# 9. Category Energy

## 9.1. Heat Exchange

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

The program is part of category 4 – energy. Programs for heat exchange calculations are not rare. Beside the design and the used materials, many different coefficients depending on the operation mode and other process circumstances have to be taken into consideration. On site many parameters which are taking influence on the heat transfer are not constant. On site the required coefficients are not always available. The target of the program is to provide a calculation tool with a minimum of required variables that is useful in practice. There are the temperature for inlet and outlet of the heat exchanger, the flow rate and the medium parameters heat capacity and density. These variables are provided for both lines of the heat exchanger, which are cycle line and main line. The cycle line is assumed to be a line with constant temperature conditions at the inlet and a various flow rate. The temperature outlet is calculated just for information purpose. The main line is assumed to be the line that is prepared for the further required process conditions. Usually the temperature can be various at the inlet and flow rate and outlet temperature are constant according to the process requirements after the heat exchange unit. However one of the following variables can be selected as result of the calculation: inlet temperature and flow rate for the cycle line, inlet and outlet temperature and flow rate for the main line and the transmission rate. The transmission rate defines the losses that occur while the heat transfer from one side to the other side of the heat exchanger takes place.

For each line a separate selection of medium is provided. By selection the corresponding values for heat capacity and fluid density are displayed. The shown values refer to a temperature of 20°C and atmospheric pressure. By clicking the button for the value transfer, the values will be incurred for the calculation.

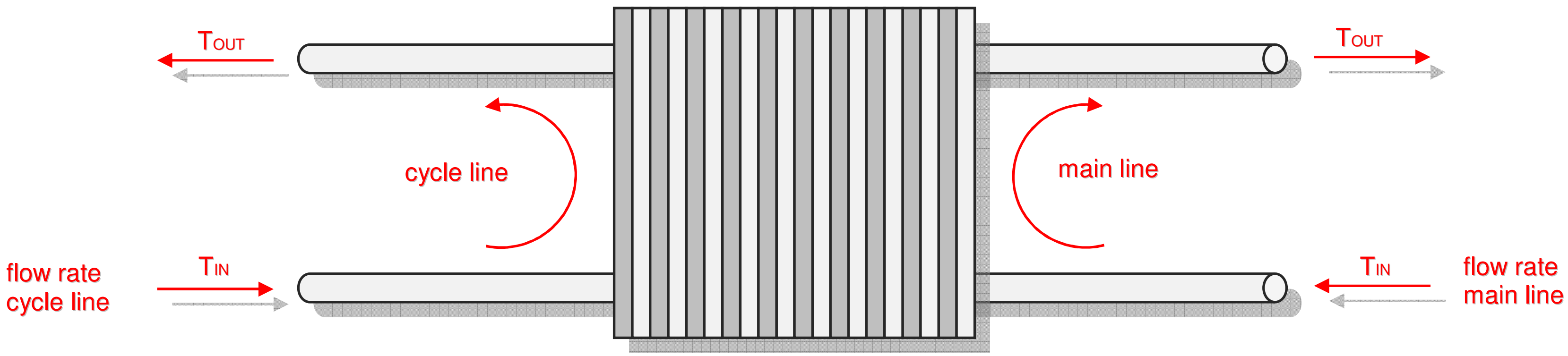



Figure 69: sketch heat exchange

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

**flow rate - cycle line**

It is the flow rate of the fluid in the cycle line. Inside the heat exchanger the flows for the cycle line and the main pipeline come close together and are separated only by the walls of the heat exchanger. A heat transfer takes place and thermal energy will go over from the warm flow to the cold flow.

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 999999.
The replacement value is 10.
The number of digits is 10.

**density of the fluid - cycle line**

It is the density of the fluid in the cycle line. The density of a material depends on different parameters. One of these is the temperature. In the program a selection is provided for different materials. If not otherwise stated the values belong to a temperature of 20°C.

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.

**capacity of the fluid - cycle line**

It is the specific heat capacity of the fluid in the cycle line. The specific heat capacity is a measure for the ability of a material to store thermal energy. At least it is the thermal energy that can be stored inside the material per kilogram and Kelvin. The specific heat capacity of a material depends on different parameters. One of these is the temperature. In the program a selection is provided for different materials. If not otherwise stated the values belong to a temperature of 20°C.

The variable type is Input or Output.
The unit is kilo-Joule per kilogram and Kelvin [kJ / (kg K)].
The minimum limit is 0.001.
The maximum limit is 50.
The replacement value is 4.82.
The number of digits is 10.

**temperature inlet - cycle line**

It is the temperature of the fluid in the cycle line. Inside the heat exchanger the flows for the cycle line and the main pipeline come close together and are separated only by the walls of the heat exchanger. A heat transfer takes place and thermal energy will go over from the warm flow to the cold flow.

The variable type is Input or Output.
The unit is degree Celsius [°C].
The minimum limit is -200.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 10.

**flow rate - main pipeline**

It is the flow rate of the fluid in the main pipeline. Inside the heat exchanger the flows for the cycle line and the main pipeline come close together and are separated only by the walls of the heat exchanger. A heat transfer takes place and thermal energy will go over from the warm flow to the cold flow.

The variable type is Input or Output.
The unit is meter cube per hour [m³ / h].
The minimum limit is 0.0001.
The maximum limit is 999999.
The replacement value is 10.
The number of digits is 10.

**density of the fluid - main pipeline**

It is the density of the fluid in the main pipeline. The density of a material depends on different parameters. One of these is the temperature. In the program a selection is provided for different materials. If not otherwise stated the values belong to a temperature of 20°C.

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.

**capacity of the fluid - main pipeline**

It is the specific heat capacity of the fluid in the main pipeline. The specific heat capacity is a measure for the ability of a material to store thermal energy. At least it is the thermal energy that can be stored inside the material per kilogram and Kelvin. The specific heat capacity of a material depends on different parameters. One of these is the temperature. In the program a selection is provided for different materials. If not otherwise stated the values belong to a temperature of 20°C.

The variable type is Input or Output.
The unit is kilo-Joule per kilogram and Kelvin [kJ / (kg K)].
The minimum limit is 0.001.
The maximum limit is 50.
The replacement value is 4.82.
The number of digits is 10.

**temperature inlet - main pipeline**

It is the temperature of the fluid at the inlet of the heat exchanger in the main pipeline. Inside the heat exchanger the flows for the cycle line and the main pipeline come close together and are separated only by the walls of the heat exchanger. A heat transfer takes place and thermal energy will go over from the warm flow to the cold flow.

The variable type is Input or Output.
The unit is degree Celsius [°C].
The minimum limit is -200.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 10.

#### temperature outlet – both lines

It is the temperature of the fluid at the outlet of the heat exchanger in both of the lines. For the main pipeline it is possible to select the variable type (input or output). Inside the heat exchanger the flows for the cycle line and the main pipeline come close together and are separated only by the walls of the heat exchanger. A heat transfer takes place and thermal energy will go over from the warm flow to the cold flow.

The variable type is Input or Output.
The unit is degree Celsius [°C].
The minimum limit is -200.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 10.

#### thermal flow (Q)

It is the thermal flow that is required for the heat transition from the warm to the cold side of the heat exchanger. The thermal flow is at least the power rate that is required to increase the flow temperature on the cold side of the heat exchanger from the inlet temperature value up to the outlet temperature value. For the calculations the thermal flow is assumed to be constant.

The variable type is Input.
The unit is kilowatt [kW].
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.

#### eff. transmission rate

It is the effective transmission rate for the heat exchanger. The heat exchange is practically not possible without any losses. This is taken into consideration by the transmission rate. It depends on the material and the construction of the heat exchanger, as well as on the surrounding circumstances and will practically never reach the 100%. At least it means that the heat exchanger has to be operated with an increased flow rate in order to balance the losses.

The variable type is Input or Output.
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.

#### factor heat transition (k)

It is the heat transition factor that is relevant for the transition of the heat flow from the warm to the cold side of the heat exchanger unit. The heat transition factor depends on many different parameters. The program provides a small selection of rough value items. By selecting an item, the average value of the corresponding range will be transferred into the numeric field for the k-factor. The factor is at least a value for the thermal flow (power rate) that can occur per square meter and Kelvin.

The variable type is Input.
The unit is watt per meter square and Kelvin [W / (m² K)].
The minimum limit is 1.
The maximum limit is 9999.
The variable has no replacement value.
The number of digits is 4.

**heat exchanger area (A)**

It is the effective area of the heat exchanger that is required due to the calculated thermal flow and the expected factor for the heat transition. The area is an important parameter in order to ensure that the heat transfer from the warm side to the cold side of the heat exchanger can take place, properly. It is the area where the fluid flows are indirectly in contact and where they are separated by the walls of the heat exchanger elements, only.

The variable type is Input.
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.

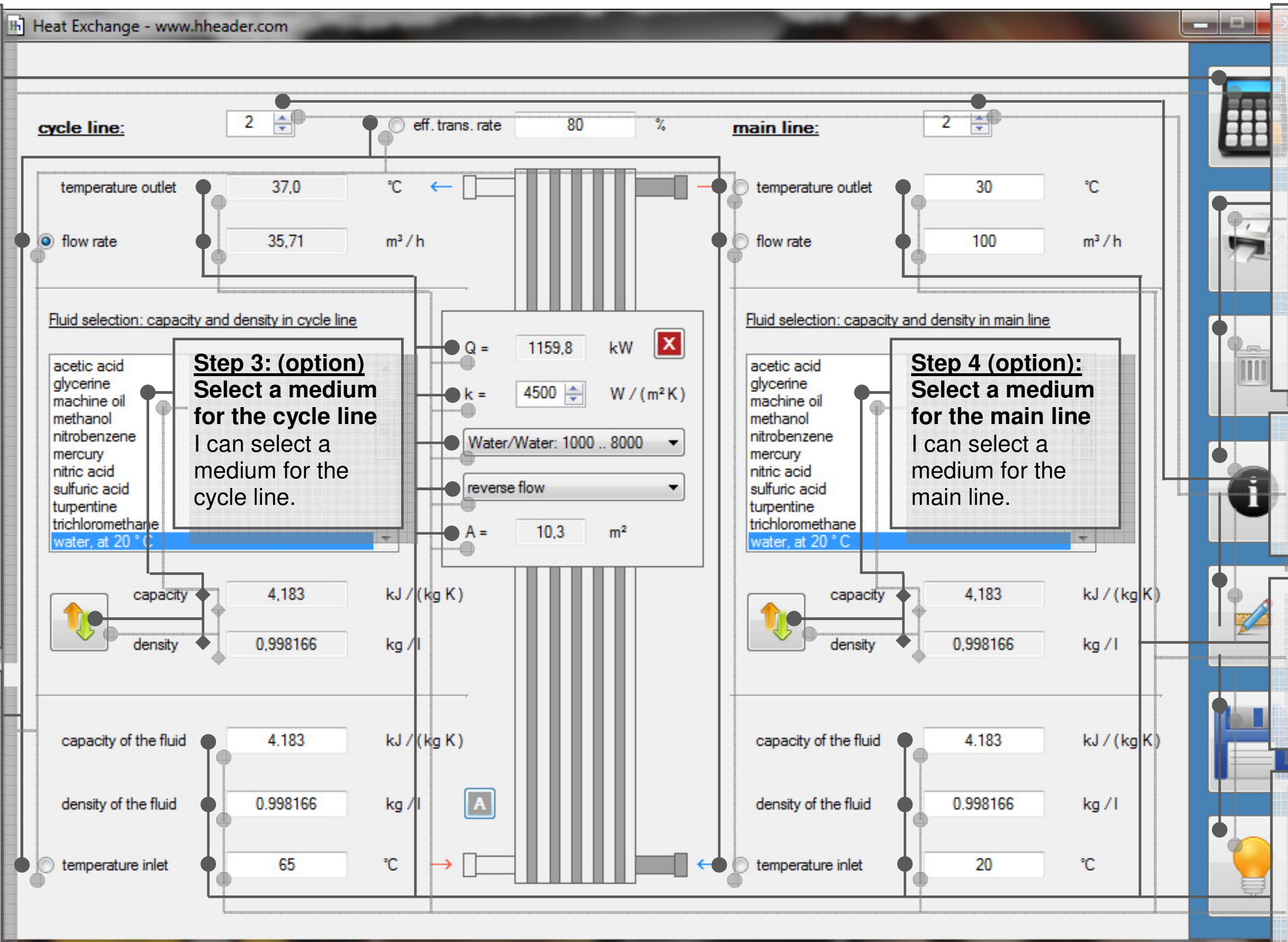
The calculation will be interrupted automatically in case it results implausible values or there have been implausible values entered before.
Regarding this there are eleven different cases defined:

- Case 1: The temperatures at the inlet and outlet in the cycle line are equal.
- Case 2: The temperatures at the inlet and outlet in the main line are equal.
- Case 3: The temperatures at the inlet in the cycle line and at the outlet in the main line are equal.
- Case 4: The temperatures at the inlet in the cycle line and at the inlet in the main line are equal.
- Case 5: The flow rate in the cycle line results a value < or = 0.
- Case 6: The temperature at the inlet in the cycle line results < -230°C.
- Case 7: The flow rate in the main line results a value < or = 0.
- Case 8: The temperature at the inlet in the main line results < -230°C.
- Case 9: The temperature at the outlet in the main line results < -230°C.
- Case 10: The transmission rate results a value < or = 0.
- Case 11: The transmission rate results a value > 100.

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

**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 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 3: (option)**
**Select a medium for the cycle line**
I can select a medium for the cycle line.

**Step 4 (option):**
**Select a medium for the main line**
I can select a medium for the main line.

Figure 70: form heat exchange

**Step 8:**
**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 5:**
**Decimal places**
I can select the number of decimal places.

**Step 7:**
**Check result**
After clicking the Calculate-Button I can check the result.

**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.

## 9.2. Thermal Combustion

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

The program is part of category 4 – energy. Combustion chambers can be built and designed for many different use cases. At least and in every case some kind of fuel or combustible is required. No matter what kind of combustion chamber and no matter which combustible is used, the energy balance is always an interesting part for these types of plants, especially if burners are used for increasing the temperature of an airflow or mass-flow. This can be found in regenerative thermal oxidation systems or steam boilers for example. At least it is important, that the required energies respectively the power rates for heating up the burner supply air, for heating up the main airflow or mass-flow (stream) and for the expected losses, which are predominantly convectional losses, are defined. In case if the main airflow or mass-flow (stream) has any combustible content, this can be taken into consideration, if its specific fuel value and its concentration are known. Finally the focus is on the demand of the used combustible, which is resulting out of the energy balance consideration. It is also an important factor for the evaluation of the operation costs and the profitable efficiency of the plant operation. The demand of the combustible, with respect to the specific fuel value, is displayed as the flow rate that is in relation to the required power rate. The displayed resulting flow rates for the combustible are: flow rate for heating up of the stream, flow rate to balance the convectional losses, flow rate for heating up the burner supply air, flow rate that is equal to the energy intake by the TOC-content (Total Oxidative Carbon). Therefore the flow rate for heating up the stream, the flow rate to balance the convectional losses and the flow rate for heating up the burner supply air are summed up. The flow rate that is equal to the energy intake by the TOC-content is subtracted from the sum-up in case if the TOC-intake should be considered. This can be chosen via the corresponding checkbox in the upper part on the left side of the main form. The result is multiplied by an empirical determined factor to make sure that the total demand is not underestimated (reserve included). The factor can be adjusted in a range from 0% to 30%.

The calculations can be set into relation of two different units: these are meter cube or kilogram. The units can be switched over for the following variables: specific fuel value for the combustible, flow rate, concentration of TOC, specific heat capacity for the airflow and the flow rates for the demand of the combustible. Be aware that the selection will only change the designation of the units. The given values are changing with respect to the density. This has to be taken into consideration manually and the corresponding values have to be adapted accordingly. Otherwise it is obvious that a density of 1kg / m³ will be basis for the carried out calculations, consequently.

Auxiliary calculations for the specific fuel value of the combustible and the power rate that is required for the heat up of the burner supply air are also provided. Regarding the specific fuel value there is a selection of different combustibles provided. The selection provides the values in the unit kilowatt by hours per kilogram. Via the given density and the concentration of the combustible this value can also be converted into kilowatt by hours per meter cube. The required power rate for heating up the burner supply air can be calculated separately. The calculated values can be transferred directly into the main form by the corresponding transfer buttons.

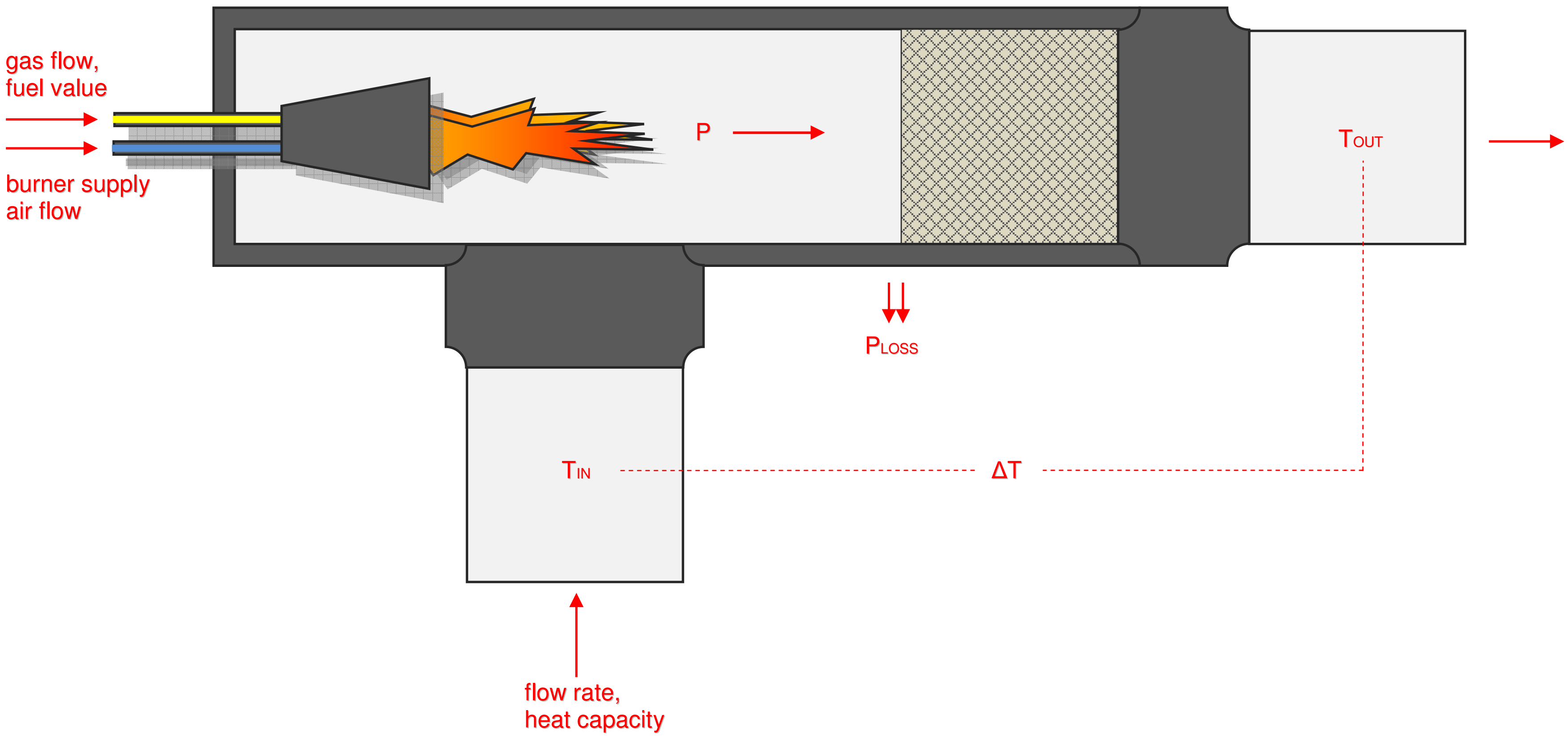



Figure 71: sketch thermal combustion

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

**specific fuel value – Combustion**

It is the specific fuel value of the combustible material that is used for the thermal energy intake by the burners. The specific fuel value is a measure for the energy that is released from a material by combustion in relation to a defined volume or a defined mass of this material.

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

- kilowatt by hours per meter cube [kWh / m³],
- kilowatt by hours per kilogram [kWh / kg].

The minimum limit is 0.01.
The maximum limit is 100.
The replacement value is 0.5.
The number of digits is 10.

**temperature inlet - Combustion**

It is the temperature at the inlet of the combustion chamber before the flow is getting into contact with the heat inside the combustion chamber. The temperature difference between inlet and outlet is at least the important value for the evaluation of the energy demand. In case any heat exchanging effects can be disregarded, the combustion chamber temperature has to be considered.

The variable type is Input.
The unit is degree Celsius [°C].

The minimum limit is -200.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 10.

**temperature outlet - Combustion**

It is the temperature at the outlet of the combustion chamber after the flow was getting into contact with the heat inside the combustion chamber. The temperature difference between inlet and outlet is at least the important value for the evaluation of the energy demand. In case any heat exchanging effects can be disregarded, the combustion chamber temperature has to be considered.

The variable type is Input.
The unit is degree Celsius [°C].

The minimum limit is -200.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 10.

**flow rate - Combustion**

It is the flow rate of the matter that is transported into the combustion chamber in order to be combusted. Initially some kind of worst case should be assumed. Therefore it is supposed, that a material or fluid has to be combusted, which has an extreme low specific fuel value respectively only parts or ingredients of the fluid are combustible - e.g. air with a content of TOC (Total Oxidative Carbon).

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

- meter cube per hour [$m^3$ / h],
- kilogram per hour [kg / h].

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

**concentration of TOC - Combustion**

It is the concentration of TOC (Total Oxidative Carbon) in the flow rate. Initially some kind of worst case should be assumed. Therefore it is supposed, that a material or fluid has to be combusted, which has an extreme low specific fuel value respectively only parts or ingredients of the fluid are combustible - e.g. air with a content of TOC (Total Oxidative Carbon). This is the TOC content as the mass of Total Oxidative Carbon in relation to a defined volume or mass of the fluid.

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

- milligram per meter cube [mg / m³],
- milligram per kg [mg / kg].

The minimum limit is 0.001.
The maximum limit is 1000000.
The replacement value is 300.
The number of digits is 10.

**temperature difference - Combustion**

It is the temperature difference between the inlet and the outlet temperature of the unit. The temperature difference between inlet and outlet is at least the important value for the evaluation of the energy demand. In case any heat exchanging effects can be disregarded, the difference between inlet temperature and combustion chamber temperature has to be considered.

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.

**specific heat capacity - Combustion**

It is the specific heat capacity of the matter flow that is transferred into the combustion chamber. The specific heat capacity is a measure for the ability of a material to store thermal energy. At least it is the thermal energy that can be stored inside the material per kilogram and Kelvin. The specific heat capacity of a material depends on different parameters. One of these is the temperature. If not otherwise stated the values belong to a temperature of 20°C.

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

- kilowatt by hours per 1000 meter cube and Kelvin [kWh / ($10^3$ $m^3$ K)],
- kilowatt by hours per 1000 kilogram and Kelvin [kWh / ($10^3$ kg K)].

The minimum limit is 0.01.
The maximum limit is 100.
The replacement value is 0.5.
The number of digits is 10.

**specific fuel value TOC - Combustion**

It is the specific fuel value of the TOC (Total Oxidative Carbon) that is content of the matter flow that is transferred into the combustion chamber. The specific fuel value is a measure for the energy that is released from a material by combustion in relation to a defined volume or a defined mass of this material.

The variable type is Input.
The unit is kilowatt by hours per kilogram [kWh / kg].
The minimum limit is 0.01.
The maximum limit is 100.
The replacement value is 0.5.
The number of digits is 10.

**convection losses - Combustion**

Whenever a construction or a unit handles with thermal energy and fluid flows, it is obvious, that there will be losses according to convection and similar mechanism. This is axiomatic however the insulation and the walls of the unit will be designed. Regarding the evaluation of the losses and the heat transition, there are many formulas and coefficients known. In case if the circumstances are always equal: always equal temperatures inside and outside the unit, always equal properties and thicknesses for the insulation, always equal flow rates with equal compositions, always equal pressures, etc., the calculations meet the real conditions. On site usually the conditions and circumstances change by time. Due to this it has been seen, that a rough base calculation and further an observation of the average energy balances, is at least more close to the real behavior of the plant than a conservative calculation. Because of this a fix value can be entered for the estimated power losses, which is multiplied by the number of units.

