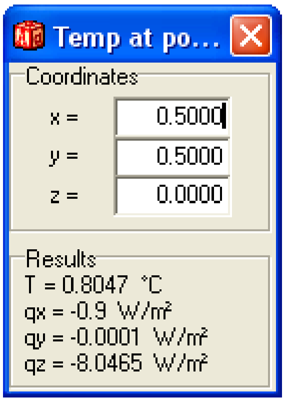
Input in pre-processor:



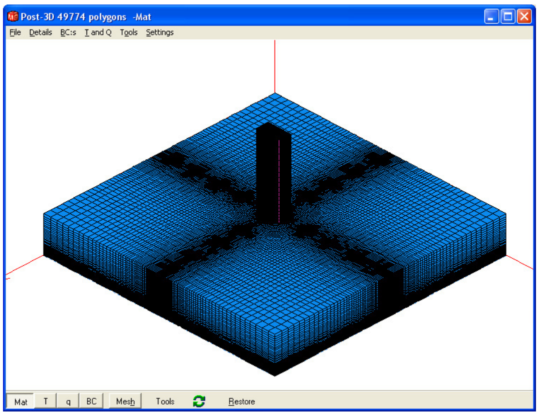


The time to solve this problem with 840 000 nodes is about 6 min on a Intel Core 2 Duo 2,4 GHz. The heat flow is 0.5394 W and the lowest temperature is 0,8047 °C (see menu item **Output/Temp at point**):





Numerical mesh:



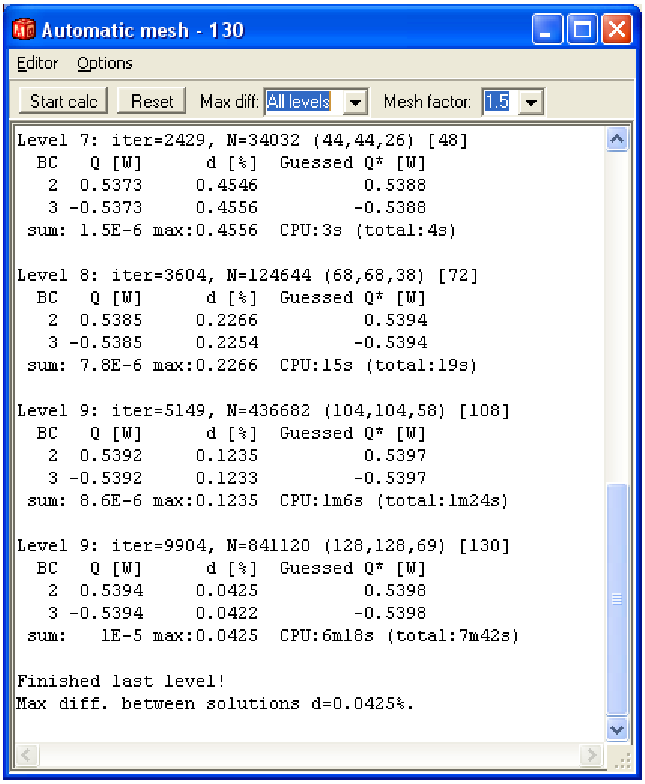
To make these calculations do as follows:

Copy the material file **DEFAULT_ISO_TESTCASES.MTL** to the same folder where HEAT3.exe is.

1. Start HEAT3 standard version
2. Open ISO10211_CASE4.H3P
3. Press **Start Steady-state calculation** (F9)

We can also use the automatic mesh feature and combine results for different meshes in order to guess a more exact heat flow. This will give q=0,5398 W and take about 8 minutes in total:

1. Start HEAT3 standard version
2. Open ISO10211_CASE4.H3P
3. Go to menu **Solve/Automatic mesh and L3D window**
4. Check item **Options/Calculate L3D** (see figure below)
5. Set the drop down list box **Max diff:** to **All Levels**
6. Press **Start Calc**



With the special version of HEAT3 (50 million nodes) a calculation takes about 4,5 hours using 15 million nodes and gives a heat flow of 0.5398 and a guessed heat flow of 0.5399: