

# Static and ventilated air gaps Simu-Therm 8.0

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# 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.

<i>parameter</i>	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	

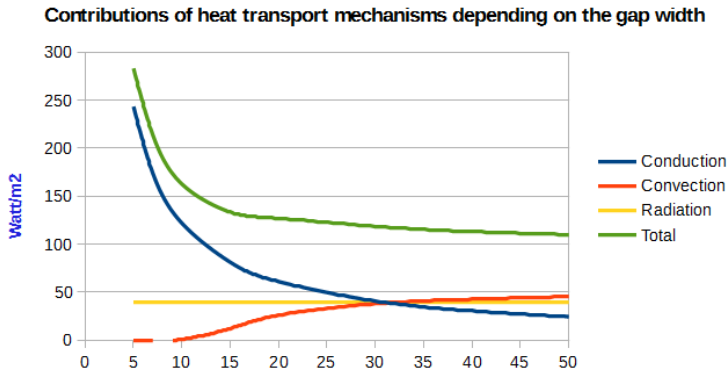
## Example 1: Low temperature, low emissivity

### Vertical air gap with polished metal side walls

0.1 Emissivity (total)

100 °C Temperature hot face

60 °C Temperature cold face



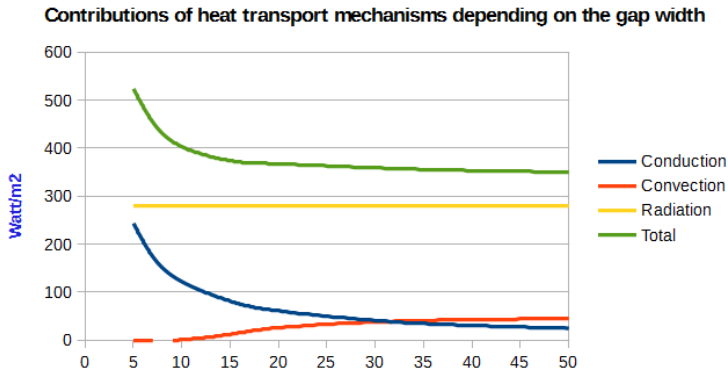
## Example 2: Low temperature, high emissivity

### 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

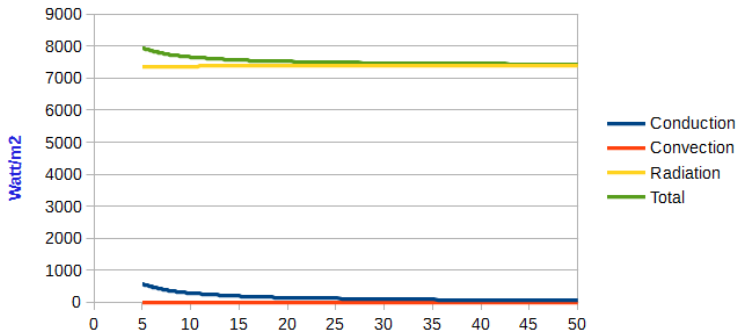
### Vertical air gap with hot ceramic side walls

0.7 Emissivity (total)

800 °C Temperature hot face

760 °C Temperature cold face

Contributions of heat transport mechanisms depending on the gap width





# 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.

The screenshot shows a software interface for defining wall layers. The title is "wall layers from inside to outside". It contains a table with columns "mm" and "Material". The table has three rows: "150 fiber module 1300-200", "80 < air gap e =0.099", and "1.0 ALUMINIUM sheet". A pink circle with the number "1" points to the "1.0" value in the "mm" column of the third row. Below the table is a button labeled "layer properties", with a pink circle and the number "2" pointing to it. Below the button are two radio button options: "calculate as air gap (static air)" (selected) and "air gap with flowing draft". A pink circle with the number "3" points to the "static air" option. At the bottom, there are two input fields: "0" for "conductivity correction factor" and ".0 W/mK" for "heat bridge conductivity". A "Calc" button is to the right of the second input field.

mm	Material
150	fiber module 1300-200
80 <	air gap e =0.099
1.0	ALUMINIUM sheet

layer properties

☒ calculate as air gap (static air)  
☐ air gap with flowing draft

0 conductivity correction factor  
.0 W/mK heat bridge conductivity

Calc

# 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

The screenshot shows the 'Static air gap (without air flow)' dialog box. It contains the following elements:

- Gap is filled with:** Two radio buttons: 'ambient air' (selected) and 'combustion atmosphere'.
- factor circular convection:** A text input field containing '1' (callout 3) and an 'info' button (callout 4).
- INSIDE lateral face:** A section with a text input field for emissivity containing '0.9' (callout 1), a 'curve' button (callout 5), and a table with 3 rows and 2 columns (°C and emissivity).
- OUTSIDE lateral face:** A section with a text input field for emissivity containing '0.1' (callout 2), a 'curve' button (callout 5), and a table with 3 rows and 2 columns (°C and emissivity).
- Buttons:** 'Esc', 'Help', and 'OK' at the bottom.