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

**heat up burner supply air - Combustion**

In case if primary burners are used for the intake of the thermal energy, they are operated with a controlled addition of supply air in order to get an adequate combustion (keyword: lambda). Heating up the flow of burner supply air will consume thermal energy, which has also to be taken into the system via the burners. On site usually the conditions and circumstances change by time. The fuel or gas flow and with it the flow rate of the burner supply air will change according to the temperature control. Due to this it has been seen, that a rough base calculation and further an observation of the average energy balances is at least more close to the real behavior of the plant than a conservative calculation. Because of this a fix value can be entered for the estimated power rate, which is required to heat up the burner supply air. This fix value can be multiplied by the number of burners. An evaluation for the power rate that is required to heat up the burner supply air can be done on the *TabPage* with the auxiliary calculations.

The variable type is Input.
The unit is kilowatt [kW / burner].
The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

**number of units - Combustion**

It is the amount of units that are involved in the process. According to the descriptions for the convection losses a fix value can be entered for the estimated power losses of each unit, which is multiplied by the number of units.

The variable type is Input.
The variable has no unit [-].
The minimum limit is 0.
The maximum limit is 100.
There is no replacement value provided.
The number of digits is 3.

**heat up stream - Combustion: required power rates**

It is the power rate that is required to heat up the total fluid flow rate as main stream.

The variable type is Output.
The unit is kilowatt [kW].
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.

**number of burners - Combustion**

It is the amount of burners that are involved in the process. According to the descriptions for the heat up of the burner supply air a fix value can be entered for the estimated power losses of each unit, which is multiplied by the number of units. An evaluation for the power rate that is required to heat up the burner supply air can be done on the *TabPage* with the auxiliary calculations.

The variable type is Input.
The variable has no unit [-].
The minimum limit is 0.
The maximum limit is 100.
There is no replacement value provided.
The number of digits is 3.

**convection loss - Combustion: required power rates**

It is the power rate that is required to equalize the assumed convection losses for the involved units.

The variable type is Output.
The unit is kilowatt [kW].
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.

**heat up burner supply air - Combustion: required power rates**

It is the power rate that is required to heat up the burner supply air for the involved burners.

The variable type is Output.
The unit is kilowatt [kW].
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.

**TOC intake - Combustion: required power rates**

It is the power rate that is taken into the system by the TOC-content of the flow rate. This power rate can be subtracted from the sum up again. Although the power rate for the TOC-intake is subtracted from the sum up, the total required power rate can be greater than the sum up, if the result is multiplied by an adequate average factor for considering a power reserve.

The variable type is Output.
The unit is kilowatt [kW].
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.

**sum up - Combustion: required power rates**

It is the sum up of the following power rates: heating up the stream, convection losses and heating up the burner supply air.

The variable type is Output.
The unit is kilowatt [kW].
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 required incl. reserve - Combustion: required power rates**

It is the total required power rate including the consideration of a probate power reserve, which is adjustable in a range from 0% to 30%. To determine the value, at first the sum up of the power rates heat up stream, convection losses and heat up burner supply air is calculated. Then the power rate for the TOC-intake is subtracted from the sum up. The result is multiplied by an adequate average factor (reserve).

The variable type is Output.
The unit is kilowatt [kW].
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.

**heat up stream - Combustion: required flow rates**

It is the flow rate of the combustible matter that is required to heat up the total fluid flow rate as main stream.

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

- meter cube per hour [$m^3$ / h],
- 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.

**heat up burner supply air - Combustion: required flow rates**

It is the flow rate of the combustible matter that is required to heat up the burner supply air for the involved burners.

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

- meter cube per hour [$m^3$ / h],
- 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.

**convection loss - Combustion: required flow rates**

It is the flow rate for the combustible matter that is required to equalize the assumed convection losses for the involved units.

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

- meter cube per hour [$m^3$ / h],
- 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.

**sum up - Combustion: required flow rates**

It is the sum up of the following flow rates: heat up stream, convection losses, heat up burner supply air.

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

- meter cube per hour [$m^3$ / h],
- 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.

**TOC intake - Combustion: required flow rates**

It is the flow rate of the combustible matter that is taken into the system by the TOC-content of the flow rate. This power rate can be subtracted from the sum up again. Although the power rate for the TOC-intake is subtracted from the sum up, the total required power rate can be greater than the sum up, if the result is multiplied by an adequate average factor for considering a power reserve.

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

- meter cube per hour [m³ / h],
- 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.

**total required incl. reserve - Combustion: required flow rates**

It is the total required flow rate of the combustible matter including the consideration of a probate power reserve, which can be adjusted in a range from 0% to 30%. To determine the value, at first the sum up of the flow rates heat up stream, convection losses and heat up burner supply air is calculated. Then the flow rate for the TOC-intake is subtracted from the sum up. The result is multiplied by an adequate average factor (reserve).

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

- meter cube per hour [m³ / h],
- 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.

**specific fuel value by mass – Auxiliary Calculations**

It is the specific fuel value of the combustible material that is used for the thermal energy intake by the burners. The specific fuel value is a measure for the energy that is released from a material by combustion in relation to a defined mass of this material.

The variable type is Input.
The unit is kilowatt by hours per kilogram [kWh / kg].
The minimum limit is 0.01.
The maximum limit is 100.
The replacement value is 0.5.
The number of digits is 10.

**density of the combustible – Auxiliary Calculations**

It is the density of the fuel or the combustible material that is used for the thermal energy intake by the burners. Be aware that the density depends on different parameters as temperature and pressure for example. The density under standard conditions, at a temperature of 0°C and an atmospheric pressure of 1013 mbar absolute, should be considered.

The variable type is Input.
The unit is kilogram per meter cube [kg / m³].
The minimum limit is 0.001.
The maximum limit is 29000.
The replacement value is 1.2.
The number of digits is 10.

**eff. concentration – Auxiliary Calculations**

It is the effective concentration of the combustible in relation to the total mass of the mixture. In case if there is a mixture of different compounds with a concentration of a combustible, this can be considered by the percentage value.

The variable type is Input.
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.

**specific fuel value by volume – Auxiliary Calculations**

It is the specific fuel value of the combustible material that is used for the thermal energy intake by the burners. The specific fuel value is a measure for the energy that is released from a material by combustion in relation to a defined volume of this material.

The variable type is Output.
The unit is kilowatt by hours per meter cube [kWh / 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.

### temperature outside – Auxiliary Calculations

It is the temperature outside the unit from where the burner supply air is taken. The temperature difference between the outer temperature and the temperature inside the combustion chamber is at least the important value for the evaluation of the required power rate to increase the burner supply air flow from the outer temperature to the combustion chamber temperature.

The variable type is Input.
The unit is degree Celsius [°C].
The minimum limit is -200.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 10.

### temperature chamber – Auxiliary Calculations

It is the temperature inside the combustion chamber. The temperature difference between the outer temperature and the temperature inside the combustion chamber is at least the important value for the evaluation of the required power rate to increase the burner supply air flow from the outer temperature to the combustion chamber temperature.

The variable type is Input.
The unit is degree Celsius [°C].
The minimum limit is -200.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 10.

### temperature difference – Auxiliary Calculations

It is the temperature difference between the outer temperature and the temperature inside the combustion chamber. This is at least the important value for the evaluation of the required power rate to increase the burner supply air flow from the outer temperature to the combustion chamber temperature.

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.

### flow rate burner supply air – Auxiliary Calculations

It is the flow rate for the burner supply air. In case if primary burners are used for the intake of the thermal energy, they are operated with a controlled addition of supply air in order to get an adequate combustion (keyword: lambda). Heating up this flow of burner supply air will consume thermal energy, which has also to be taken into the system via the burners.

The variable type is Input.
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 100.
The number of digits is 10.

**specific heat capacity – Auxiliary Calculations**

It is the specific heat capacity of the burner supply air. In case if primary burners are used for the intake of the thermal energy, they are operated with a controlled addition of supply air in order to get an adequate combustion (keyword: lambda). The specific heat capacity is a measure for the ability of a material to store thermal energy. At least it is the thermal energy that can be stored inside the material per kilogram and Kelvin. The specific heat capacity of a material depends on different parameters. One of these is the temperature. If not otherwise stated the values belong to a temperature of 20°C. Taking the density into consideration, the specific heat capacity can be set into relation to the volume as well. Therefore be aware that the density depends on different parameters as temperature and pressure for example. The density under standard conditions, at a temperature of 0°C and an atmospheric pressure of 1013 mbar absolute, should be considered.

