Web Application: Frictional Pressure Gradient in Straight Pipes and U-Bends

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Introduction

The purpose of the developed program is to calculate pressure gradients in two phase flow in horizontal pipes based on flow patterns. Besides calculating pressure drops in straight tubes, the program provides the possibility of calculating pressure drops in U-Bends with three different orientations.

The correlations used in the calculations are taken from the following publications:

> Leszek Wojtan, Thierry Ursenbacher, John R. Thome: Investigation of flow boiling in horizontal tubes: Part I—A new diabatic two-phase flow pattern map; April 2005
>
> Leszek Wojtan, Thierry Ursenbacher, John R. Thome: Investigation of flow boiling in horizontal tubes: Part II - Development of a new heat transfer model for stratified-wavy, dryout and mist flow regimes; April 2005
>
> Jesús Moreno Quibén, John R. Thome: Flow pattern based two-phase frictional pressure drop model for horizontal tubes. Part I: Diabatic and adiabatic experimental study; April 2007
>
> Jesús Moreno Quibén, John R. Thome: Flow pattern based two-phase frictional pressure drop model for horizontal tubes, Part II: New phenomenological model. April 2007
>
> Ricardo J. Da Silva Lima, John R. Thome: Two-phase frictional pressure drops in U-bends and contiguous straight tubes for different refrigerants, orientations, tube, and bend diameters: Part 1. Experimental results. Nov 2012
>
> Ricardo J. Da Silva Lima, John R. Thome: Two-phase frictional pressure drops in U-bends and contiguous straight tubes for different refrigerants, orientations, tube, and bend diameters: Part 2. New models. Nov 2012

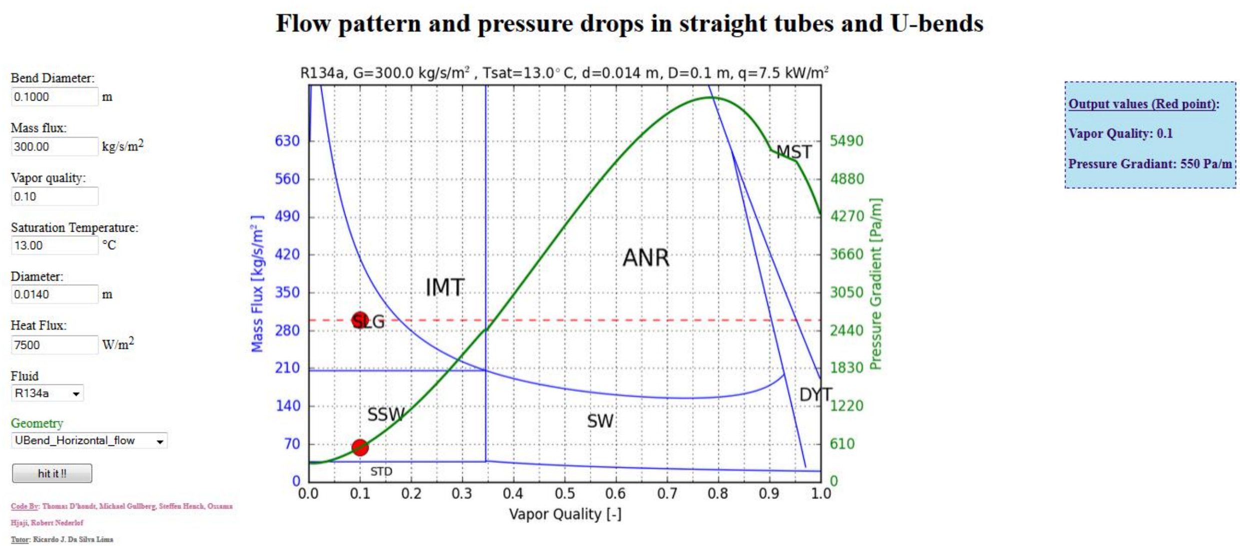
The following short manual describes the usage, in/outputs and the limitations of the web application for calculating pressure gradients in straight tubes and U bends

Web Layout and User interface

Figure 1 depicts the user interface of the program which can be accessed with a browser. On the left side all input parameters for the computation are listed. These are from top to bottom: The bend diameter of the U-bend in meters, the mass flux of the fluid flowing through the pipe in $kg/(s*m^2)$, one vapor quality, the saturation temperature of the used fluid in K, the inner diameter of the pipe in m and the heat flux in W/m^2. The last two fields are dropdown menus, which let the user change the used fluid and the geometry of the calculated pipe.

