7. Category Flow

7.1. Flow Rates

7.1.1. Purpose (What can it be used for? What can it not be used for?)

The program is part of category 2 – flow rates. Whenever a fluid, either liquid or gas, is forced passing through a defined pathway, there are defined process values in a direct coherence to each other, if the frictional losses should be disregarded. At first there are the geometrical dimensions of the pipe or a vessel for example. The important geometrical dimensions are diameter respectively the area and the length. A certain amount of gas or liquid can be moved through the pipe or vessel in a certain time, which results the flow rate at least. Area and flow rate together will result a corresponding velocity.

The length of the pipe or it can also be the height of a vessel is important for the determination of the volume. Flow rate and volume are in coherence with the time it takes, to pass through the pipe work or the vessel or to fill it up.

The program provides the calculations between the above mentioned variables. It is divided up into two parts. In the first part diameter respectively area, flow rate and velocity are selectable. The selected variable will be the calculated one as an output variable. The others are input variables. In the second part length, volume and time are selectable. The selected variable will be the input variable. The residual two are output variables and will be calculated.

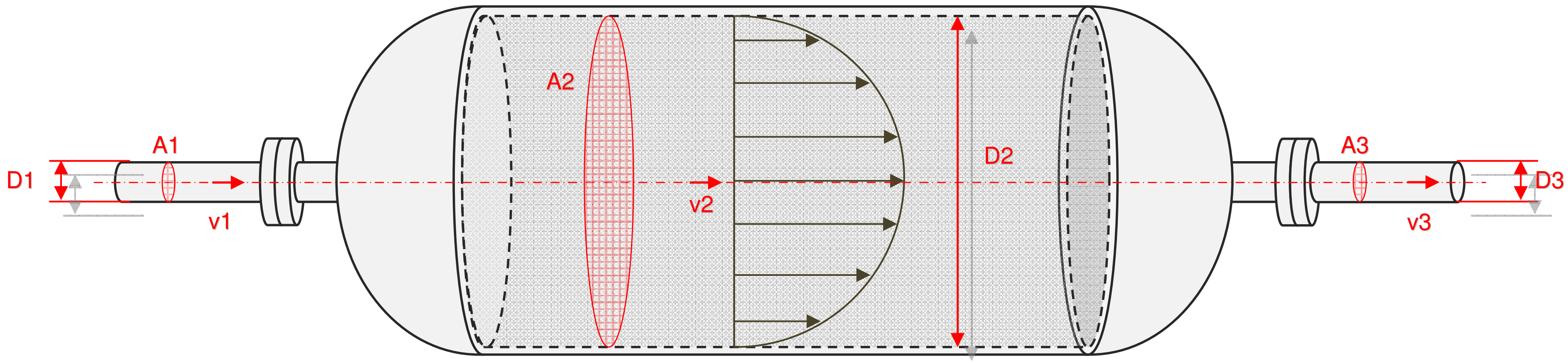


Figure 43: sketch flow rates

7.1.2. Variables (What are the input and output values? What are their limits?)

diameter

It is the inner diameter of the pipes or vessels, which are focus for the calculations. If the results should be more exactly, the real inner diameter has to be filled – remember that the nominal diameter is different from the inner diameter and depends on the type and material especially for pipes.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- millimeter [mm],
- centimeter [cm],
- meter [m].

The minimum limit is 0.1.
The maximum limit is 99999.
The replacement value is 200.
The number of digits is 15.

area

It is the area of the pipes or vessels, which are focus for the calculations. The pipe or vessel itself can either have a circular section and a corresponding diameter or any other section. It is selectable. If the selection for the circular section is checked, the area is calculated from the diameter else a value for the area can be entered directly. The area of the pipes or vessels and the flow rate of the fluid going through the pipes or vessels will result the fluid velocity.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- millimeter square [mm²],
- centimeter square [cm²],
- meter square [m²].

The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 15.

flow rate

It is the flow rate of the fluid going through the pipes or vessels, which are focus for the calculations. The flow rate and the pipe or vessel area will result the velocity of the fluid.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- meter cube per hour [m^3 / h],
- liters per second [l / s],
- liters per minute [l / min],
- liters per hour [l / h].

The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 15.

velocity

It is the velocity of the fluid going through the pipes or vessels, which are focus for the calculations. The velocity of the fluid depends on the flow rate and the pipe or vessel area.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- kilometer per hour [km / h],
- meter per hour [m / h],
- meter per minute [m / min],
- meter per second [m / s],
- centimeter per second [cm / s],
- millimeter per second [mm / s].

The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 15.

length

It is the length of the pipe or it can also be the height of a vessel, which is filled up or where a flow is passing through. In case the length is selected as an Output, it can be determined either by volume and area or by time and velocity.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- millimeter [mm],
- centimeter [cm],
- meter [m].

The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 15.

volume

It is the volume of the pipe work or it can also be the volume of a vessel for example, which is filled up or where a flow is passing through. In case the volume is selected as an Output, it can be determined either by length and area or by time and flow rate.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- millimeter cube [mm^3],
- centimeter cube [cm^3],
- liter [l],
- meter cube [m^3].

The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 15.

time

It is the transfer duration, which is the time that it takes the fluid to pass through the piping system or a vessel for example. In case the time is selected as an Output, it can be determined either by length and velocity or by volume and flow rate.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- second [s],
- minute [min],
- hour [h],
- days [d].

The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 15.

7.1.3. Operation (How can it be used? How to proceed?)

Step 6:
Fill the Input-*TextBoxes*
I enter the values for the input variables. I should respect the variable limits and take care that the entered values are numeric.

Step 4:
Select the variable to be calculated
By clicking on the corresponding *RadioButton* I can choose the variable to be calculated. It is like executing an internal conversion of the equation.

Step 5:
Select the given variable
One of the three variables is an Input and the other two are Outputs. The selected variable is the Input. The other two will be calculated.

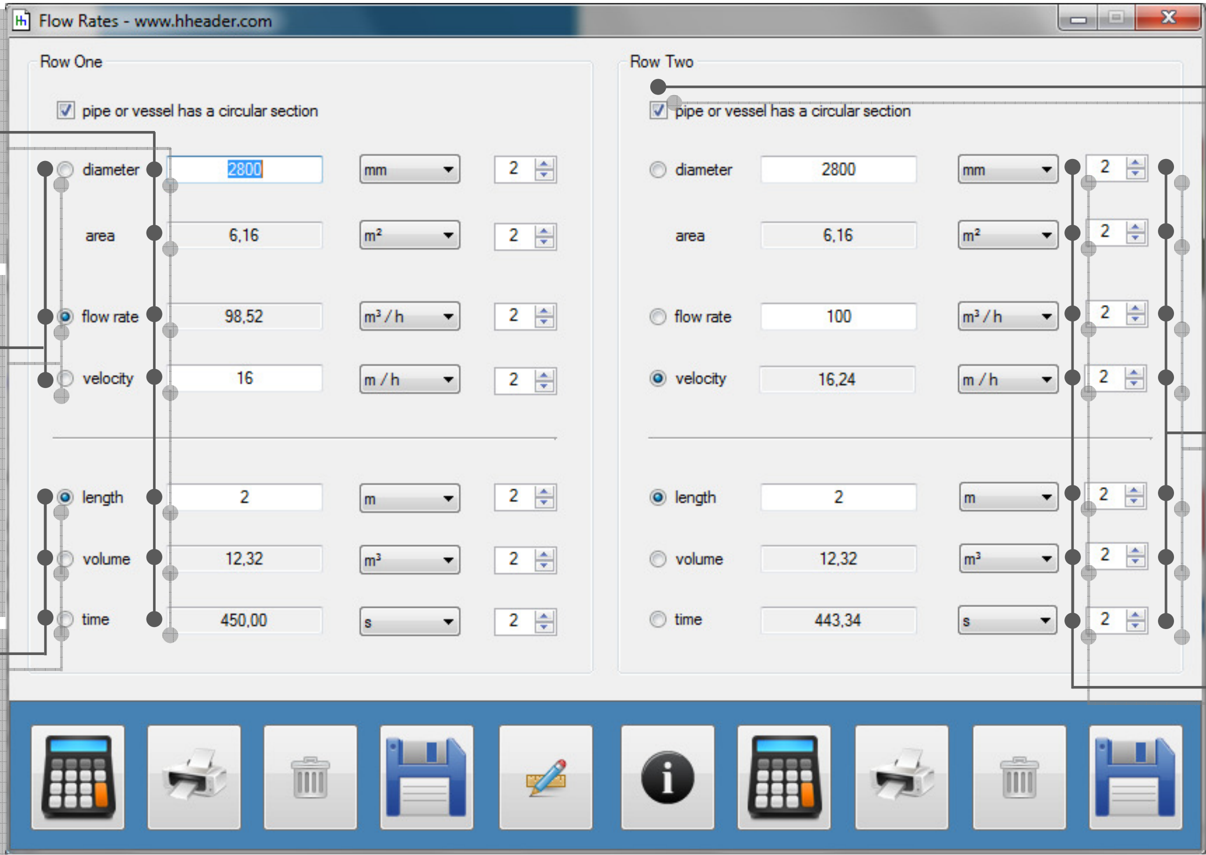


Figure 44: form flow rates

Step 1:
Pipe or vessel section
I can select if the section of the pipe or vessel is circular or not. In case the *CheckBox* is selected, the diameter is an Input and the area will be calculated. If the *CheckBox* is not selected, the *TextBox* for the diameter will disappear and the area becomes an Input.

Step 2:
Decimal places
I enter the number of decimal places for the variables. It is valid only if the corresponding variable is selected as an Output. The input variables can get more or less decimal numbers according to the number of digits.

