Static and ventilated air gaps Simu-Therm 8.0

Hilger & Daniel Software GmbH
www.simu-therm.de

Contents

Structure of this tutorial

The tutorial enables you to use air gap layers in your heat loss calculation with Simu-Therm 8.0. Here "air gaps" are layers in a wall structure not filled with solid material. They may contain ambient air, a specified gas or vacuum.
First you get a short overview on the heat transfer mechanisms in air gaps. Basic examples give an impression of how those mechanisms contribute to the heat transfer under different conditions.
In the second part you learn step by step how to enter static and ventilated air gaps in Simu-Therm 8.0.

Heat transport mechanisms in air gaps

Heat is passed across air spaces in three ways:
heat conduction of air
circular convection of air
thermal radiation exchange of the surfaces

The amount of heat transport depends

in case of conduction and convection:
on **gap width, mean temperature, temperature difference**

in case of thermal radiation:
on **gap width, mean temperature, temperature difference, emissivities of the surfaces**

Impact of parameters on heat transfer

Impact on the three heat transfer mechanisms, if one of the parameters (e.g. gap width, mean temperature) is increased.

parameter	conduction	convection	radiation
gap width	falls rapidly	grows rapidly	
mean temperature	grows slightly	falls	grows rapidly
temper. difference	grows	grows	grows
air pressure		grows rapidly	

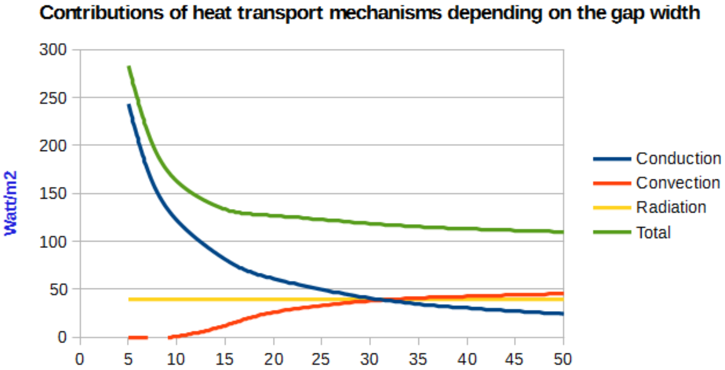
Example 1: Low temperature, low emissivity

Vertical air gap with polished metal side walls

0.1 Emissivity (total)

100 °C Temperature hot face

60 °C Temperature cold face



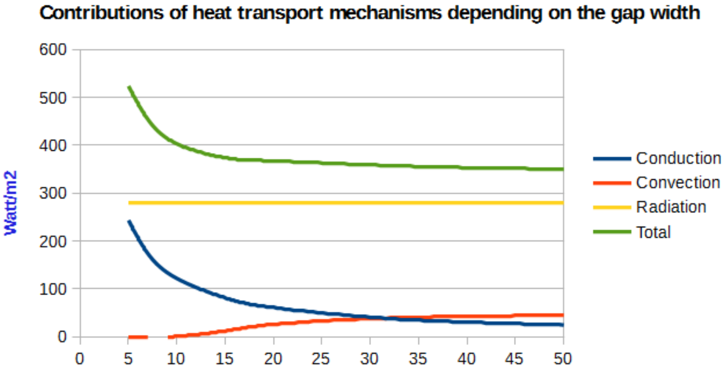
Example 2: Low temperature, high emissivity

