6. Category Pressure

6.1. Safety Distance

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

The program is part of category 1 - pressure. It is for determination of the accurate safety distance to be considered during pressure tests or also during operating the system. During pressure tests and also during operation of a pressurized system a certain distance has to be considered for safety reasons. It is at least to protect personnel from any risk caused by the pressurization of a closed system. In order to do this with the right measure, the safety distance can be calculated according to the actual rules. The safety distance can be determined for two different fluids: for liquids and for gases. This is divided up into hydraulic and pneumatic systems. For both, liquids and gases there are two different empirical formulas for calculating the safety distance.
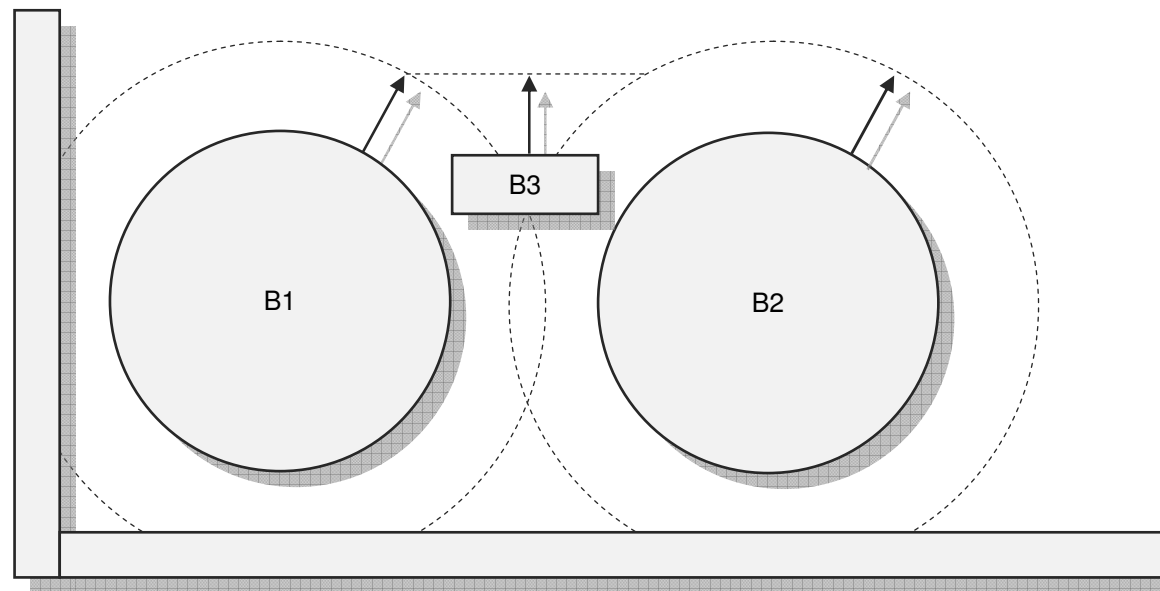
Figure 28: sketch safety distance for pressurized systems

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

spec. distance limit

It is the specified distance limit. Usually the safety distance is defined by the energy of the pressurized system. The energy of the system results out of pressure and volume.

R = 30 m for E ≤ 135.5 MJ
R = 60 m for 135.5 MJ ≤ E ≤ 271 MJ

The specified distance limit can be decreased, if there are plausible reasons confirming to the rules. To consider the specified distance limit the box beside the tag has to be checked. If the box is unchecked the result will be the value which is calculated by the formula. The variable is relevant for both systems (hydraulic and pneumatic).

The variable type is Input.
The unit is meter [m].
The minimum limit is 30.
The maximum limit is 30000.
The replacement value is 60.
The number of digits is 10.

pressure

It is the value that has to be considered for the test or operation pressure. Be aware that the value during a pressure test is usually greater than the nominal pipe pressure value. The variable is relevant for both systems (hydraulic and pneumatic).

The variable type is Input.
The unit is meters [bar].
The minimum limit is 0.01.
The maximum limit is 999.
The replacement value is 2.
The number of digits is 10.

diameter

It is the maximum diameter occurring in the total pressurized system. This has to be taken into consideration even if it is only a small part of the system. The variable is relevant for both systems (hydraulic and pneumatic).

The variable type is Input.
The unit is millimeter [mm].
The minimum limit is 0.1.
The maximum limit is 99999.
The replacement value is 200.
The number of digits is 10.

factor

It is a factor for the pressurized liquid. For water a factor of 150 is plausible. In general liquids or gases can be used as fluid, but for the calculation of the safety distance this factor is considered for the hydraulic systems, only. The variable is relevant for hydraulic systems.

The variable type is Input.
This variable has no unit [-].
The minimum limit is 10.
The maximum limit is 3000.
The replacement value is 150.
The number of digits is 10.

density

It is the density of the fluid which is filled into the system. In general liquids or gases can be used as fluid, but for the calculation of the safety distance the density is considered for the hydraulic systems, only. The variable is relevant for hydraulic systems.

The variable type is Input.
The unit is kilogram per meter cube [kg / m³].
The minimum limit is 0.001.
The maximum limit is 9999.
The replacement value is 1000.
The number of digits is 10.

length

It is the total pipe length of the complete pressurized system. In general liquids or gases can be used as fluid, but for the calculation of the safety distance the length is considered for the pneumatic systems, only. The variable is relevant for pneumatic systems.

The variable type is Input.
The unit is meters [m].
The minimum limit is 0.1.
The maximum limit is 99999.
The replacement value is 10.
The number of digits is 10.

volume

It is the volume of the system calculated by the given parameters length and diameter. In general liquids or gases can be used as fluid, but for the calculation of the safety distance the length is considered for the pneumatic systems, only. The variable is relevant for pneumatic systems.

The variable type is Output.
The unit is meter cube [m³].
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.

min. safety distance

It is the calculated minimum safety distance to be considered for the pressure test or if relevant during operation. The zone in the space of the safety distance is restricted and has to be clearly marked (use labels, warning plates, barrier tape etc.) while the system is pressurized.

The variable type is Output.
The unit is meter [m].
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.

In every case minimum the following rules have to be considered:

- The zone in the space of the safety distance is restricted and has to be clearly marked (use labels, warning plates, barrier tape etc.).

- Everyone has to respect the safety distance and the safety zone.

- Everyone on site has to be informed about the course of action, before it starts.

- Provisions to protect from possibly blasted fragments have to be taken.

Technical standards, rules and even laws are changing from time to time. Due to this fact the user has to check regularly, if the application is up to date and in coherence with the actual standards, rules and laws before using the results for further actions or evaluations. This is relevant for time and place of the appliance!

6.1.3.   Operation (How can itbe used? How to proceed?)

Step 1:
Select the type of system (hydraulic or pneumatic)
For the two different systems (hydraulic and pneumatic) with two different calculations there are two separate *TabPages*.

Step 2:
Activate or deactivate specified distance limit
I can activate or deactivate the consideration of the specified distance limit. If the *CheckBox* is checked, the specified distance limit is taken into consideration else not.

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

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 6:
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.

Figure 29: form safety distance hydraulic systems

Step 1:
Select the type of system (hydraulic or pneumatic)
For the two different systems (hydraulic and pneumatic) with two different calculations there are two separate *TabPages*.

Step 2:
Activate or deactivate specified distance limit
I can activate or deactivate the consideration of the specified distance limit. If the *CheckBox* is checked, the specified distance limit is taken into consideration else not.

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

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hydraulic pressure tests | pneumatic pressure tests

spec. distance limit	30	m
pressure	42	bar
diameter	200	mm
length of the system	1000	m
volume	31,42	m³
min. safety distance	34,63	m

Figure 30: form safety distance pneumatic systems

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 6:
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.

6.2. Osmotic Pressure

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

The program is part of category 1 – pressure. It includes the basic calculations for the osmotic pressure due to the ideal gas law. According to the ideal gas law and by taking the van 't Hoff factor into consideration the osmotic pressure can be calculated for a given temperature and a given salt concentration (salinity) of the water. Thereby the osmotic pressure increases by increasing temperature. For reverse osmosis plants we often find a decreasing membrane pressure while increasing temperature. This is because the viscosity of the water decreases while the temperature is increasing. In order to evaluate the pressure circumstances for these systems both, the change of the osmotic pressure and the change of the water viscosity have to be taken into consideration.
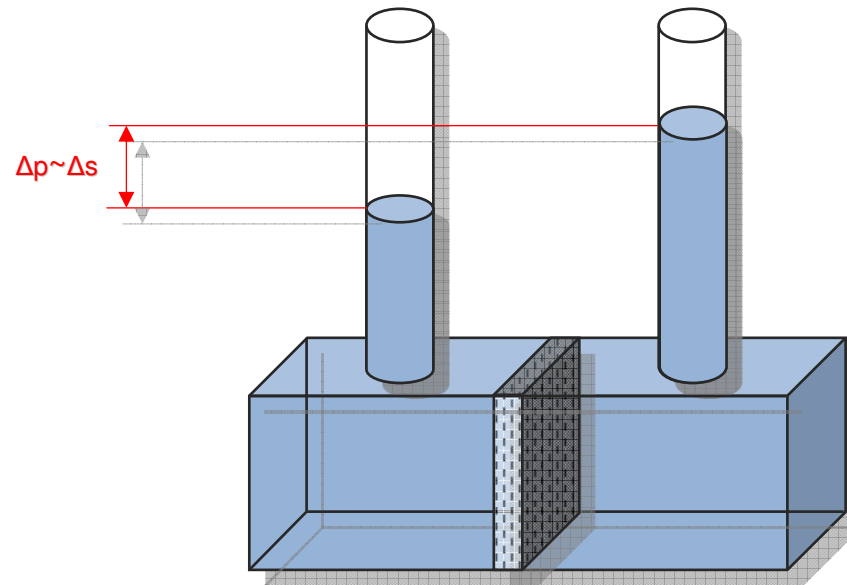

Figure 31: sketch osmotic pressure

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

factor by van 't Hoff

It is a measure for the dissociation rate of matter. The factor by van 't Hoff is the amount of dissociated parts of matter in relation to the amount of parts before the dissociation of the matter.