Step 3:
Units
There is a choice of different units for each variable.

Step 8:
Check results
After clicking the Calculate-Button I can check the results.

Step 7:
Calculate result
After I entered the input values I can calculate the result. Before the calculation starts, all the input values are checked by an internal routine. Whenever entered values decrease the corresponding min limits or increase the corresponding max limits or are not numeric, there will be a message according to the fault. The values will be corrected automatically by the internal routine.

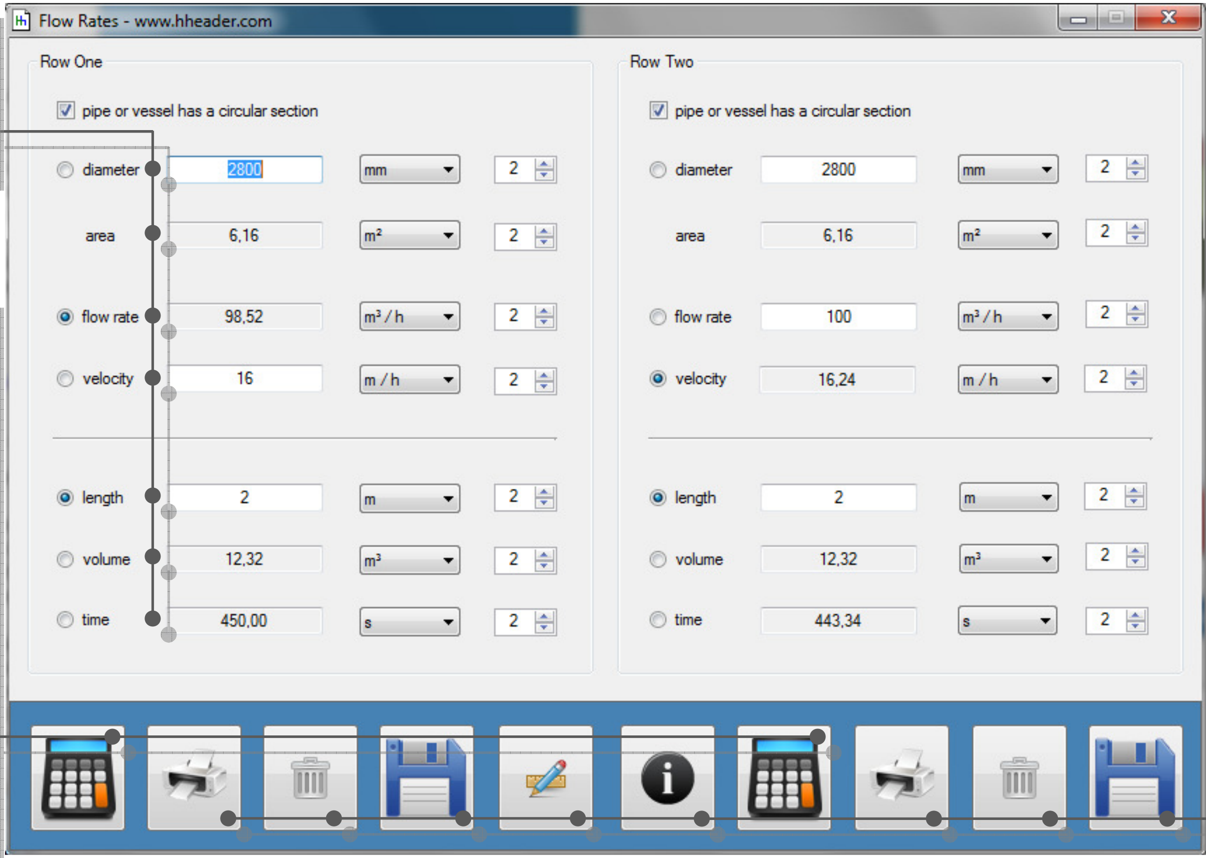


Figure 45: form flow rates

Step 9:
Further actions
After the calculation I can have the following options: Print Data, Erase Data, Program Information, Notes, Save or Restore Values, Hint. While printing a new calculation is done automatically. Clicking the Erase-Button will empty all the *TextBoxes* at once.

7.2. Charges

7.2.1. Purpose (What can it be used for? What can it not be used for?)

The program is part of category 2 – flow rates. Each flow (e.g. air- or water flow) can include a certain content of matter, which is perforce transported with the flow, either as particles or also possibly dissolved or evaporated within the fluid. Sometimes it can be of interest to know the total mass of matter transferred as part of the flow rate by time. Especially if there is a charge limit according to a maximum accumulation for example or for any other reason. The program provides required calculations regarding this subject. A measure for the matter content is its concentration. It defines how many parts of matter are included in how many fluid flow units. Due to this there are three main parameters to be taken into consideration: the flow rate of the fluid, the concentration of matter and the time of operation. Knowing about these parameters enables to calculate also further variables like the mass of matter or the by time transferred volume.

In case an operation has started already before and the total mass of matter, which is the charge limit, is known as a fixed parameter, it is comfortable to have the option to enter the previous runtime in order to get the total mass divided up into previous and residual mass. This is also provided by this program. Further the residual runtime and also the corresponding to the runtimes transferred volumes can be calculated. If a dividing of previous and residual parameters is not required, the previous runtime can be just kept as zero.

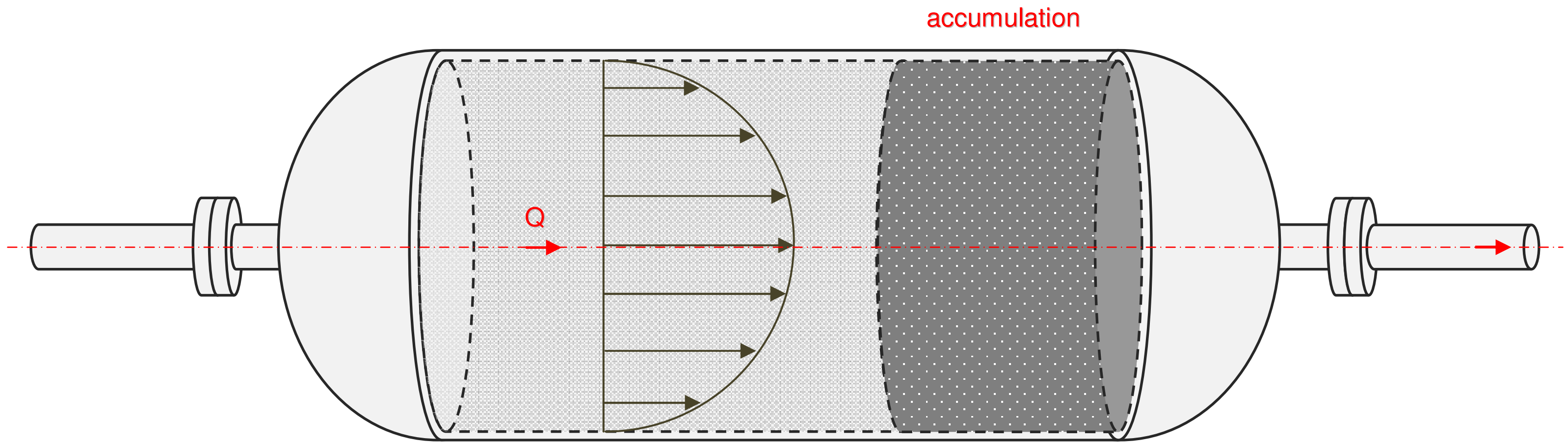


Figure 46: sketch charges

7.2.2. Variables (What are the input and output values? What are their limits?)

total charge limit

It is the total mass of matter that is transferred by time as partly content of the flow rate. It is supposed, that a certain part of the flow rate is matter. The measure for this is the concentration defined by the mass of matter in relation to a volume unit. The flow rate multiplied by the concentration multiplied by time results the transferred mass of matter.

The variable type is Input.
For this variable a selection of different units is provided:

- milligram [mg],
- gram [g],
- kilogram [kg],
- tons [tons].

The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

concentration

It is the concentration of matter as partly content of the flow rate. It is supposed, that a certain part of the flow rate is matter. The measure for this is the concentration defined by the mass of matter in relation to a volume unit. The flow rate multiplied by the concentration multiplied by time results the transferred mass of matter.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- parts per quadrillion [ppq],
- parts per trillion [ppt],
- parts per billion [ppb],
- parts per million [ppm],
- per mille [per mille],
- percent [%],
- microgram per liter [µg / l],
- milligram per liter [mg / l],
- grams per liter [g / l],
- grams per meter cube [g / m^3],
- kilograms per meter cube [kg / m^3].

The minimum limit is 0.0001.
The maximum limit is variable. The concentration is not allowed to exceed 100% or the density value.
The replacement value is 100.
The number of digits is 10.

flow rate

It is the flow rate for the fluid, which transfers the matter content. The flow rate multiplied by the concentration multiplied by time results the transferred mass of matter. The flow rate multiplied by the density is equal the mass flow.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- meter cube per hour [m^3 / h],
- liter per second [l / s],
- liter per minute [l / min],
- liter per hour [l / h].

The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

density

It is the density of the fluid, which is transferred trough the piping system. It is not the density of the matter! It is obvious, that the temperature takes influence on the density. The density is the limiting value for the concentration.

The variable type is Input.
The unit is kilogram per liter [kg / l].
The minimum limit is 0.000001.
The maximum limit is 33.33.
The replacement value is 1.
The number of digits is 10.

mass flow

It is the mass flow for the fluid, which transfers the matter content. The mass flow divided by the density is equal to the flow rate. The flow rate multiplied by the concentration multiplied by time results the transferred mass of matter.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- kilogram per second [kg / s],
- kilogram per minute [kg / min],
- kilogram per hour [kg / h],
- tons per hour [tons / h].