Vertical air gap with ceramic side walls

0.7 Emissivity (total)

100 °C Temperature hot face

60 °C Temperature cold face



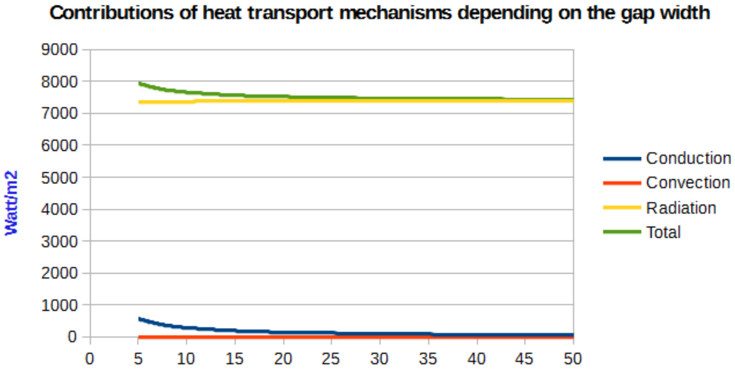
Example 3: High temperature, high emissivity

Vertical air gap with hot ceramic side walls

0.7 Emissivity (total)

800 °C Temperature hot face

760 °C Temperature cold face

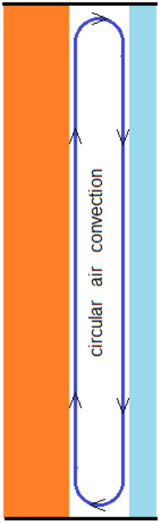


Static vertical air gap

The concept of a static air gap is applicable if the air is trapped in the cavity. This means that the air is not exchanged over a long time.

Properties of static gaps:

1. a static air space is no heat sink in the heat loss calculation
2. the thermal steady state heat balance of the air volume is settled. The cold face exactly absorbs the heat amount released by the hot face.
3. convective air flow may circulate driven by density difference, depending on the orientation of the wall

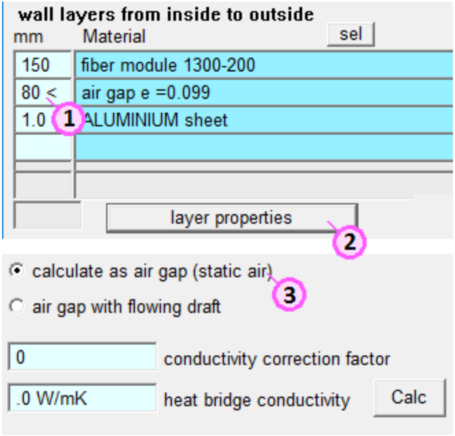


Enter a static air gap

Example: Vertical static air gap - width 80 mm
Hot face: fiber module, cold face: aluminium sheet

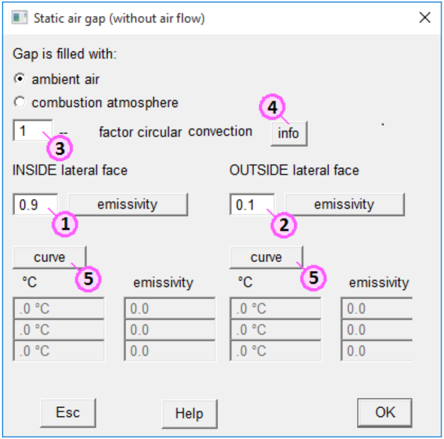
Do **ALWAYS** enter air gaps via **'layer properties'**. Otherwise the major heat transfer (convection, radiation) is not calculated correctly.

1. on the calculation page enter a 80 mm layer
2. click on **'layer properties'** The layer dialog pops up.
3. in the layer dialog select **'.. static air'**. The static air gap dialog pops up.



Static air gap dialog

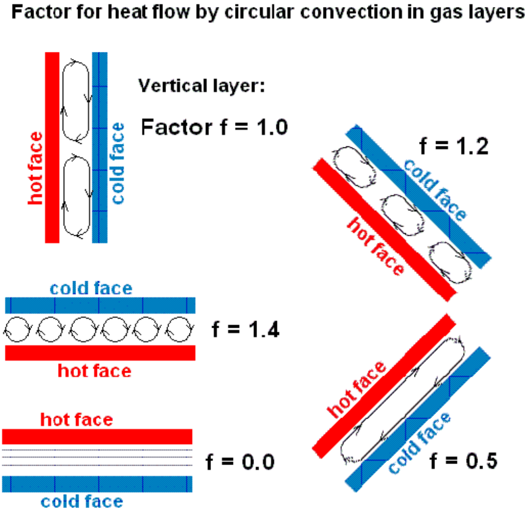
1. enter hot face emissivity **0.9** (fiber module)
2. enter cold face emissivity **0.1** (aluminium)
3. enter factor for convection depending on the orientation of the wall. The value 1.0 holds for a vertical wall
4. click on **'info'** to display an information graph, see next slide
5. if a wide temperature range has to be covered, the emissivities can be given as curves with 3 points, overriding the constant values