Following up some values for the van 't Hoff factor (used abbreviation fvH).

- Glucose (sugar) $C6H12O6$: fvH = 1.
- Sodium chloride (salt) NaCl: fvH = 2.
- Magnesium sulfate (inorganic salt) MgSO4: fvH = 2.
- Sulfuric acid H2SO4: fvH = 2.28.
- Potassium sulfate K2SO4: fvH = 3.
- Potassium ferricyanide K3[Fe(CN)6]: fvH = 4.

The variable type is Input.
This variable has no unit [-].
The minimum limit is 0.3.
The maximum limit is 5.
The replacement value is 2.
The number of digits is 10.

salinity

It is a measure for the amount of salt dissolved in a certain amount of water, which means at least the concentration of salt. There is a relation between the electrical conductivity and the concentration of matter in water. This is why the salinity can also be given as electrical conductance. The osmotic pressure increases while the electrical conductivity respectively the salt concentration increases.

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

- mol per liter [mol / l],
- gram per liter [g / l],
- milligram per liter [mg / l],
- gram / kilogram [g / kg],
- percent [%],
- parts per million [ppm],
- micro-Siemens per centimeter [µS / cm],
- milli-Siemens per centimeter [mS / cm].

The minimum limit is 0.0001.
The maximum limit is dynamic.
The replacement value is 1.
The number of digits is 10.

The maximum limit for the input value of the salinity is dynamic. That means it depends on the selected unit. The maximum limit values which are according to the selectable units are shown in the table below. They are based on a maximum assumed salt concentration of 280g per kg at a temperature of 100°C.

The dynamic maximum limits for the selectable salinity units are as follows:

- for the unit [mol / l] the maximum limit is 5,
- for the unit [g / l] the maximum limit is 280,
- for the unit [mg / l] the maximum limit is 280000,
- for the unit [g / kg] the maximum limit is 280,

- for the unit [%] the maximum limit is 28,
- for the unit [ppm] the maximum limit is 280000,
- for the unit [µS / cm] the maximum limit is 528302,
- for the unit [mS / cm] the maximum limit is 529.

temperature

It is the temperature of the water with the dissolved matter. The temperature range for the use case is assumed to be 0°C < T < 100°C. The calculation will be aborted in case if it results a temperature value that is implausible for the use case (either < 0°C or > 100°C).

The variable type is Input or Output.
The unit is degree Celsius [°C].
The minimum limit is 0.
The maximum limit is 100.
The replacement value is 20.
The number of digits is 10.

osmotic pressure

It is the osmotic pressure, which is caused by the grade of salinity, the temperature conditions of the solution and the considered van 't Hoff factor.

The variable type is Input or Output.
The unit is bar [bar].
The minimum limit is 0.01.
The maximum limit is 500.
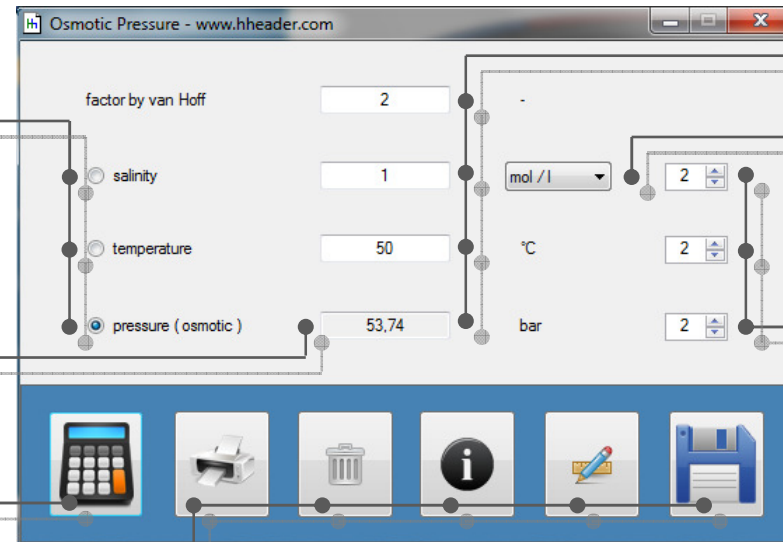The replacement value is 20.
The number of digits is 10.

Of course osmotic mechanisms are also possible between gases. Be aware that this program is based on a use case where salt (exactly NaCl) is dissolved in water. The unit conversions are based on a molar mass of 55.44 g. This is not relevant for the unit mol / l, but for all residual salinity units. Other use cases are not considered by this program. Never the less it is obvious that diverse considerations are possible by a variation of the van 't Hoff factor. Further the program does not consider any plausibility checks regarding the dissolubility for example. The user has to take care for things like this him or herself!

6.2.3.   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.

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:
Select the unit for the salinity
I select the unit for the salinity by clicking on the *ComboBox*. It is the unit for the salt concentration.

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.

Figure 32: form osmotic pressure

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.

6.3. Pressure Surge Analysis

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

The program is part of category 1 – pressure. It evaluates the pressure surges to be expected by water hammering. For evaluation of safety conditions and documentation purpose it can be required to do a pressure surge analysis for the pipe installation set-up. Especially if pipe diameter or pipe length are increasing very high pressure surges can appear. In this case it is recommended to evaluate the situation and the probability of high pressure surges. Therefore two different types of pressure surge can be calculated: the maximum pressure surge caused by a suddenly stopped water flow and the damped pressure surge caused by a more or less slowly closing valve.

The scope of application for the two methods is defined by the comparison of the valve close time (Tc) and the reflection time of the surge (Tr). If the valve close time (Tc) is less than the reflection time of the surge (Tr), only the maximum pressure surge is relevant. If the valve close time (Tc) is equal or greater than the reflection time of the surge (Tr), the dumped pressure surge can be used for evaluation purposes. The reflection time of the surge depends on the pipe length and the wave propagation. The reflection time is calculated internally.
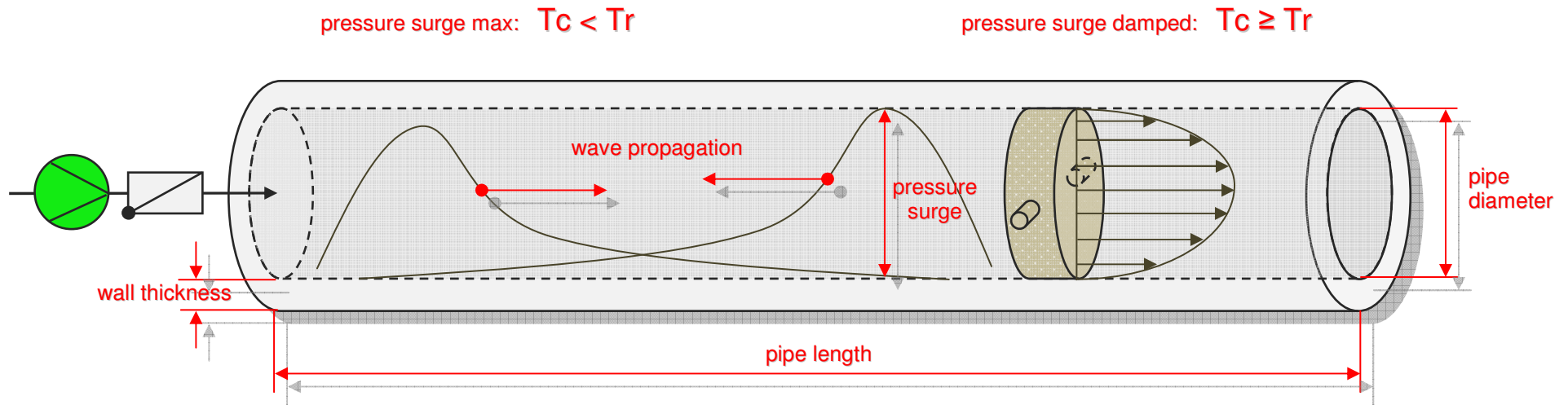

Figure 33: sketch pressure surge

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

density

It is the density of the liquid which flows through the system. For water a default value of 1000 kg/m³ can be assumed. Beside other criteria the temperature of the water takes influence on its density. Water has its highest density value at a temperature of 4°C. In case if the temperature should be considered, the density as function of the temperature for water can be determined with help of the program "Water Density", which is also part of category 1 – pressure.

The variable type is Input.
The unit is kilogram per meter cube [kg / m³].
The minimum limit is 0.001.
The maximum limit is 9999.
The replacement value is 1000.
The number of digits is 10.

spec. compressibility

It is the specific modulus of compressibility. If gases, fluids or solids are pressurized it will result a change of their volume. By this the density of the object will change also. The compressibility is a measure for this behavior. The modulus of compressibility defines it for different materials. The base unit is N / m² or Pa. E.g. some values: air 1.01 10^5 Pa, oil 1.0 - 1.6 GPa, water 2.08 GPa.