The variable type is Input.
The unit is kilowatt by hours per 1000 meter cube and Kelvin
[kWh / ($10^3$ $m^3$ K)].
The minimum limit is 0.01.
The maximum limit is 100.
The replacement value is 0.5.
The number of digits is 10.

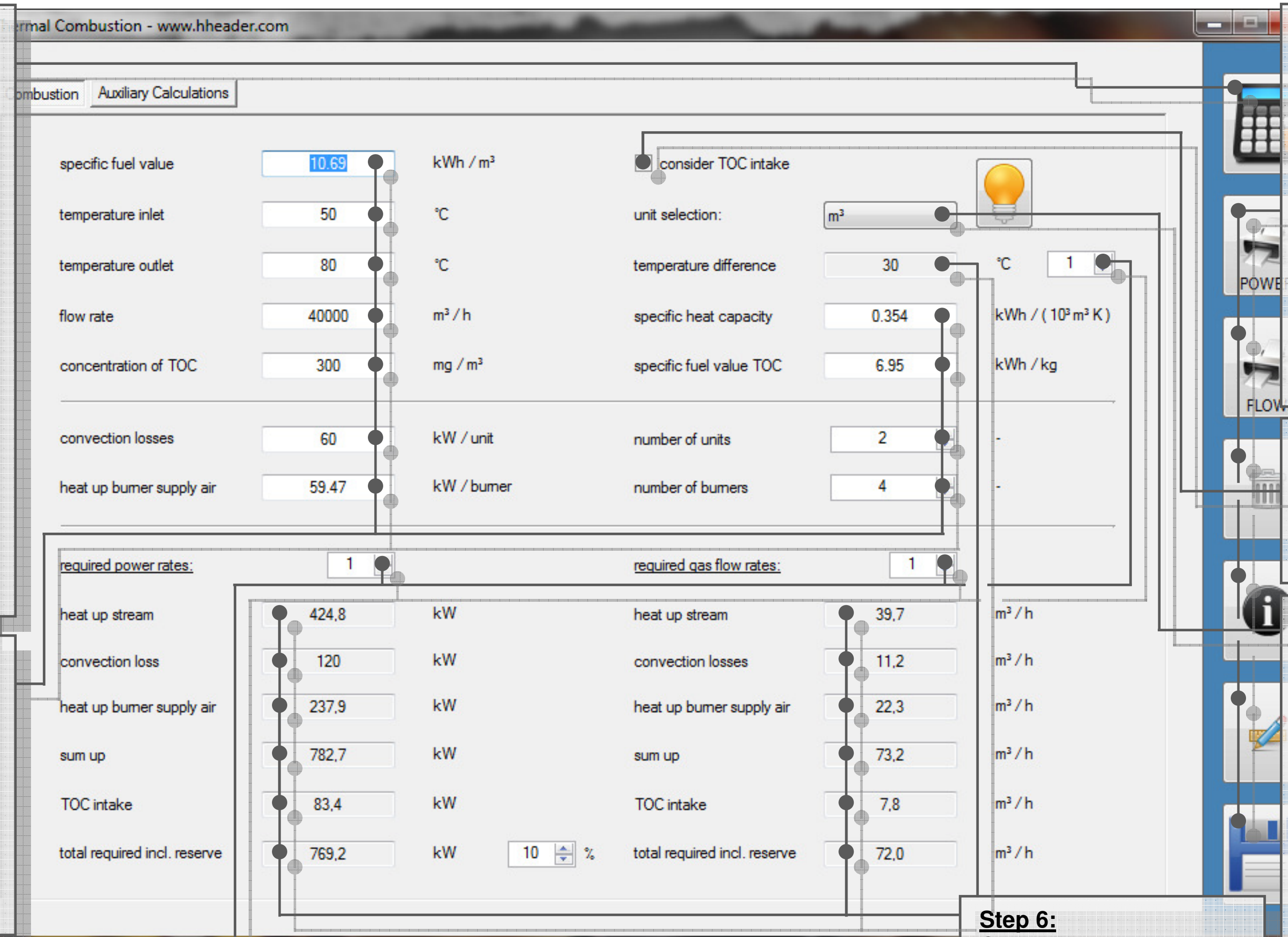
**power rate burner supply air – Auxiliary Calculations**

In case if primary burners are used for the intake of the thermal energy, they are operated with a controlled addition of supply air in order to get an adequate combustion (keyword: lambda). Heating up the flow of burner supply air will consume thermal energy, which has also to be taken in via the burners. On site usually the conditions and circumstances change by time. The fuel or gas flow and with it the flow rate of the burner supply air will change according to the temperature control. Due to this it has been seen, that a rough base calculation and further an observation of the average energy balances is at least more close to the real behavior of the plant than a conservative calculation. According to this the calculated value should be seen as a first rough base evaluation.

The variable type is Output.
The unit is kilowatt [kW].

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.

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




**Step 1:**
**Select the relation unit (m³ or kg)**
I can choose between two different relation units. These are meter cube or kilogram. I am aware that the selection will only change the designation of the units. The given values are changing with respect to the density. This has to be taken into consideration manually.

**Step 2:**
**Consider TOC intake**
I can select, if the TOC-intake is considered or 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 4:**
**Decimal places**
I can select the number of decimal places.

**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 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. While printing a new calculation is done automatically. Clicking the Erase-Button will empty all the *TextBoxes* at once.

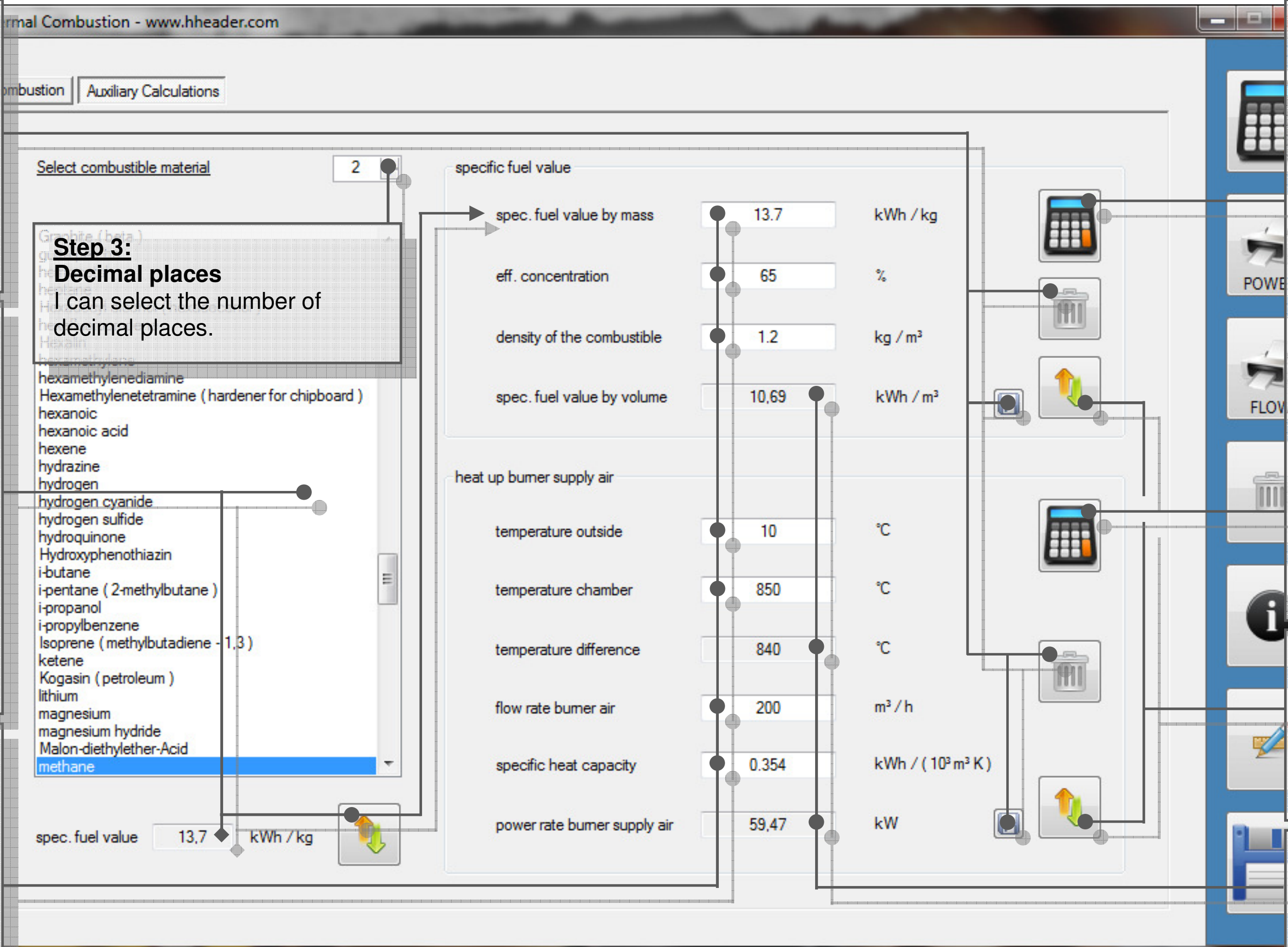
Figure 72: form thermal combustion - combustion

**Step 7: (option)**
**Further actions**
After the calculation I can have the following options: Erase Data, Program Information, Notes, Save or Restore Values for the calculations.