The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

total duration

It is the total duration that it takes to transfer the charge limit by the flow rate. The charge limit over flow rate by concentration is the time for transferring the mass of matter.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- second [s],
- minute [min],
- hour [h],
- days [days],
- weeks [weeks],
- months [months],
- years [years].

The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

eff. previous runtime

It is the effective previous runtime. This variable can be entered as an option in case if a transfer was started already before. In this case the total duration will be divided up into the effective previous runtime and the residual runtime. Corresponding to this the previous transferred mass and the residual mass are calculated. The sum of previous mass and residual mass is the total charge limit. Also the corresponding volumes are calculated accordingly. The sum of previous volume and residual volume is the total volume.

The variable type is Input.
For this variable a selection of different units is provided:

- second [s],
- minute [min],
- hour [h],
- days [days],
- weeks [weeks],
- months [months],
- years [years].

The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

residual runtime

It is the residual runtime. If a transfer was started already before, the total duration will be divided up into the effective previous runtime and the residual runtime. Corresponding to this the previous transferred mass and the residual mass are calculated. The sum of previous mass and residual mass is the total charge limit. Also the corresponding volumes are calculated accordingly. The sum of previous volume and residual volume is the total volume.

The variable type is Output.
For this variable a selection of different units is provided:

- second [s],
- minute [min],
- hour [h],
- days [days],
- weeks [weeks],
- months [months],
- years [years].

There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

previous mass

It is the previous transferred mass. If a transfer was started already before, the total duration will be divided up into the effective previous runtime and the residual runtime. Corresponding to this the previous transferred mass and the residual mass are calculated. The sum of previous mass and residual mass is the total charge limit. Also the corresponding volumes are calculated accordingly. The sum of previous volume and residual volume is the total volume.

The variable type is Output.
For this variable a selection of different units is provided:

- milligram [mg],
- gram [g],
- kilogram [kg],
- tons [tons].

There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

residual mass

It is the residual mass to be transferred. If a transfer was started already before, the total duration will be divided up into the effective previous runtime and the residual runtime. Corresponding to this the previous transferred mass and the residual mass are calculated. The sum of previous mass and residual mass is the total charge limit. Also the corresponding volumes are calculated accordingly. The sum of previous volume and residual volume is the total volume.

The variable type is Output.
For this variable a selection of different units is provided:

- milligram [mg],
- gram [g],
- kilogram [kg],
- tons [tons].

There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

total volume

It is the total volume, which is required to transfer the full charge limit mass of matter content in the flow. The flow rate multiplied by the total duration will result the total volume. The sum of previous volume and residual volume is the total volume.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- millimeter cube [mm^3],
- centimeter cube [cm^3],
- liter [l],
- meter cube [m^3].

There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

previous volume

It is the previous volume, which was required to transfer the previous mass of matter content in the flow. The flow rate multiplied by the previous runtime will result the previous volume. The sum of previous volume and residual volume is the total volume.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- millimeter cube [mm^3],
- centimeter cube [cm^3],
- liter [l],
- meter cube [m^3].

There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

residual volume

It is the residual volume, which will be required to transfer the residual mass of matter content in the flow. The flow rate multiplied by the previous runtime will result the previous volume. The sum of previous volume and residual volume is the total volume.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- millimeter cube [mm^3],
- centimeter cube [cm^3],
- liter [l],
- meter cube [m^3].

There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

7.2.3. Operation (How can it be used? How to proceed?)

Step 5:
Fill the Input-*TextBoxes*
I enter the values for the input variables. I should respect the variable limits and take care that the entered values are numeric.

Step 4:
Select the given variable
Between flow rate and mass flow it is possible to choose the input and output variable. If the *CheckBox* is selected, the mass flow can be entered as given value and the flow rate will be calculated via the density. If the *CheckBox* is not selected, the flow can be entered as given value and the mass flow will be calculated via the density.

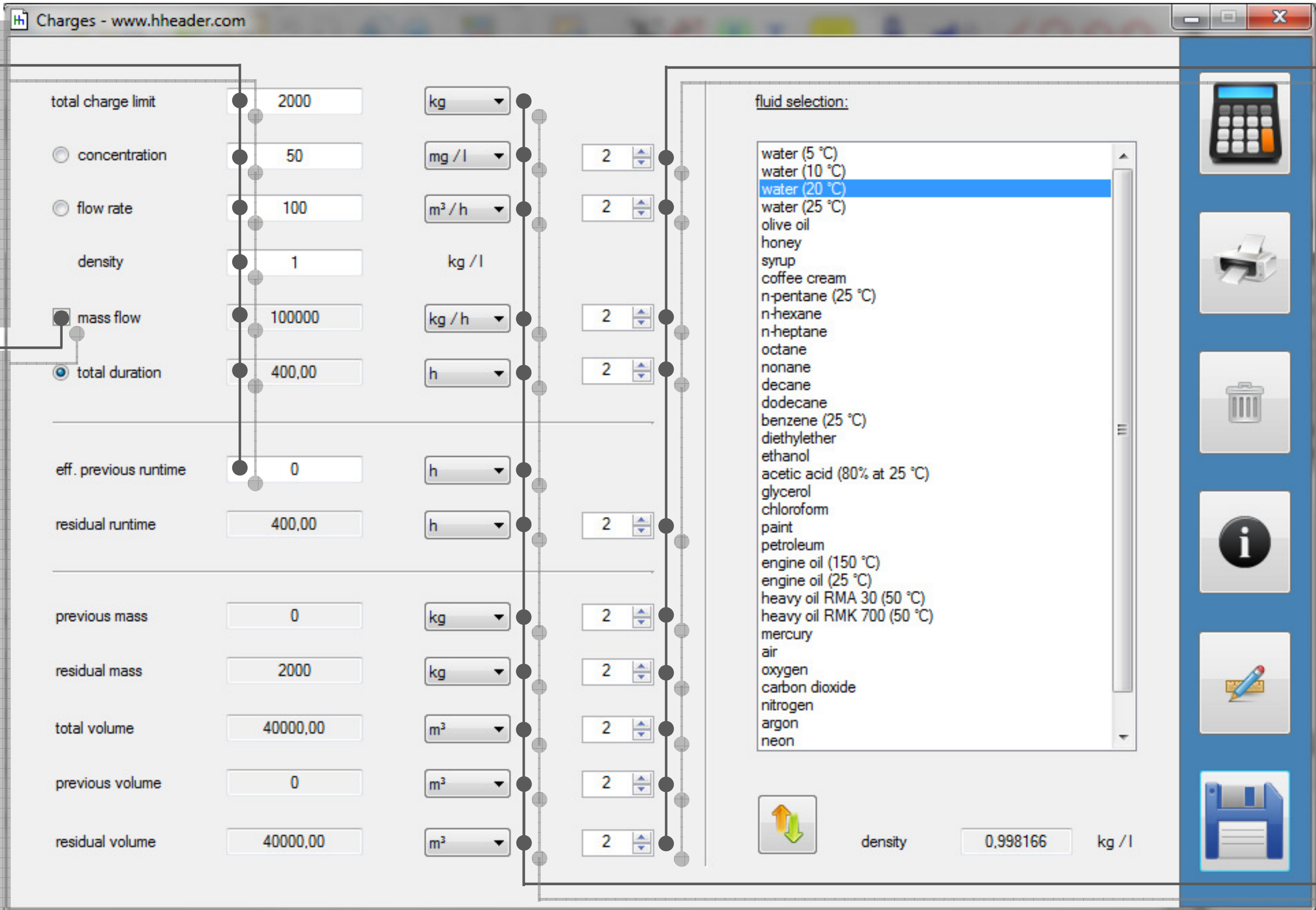


Figure 47: form charges

Step 2:
Decimal places
I enter the number of decimal places for the variables. It is valid only if the corresponding variable is selected as an Output. The input variables can get more or less decimal numbers according to the number of digits.

Step 3:
Units
There is a choice of different units for each variable.

Step 7:
Calculate result
After I entered the input values I can calculate the result. Before the calculation starts, all the input values are checked by an internal routine. Whenever entered values decrease the corresponding min limits or increase the corresponding max limits or are not numeric, there will be a message according to the fault. The values will be corrected automatically by the internal routine.

Step 6:
Select the variable to be calculated
By clicking on the corresponding *RadioButton* I can choose the variable to be calculated. It is like executing an internal conversion of the equation.