The variable type is Input.
The unit is Giga-Pascal [GPa].
The minimum limit is 0.1.
The maximum limit is 1000.
The replacement value is 210.
The number of digits is 10.

elasticity

It is the modulus of elasticity for the pipe or vessel material. If solid objects are applied by forces or pressures, they will be deformed. Unless the forces are not too high the behavior is elastic. The modulus of elasticity defines it for different materials. Remember: 1 GPa = 10^9 Pa = 10^9 N / m² = 10^9 / 10^6 N / mm² = 10^9 / 10^9 kN / mm²=1 kN / mm².

The variable type is Input.
The unit is kilo-Newton per millimeter square [kN / mm² = GPa].
The minimum limit is 0.1.
The maximum limit is 999.
The replacement value is 210.
The number of digits is 10.

poisson number

It is the poisson number for the pipe or vessel material. If solid objects are deformed by high forces, the cross section will decrease while there is an elongation. A measure for this behavior is the poisson number. It is defined for different materials.

The variable type is Input.
The variable has no unit [-].
The minimum limit is 0.01.
The maximum limit is 0.9.
The replacement value is 0.3.
The number of digits is 10.

diameter (inner)

It is the inner diameter of the installed pipe or vessel, which is focus for the pressure surge analysis. If the results should be more exactly, the real inner diameter has to be filled – remember that the nominal values given by the pipe designation are sometimes not accurate and depend on the type and material of the pipes.

The variable type is Input.
The unit is millimeter [mm].
The minimum limit is 0.1.
The maximum limit is 99999.
The replacement value is 200.
The number of digits is 10.

eff. wall thickness

It is the effective wall thickness of the installed pipe, which is focus for these vacuum calculations. If the results should be more exactly, the real inner and outer diameters have to be considered – remember that the nominal values given by the pipe designation are sometimes not accurate and depend on the type and material of the pipes.

The variable type is Input.
The unit is millimeter [mm].
The minimum limit is 0.1.
The maximum limit is 250.
The replacement value is 25.
The number of digits is 10.

wave propagation

It is the propagation, which is at least the speed of the wave caused by the reflection of the pressure surge at the pipe walls and other installation compounds.

The variable type is 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].

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 rate

It is the flow rate going through the pipes and vessels that has to be assumed under normal operation circumstances and before the pressure surge respectively water hammering appears.

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

- meter cube per hour [m³ / 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.

velocity

It is the velocity of the fluid caused by the flow rate and the inner pipe or vessel diameter that has to be assumed under normal operation circumstances and before the pressure surge respectively water hammering appears.

The variable type is 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].

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.

pressure surge max

It is the maximum theoretical pressure surge, which is calculated from the entered variables. In case of the maximum pressure surge it is assumed, that the movement of the fluid is stopped at a sudden. For the influence of a by time closing valve a calculation for a resulting damped pressure surge can be executed. It will result lower values, which can be basis for practical design criteria. Note: The surge always comes in addition to the operation pressure.

The variable type is Output.
The unit is bar [bar].
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.

length of the system

It is the total length of the piping system trough that the focused water column flows. Hint: length by cross section equals the volume. Volume by density equals the mass of the water column that has to be stopped by the installed compounds - just to get an idea about the power of the water hammering that can be expected. The length of the pipe system and the wave propagation are variables for the calculation of the reflection time.

The variable type is Input.
The unit is meter [m].
The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

pressure surge damped

The influence of a by time closing valve will cause a damped pressure surge. This will result lower values than the maximum theoretical pressure surge. It can be basis for practical design criteria. Note: the surge always comes in addition to the operation pressure.

The variable type is Output.
The unit is bar [bar].
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.

valve close time

It is the time that it takes to move the valve from open position to close position. It is obvious, that the more time it takes to close the valve, the less power for the pressure surge can be expected. That means in case if the calculated pressure surge could be hazardous for the installation set-up or further even for personnel, the risk of damage can be reduced by ensuring an extended close time for the valve.

The variable type is Input.
The unit is second [s].
The minimum limit is dynamic (Tmin=Tr).
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

The scope of application for the two methods (pressure surge max and damped) is defined by the comparison of the valve close time (Tc) and the reflection time of the surge (Tr). If the valve close time (Tc) is less than the reflection time of the surge (Tr), only the maximum pressure surge is relevant. If the valve close time (Tc) is equal or greater than the reflection time of the surge (Tr), the dumped pressure surge can be used for evaluation purposes. The reflection time of the surge depends on the pipe length and the wave propagation. The reflection time is calculated internally.

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

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 4:
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 result.

Step 7:
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 2: (option)
elasticity
By selecting a pipe or vessel material the elasticity is shown in the *TextBox* below. It is an average value. Using the Transfer-Button will move the value into the Input-*TextBox*.

Step 3: (option)
Poisson number
By selecting a pipe or vessel material the poisson number is shown in the *TextBox* below. It is an average value. Using the Transfer-Button will move the value into the Input-*TextBox*.

Step 1:
Select the units
I select the units for wave propagation, velocity and flow rate by clicking on the corresponding *ComboBox*.

Figure 34: form pressure surge analysis

6.4. Vacuum Calculations

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

The program is part of category 1 – pressure. If the pipe or vessel installation set-up reaches certain heights, there is a danger of damaging compounds by vacuum, especially if an unintended or accidental lowering of the water level takes place. To avoid this there are two possibilities in general: to maintain the required design criteria or to ensure an adequate vent at the top of the installation set-up. By using this program, the design criteria can be checked and a proper vent diameter can be calculated according to the system height. The calculation for the design criteria check-up is based on the following question: what is the value for a pressure outside the compound (e.g. pipe, vessel, etc.) causing the same stress as a corresponding vacuum inside the compound. The result is a critical pressure difference between the outside and the inside of the compound. By this also the actual pressure difference that can occur has to be taken into consideration. To evaluate if the system is safe or not a safety factor is calculated by the entered values. Thereby a safety factor of minimum 2.5 is required for a safe system.
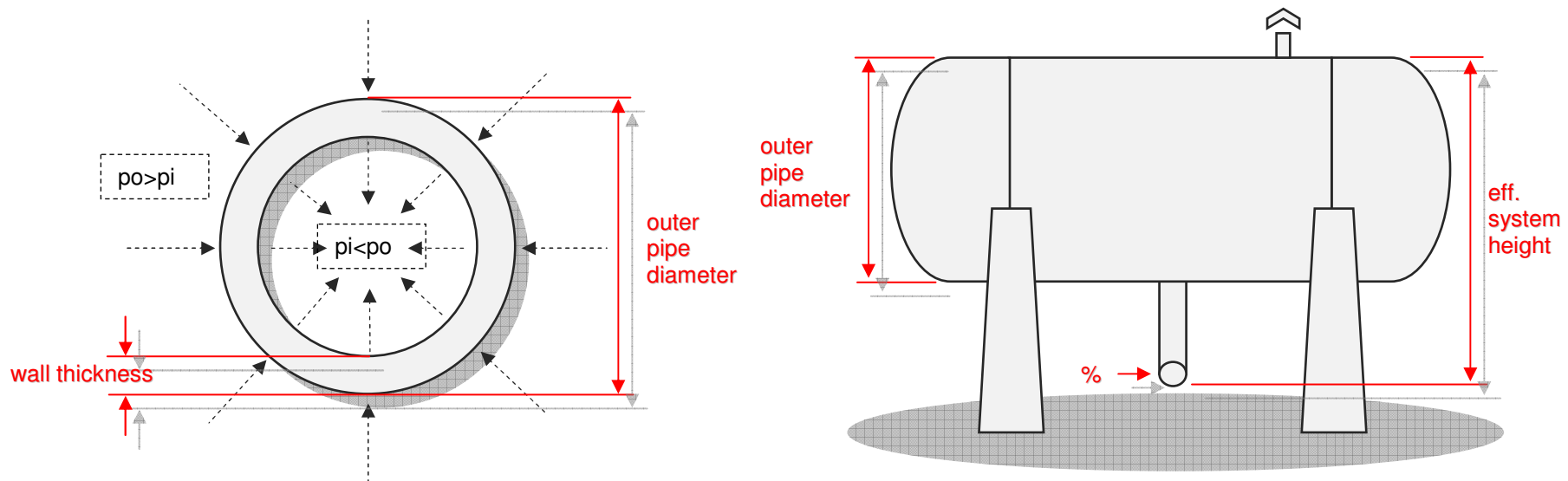

Figure 35: sketch vacuum calculations

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

elasticity

It is the modulus of elasticity for the pipe or vessel material. If solid objects are applied by forces or pressures, they will be deformed. Unless the forces are not too high the behavior is elastic. The modulus of elasticity defines it for different materials. Remember: 1 GPa = 10^9 Pa = 10^9 N / m² = 10^9 / 10^6 N / mm² = 10^9 / 10^9 kN / mm²=1 kN / mm².

The variable type is Input.
The unit is kilo-Newton per millimeter square [kN / mm² = GPa].
The minimum limit is 0.1.
The maximum limit is 999.
The replacement value is 210.
The number of digits is 8.

diameter (outer)

It is the outer diameter of the installed pipe or vessel, which is focus for these vacuum calculations. If the results should be more exactly, the real outer diameter has to be considered – remember that the nominal values given by the pipe designation are sometimes not accurate and depend on the type and material of the pipes.

The variable type is Input.
The unit is millimeter [mm].
The minimum limit is 0.1.
The maximum limit is 10000.
The replacement value is 200.
The number of digits is 8.

poisson number

It is the poisson number for the pipe or vessel material. If solid objects are deformed by high forces, the cross section will decrease while there is an elongation. A measure for this behavior is the poisson number. It is defined for different materials.