Info graph for convection factor

Determine the factor for convective heat transfer in an air gap depending on the orientation.

find an appropriate factor and enter it in the air gap dialog
for instance use the factor 1.0 for vertical walls

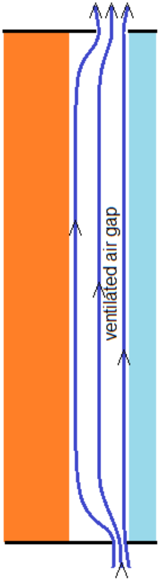


Ventilated vertical air gap

The concept of ventilated air gap means air flow from an entry to an exit driven either by thermal uplift (natural convection) or by forced convection. There are no leaks allowed between entry and exit

Properties of ventilated gaps:

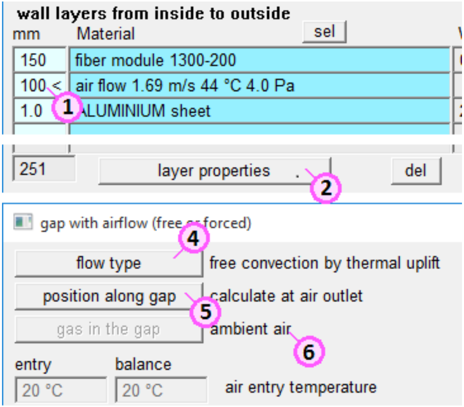
1. a ventilated air space is a heat sink in the heat loss calculation,
2. the thermal steady state heat balance of the wall is not settled, because the air flow draws heat from the wall.
3. at the entry the air is colder than at the exit. That is why the wall temperature too is slightly different at both ends. In S-T the heat loss can be calculated at entry, exit or in the middle.



Enter a ventilated air gap

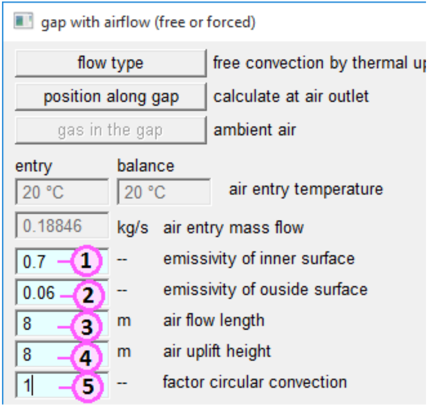
Example: Vertical wall - free convection - width 100 mm - height 8m

1. on the calculation page enter a 100 mm layer
2. click on **'layer properties'**. The layer dialog pops up.
3. in the layer dialog select **'air gap with flowing draft'**. The dialog for ventilated air gap pops up.
4. select the flow type **'free convection by thermal uplift'**
5. select the position **'calculate at air outlet'**
6. default setting: Air entry temperature = ambient temperature



Ventilated air gap dialog, part 1

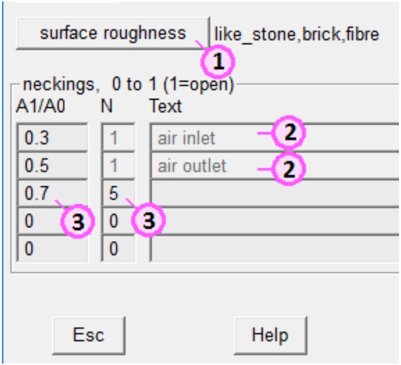
1. enter hot face emissivity **0.7** (ceramic material)
2. enter cold face emissivity **0.06** (polished aluminium sheet)
3. enter the flow length **8 m** This is the length of the way the air passes from inlet to outlet.
4. enter the uplift height **8 m** This is the height providing the uplift of the flow. It is normally $\leq$ the flow length, "$=$" in case of a vertical wall.
5. enter factor for convection depending on the orientation of the wall, see slide **Static air gap dialog**