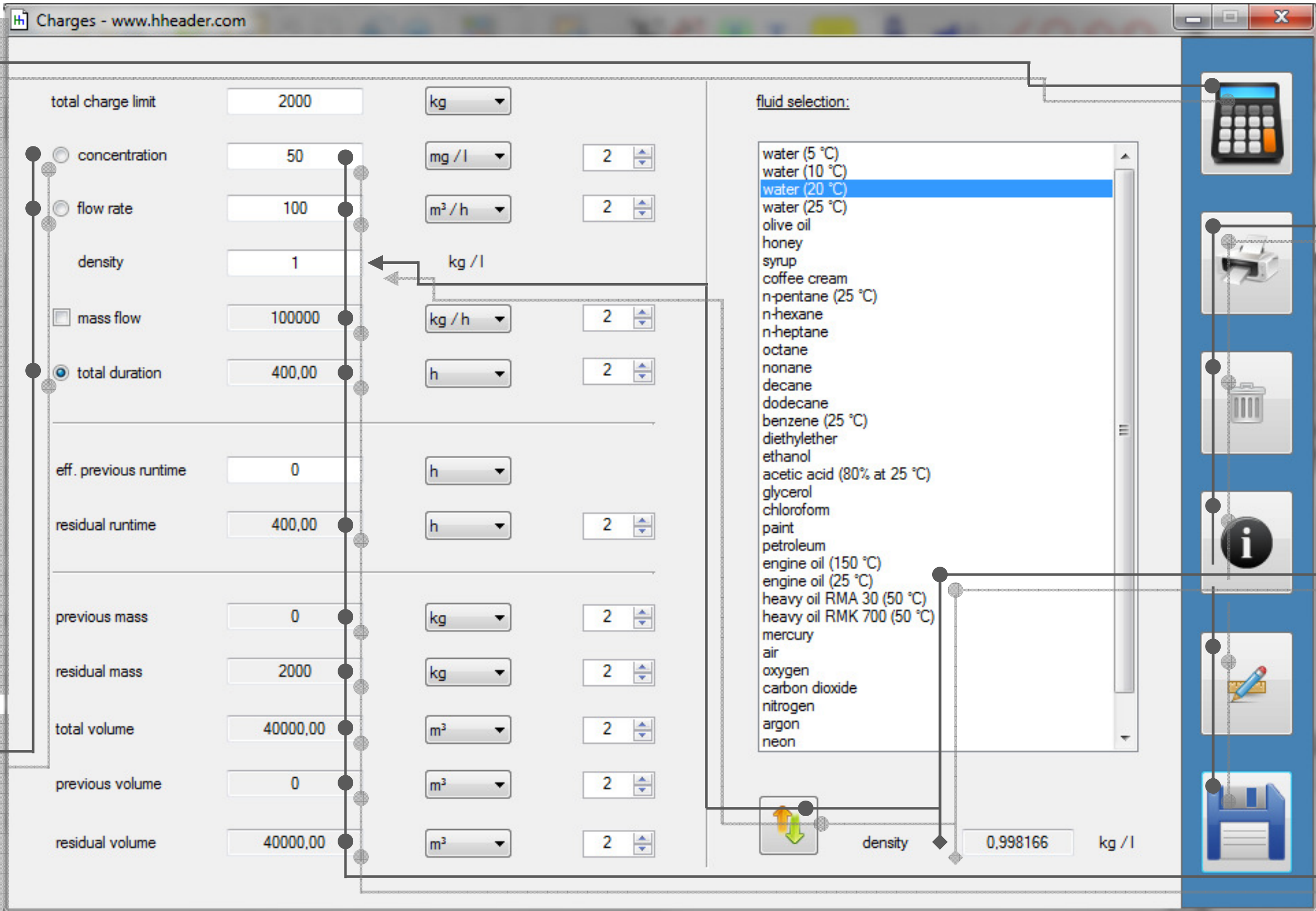


Figure 48: form charges

Step 9:
Further actions
After the calculation I can have the following options: Print Data, Erase Data, Program Information, Notes, Save or Restore Values, Hint. While printing a new calculation is done automatically. Clicking the Erase-Button will empty all the *TextBoxes* at once.

Step 1: (option)
density
By selecting a fluid the corresponding density is shown in the *TextBox* below. It is an average value. Using the Transfer-Button will move the value into the Input-*TextBox*.

Step 8:
Check results
After clicking the Calculate-Button I can check the results.

7.3. Operating Conditions

7.3.1. Purpose (What can it be used for? What can it not be used for?)

The program is part of category 2 – flow rates. For any type of gas flow there are different parameters relevant regarding the properties and the behavior under different physical circumstances. While gas is moving from one process stage to another, parameters like pressure, temperature and humidity can change and take effect on the system. Because temperature, pressure and humidity will take influence also on the gas density, it is required to consider gas flow rates under a defined standard condition in order to carry out an adequate evaluation. The standard condition is defined at a temperature of 0°C and a pressure of 1013.25 mbar. Changing the pressure or the temperature will lead to an operating condition and result a different flux. Depending on the parameters and circumstances water can evaporate into the air flow or saturate from the air flow. The program can evaluate the properties and the behavior of an air flow while changing from one duty point with a defined temperature, pressure and humidity to another duty point with a defined temperature, pressure and humidity. It is also possible to consider a full saturation of water, in case if the air flow passes an air scrubber during the process for example. So there are always two duty points in focus for the calculations: duty point one (DP1) and duty point two (DP2). For duty point one temperature, pressure, humidity and the operation flow rate can be entered as input variables. The input variables for duty point two are temperature and pressure, the humidity and the operation flux are calculated. The following parameters are determined for both duty points: saturation vapor pressure, partial pressure H2O vapor, moisture content, saturation temperature, standard flux (rheumy and dry), air mass flow (rheumy and dry) and the water mass flow (flow H2O content). Beside this also the dew point at a constant pressure, the remaining water capacity and the condensation rate are determined.

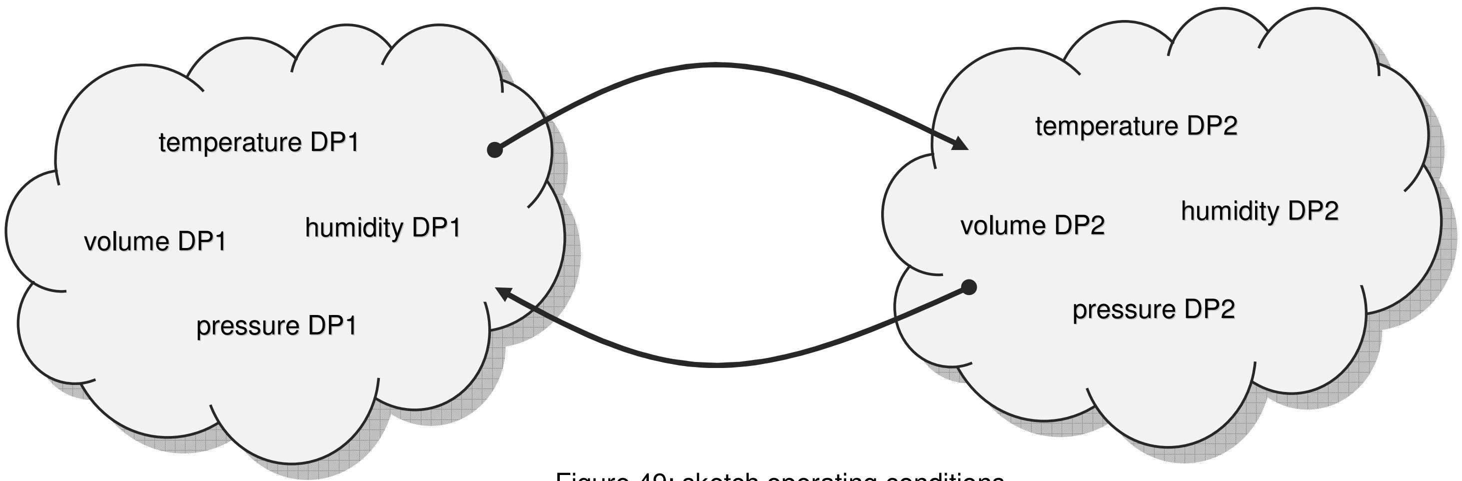


Figure 49: sketch operating conditions

Terms of pressure

Handling the steam table requires to be familiar with some different terms of pressure. The following descriptions should give an adequate overview regarding the use of the programs.

zero pressure (vacuum)

The zero pressure (vacuum) is the pressure in a physically perfect vacuum (empty space, e.g. outer space). The theoretical value is zero bar. It is the reference value for the absolute pressure value.

atmospheric pressure

The atmospheric pressure is an external pressure, which is affected by many different and various parameters (weather, altitude, etc.). The atmospheric pressure is changing continuously and is never constant.

standard pressure

The standard pressure is a reference point for many physically and technically procedures (1013.25 mbar absolute). It is the value of the assumed atmospheric pressure at the mean sea-level on earth.

gauge pressure

The gauge pressure is the measured differential pressure to the surrounding ambient pressure. It is a relative pressure. Pressure measuring can only take place to a reference pressure level.

zero pressure altitude

The zero pressure altitude is the altitude measured from the earth surface, where the pressure is almost equal the zero pressure (vacuum). This is approximately 100 km above the mean-sea level (Kármán-Line).

ambient pressure

The ambient pressure is the external pressure at a defined location. In most cases this is equal to the atmospheric pressure as long as rooms are not pressure-capsulated. The ambient pressure can also be artificially induced e.g. in a pressure chamber.

differential pressure

The differential pressure is the difference between two pressure levels ($\Delta p = p1 - p2$). Pressure measuring can only take place to a reference pressure level.

absolute pressure

The absolute pressure is the differential pressure to the zero pressure of a physically perfect vacuum.

Relations

+ generally	The absolute pressure value is equal to gauge pressure value plus the atmospheric pressure value.	$p_{abs} = p_{gauge} + p_{atm}$
+ practically	The absolute pressure value is equal to gauge pressure value plus the standard pressure value of 1013.25 mbar (location earth, mean see level).	$p_{abs} = p_{gauge} + p_{sta}$

Notes:

The air flow and also the contained water content are assumed to be ideal gases regarding the relations of this program. This is justifiable up to a pressure of 15 bar (198.47 °C) for air.

The maximum limit for the saturation temperature is according to the steam table values for saturated steam at 374.14 °C (220.9 bar). The minimum limit for the saturation temperature is according to the approximate Goff-Gratch equation (approximately -100 °C). This equation is used for the values below 50°C.

Further keep in mind that the partial pressure is limited by the saturation vapor pressure and water contents exceeding the limits given by the saturation vapor pressure value can only be moved by the air flow as fog. Fog is disregarded for the corresponding calculations.

Upon closer inspection the saturation vapor pressure is not only in coherence with the temperature, but also slowly increasing with respect to the operation pressure. This influence is disregarded for the corresponding calculations.