The variable type is Input.
The variable has no unit [-].
The minimum limit is 0.01.
The maximum limit is 0.9.
The replacement value is 0.3.
The number of digits is 8.

wall thickness pipe

It is the effective wall thickness of the installed pipe, which is focus for these vacuum calculations. If the results should be more exactly, the real inner and outer diameters have to be considered – remember that the nominal values given by the pipe designation are sometimes not accurate and depend on the type and material of the pipes.

The variable type is Input.
The unit is millimeter [mm].
The minimum limit is 0.1.
The maximum limit is 9999.
The replacement value is 10.
The number of digits is 8.

critical pressure

It is the value for the differential pressure between the inside and the outside of the pipe or vessel, which can cause a damage of the pipe or vessel system. Regarding this an outer pressure of x above atmospheric pressure or an inner pressure of x below atmospheric pressure will have the same stress effects. To decrease the risk of damaging the system a safety factor has to be considered. The critical differential pressure divided by the base pressure value should be > 2.5.

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.

safety factor

By comparing the actual differential pressure value and the critical differential pressure the risk of damages can be evaluated (safety factor). To decrease the risk of damaging the system a safety factor has to be considered. The critical differential pressure divided by the base pressure value should be > 2.5.

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.

pressure value

It is the value of the actual differential pressure that can occur between the inside and the outside of the pipe or vessel. By comparing the pressure value and the critical differential pressure the risk of damages can be evaluated (safety factor). To decrease the risk of damaging the system a safety factor has to be considered. The critical differential pressure divided by the base pressure value should be > 2.5.

The variable type is Input.
The unit is millibar [mbar].
The minimum limit is 200.
The maximum limit is 999999.
The replacement value is 1013.25.
The number of digits is 8.

% of the diameter (selection)

This value considers a percentage value of the inner pipe diameter. This can be done, if it is ensured that the draining is only possible via a draining pipe with a smaller diameter or if it is assumed, that a leakage with a reduced opening measure occurs (refer to the sketch).

The variable type is Input.
The unit is percent [%].
The minimum limit is 1.
The maximum limit is 100.
There is no replacement provided for this variable.
The number of digits is 8.

% of the area (selection)

This value considers a percentage value of the inner pipe area. This can be done, if it is ensured that the draining is only possible via a draining pipe with a smaller area or if it is assumed, that a leakage with a reduced opening measure occurs (refer to the sketch).

The variable type is Input.
The unit is percent [%].
The minimum limit is 1.
The maximum limit is 100.
There is no replacement provided for this variable.
The number of digits is 8.

eff. system height (selection)

It is the effective height of the total system beginning at the very top going down to the bottom where the water is drained or could be draining assuming the worst accidental case (refer to the sketch). Internally the velocity is calculated that can be assumed according to the height value, if the water is drained at the bottom. Optional the velocity can also be entered directly. For the two selections a *ComboBox* is provided.

The variable type is Input.
The unit is meter [m].
The minimum limit is 0.1.
The maximum limit is 15.
The replacement value is 5.
The number of digits is 8.

eff. system velocity (selection)

If the eff. system height is selected as an input variable, the velocity is calculated internally by the height value. In this case it is assumed that a draining takes place, either by an unintended opening of the drain valve or a leakage. The velocity can also be entered directly. For the two selections a *ComboBox* is provided. If the velocity is entered directly also the consideration for the nominal pipe flow rate can be done. It is obvious that the %-value should be adjusted to 100% in this case.

The variable type is Input.
The unit is meter per second [m / s].
The minimum limit is 0.1.
The maximum limit is 15.
The replacement value is 5.
The number of digits is 8.

diameter vent

It is the calculated diameter for a proper vent pipe or a combination of vent pipes to be installed at the top of the system. The vent is required to ensure a sufficient air flow from the atmosphere into the pipe in order to equalize the pressure circumstances and by this to avoid building up a vacuum caused by a lowering or even falling water column.

The variable type is Input.
The unit is either inch ["] (from 1/8" up to 6") or it is diameter nominal [DN] (from DN 200 to DN 1500), which is almost the measure in millimeter.
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.

The calculated result for the vent is the minimum that should be chosen. It is recommended to choose the next bigger size to increase the safety. Further it is clear that the material parameters like elasticity and poisson number have to be exact and that they can change by age or due to extra stress cases that occurred while transportation or installation for example. Keep this in mind!

In the following a table including all the possible results for the vent is shown. The order is ascending together with the increasing area, which results from the determined vent pipe diameter and the amount of pipes. Sometimes two combinations have equal total areas for example 1 x DN 800 and 4 x DN 400. That means it is possible to install either 1 vent pipe DN 800 or 4 vent pipes DN 400. The squares of the diameters are relevant. In general this is the case whenever 1 x D is directly followed by 4 x D/2. There are eight pairs like this in total.

No.	Vent	No.	Vent	No.	Vent	No.	Vent	No.	Vent
1	1 x 1/8"	16	1 x DN 250	31	2 x DN 400	46	4 x DN 450	61	2 x DN 1100
2	1 x 1/4"	17	2 x DN 200	32	1 x DN 600	47	2 x DN 700	62	3 x DN 900
3	1 x 3/8"	18	1 x DN 300	33	4 x DN 300	48	1 x DN 1000	63	4 x DN 800
4	1 x 1/2"	19	3 x DN 200	34	3 x DN 350	49	4 x DN 500	64	2 x DN 1200
5	1 x 3/4"	20	1 x DN 350	35	2 x DN 450	50	3 x DN 600	65	3 x DN 1000
6	1 x 1"	21	2 x DN 250	36	3 x DN 400	51	1 x DN 1100	66	4 x DN 900
7	1 x 1 1/4"	22	1 x DN 400	37	1 x DN 700	52	2 x DN 800	67	3 x DN 1100
8	1 x 1 1/2"	23	4 x DN 200	38	4 x DN 350	53	1 x DN 1200	68	4 x DN 1000
9	1 x 2"	24	2 x DN 300	39	2 x DN 500	54	4 x DN 600	69	3 x DN 1200
10	1 x 2 1/2"	25	3 x DN 250	40	3 x DN 450	55	3 x DN 700	70	2 x DN 1500
11	1 x 3"	26	1 x DN 450	41	1 x DN 800	56	2 x DN 900	71	4 x DN 1100
12	1 x 4"	27	2 x DN 350	42	4 x DN 400	57	3 x DN 800	72	4 x DN 1200
13	1 x 5"	28	1 x DN 500	43	2 x DN 600	58	4 x DN 700	73	3 x DN 1500
14	1 x 6"	29	4 x DN 250	44	3 x DN 500	59	2 x DN 1000	74	4 x DN 1500
15	1 x DN 200	30	3 x DN 300	45	1 x DN 900	60	1 x DN 1500	75	out of range

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

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 4:
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 result. The indication fields show me if the system is safe (green) or if the system is not safe (red) without installing a vent pipe.

Step 7:
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)
elasticity
By selecting a pipe or vessel material the elasticity is shown in the *TextBox* below. It is an average value. Using the Transfer-Button will move the value into the Input-TextBox.

Step 2: (option)
Poisson number
By selecting a pipe or vessel material the poisson number is shown in the *TextBox* below. It is an average value. Using the Transfer-Button will move the value into the Input-*TextBox*.

Step 3:
Select the variables
For the percentage value and the velocity calculation I can select different input variables as basis for the calculation.

Figure 36: form vacuum calculations

6.5. Water Density

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

The program is part of category 1 – pressure. For water a default value of 1000 kg/m³ is often assumed. Beside other criteria the temperature of the water takes influence on its density. Water has its highest density value at a temperature of 4°C. A change of the temperature will cause a change of the density value. This program provides the water density as a function (approximation) of the temperature. That means I can enter a temperature value and I will get the corresponding density value for this temperature as result. Be aware that this is only relevant for water! Thereupon further calculations are possible.

For this the following circumstances should be imagined:
There is a vessel filled up to a certain level respectively there is a corresponding pressure at the bottom of the vessel. The vessel has an opening sideways near the bottom. For the opening there are two cases provided. Case one is a small opening. This can have a circular shape with a corresponding diameter or it can have any other shape with a corresponding area. The value for the diameter can be entered as given variable and the resulting area will be calculated or the area can be entered as given variable and the proper diameter for this will be calculated. Case two is a wide opening with measures for height and width. The cases are selectable.

Further factors regarding the fluid friction and the restriction for the opening can be entered. Based on the given variables level or pressure and friction factor there is a theoretical maximum value for the velocity of the draining fluid. Taking also the size and restriction of the opening into consideration a resulting flow rate is calculated, which is in coherence to the resulting velocity. The resulting velocity can be expected as the almost real value in opposite to the theoretical maximum velocity.

The vessel itself can also either have a circular base shape and a corresponding diameter or any other base shape and a corresponding area. This is also selectable. The volume results out of the vessel base area and the level. By all these measures the time it takes to drain all the volume by gravity is calculated.

By the way this is a process we face every day: for example when we unplug our sink or bath tub. To describe the procedure by mathematics requires a differential equation. This ends with a root zero – a practicable solution can be found by an approximation. Human is flying through the air or moving electrons over distances, but human is not able to describe how water drains away.

If the fluid is not water, the calculation of the density by temperature is of course not relevant. In this case the calculation for the density by temperature can be deselected and the density becomes an input value. Then the factors for fluid friction and restriction need to be adapted accordingly.