**Step 1: (option)**
**Select the combustible**
I can select the used combustible. The specific fuel value will be displayed in the *TextBox* below, accordingly. By using the transfer button the value will be transferred to the corresponding calculation variable.

**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 3:**
**Decimal places**
I can select the number of decimal places.




**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: (option)**
**Transfer results**
After clicking the Calculate-Button I can check the results into the main sheet.

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

Figure 73: form thermal combustion – auxiliary calculations

## 9.3. Energy Balance – Position Energy

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

The program is part of category 4 – energy. Energy cannot get lost - energy can be converted from one kind to another kind. There are many different kinds of energy. Energy can appear, can be stored and can be converted. Some of these kinds, which are often relevant for technical processes, are: position energy, kinetic energy, thermal energy, pressure volume work, potential energy spring, electrical capacitive energy, electro-magnetic energy, electric term energy, radiant energy, kinetic gas energy. The program provides the corresponding calculations for the mentioned energy kinds. The law of conservation of energy is a powerful tool to evaluate technical or process circumstances. Although the use cases are sometimes very different, we often find similar coherences between the single kinds of energy. Just to give an example: the energy that can be stored in a mechanical spring is defined as ½ by the spring rate value by the square of the elongation. The energy that can be stored in an electrical capacitor is defined as ½ by the capacitance value by the square of the voltage. Things that seem quite different on the first view can be sometimes very similar to each other. So it is obvious, that it can make sense to compare the different kinds of energy and to use the law of conservation of energy for practical evaluations. In every case we must be aware that the energy can never be converted from one kind to another to hundred percent. Parts of the energy will convert into other kinds, too. This is what we call losses, but the energy is only lost in reference to the considered process. In many cases these losses are converted into thermal energy. The energy input minus the energy losses is the energy output. The energy output in relation to the energy input is the efficiency rate, which is an important measure to be taken into consideration for the law of conservation of energy.

The position energy is the energy that is stored in an object in relation to other objects or levels according to the height difference and the force by gravity. If an object is placed on a high position in relation to a reference position, it has its position energy, accordingly. If the object is released and it can move from its position downwards to the reference position, the energy is converted from position energy to kinetic energy. The height is in coherence with the speed that can be reached through this. Relevant for the position energy are the mass of the object, the height and the gravity.

For the calculation one of the following variables can be selected as output variable: mass, gravity, height, position energy. The output variable will be calculated. The residual three variables are given input variables.

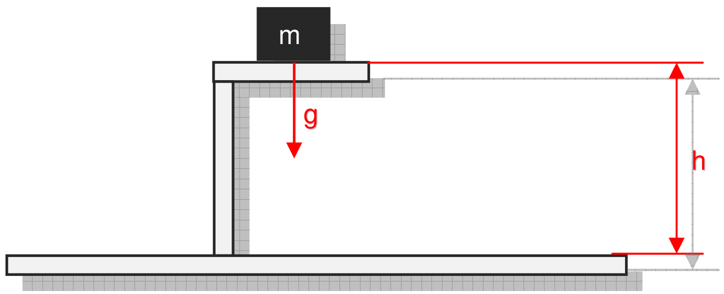


Figure 74: sketch energy balance - position energy

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

**mass**

It is the mass of the object that has the relevant position.

The variable type is Input or Output.
The unit is kilogram [kg].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**gravity**

It is the actual gravity at the position of the object.

The variable type is Input or Output.
The unit is meter per second square [m / s²].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**height**

It is the effective height of the object that has the relevant position.

The variable type is Input or Output.
The unit is meter [m].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**position energy**

It is the actual position energy that the object has in the relevant position.

The variable type is Input or Output.
The unit is kilo-joule [kJ].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

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

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

**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 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.

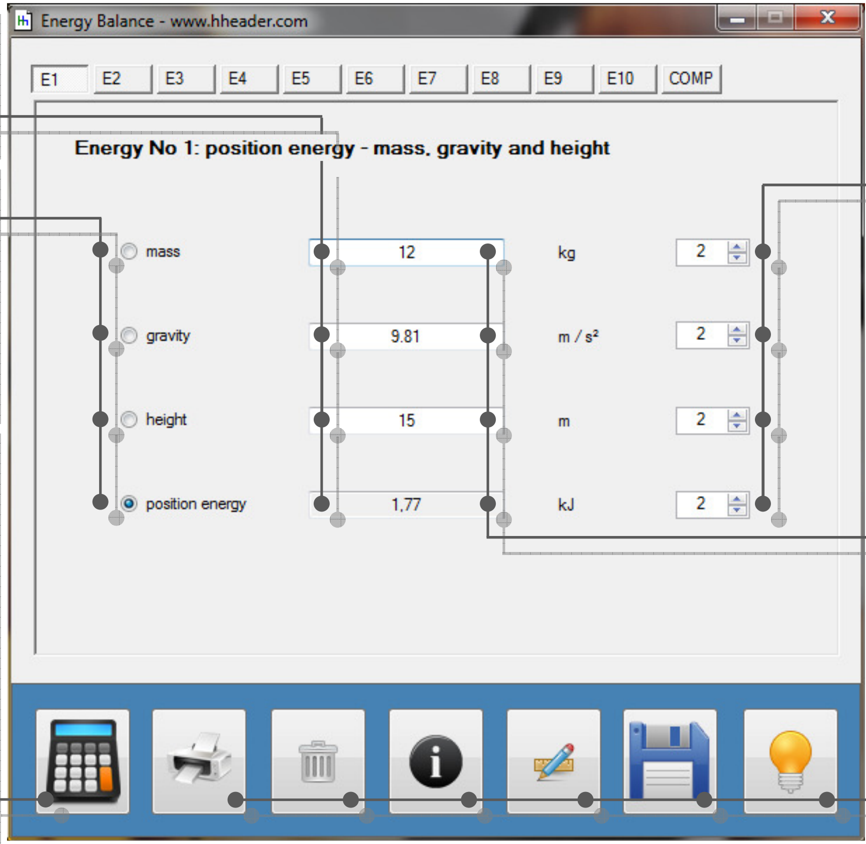



Figure 75: form energy balance – position energy

**Step 2:**
**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 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 6:**
**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.

## 9.4. Energy Balance – Kinetic Energy

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

The program is part of category 4 – energy. Energy cannot get lost - energy can be converted from one kind to another kind. There are many different kinds of energy. Energy can appear, can be stored and can be converted. Some of these kinds, which are often relevant for technical processes, are: position energy, kinetic energy, thermal energy, pressure volume work, potential energy spring, electrical capacitive energy, electro-magnetic energy, electric term energy, radiant energy, kinetic gas energy. The program provides the corresponding calculations for the mentioned energy kinds. The law of conservation of energy is a powerful tool to evaluate technical or process circumstances. Although the use cases are sometimes very different, we often find similar coherences between the single kinds of energy. Just to give an example: the energy that can be stored in a mechanical spring is defined as ½ by the spring rate value by the square of the elongation. The energy that can be stored in an electrical capacitor is defined as ½ by the capacitance value by the square of the voltage. Things that seem quite different on the first view can be sometimes very similar to each other. So it is obvious, that it can make sense to compare the different kinds of energy and to use the law of conservation of energy for practical evaluations. In every case we must be aware that the energy can never be converted from one kind to another to hundred percent. Parts of the energy will convert into other kinds, too. This is what we call losses, but the energy is only lost in reference to the considered process. In many cases these losses are converted into thermal energy. The energy input minus the energy losses is the energy output. The energy output in relation to the energy input is the efficiency rate, which is an important measure to be taken into consideration for the law of conservation of energy.