Be aware that all the mentioned facts will take influence on the accuracy of the calculations!

7.3.2. Variables (What are the input and output values? What are their limits?)

temperature

It is the temperature which is corresponding to the considered duty point. The range for this variable is according to an adequate accuracy for the calculations (due to the approximate Goff-Gratch equation and the Steam Table - saturation conditions).

The variable type is Input.
The unit is degree Celsius [°C].
The minimum limit is -100.00.
The maximum limit is 374.14.
The replacement value is 20.
The number of digits is 10.

eff. relative humidity

It is the effective relative humidity which is corresponding to the considered duty point. The relative humidity is the percentage value of the actual partial pressure value (H_2O) in relation to the saturation pressure value (H_2O).

The variable type is Input for DP1 or Output for DP2.
The unit is percent [%].
The minimum limit is 0.1.
The maximum limit is 100.
The replacement value is 50.
The number of digits is 10.

pressure (absolute)

It is the absolute pressure value which is corresponding to the considered duty point. Under standard circumstances the pressure of the earth atmosphere is specified as 1013.25 mbar (mean sea level).

The variable type is Input.
The unit is millibar [mbar].
The minimum limit is 100.
The maximum limit is 220900.
The replacement value is 1013.25.
The number of digits is 10.

saturation vapor pressure

It is the saturation vapor pressure value (H_2O) which is corresponding to the considered duty point. The saturation vapor pressure is depending on the temperature. In capsulated system it is the pressure value where the liquid and gaseous states of aggregation are in balance.

The variable type is Output.
The unit is millibar [mbar].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

partial pressure H2O vapor

It is the partial pressure for the water vapor which is corresponding to the considered duty point. There is a partial pressure for each ingredient of the gas composition. The sum-up of all partial pressures will result the total system pressure. The partial pressure value is the pressure which would be generated in case if only the corresponding compound would exist in the considered volume.

The variable type is Output.
The unit is millibar [mbar].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

saturation temperature

It is the saturation temperature for the water vapor which is corresponding to the considered duty point. The saturation temperature in in coherence with the saturation pressure. It is the temperature where the water vapor has its minimum thermal energy without precipitating or where the liquid water has its maximum thermal energy without evaporating.

The variable type is Output.
The unit is degree Celsius [°C].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

moisture content

It is the moisture content which is corresponding to the considered duty point. The moisture content is the mass of water in one meter cube of the gas composition. Thereby the partial and the saturation pressures are relevant. The moisture content is the reciprocal value of the specific volume steam table value from the Steam Table.

The variable type is Output.
The unit is gram or kilogram per meter cube [g / m^3] or [kg / m^3].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

operation flux

It is the operation flux which is corresponding to the considered duty point. It is the flux that can be measured at the actual values for temperature, pressure and humidity.

The variable type is Input for DP1 and Output for DP2.
The unit is meter cube per hour [m^3 / h].
The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 10.
The number of digits is 10.

standard flux (rheumy)

It is the rheumy standard flux which is corresponding to the considered duty point. It is the rheumy flux that is according to a temperature of 0°C and a pressure of 1013.25 mbar.

The variable type is Output.
The unit is meter cube per hour [m^3 / h].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

air mass flow (rheumy)

It is the rheumy air mass flow which is corresponding to the considered duty point. For the determination of this value the operation flux is relevant.

The variable type is Output.
The unit is kilogram per hour [kg / h].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

standard flux (dry)

It is the dry standard flux which is corresponding to the considered duty point. It is the dry flux that is according to a temperature of 0°C and a pressure of 1013.25 mbar.

The variable type is Output.
The unit is meter cube per hour [m^3 / h].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

air mass flow (dry)

It is the dry air mass flow which is corresponding to the considered duty point. For the determination of this value the standard flux (dry) and the standard density of air is relevant.

The variable type is Output.
The unit is kilogram per hour [kg / h].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

flow H2O content

It is the water content of the rheumy air mass flow which is corresponding to the considered duty point. It is at least resulting from the difference of rheumy and dry air mass flow.

The variable type is Output.
The unit is kilogram per hour [kg / h].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

remaining capacity H2O

It is the remaining water capacity for the corresponding duty point. It is a measure for the mass flow of water that can additionally evaporate into the air. It is in coherence to the difference of saturation pressure and partial pressure under consideration of the flow rate. The remaining water capacity is standing in opposite to the total condensation rate which is a measure for the mass flow of water that will saturate from the air.

The variable type is Output.
The unit is gram per kilogram [kg / h].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

dew point

It is the temperature that must be decreased at a constant pressure in order to start saturating water from the rheumy air flow. It can be at least relevant for both duty points.

The variable type is Output.
The unit is degree Celsius [°C].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

total condensation rate

It is the total condensation rate for duty point two at least. It is a measure for the mass flow of water that will saturate from the air in case if the remaining water capacity is zero. The total condensation rate is standing in opposite to the remaining water capacity which is a measure for the mass flow of water that can additionally evaporate into the air.

The variable type is Output.
The unit is kilogram per hour [kg / h].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

7.3.3. Operation (How can it be used? How to proceed?)

Step 3:
Calculate result
After I entered the input values I can calculate the result. Before the calculation starts, all the input values are checked by an internal routine. Whenever entered values decrease the corresponding min limits or increase the corresponding max limits or are not numeric there will be a message according to the fault. The values will be corrected automatically by the internal routine.

Step 2:
Fill the Input-*TextBoxes*
I enter the values for the input variables. I should respect the variable limits and take care that the entered values are numeric.

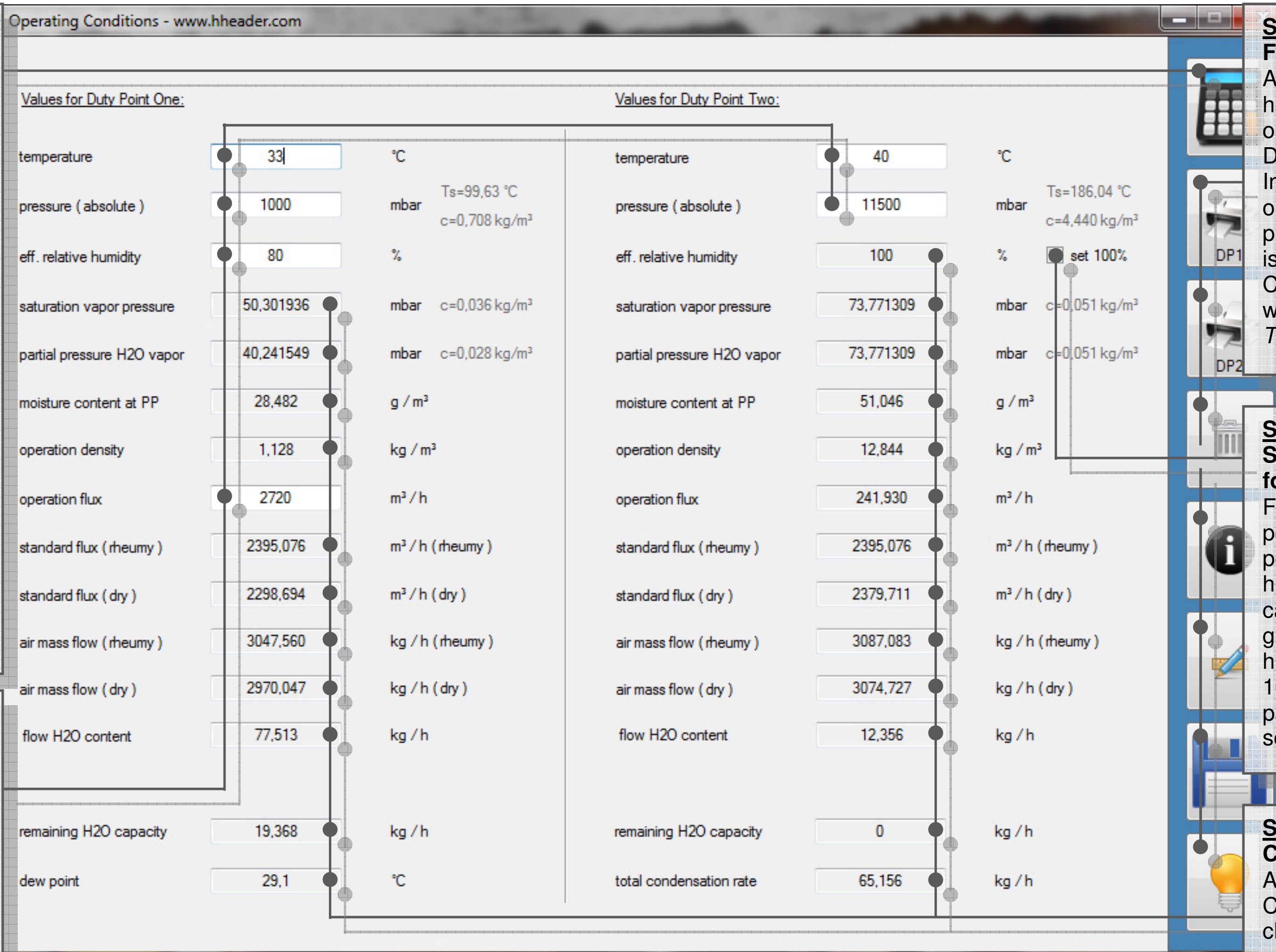


Figure 50: form operating conditions

Step 5:
Further actions
After the calculation I can have the following options: Print Data, Erase Data, Program Information, Notes, Save or Restore Values. While printing a new calculation is done automatically. Clicking the Erase-Button will empty all the *TextBoxes* at once.