It is obvious that the base force for all procedures simulated by this program is earth gravity.
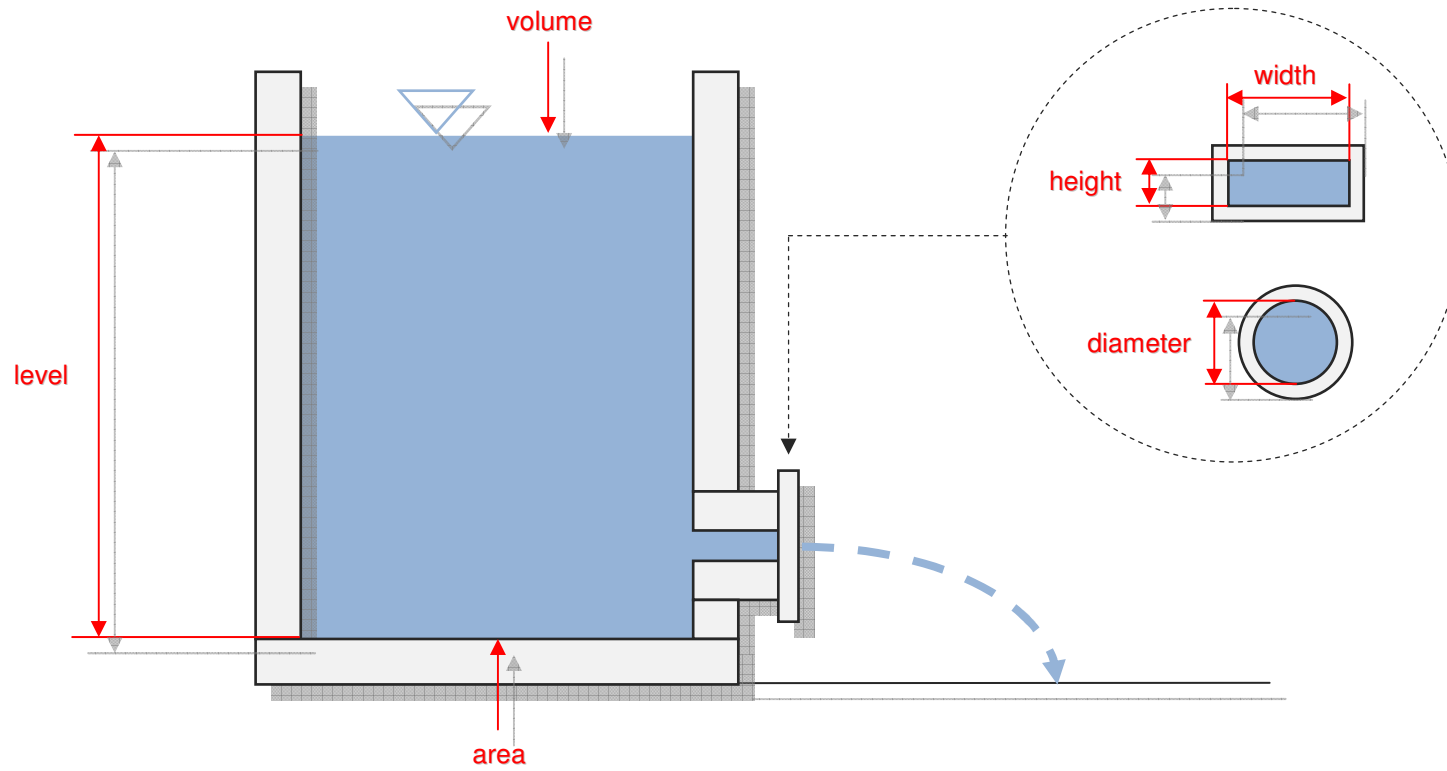
Figure 37: sketch water density

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

temperature

It is the temperature of the water inside the vessel. For water a default value of 1000 kg/m³ can be assumed. Beside other criteria the temperature of the water takes influence on its density. Water has its highest density value at a temperature of 4°C. The temperature will be considered, if the *CheckBox* is not selected. It is obvious that the calculation of the density by temperature is only relevant for water!

The variable type is Input.
The unit is degree Celsius [°C].
The minimum limit is 0.1.
The maximum limit is 100.
The replacement value is 20.
The number of digits is 6.

density

It is the density of the liquid inside the vessel. For water a default value of 1000 kg/m³ can be assumed. Beside other criteria the temperature of the water takes influence on its density. Water has its highest density value at a temperature of 4°C. The temperature will be considered, if the *CheckBox* is not selected. It is obvious that the calculation of the density by temperature is only relevant for water!

The variable type is Input or Output.
The unit is kilogram per meter cube [kg / m³].
The minimum limit is 0.001.
The maximum limit is 9999.
The replacement value is 1000.
The number of digits is 6.

factor for friction

It is a general factor considering the fluid friction. The friction coefficient for water can be assumed to be equal 0.97 for example. The losses for the opening itself caused by edges or a flange are considered by the restriction factor.

The variable type is Input.
The variable has no unit [-].
The minimum limit is 0.1.
The maximum limit is 1.
The replacement value is 0.97.
The number of digits is 6.

factor for restriction

It is a factor evaluating the losses for the opening itself caused by edges or a flange for example. This is important, especially if the opening is small. Regarding this, a sharp-edged opening can have a restriction factor of about 0.6 or 0.65 for example, a flanged opening has possibly 0.98.

The variable type is Input.
The variable has no unit [-].
The minimum limit is 0.1.
The maximum limit is 1.
The replacement value is 0.97.
The number of digits is 6.

The factors for friction and restriction can be activated or deactivated via the corresponding *CheckBoxes*. In case if the *CheckBox* is checked, a value of 1.00 will be considered, internally. This means at least, that the factor is disregarded. In case if the *CheckBox* is not checked, the actual value of will be considered.

level

It is the level of the liquid inside the vessel. This level, the density and the gravity will cause a pressure at the bottom of the vessel. In reverse, by pressure, density and gravity the level inside the vessel can be determined.

The variable type is Input or Output.
The unit is meter [m].
The minimum limit is 0.1.
The maximum limit is 99999.
The replacement value is 1000.
The number of digits is 6.

pressure

It is the pressure at the bottom of the vessel. By the pressure, the density and the gravity the level inside the vessel can be determined. In reverse, level, density and gravity will cause a pressure at the bottom of the vessel.

The variable type is Input or Output.
The unit is bar [bar].
The minimum limit is 0.01.
The maximum limit is 999.
The replacement value is 2.
The number of digits is 6.

max. velocity

Based on the given variables level or pressure and friction factor there is a theoretical maximum value for the velocity of the draining liquid. Taking also the size and restriction of the opening into consideration a resulting flow rate is calculated, which is in coherence to the resulting velocity. The resulting velocity can be expected as the almost real value in opposite to the theoretical maximum velocity.

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 0.1.
The maximum limit is 99999.
The replacement value is 1000.
The number of digits is 6.

flow rate

Based on the given variables level or pressure and friction factor and also taking the size and restriction of the opening into consideration a resulting flow rate can be calculated, which is in coherence to the resulting velocity, which can be expected as the almost real value in opposite to the theoretical maximum velocity.

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

- meter cube per hour [m³ / h],
- liter per second [l / s],
- liter per minute [l / min],
- liter per hour [l / 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.

res. velocity

It is the resulting velocity. Based on the given variables level or pressure and friction factor and also taking the size and restriction of the opening into consideration a resulting flow rate can be calculated. This flow rate multiplied by the opening area results a velocity, which can be expected as the almost real value in opposite to the theoretical maximum velocity.

The variable type is 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].

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.

diameter (vessel dimensions)

It is the diameter for the vessel in case if it is a cylindrical vessel. The vessel itself can either have a circular base and a corresponding diameter or any other base shape and a corresponding area. It is selectable. The volume results out of the area and the level. By all these measures the time it takes to drain all the volume by gravity is calculated.

The variable type is Input.
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 6.

Keep in mind that the values for level, pressure, maximum velocity, flow rate and resulting velocity are start values. The values describe the circumstances right at the moment where the draining starts. While draining the level will decrease continuously which means that also pressure, maximum velocity, flow rate and resulting velocity will also decrease, of course.

area (vessel dimensions)

It is the area for the vessel in case if it is not a cylindrical vessel. The vessel itself can either have a circular base and a corresponding diameter or any other base shape and a corresponding area. It is selectable. The volume results out of the area and the level. By all these measures the time it takes to drain all the volume by gravity is calculated.

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

- millimeter square [mm²],

- centimeter square [cm²],

- meter square [m²].

The minimum limit is 0.1.
The maximum limit is 99999.
The replacement value is 1000.
The number of digits is 6.

volume (vessel dimensions)

It is the volume of the liquid inside the vessel. The vessel itself can either have a circular base and a corresponding diameter or any other base shape and a corresponding area. It is selectable. The volume results out of the area and the level. By all these measures the time it takes to drain all the volume by gravity is calculated.

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

- meter cube [m³],

- liter [l].

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.

time (vessel dimensions)

It is the time that it takes to drain away all the liquid inside the vessel. The vessel itself can either have a circular base and a corresponding diameter or any other base shape and a corresponding area. It is selectable. The volume results out of the area and the level. By all these measures the time it takes to drain all the volume by gravity is calculated by a differential equation.

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

- second [s],

- minute [min],

- hour [h],

- day [d].