The kinetic energy is the energy an object has according to its mass and its speed. Hereby the square of the speed is relevant. This program does not provide relative calculations.

For the calculation one of the following variables can be selected as output variable: mass, speed, kinetic energy. The output variable will be calculated. The residual two variables are given input variables.

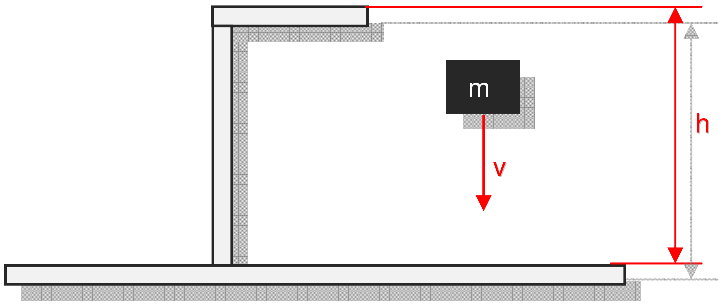



Figure 76: sketch energy balance - kinetic energy

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

**mass**

It is the mass of the object that is moving.

The variable type is Input or Output.
The unit is kilogram [kg].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**speed**

It is the actual speed of the object.

The variable type is Input or Output.
The unit is meter per second [m / s].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**kinetic energy**

It is the actual kinetic energy that the object has at the relevant speed.

The variable type is Input or Output.
The unit is kilo-joule [kJ].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

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

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

**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 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.

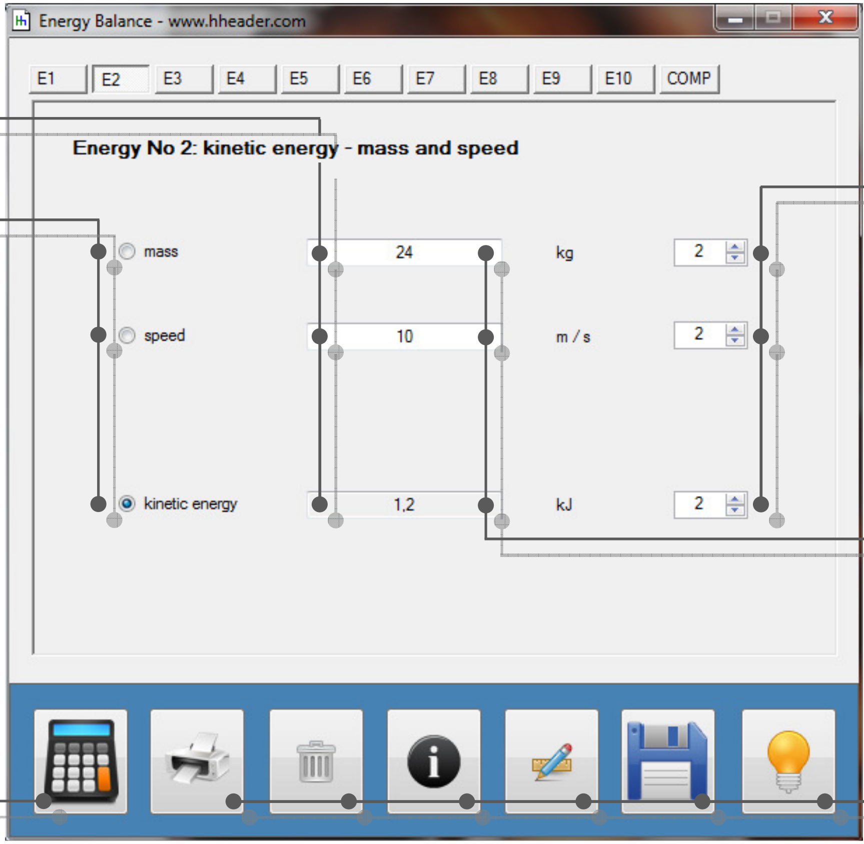



Figure 77: form energy balance – kinetic energy

**Step 2:**
**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 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 6:**
**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.

## 9.5. Energy Balance – Thermal Energy

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

The program is part of category 4 – energy. Energy cannot get lost - energy can be converted from one kind to another kind. There are many different kinds of energy. Energy can appear, can be stored and can be converted. Some of these kinds, which are often relevant for technical processes, are: position energy, kinetic energy, thermal energy, pressure volume work, potential energy spring, electrical capacitive energy, electro-magnetic energy, electric term energy, radiant energy, kinetic gas energy. The program provides the corresponding calculations for the mentioned energy kinds. The law of conservation of energy is a powerful tool to evaluate technical or process circumstances. Although the use cases are sometimes very different, we often find similar coherences between the single kinds of energy. Just to give an example: the energy that can be stored in a mechanical spring is defined as ½ by the spring rate value by the square of the elongation. The energy that can be stored in an electrical capacitor is defined as ½ by the capacitance value by the square of the voltage. Things that seem quite different on the first view can be sometimes very similar to each other. So it is obvious, that it can make sense to compare the different kinds of energy and to use the law of conservation of energy for practical evaluations. In every case we must be aware that the energy can never be converted from one kind to another to hundred percent. Parts of the energy will convert into other kinds, too. This is what we call losses, but the energy is only lost in reference to the considered process. In many cases these losses are converted into thermal energy. The energy input minus the energy losses is the energy output. The energy output in relation to the energy input is the efficiency rate, which is an important measure to be taken into consideration for the law of conservation of energy.

The thermal energy is the energy that can be stored as a temperature difference inside a material. Relevant is the heat capacity of the material. The specific heat capacity is a measure for the ability of a material to store thermal energy. At least it is the thermal energy that can be stored inside the material per kilogram and Kelvin. The heat capacity by mass and by the temperature difference result the thermal energy.

For the calculation one of the following variables can be selected as output variable: mass, heat capacity, temperature difference, thermal energy. The output variable will be calculated. The residual three variables are given input variables.

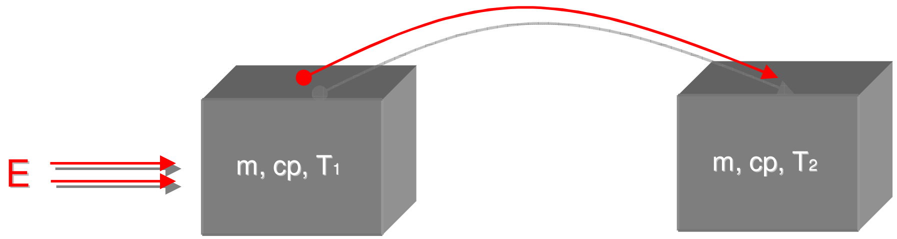



Figure 78: sketch energy balance - thermal energy

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

**mass**

It is the mass of the object that is considered.

The variable type is Input or Output.
The unit is kilogram [kg].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**heat capacity**

It is the specific heat capacity of the object. The specific heat capacity is a measure for the ability of a material to store thermal energy. At least it is the thermal energy that can be stored inside the material per kilogram and Kelvin. The specific heat capacity of a material depends on different parameters. One of these is the temperature.

The variable type is Input or Output.
The unit is kilo-joule per kilogram and Kelvin [kJ / (kg K)].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**temp. difference**

It is the temperature difference that is available for the system.

The variable type is Input or Output.
The unit is degree Celsius [°C].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**thermal energy**

It is the thermal energy for the considered system.