Step 1:
Select humidity result for duty point two
For the humidity of duty point two there are two possibilities. One: the humidity can be calculated due to the given values. Two: the humidity can be set to 100% in case if the air is passing through an air scrubber for example.

Step 4:
Check result
After clicking the Calculate-Button I can check the result.

7.4. Standard Conditions

7.4.1. Purpose (What can it be used for? What can it not be used for?)

The program is part of category 2 – flow rates. On site we often find an installed system for the treatment of process- or exhaust air. Therefore the air is usually extracted by suction from different locations of the plant. Generally this is done by a fan. The required flow rates depend on different parameters. The performance of the fan and the pipe installation set-up will amongst other things result corresponding pressures on the suction and pressure side of the fan. Another important parameter is the gas temperature. In order to draw a balance with a sum up and a comparison of all the different flow rates, it is required to consider the flow rate values under equal conditions. These are at least the nominal standard conditions at a temperature of 0 °C and a pressure of 1013.25 mbar. By the way it is obvious, that the humidity will also take influence on the calculation values. In this program the influence of the humidity is disregarded for mainly two practical reasons. One: in most cases there are permanent flow rate measurements fix installed into the pipes. These measurements have always a certain inaccuracy, which is mainly based on the fact, that it is impossible to get a proper average value for the entire pipe area with a fix installed device. It is not rare, that the measurement inaccuracy is bigger than the humidity influence. Two: in most cases there are no permanent humidity measurements installed into the pipe. The manual measuring of the humidity can be extensive and the humidity can also change depending on the process in a short term. By this program the flow rates of twelve different rows respectively lines can be compared and summed up. The rows that should be included in the calculation can be selected via *CheckBoxes*. For each line the operation flux, the actual temperature and the actual gauge pressure can be entered as input variables. The nominal standard flux and the difference between operation and standard flux will be calculated. At the end the standard flow rates of all selected lines will be summed up. For each line it is possible to enter a designation and an additional note in order to classify the single calculations clearly.

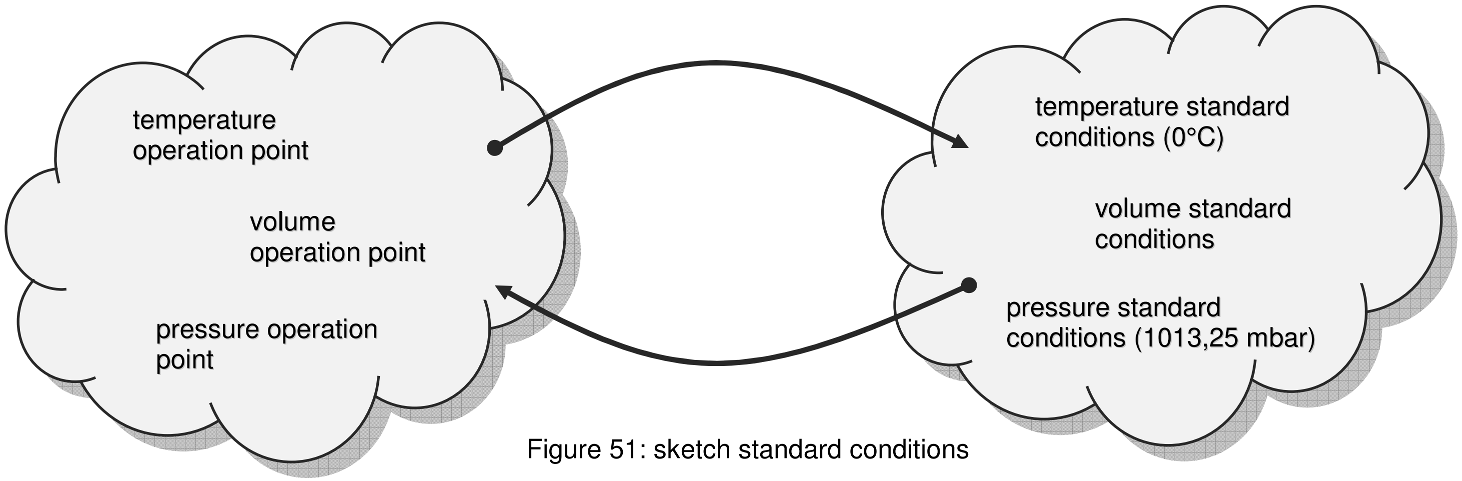


Figure 51: sketch standard conditions

7.4.2. Variables (What are the input and output values? What are their limits?)

operation flux

It is the operation flux that can be measured at the actual values for temperature and pressure.

The variable type is Input.
The unit is meter cube per hour [m^3 / h].
The minimum limit is 0.001.
The maximum limit is 99999999.
The replacement value is 100.
The number of digits is 10.

pressure (gauge)

It is the gauge pressure value. Under nominal circumstances the pressure of the earth atmosphere is specified as 1013.25 mbar. The gauge measures the differential pressure to the atmosphere. In this case the gauge shows zero if the absolute pressure is 1013.25 mbar. The range for the variable is according to an adequate accuracy for the calculations.

The variable type is Input.
The unit is millibar [mbar].
The minimum limit is -500.
The maximum limit is 9999.
The replacement value is 50.
The number of digits is 8.

temperature

It is the temperature of the gas flow at the position of the measurement of the operation flux.

The variable type is Input.
The unit is degree Celsius [°C].
The minimum limit is -100.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 8.

standard flux

It is the standard flux that is according to a temperature of 0°C and an absolute pressure of 1013.25 mbar, which refers to a gauge pressure of 0 mbar (nominal conditions).

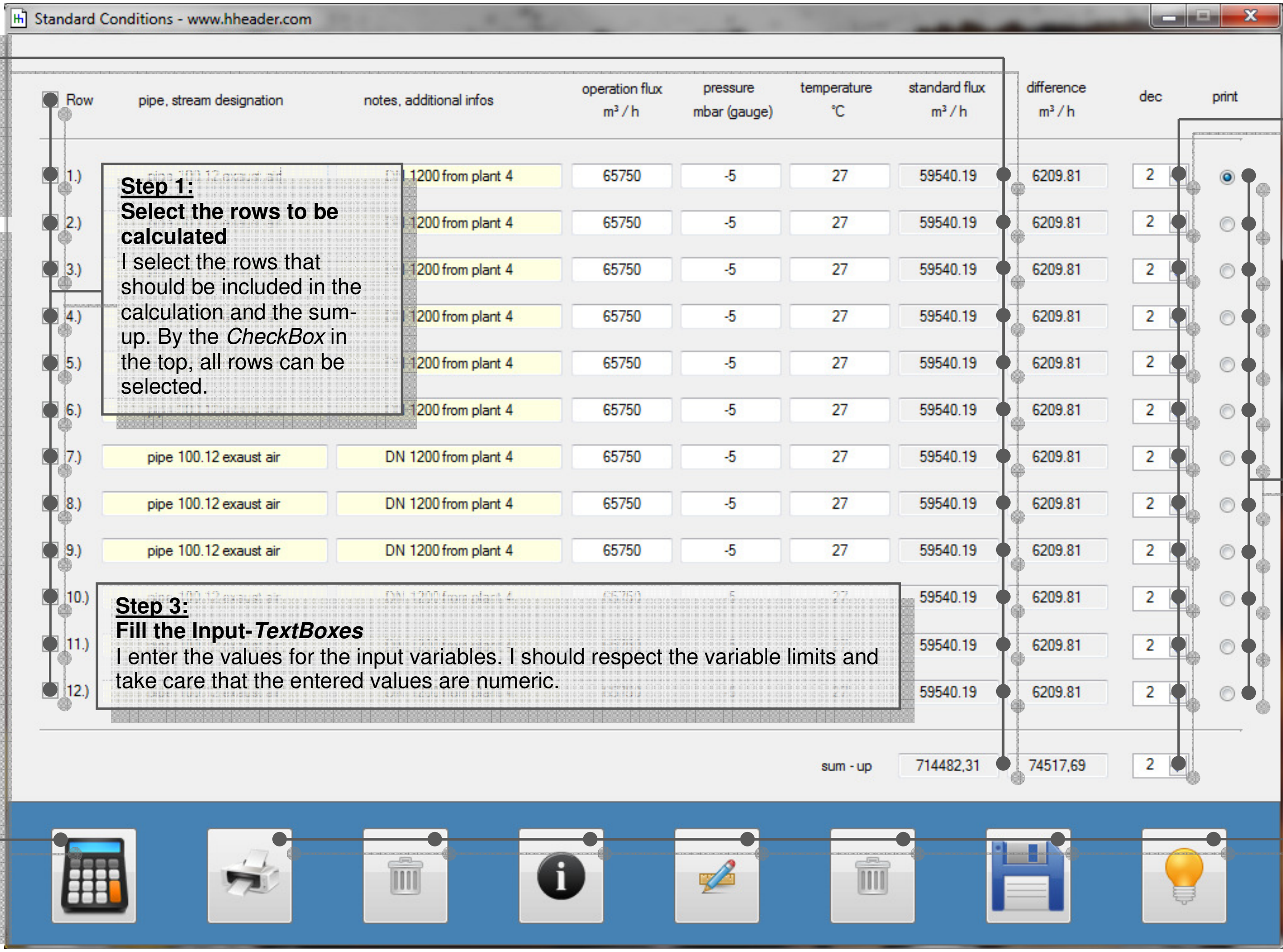
The variable type is Output.
The unit is meter cube per hour [m^3 / h].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

difference

It is the difference between the operation flux and the standard flux. This value is just for information and evaluation purpose.

The variable type is Output.
The unit is meter cube per hour [m^3 / h].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

7.4.3. Operation (How can it be used? How to proceed?)



Step 1:
Select the rows to be calculated
I select the rows that should be included in the calculation and the sum-up. By the *CheckBox* in the top, all rows can be selected.