Ventilated air gap dialog, part 2

In this part we determine the roughness and add neckings in the flow path which slow down the air flow. Note that every necking decreases the velocity of the flow and raises its exit temperature.

1. select surface type **brick, fiber** if at least one surface is not blank metal.
2. enter neckings for entry and exit **0.3, 0.5**, see slide 'Ventilated vertical air gap'
3. assume that there are 5 construction obstacles in the flow path with 70% free path at every obstacle.



Weather shield on a tube

Only the half cross section of the cap is available for each side of the tube.

1. enter H as air uplift height
2. enter L as air flow length

where $L = 2 \times \pi \times R \times a/360$

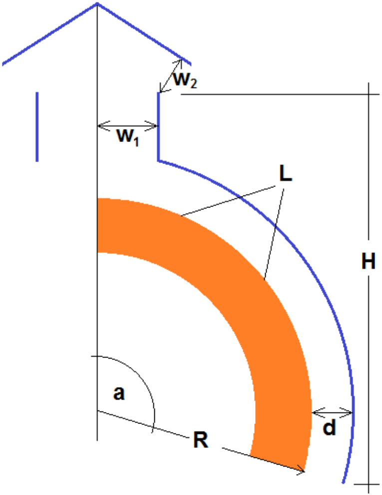
3. if $w_1 < d$ or $w_2 < d$ set air outlet

necking $N_o = \frac{w_1}{d}$ or $N_o = \frac{w_2}{d}$

Example: $a = 105$, $R = 1.5m$,
$d = 80mm$, $w_1 = 60mm$, $w_2 = 50mm$

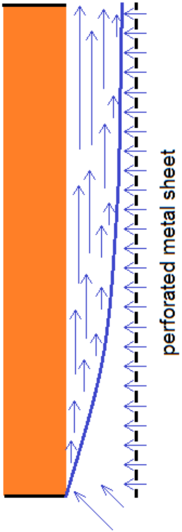
Then $N_o = \frac{50}{80} = 0.625$

and $L = 2 \times \pi \times 1,5 \times 105/360 = 2.75m$



Air space behind perforated metal sheet

To prevent people from touching a hot furnace shell, a grid or a perforated sheet may be used in place of a weather shield.
1. Assume that the grid is distant from the path of the natural convection around the shell, so that at any point the air flow through the grid is directed towards the shell.
Then the convection between grid and shell is similar to the normal natural convection.
We recommend to treat the case as standard convection, e.g. with ASTM 04.
As the grid forms an obstacle to the radiation, the surface emissivity should be modified as shown on the next slide.



Adjust emissivity in case of perforated sheet

To take into account that the radiation is decreased by the grid, we will replace the shell emissivity E_{sh} by an equivalent emissivity E_{eq}. The emissivity of the grid is E_{grid}.

$$q = 1 - (1-f)(1-E_{sh})(1-E_{grid}) \qquad (1)$$

$$E_{eq} = E_{sh}\frac{f + (1-f)E_{grid}}{q} \qquad (2)$$

Example: $f = 0.6$ (60% open), $E_{sh} = 0.3$ $E_{grid} = 0.1$
then $q = 1 - 0.4 \times 0.7 \times 0.9 = 1 - 0.252 = 0.748$
$E_{eq} = 0.3\frac{0.6+0.4\times0.1}{0.6976} = 0.3\frac{0.64}{0.748} = 0.257$
In Simu-Therm enter **0.257 in place of 0.3**.