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.

diameter (opening dimensions)

It is the diameter of the vessel opening and it is activated, if a small opening for the vessel is assumed. The vessel has an opening sideways near the bottom. For the opening there are two cases provided. Case one is a small opening. This can have a circular shape with a corresponding diameter or it can have any other shape with a corresponding area. I can enter a value for the diameter and the resulting area will be calculated or I can enter an area and the proper diameter for this will be calculated. Case two is a wide opening with measures for height and width. The cases are selectable.

The variable type is Input or Output.
The unit is millimeter [mm].
The minimum limit is 0.1.
The maximum limit is 99999.
The replacement value is 200.
The number of digits is 6.

area (opening dimensions)

It is the area of the vessel opening and it is activated, if a small opening for the vessel is assumed. The vessel has an opening sideways near the bottom. For the opening there are two cases provided. Case one is a small opening. This can have a circular shape with a corresponding diameter or it can have any other shape with a corresponding area. I can enter a value for the diameter and the resulting area will be calculated or I can enter an area and the proper diameter for this will be calculated. Case two is a wide opening with measures for height and width. The cases are selectable.

The variable type is Input or Output.
The unit is millimeter square [mm²].
The minimum limit is 0.1.
The maximum limit is 99999.
The replacement value is 1000.
The number of digits is 6.

width (opening dimensions)

It is the width of the vessel opening and it is activated, if a wide opening for the vessel is assumed. There is a vessel filled up to a certain level respectively there is a corresponding pressure at the bottom of the vessel. The vessel has an opening sideways near the bottom. For the opening there are two cases provided. Case one is a small opening. This can have a circular shape with a corresponding diameter or it can have any other shape with a corresponding area. I can enter a value for the diameter and the resulting area will be calculated or I can enter an area and the proper diameter for this will be calculated. Case two is a wide opening with measures for height and width. The cases are selectable.

The variable type is Input.
The unit is millimeter square [mm²].
The minimum limit is 0.1.
The maximum limit is 99999.
The replacement value is 1000.
The number of digits is 6.

height (opening dimensions)

It is the height of the vessel opening and it is activated, if a wide opening for the vessel is assumed. There is a vessel filled up to a certain level respectively there is a corresponding pressure at the bottom of the vessel. The vessel has an opening sideways near the bottom. For the opening there are two cases provided. Case one is a small opening. This can have a circular shape with a corresponding diameter or it can have any other shape with a corresponding area. I can enter a value for the diameter and the resulting area will be calculated or I can enter an area and the proper diameter for this will be calculated. Case two is a wide opening with measures for height and width. The cases are selectable.

The variable type is Input.
The unit is millimeter square [mm²].
The minimum limit is 0.1.
The maximum limit is 99999.
The replacement value is 1000.
The number of digits is 6.

Keep in mind that the values for level, pressure, maximum velocity, flow rate and resulting velocity are start values. The values describe the circumstances right at the moment where the draining starts. While draining the level will decrease continuously which means that also pressure, maximum velocity, flow rate and resulting velocity will also decrease, of course.

The values for theorem velocity and the theorem time are calculated directly without taking any factors into consideration. The value for the average flow rate is a theoretical value, which is calculated by division of the vessel volume and the drain time.

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

Step 4:
Select diameter or area for the opening (case opening not wide)
I can select, if the diameter or the area should be the given variable. If the diameter is selected, it has the variable type Input. Then the area will be calculated. If the area is selected, it has the variable type Input. Then the diameter will be calculated.

Step 2:
Select wide opening
I can select if the opening is small or wide. If the *CheckBox* is selected, the opening is wide. In this case the input parameters are height and width else they are diameter and area.

Step 1:
Density as In- / Output
If the *CheckBox* is not selected, the density has the variable type Output. That means it is calculated by temperature. If the *CheckBox* is selected, the density has the variable type Input. That means I can enter a density value.
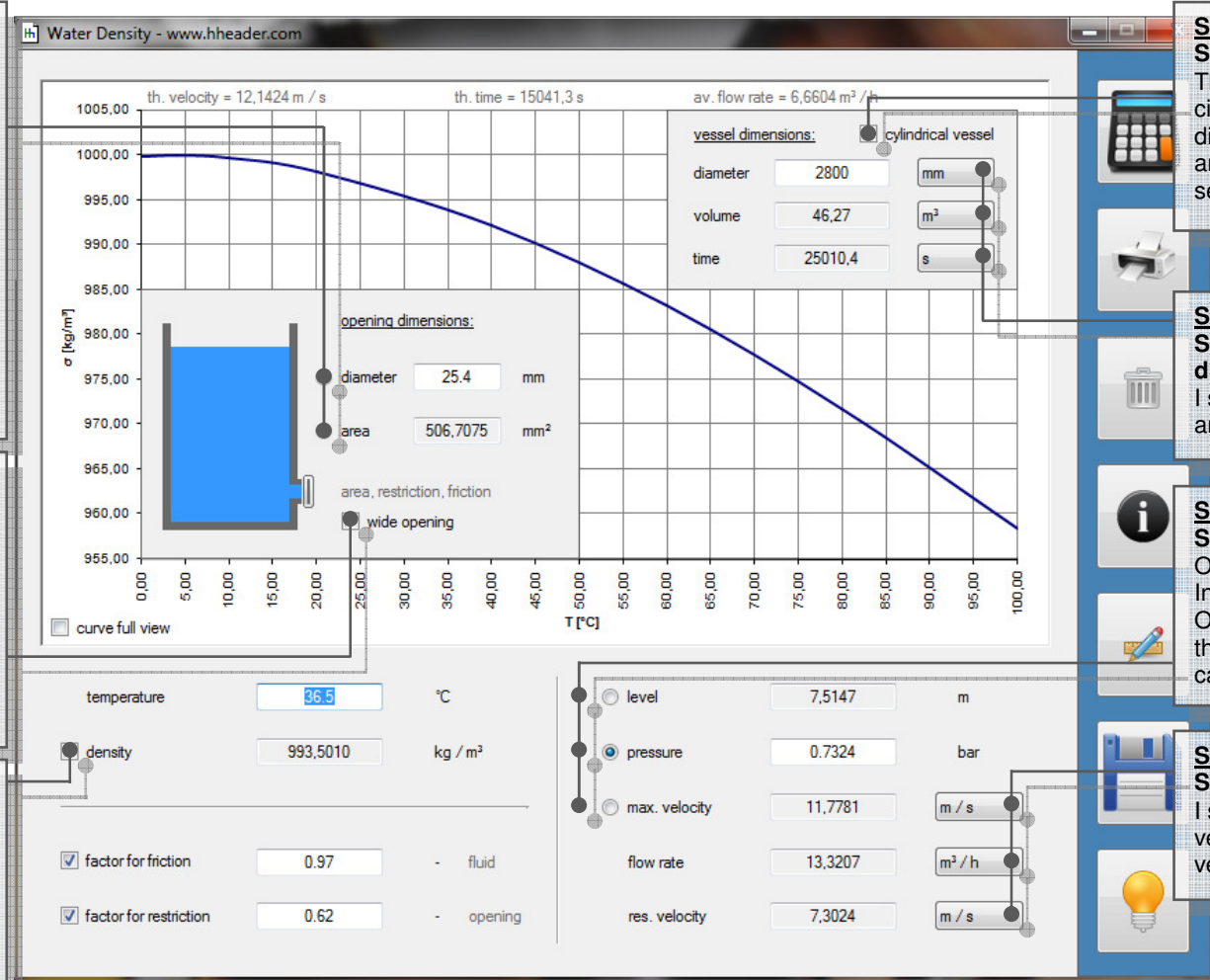
Step 3:
Select vessel shape
The vessel itself can either have a circular base and a corresponding diameter or any other base shape and a corresponding area. It is selectable.

Step 5:
Select the units for vessel dimensions
I select the units for diameter or area, volume and time.

Step 4:
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.

Step 5:
Select the units
I select the units for maximum velocity, flow rate and resulting velocity.