Step 2:
Decimal places
I enter the number of decimal places for the variables. The input variables can get more or less decimal numbers according to the number of digits.

Step 3:
Fill the Input-*TextBoxes*
I enter the values for the input variables. I should respect the variable limits and take care that the entered values are numeric.

Step 4:
Calculate result
After I entered the input values I can calculate the result. Before the calculation starts, all the input values are checked by an internal routine. Whenever entered values decrease the corresponding min limits or increase the corresponding max limits or are not numeric there will be a message according to the fault. The values will be corrected automatically by the internal routine.

Step 5:
Check result
After clicking the Calculate-Button I can check the result.

Step 6:
Further actions
After the calculation I can have the following options:
Print a Row, Erase Data, Program Information, Notes, Save or Restore Values. While printing a new calculation is done automatically.
Clicking the Erase-Button will empty all the *TextBoxes* at once.

Figure 52: form standard conditions

7.5. Permeability

7.5.1. Purpose (What can it be used for? What can it not be used for?)

The program is part of category 2 – flow rates. Depending on the properties and the composition of a material, fluids can pass through it more or less easy or sometimes even not at all. However it can be useful to have a possibility to compare different materials or systems regarding this behavior. A measure for this behavior is the permeability. It can be calculated considering the fluid viscosity, the flow rate, the area of the material and the pressure difference between the inlet and outlet side.

The permeability coefficient is also a measure for this. With the permeability coefficient also the fluid density is considered. To illustrate the permeability coefficient: it is like the velocity that results, if a fluid is forced passing through a system by gravity. The permeability coefficient is useful to evaluate the permeability of a material under equal circumstances. Therefore ranges for the permeability coefficient have been stated in a German standard.

If the permeability coefficient is greater than 10 ^ –2 m / s, it results a very high permeability.

If the permeability coefficient is in a range from 10 ^ –2 to 10 ^ –4 m / s, it results a high permeability.

If the permeability coefficient is in a range from 10 ^ –4 to 10 ^ –6 m / s, it results an average permeability.

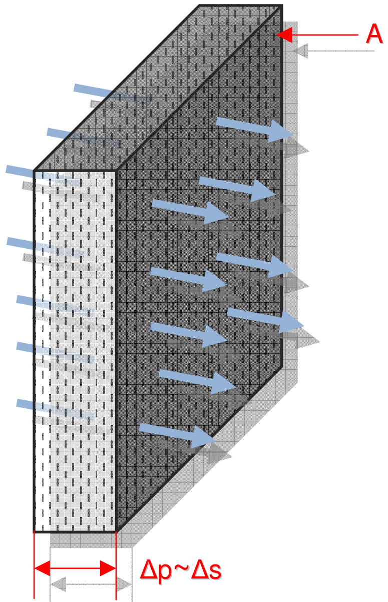


Figure 53: sketch permeability

If the permeability coefficient is in a range from 10 ^ –6 to 10 ^ –8 m / s, it results a low permeability.

If the permeability coefficient is in a range from 10 ^ –8 to 10 ^ –9 m / s, it results a very low permeability.

If the permeability coefficient is less than 10 ^ –9 m / s, it means that the matter is almost not permeable at all.

7.5.2. Variables (What are the input and output values? What are their limits?)

viscosity

It is the dynamic viscosity of the fluid, which is transferred through the system. It is obvious, that the temperature takes influence on the viscosity. For the selectable items the values refer to the viscosity at a temperature of 20°C, if not otherwise noted.

The variable type is Input or Output.
The unit is milli-Pascal by second [mPa s].
The minimum limit is 0.0001.
The maximum limit is 9999999.
The replacement value is 1.
The number of digits is 10.

flow rate

It is the flow rate of the fluid going through the system, a membrane for example, which is focus for the calculations.

The variable type is Input or Output.
The unit is meter cube per hour [m^3 / h].
The minimum limit is 0.0001.
The maximum limit is 9999999.
The replacement value is 1.
The number of digits is 10.

area

It is the total area of the system, a membrane for example, which is focus for the calculations and which is through passed by the fluid.

The variable type is Input or Output.
The unit is meter square [m^2].
The minimum limit is 0.0001.
The maximum limit is 9999999.
The replacement value is 1.
The number of digits is 10.

distance

It is the distance, which is focus for the calculations and which is crossed by the fluid.

The variable type is Input or Output.
The unit is millimeter [mm].
The minimum limit is 0.0001.
The maximum limit is 9999999.
The replacement value is 1.
The number of digits is 10.

pressure difference

It is the pressure difference between the inlet and outlet of the system, a membrane or a filter layer for example, which is focus for the calculations.

The variable type is Input.
The unit is bar [bar].
The minimum limit is 0.01.
The maximum limit is 4000.
The replacement value is 2.
The number of digits is 10.

density

It is the density of the fluid that is passing through the system, a membrane for example, which is focus for the calculations. It is obvious, that the temperature takes influence on the density. For the selectable items the values refer to the density at a temperature of 20°C, if not otherwise noted.

The variable type is Input.
The unit is kilogram per liter [kg / l].
The minimum limit is 0.000001.
The maximum limit is 33.33.
The replacement value is 1.
The number of digits is 10.

permeability

It is the permeability of the system, a membrane for example, which is focus for the calculations. Depending on the properties and the composition of a material, fluids can pass through it more or less easy. A measure behavior is the permeability. According to the formula variables, the unit for the permeability results in meter square [m²].In practice the unit Darcy [Darcy] is often used. The relation is 1 Darcy equals 9.86923 by 10 ^ -13 m², which is approximately 10 ^ -12 m².

The variable type is Input or Output.
The unit is Darcy [Darcy].
The minimum limit is 0.0001.
The maximum limit is 9999999.
The replacement value is 1.
The number of digits is 10.

perm. coefficient

It is the permeability coefficient of the system, a membrane for example, which is focus for the calculations. Depending on the properties or the composition of a material, fluids can pass through it more or less easy. A measure behavior is the permeability. The permeability coefficient is also a measure for this. With the permeability coefficient also the fluid density is considered. To illustrate the permeability coefficient: it is like the velocity that results, if a fluid is forced passing through a system by gravity.

The variable type is Output.
The unit is 10 ^ - 9 by meter per second [10 ^ -9 m / s].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

7.5.3. Operation (How can it be used? How to proceed?)

Step 2:
Select the variable to be calculated
By clicking on the corresponding *RadioButton* I can choose the variable to be calculated. It is like executing an internal conversion of the equation.

Step 6:
Check result
After clicking the Calculate-Button I can check the result.

Step 5:
Calculate result
After I entered the input values I can calculate the result. Before the calculation starts, all the input values are checked by an internal routine. Whenever entered values decrease the corresponding min limits or increase the corresponding max limits or are not numeric there will be a message according to the fault. The values will be corrected automatically by the internal routine.

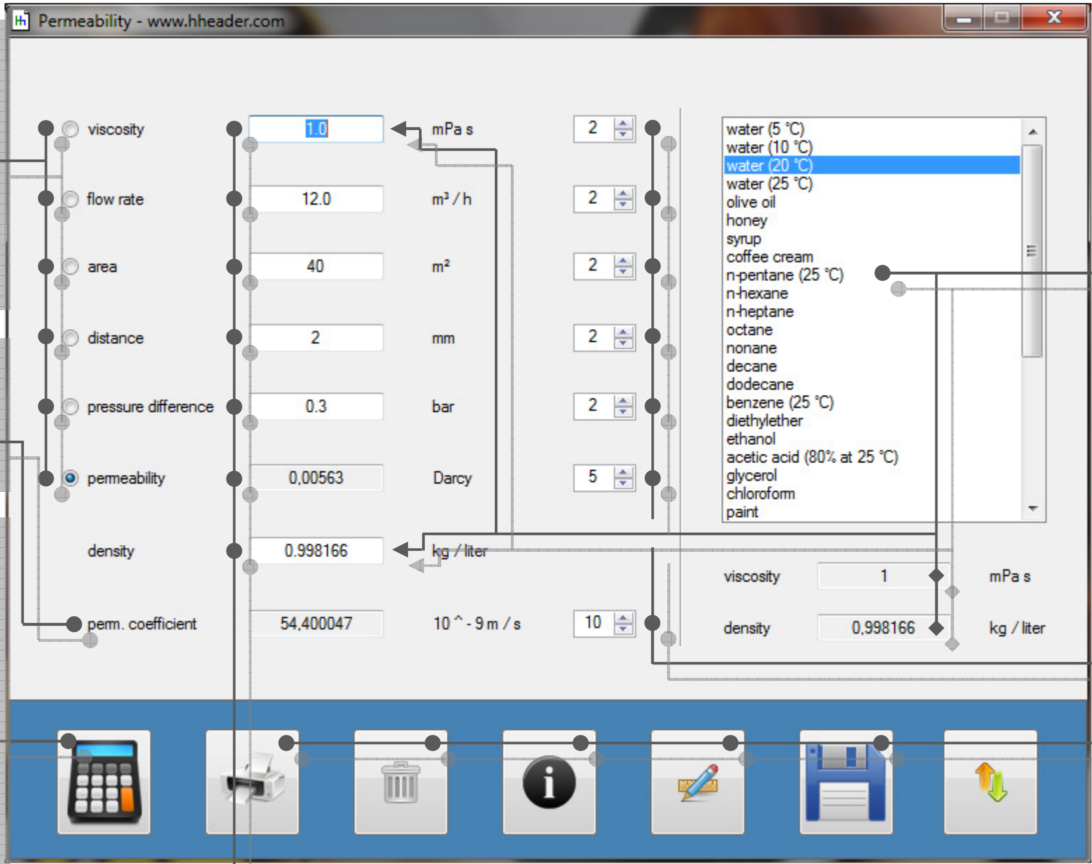


Figure 54: form permeability

Step 3:
Fill the Input-*TextBoxes*
I enter the values for the input variables. I should respect the variable limits and take care that the entered values are numeric.