When a parameter is changed in the value fields, the user has to click the "hit it" button, to start a new calculation. When changing the drop down menus, a new calculation is automatically started.

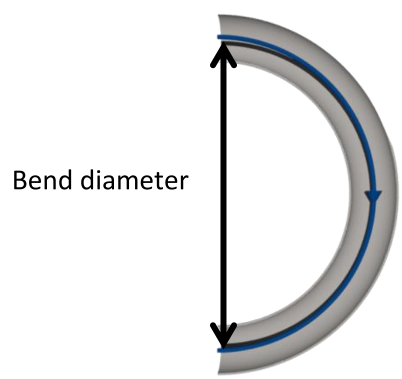
The result of the pressure gradient computation is displayed in one graph on the right of the webpage. More detail about this graph is given in the output section.



Inputs

In the following section, the input parameters are explained in more detail.

The first input parameter is the **bend diameter**. It is not used when the Geometry dropdown menu is set to straight tube. Figure 2 depicts that the bend diameter is defined as the diameter of the middle line of the U bend.



The **mass flux** field requires as an input the mass flux in kg/(s*m^2) in the pipe.

The vapor quality input has no impact on the computation. The only reason of this field is to provide the opportunity to get the pressure gradient for a specific vapor quality as a numerical output. Additionally, the entered vapor quality will be shown as a red dot in the output graph.

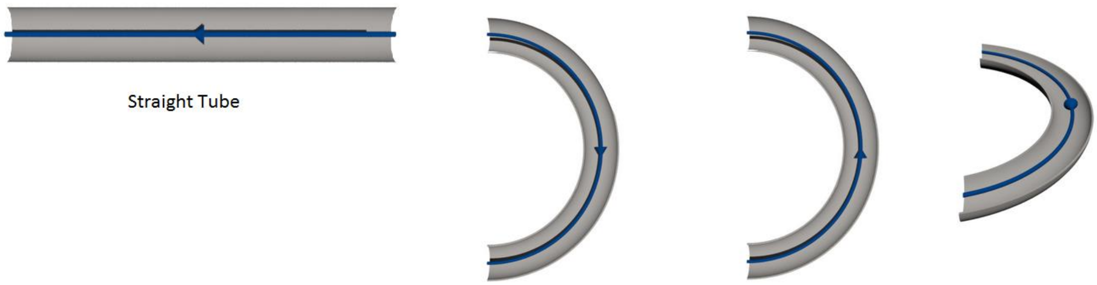
The **saturation temperature** is dependent of the fluid and the pressure in the pipe. As the pressure will be different from one application to the other, the saturation temperature of the fluid is kept as an input. It has to be entered in °C.

The **diameter** field requires as an input the inner diameter of the pipe in meter.

The **heat flux** is the heating power affecting the tube, it is measured in W/m^2. The evaporation in the U-bend is highly dependent on the heat flux. The bigger it is, the quicker dryout and mist flow will be reached in a tube.

The **fluid** is the desired working fluid, which can be chosen in the drop down menu.

The **Geometry** of the tube can be chosen in the drop down menu. The different geometries available are displayed in the figure below, with 4 different options.



Straight Tube

U Bend - Vertical downflow

U Bend - Vertical upflow

U Bend - Horizontal flow

Outputs

In the following section, the output parameters of the web application are explained in more detail.

The **graph** displays the process path the fluid takes while going through the U-bend or straight tube for different vapor qualities. By doing this, the characteristics of each flow regime can be determined by comparing it with the corresponding pressure gradient.

A **pressure gradient** is obtained and displayed as a function of the vapor quality and mass flux in the graph. In the example graph above, the mass flux is set to 300 which the red line implies. For a chosen vapor quality by the user, the pressure gradient is displayed in the blue box to the right, as well as in the graph with a red dot. The pressure gradient is calculated in Pa/m, where m represents the tube length.

Program Limits

In order to make the web application showing good results which are in the range of the correlations used, a few limits had to be implemented to control the user inputs.

- The bend diameter (D) is limited to the range of 0.0025 to 1000 meter.
- The mass flux G is limited to the range of 100 to 1200 kg/(s*m^2).
- The inner tube diameter (d) is limited to the range of 10^{-7} to 0.02 meter.
- The saturation temperature is limited for each fluid by its min and max.