°C	emissivity
.0 °C	0.0
.0 °C	0.0
.0 °C	0.0

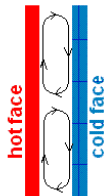
°C	emissivity
.0 °C	0.0
.0 °C	0.0
.0 °C	0.0

# Info graph for convection factor

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

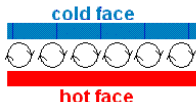
find an appropriate factor and enter it in the air gap dialog  
for instance use the factor 1.0 for vertical walls

## Factor for heat flow by circular convection in gas layers

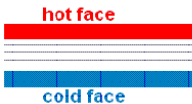


Vertical layer:

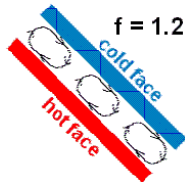
Factor  $f = 1.0$



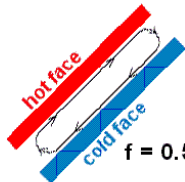
$f = 1.4$



$f = 0.0$



$f = 1.2$



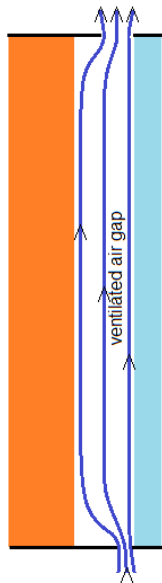
$f = 0.5$

## 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

The screenshot shows two overlapping dialog boxes in the Simu-Therm 8.0 software. The top dialog, titled 'wall layers from inside to outside', contains a table with three rows: a 150 mm 'fiber module 1300-200', a 100 mm 'air flow 1.69 m/s 44 °C 4.0 Pa' (highlighted with a pink circle 1), and a 1.0 mm 'ALUMINIUM sheet'. A pink circle 2 points to the 'layer properties' button. The bottom dialog, titled 'gap with airflow (free or forced)', has several settings: 'flow type' set to 'free convection by thermal uplift' (pink circle 4), 'position along gap' set to 'calculate at air outlet' (pink circle 5), and 'gas in the gap' set to 'ambient air' (pink circle 6). At the bottom, 'entry' and 'balance' temperatures are both set to 20 °C, with a label 'air entry temperature'.

mm	Material
150	fiber module 1300-200
100	air flow 1.69 m/s 44 °C 4.0 Pa
1.0	ALUMINIUM sheet

251 layer properties del

gap with airflow (free or forced)

flow type free convection by thermal uplift

position along gap calculate at air outlet

gas in the gap ambient air

entry balance

20 °C 20 °C air entry 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**

gap with airflow (free or forced)

flow type	free convection by thermal up	
position along gap	calculate at air outlet	
gas in the gap	ambient air	

entry	balance	
20 °C	20 °C	air entry temperature
0.18846	kg/s	air entry mass flow
0.7 - ①	--	emissivity of inner surface
0.06 - ②	--	emissivity of outside surface
8 - ③	m	air flow length
8 - ④	m	air uplift height
1 - ⑤	--	factor circular convection

## 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.

A1/A0	N	Text
0.3	1	air inlet
0.5	1	air outlet
0.7	5	
0	0	
0	0	



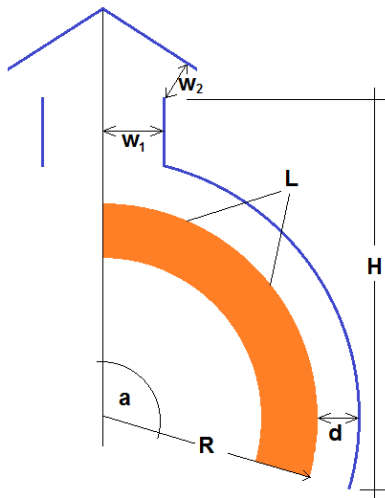
## Weather shield on a tube

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

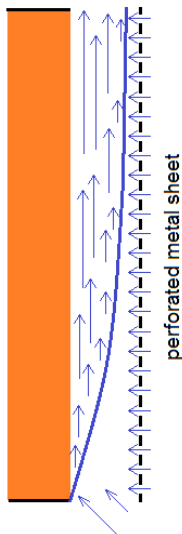
To prevent people from touching a hot furnace shell, a grid or a perforated sheet may be used in place of a weather shield.

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  $E_{grid}$ .

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

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

Example:  $f = 0.6$  (60% open),  $E_{sh} = 0.3$   $E_{grid} = 0.1$

then  $q = 1 - 0.4 \times 0.7 \times 0.9 = 1 - 0.252 = 0.748$

$$E_{eq} = 0.3 \frac{0.6 + 0.4 \times 0.1}{0.6976} = 0.3 \frac{0.64}{0.748} = 0.257$$

In Simu-Therm enter **0.257** in place of **0.3**.