Step 1: (option)
Fluid selection – viscosity and density
By selecting a fluid the corresponding values for viscosity and density are shown in the *TextBox* below. Using the Transfer-Button will move the values into the Input-*TextBoxes*.

Step 4:
Enter the number of decimal places
I enter the number of decimal places for the variables. It is valid only if the corresponding variable is selected as output. The input variables can get more or less decimal numbers according to the number of digits.

Step 7:
Further actions
After the calculation I can have the following options:
Print Data, Erase Data, Program Information, Notes, Save or Restore Values. While printing a new calculation is done automatically.
Clicking the Erase-Button will empty all the *TextBoxes* at once.

7.6. Membrane Flux

7.6.1. Purpose (What can it be used for? What can it not be used for?)

The program is part of category 2 – flow rates. An important parameter for membranes and also for other filters in the field of water treatment is the maximum load capacity in relation to the area, which is known as membrane flux. This value is usually mentioned in the data sheets of the membranes and it is also depending on the process temperature in many cases. The membrane flux is important for determination of the number of required modules, in case there is a defined flow rate that has to be treated by membranes. Taking a look at the units of the membrane flux, it becomes clear that the membrane flux it at least the velocity of the fluid passing through the membrane.

The program provides the corresponding equations for the calculation of the flow rate, the membrane flux and the required membrane area. Regarding this, each of the three variables can be selected as an output variable. The residual two will become input variables. Further the required number of modules will be calculated by the given module membrane area, which is at least the membrane area of one single module. By the determined number of modules and the module membrane area the resulting total membrane area is calculated. It is the total area of all the modules.

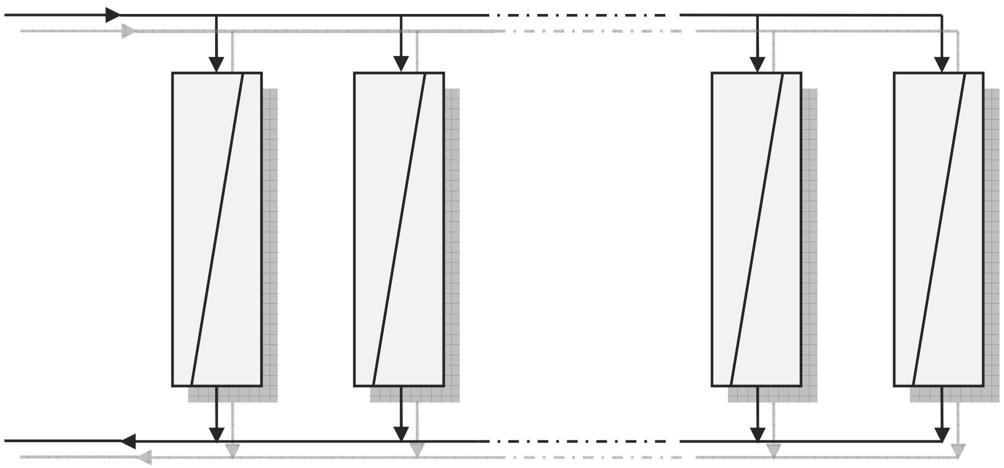


Figure 55: sketch membrane flux

7.6.2. Variables (What are the input and output values? What are their limits?)

total membrane flow rate

It is the total flow rate of the fluid going through the membrane area, which is focus for the calculations.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- meter cube per hour [m^3 / h],
- liters per second [l / s],
- liters per minute [l / min],
- liters per hour [l / h].

The minimum limit is 0.0001.
The maximum limit is 99999999.
The replacement value is 100.
The number of digits is 10.

membrane flux

It is the membrane flux that is specified for the membrane according to the properties and the load capacity.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- meter cube per meter square per hour [m^3 / (m^2 h)],
- liters per meter square per hour [l / (m^2 h)],
- liters per meter square per minute [l / (m^2 min)],
- liters per meter square per second [l / (m^2 s)],
- liters per centimeter square per minute [l / (cm^2 min)],
- liters per centimeter square per second [l / (cm^2 s)],
- liters per millimeter square per second [l / (mm^2 s)].

The minimum limit is 0.0001.
The maximum limit is 99999999.
The replacement value is 100.
The number of digits is 10.

required membrane area

It is the minimum membrane area that is required for reaching the specified membrane flux at the actual flow rate.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- kilometer square [km^2],
- meter square [m^2],
- centimeter square [cm^2],
- millimeter square [mm^2].

The minimum limit is 0.0001.
The maximum limit is 99999999.
The replacement value is 100.
The number of digits is 10.

module membrane area

It is the area of one single membrane module.

The variable type is Input.
For this variable a selection of different units is provided:

- kilometer square [km^2],
- meter square [m^2],
- centimeter square [cm^2],
- millimeter square [mm^2].

The minimum limit is 0.0001.
The maximum limit is 99999999.
The replacement value is 100.
The number of digits is 10.

number of modules

It is the number (the amount) of modules that are passed by the fluid according to the total required membrane area and the module membrane area, which is the area of one module.

The variable type is Output.
The variable has no unit [-].

There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

resulting membrane area

It is the membrane area that results from the number of modules multiplied by the module membrane area.

The variable type is Input or Output.
For this variable a selection of different units is provided:

- kilometer square [km²],
- meter square [m²],
- centimeter square [cm²],
- millimeter square [mm²].

There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

Due to the fact that only complete membranes are available and only complete membranes can be installed the resulting membrane are can deviate from the required area. The Transfer-Button in the lower part of the form below the results will initiate the following actions: select the flow rate as an output variable, iterate calculated value for the total membrane into the *TextBox* for the required membrane area. If a new calculation is triggered afterwards, the design flow rate the will be calculated.

7.6.3. Operation (How can it be used? How to proceed?)

Step 1:
Select the variable to be calculated
By clicking on the corresponding *RadioButton* I can choose the variable to be calculated. It is like executing an internal conversion of the equation.

Step 2:
Fill the Input-*TextBoxes*
I enter the values for the input variables. I should respect the variable limits and take care that the entered values are numeric.

Step 6:
Check result
After clicking the Calculate-Button I can check the results.

Step 3:
Units
There is a choice of different units for each variable.

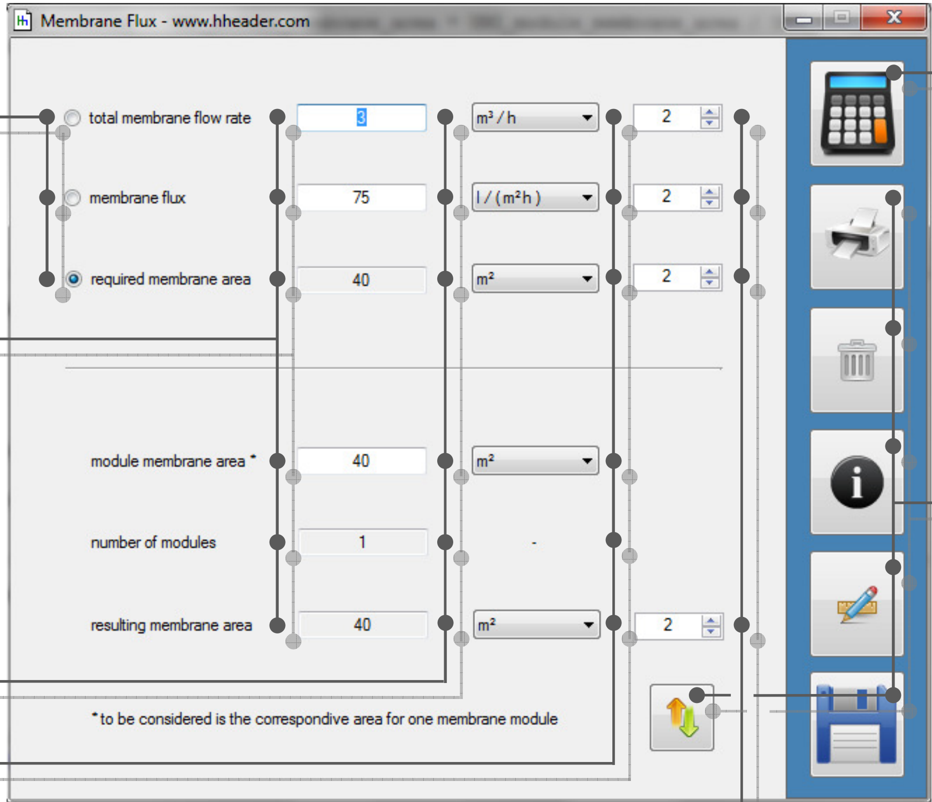


Figure 56: form membrane flux

Step 5:
Calculate result
After I entered the input values I can calculate the result. Before the calculation starts, all the input values are checked by an internal routine. Whenever entered values decrease the corresponding min limits or increase the corresponding max limits or are not numeric there will be a message according to the fault. The values will be corrected automatically by the internal routine.

Step 7:
Further actions
After the calculation I can have the following options:
Print Data, Erase Data, Program Information, Notes, Save or Restore Values or Transfer. While printing a new calculation is done automatically. Clicking the Erase-Button will empty all the *TextBoxes* at once.

Step 4:
Enter the number of decimal places
I enter the number of decimal places for the variables. It is valid only if the corresponding variable is selected as output. The input variables can get more or less decimal numbers according to the number of digits.