Figure 38: form water density / cylindrical vessel / small opening

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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.
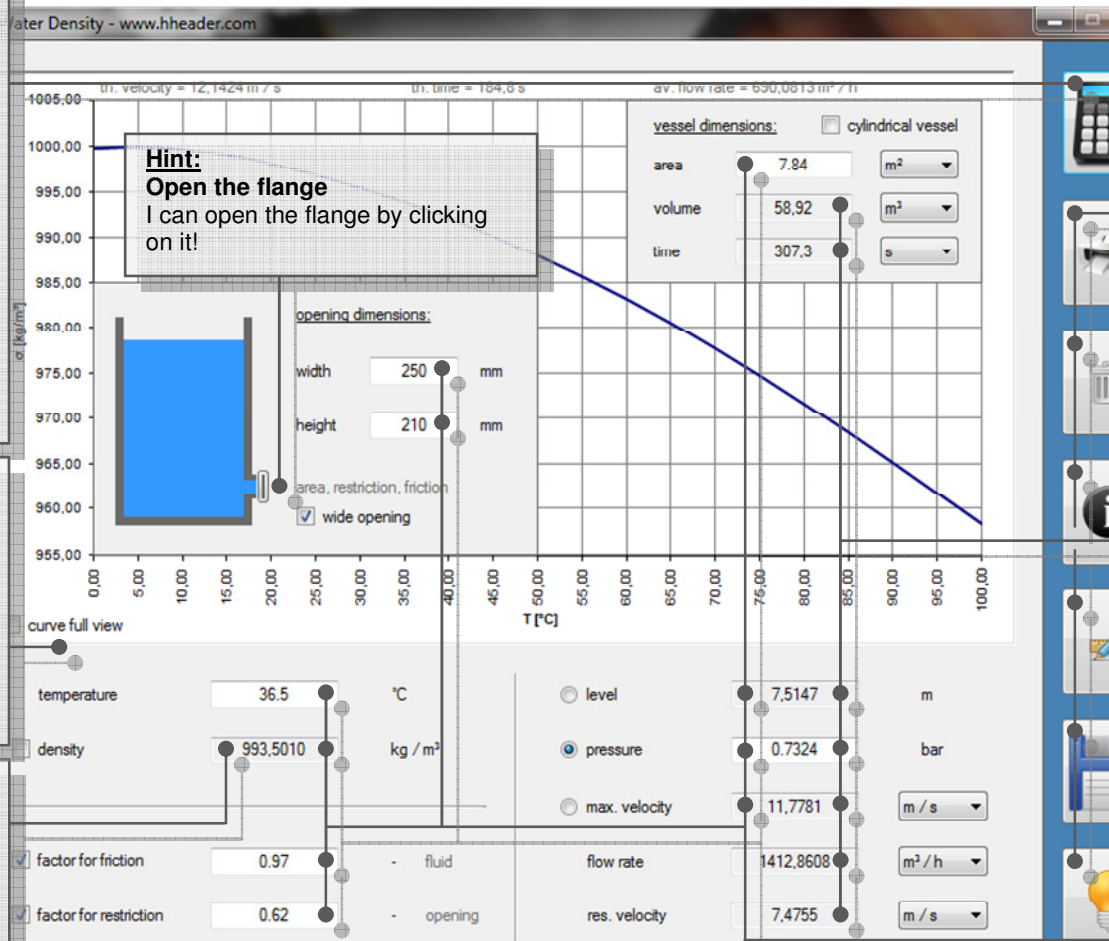
Step 10:
Curve full view
If the *CheckBox* is selected, the two Panels for vessel dimensions and opening dimensions will disappear, so there is a full view on the curve. If the *CheckBox* is unchecked the Panels will appear again.

Step 8:
Check results
After clicking the Calculate-Button or after a calculation has been executed otherwise I can check the results.

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 8:
Check results
After clicking the Calculate-Button or after a calculation has been executed otherwise, I should check the results.

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.

Hint:
Open the flange
I can open the flange by clicking on it!

Figure 39: form water density / no cylindrical vessel / wide opening

M-71

6.6.   Frictional Losses

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

The program is part of category 1 – pressure. Whenever a fluid, either liquid or gas, is forced moving through a defined pathway, especially if it is a closed system like a tube or a pipe, losses will appear due to friction and resistances caused by the surface properties. According to the dimensions and process values of the system it can be required to evaluate the losses in order to select proper equipment for defined operation purposes. For an adequate evaluation many parameters and properties have to be taken into consideration. These are divided up into different categories:

Fluid parameters
The dynamic viscosity and the density are properties of the fluid, which will take influence on the frictional losses.
The temperature effects changes of the dynamic viscosity and the density. The listed values refer to a viscosity and density at a temperature of 20°C, if not otherwise stated.

Material parameters
With the factor k the properties of the material and the design criteria of the pipe is considered. The design of the pipe, especially the composition of inner the pipe surface and its roughness take effect on the friction properties of the system.

Process parameters
The flow rate of the fluid going through the piping system is an important value. At least it is the velocity which takes influence on the friction. This is calculated by the given values for the flow rate and the pipe measures. The fluid temperature also belongs to the process values as well as control parameters like a valve that is throttled due to the process targets for example.

Dimension parameters
At least it is the velocity which takes massively influence on the friction values. The velocity is calculated by the given values for the flow rate and the pipe measures. For the pipe section two possible selections are provided:

-   circular pipe section,   -   rectangle pipe section.

Also the length will take influence on the frictional losses. The longer the pipe system is the more the frictional losses will increase. If the frictional losses are equal to the head pressure of the pump, a fluid transfer is no more possible.

Combined resulting parameters

The a-factor is a factor for the further calculations of the pipe resistance coefficient. It combines the relation between length and diameter of the pipe. It is required for the enhanced resistance coefficient a by zeta-pipe.

The relative factor k is a value for the material and design criteria of the piping system. The design of the pipe, especially the composition of the inner pipe surface and its roughness take effect on the friction properties of the system. The relative k-factor is the k-factor in relation to the pipe diameter.

It is the Reynolds number calculated by the given respectively resulting values for velocity, inner diameter, density and specific dynamic viscosity. The Reynolds number is required for further calculations of the pipe resistance coefficient. The Reynolds number also determines, if the stream is laminar or turbulent.

The pipe resistance coefficient calculated by the Reynolds number belongs to the combined parameters. For a laminar and a turbulent stream there are different equations provided. For zeta-pipe the length of the piping system is not taken into consideration. It is considered for the calculation of a-zeta-pipe.

The a-zeta-pipe is the pipe resistance coefficient calculated by the Reynolds number including the consideration of the pipe length. For laminar and turbulent streaming there are different equations.

The resistance coefficient is also important for the installed compounds like elbows, flanges, valves or other equipment. For each compound there is a resistance coefficient, which has to be multiplied by the amount of corresponding compounds. At the end all the resistance coefficients have to be summed up to a total resistance coefficient for the complete focused pipe work. The compounds which can be considered by using this calculation program are listed in the table below. Beside the density of the fluid and the velocity it is one important value for the differential pressure of the system.

As mentioned above, the differential pressure or pressure drop is depending on many different parameters. If the differential pressure is equal to the head pressure of the pump, a fluid transfer is no more possible.
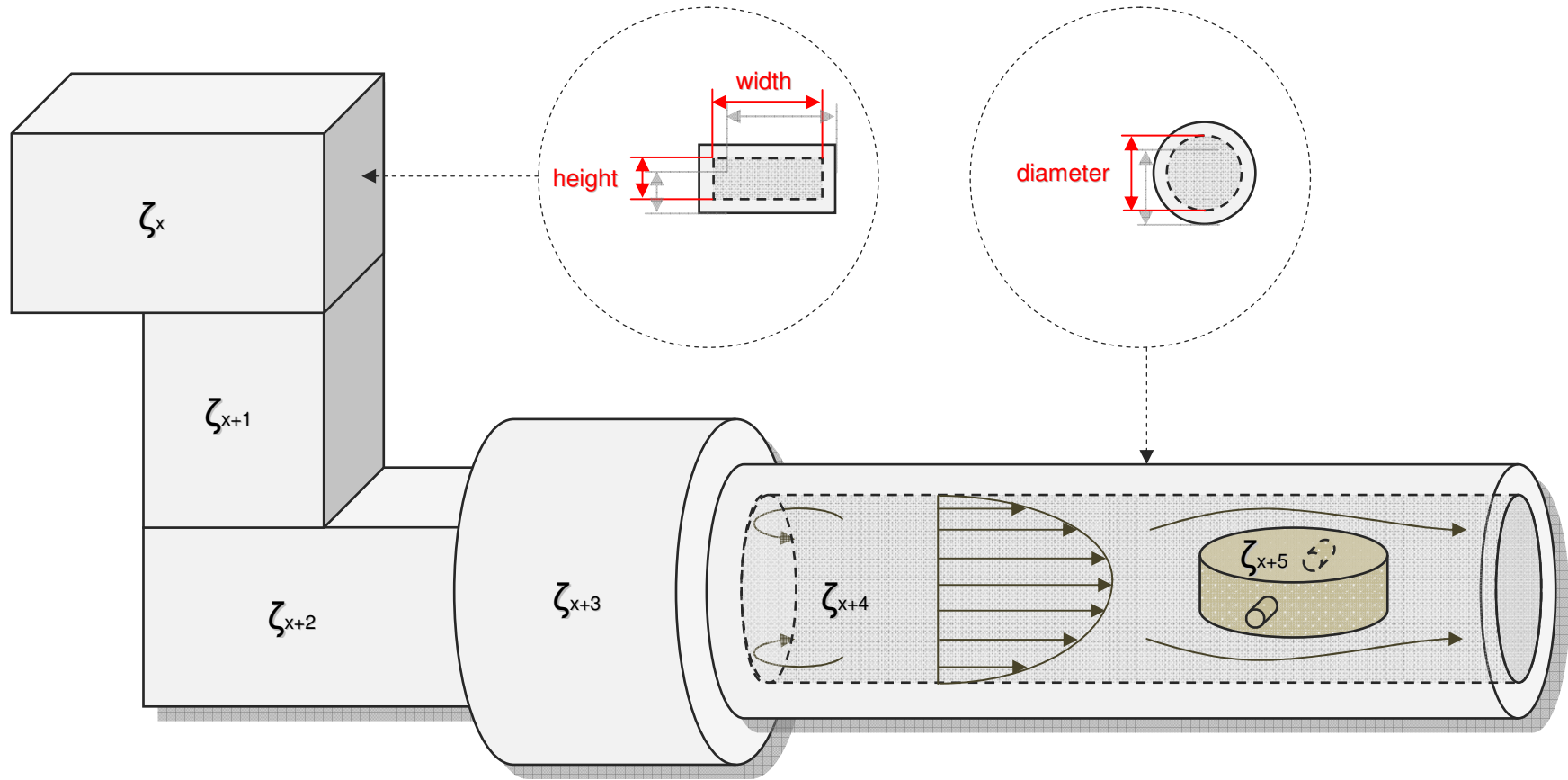
Figure 40: sketch frictional losses

Regarding the compounds which can be installed in the focused pipeline there are 14 different types (items) provided, where a zeta value can be user defined. The value of each activated item will be multiplied by its given amount in order to sum-up the zeta values. For the last four items there is an internal mathematical function applied so that these items can only be used for the by designation indicated purposes.

- flange
- elbow (90°)
- elbow (45°)
- Y-piece (standard)
- T-piece (straight)
- T-piece (separate)
- T-piece (combine)
- valve (straight)
- valves (corner)

- valves (butterfly)
- check valve (standard)
- check valve (butterfly)
- other compound
- sharp edge
- deviation (angle °)
- control valve (angle °)
- reduction (A2/A1)
- extension (A1/A2)

It is obvious that at least the zeta value itself is important for the calculation, so that the designation of the item is relevant just for a proper overview respectively for documentation purposes. What remains is that 14 different zeta values can be user defined and can be included in the calculations. **The zeta values for the installed compounds depend on the pipe diameter respectively on the pipe measures.**

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

pipe diameter

It is the inner diameter of the piping system in case if the pipe section is circular. At least it is the velocity which takes influence on the friction. This is calculated by the given values for the flow rate and the pipe area. In case if the pipe section is circular, the area of the pipe results from its diameter. In this case the pipe diameter is equal to the hydraulic diameter.

The variable type is Input.
The unit is millimeter [mm].
The minimum limit is 1.
The maximum limit is 9999999.
The replacement value is 200.
The number of digits is 10.

pipe measures (pipe height and pipe width)

The pipe height and the pipe width are the measures of the piping system in case if the pipe section has a rectangle shape. At least it is the velocity which takes influence on the friction. This is calculated by the given values for the flow rate and the pipe area. In case if the pipe section has a rectangle shape, the area of the pipe results from the multiplication of height and width. In this case the hydraulic diameter is calculated from these measures.

The variable type is Input.
The unit is millimeter [mm].
The minimum limit is 1.
The maximum limit is 9999999.
The replacement value is 200.
The number of digits is 10.

viscosity

It is the dynamic viscosity of the fluid, which is transferred trough the piping 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.
The unit is milli-Pascal by second [mPa s].
The minimum limit is 0.0001.
The maximum limit is 9999999.
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 obvious, that the temperature takes influence on the density. 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.
The unit is kilogram per liter [kg/l].
The minimum limit is 0.000001.
The maximum limit is 29.
The replacement value is 1.
The number of digits is 10.

factor k

It is the factor k for the material and design criteria of the piping system. The design of the pipe, especially the composition of inner pipe surface and its roughness take effect on the friction properties of the system. The k-factor is also required for determining the relative k-factor, which is the k-factor in relation to the pipe diameter.

The variable type is Input.
The unit is millimeter [mm].
The minimum limit is 0.000001.
The maximum limit is 9999.
The replacement value is 5.
The number of digits is 10.

pipe length

It is the length of the piping system. Of course the length will take influence on the frictional losses. The longer the pipe system is the more the frictional losses will increase. If the frictional losses are equal to the head pressure of the pump, a fluid transfer is no more possible.

The variable type is Input.
The unit is meter [m].
The minimum limit is 0.0001.
The maximum limit is 9999999.
The replacement value is 100.
The number of digits is 10.

flow rate

It is the flow rate of the fluid going through the piping system. At least it is the velocity which takes influence on the friction. This is calculated by the given values for the flow rate and the pipe measures.

The variable type is Input.
The unit is meter cube per hour [m³/h].
The minimum limit is 0.0001.
The maximum limit is 9999999.
The replacement value is 100.
The number of digits is 10.

hydr. diameter

It is the hydraulic diameter of the piping system. At least it is the velocity which takes influence on the friction. This is calculated by the given values for flow rate and pipe area. If the pipe section is circular, the hydraulic diameter is equal to the inner pipe diameter. If the pipe section has a rectangle shape, the hydraulic diameter is calculated by its measures. Further the hydraulic diameter is the denominator for the calculation of the relative k-factor.

The variable type is Output.
The unit is millimeter [mm].
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.

pipe area

It is the area of the piping system resulting from the pipe measures. At least it is the velocity which takes influence on the friction. This is calculated by the given values for flow rate and pipe measures. Further the hydraulic diameter is the denominator for the calculation of the relative k-factor.

The variable type is Output.
The unit is meter square [m²].
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.

velocity

It is the velocity of the fluid flowing through the piping system. The velocity takes influence on the friction. This is calculated by the given values for the flow rate and the area of the pipe.

The variable type is Output.
The unit is meter per second [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.

factor a

It is a factor for the further calculations of the pipe resistance coefficient. It combines the relation between length and diameter of the pipe. It is required for the enhanced resistance coefficient a by zeta-pipe.

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.

factor k-rel.

It is the relative factor k for the material and design criteria of the piping system. The design of the pipe, especially the composition of the inner pipe surface and its roughness take effect on the friction properties of the system. The relative k-factor is the k-factor in relation to the hydraulic pipe diameter.

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.

Reynolds

It is the Reynolds number calculated by the given and resulting values for velocity, inner diameter, density and specific dynamic viscosity. The Reynolds number is required for further calculations of the pipe resistance coefficient. The Reynolds number also determines if the stream is laminar or turbulent.

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.

a*zeta-pipe

It is the pipe resistance coefficient calculated by the Reynolds number including the consideration of the pipe length. For laminar and turbulent stream there are different equations relevant.

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.

zeta-pipe

It is the pipe resistance coefficient calculated by the Reynolds number. For laminar and turbulent streaming there are different equations. For zeta-pipe the length of the piping system is not taken into consideration. It is considered for the calculation of a*zeta-pipe.

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.

factor compound

It is the resistance coefficient of the single corresponding compound. For the program there is a selection of different compounds provided that can be installed into the pipe work. Each compound has its own definable resistance coefficient. This is multiplied by the amount of the installed compounds.

The variable type is Input.
The variable has no unit [-].
The minimum limit is 0.000001.
The maximum limit is 9999.
There is no defined replacement value for this variable.
The number of digits is 5.

amount

It is the amount of the corresponding installed compound. For the program there is a selection of different compounds provided that can be installed into the pipe work. Each compound has its own definable resistance coefficient. This is multiplied by the amount of the installed compounds.

The variable type is Input.
The variable has no unit [-].
The minimum limit is 0.
The maximum limit is 999.
There is no defined replacement value for this variable.
The number of digits is 3.

eff. angle

It is the corresponding angle for the compounds deviation and control valve. The control valve is assumed to be a butterfly valve that is operated by a controller. The angle for the control valve flap is adjusted in order to achieve the intended process parameters. The corresponding resistance coefficients of the two compounds are calculated by the given angle. These are multiplied by the corresponding given amounts of compounds.

The variable type is Input or Output.
The variable has no unit [-].
The minimum limit is 25.
The maximum limit is 90.
There replacement value 45.
The number of digits is 5.

zeta compound(s)

It is the resistance coefficient of all the selected compounds. For the program there is a selection of different compounds provided that can be installed into the pipe work. Each compound has its own definable resistance coefficient. This is multiplied by the amount of the installed compounds.

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.

spec. quotient

It is the specified quotient for the compounds reduction and extension. By this quotient the resistance coefficients of the two compounds are calculated. These are multiplied by the corresponding given amounts of compounds. The quotient results from the division of two areas. A1 is the area at the inlet of the compound and A2 is the area at the outlet of the compound. For the reduction A2 (outlet) is smaller than A1 (inlet). For the extension A1 (inlet) is smaller than A2 (outlet). For the reduction A2/A1 and for the extension A1/A2 has to be considered.

The variable type is Input.
The variable has no unit [-].
The minimum limit is 0.001.
The maximum limit is 1.
The replacement value is 0.5.
The number of digits is 5.

Regarding the compounds:
Each compound has its own definable resistance coefficient (factor compound). This is multiplied by the amount of the installed compounds (amount). The result is zeta compound. By selection it can be decided, if the compound is taken into consideration for the calculation or not. Internally the resistivity coefficient of all selected compounds is summed up to a total zeta compounds. Finally this is added together with the value for a*zeta pipe to a total zeta (zeta total).

zeta total

It is the total resistance coefficient for the complete focused pipe work including the installed compounds. It is the sum of the single resistance coefficients for all the pipes and all the selected compounds. Beside the density of the fluid and the velocity it is one important value for the differential pressure of the system.

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.

delta p – differential pressure, pressure drop

It is the differential pressure respectively the pressure drop or head loss which is depending on many different parameters: e.g. the properties and circumstances for the fluid, the properties of pipe material and the inner pipe surface, the dimensions of the pipe work, the process values like temperature and velocity, the amount and properties of the installed equipment. If the differential pressure is equal to the head pressure of the pump, a fluid transfer is no more possible.

The variable type is Output.
The unit is bar [bar].
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.

MANUAL

HHEADER

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

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 2: Select pipe section type
circular or rectangle shape.

Step 3: (option) Pipe design criteria selection
By selecting a pipe design the k-factor is shown in the *TextBox* below. It is an average value. Using the Transfer-Button will move the value into the Input-*TextBox*.

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: (options) Selections for the installed compounds
I can enter a value for the resistance coefficient of the different installed compounds. The value for the single compound is multiplied by the given amount of the corresponding compound. By selection it can be decided, if the compound is taken into consideration for the calculation or not.

Figure 41: form frictional losses

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Step 6: 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 8: Info calculation range
The indications show if the calculation results a laminar or a turbulent streaming.

Step 10: 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 7: Check results
After clicking the Calculate-Button or after a calculation has been executed otherwise I can check the result.

Step 9: Info calculation range
The indications show if the calculation is in range of Swamee and Jain (green) or not (red).

Figure 42: form frictional losses