The variable type is Input or Output.
The unit is kilo-joule [kJ].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

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

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

**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 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.

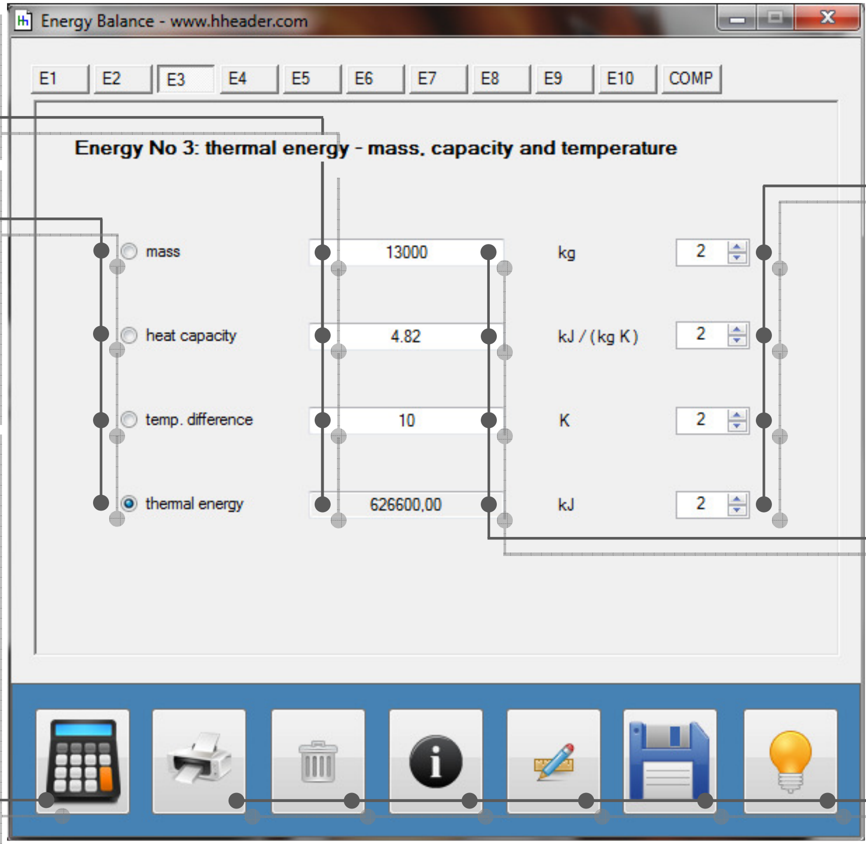



Figure 79: form energy balance – thermal energy

**Step 2:**
**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 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 6:**
**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.

## 9.6. Energy Balance – Pressure Volume Work

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

The program is part of category 4 – energy. Energy cannot get lost - energy can be converted from one kind to another kind. There are many different kinds of energy. Energy can appear, can be stored and can be converted. Some of these kinds, which are often relevant for technical processes, are: position energy, kinetic energy, thermal energy, pressure volume work, potential energy spring, electrical capacitive energy, electro-magnetic energy, electric term energy, radiant energy, kinetic gas energy. The program provides the corresponding calculations for the mentioned energy kinds. The law of conservation of energy is a powerful tool to evaluate technical or process circumstances. Although the use cases are sometimes very different, we often find similar coherences between the single kinds of energy. Just to give an example: the energy that can be stored in a mechanical spring is defined as ½ by the spring rate value by the square of the elongation. The energy that can be stored in an electrical capacitor is defined as ½ by the capacitance value by the square of the voltage. Things that seem quite different on the first view can be sometimes very similar to each other. So it is obvious, that it can make sense to compare the different kinds of energy and to use the law of conservation of energy for practical evaluations. In every case we must be aware that the energy can never be converted from one kind to another to hundred percent. Parts of the energy will convert into other kinds, too. This is what we call losses, but the energy is only lost in reference to the considered process. In many cases these losses are converted into thermal energy. The energy input minus the energy losses is the energy output. The energy output in relation to the energy input is the efficiency rate, which is an important measure to be taken into consideration for the law of conservation of energy.

Energy can be stored in a tank as a compressed gas for example. Hereby the stored energy is the product of pressure and volume. By a valve for example the energy can be released from the system, while the pressure drops.

For the calculation one of the following variables can be selected as output variable: pressure, volume, pressure-volume work. The output variable will be calculated. The residual two variables are given input variables.

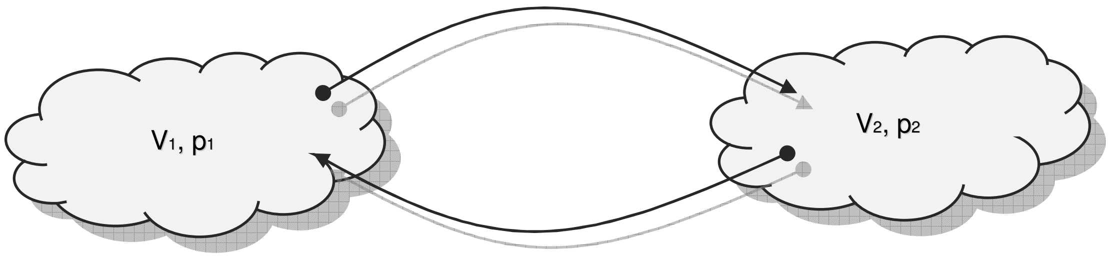



Figure 80: sketch energy balance – pressure volume work

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

**pressure**

It is the pressure of the system that is considered.

The variable type is Input or Output.
The unit is bar [bar].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**volume**

It is the volume of the system that is considered.

The variable type is Input or Output.
The unit is meter cube [$m^3$].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**pV work**

It is the pressure-volume work for the considered system. The energy can be stored in a tank as a compressed gas for example. The product of pressure by volume can be assumed as constant.

The variable type is Input or Output.
The unit is kilo-joule [kJ].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

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

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

**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 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.

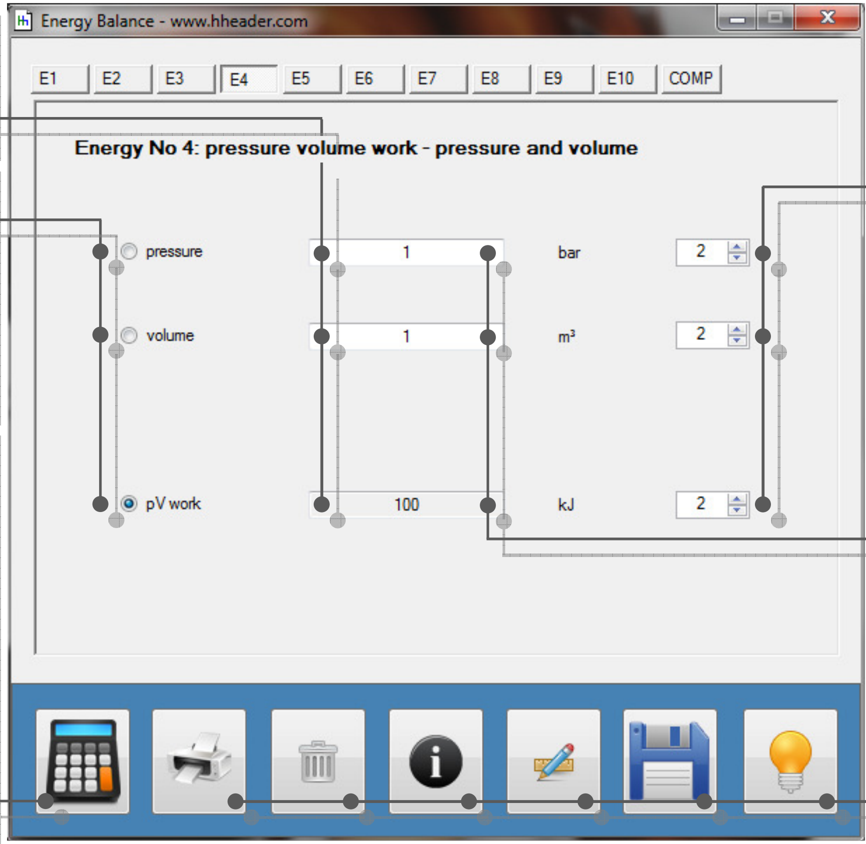



Figure 81: form energy balance – pressure volume work

**Step 2:**
**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 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 6:**
**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.

## 9.7. Energy Balance – Potential Energy Spring

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

The program is part of category 4 – energy. Energy cannot get lost - energy can be converted from one kind to another kind. There are many different kinds of energy. Energy can appear, can be stored and can be converted. Some of these kinds, which are often relevant for technical processes, are: position energy, kinetic energy, thermal energy, pressure volume work, potential energy spring, electrical capacitive energy, electro-magnetic energy, electric term energy, radiant energy, kinetic gas energy. The program provides the corresponding calculations for the mentioned energy kinds. The law of conservation of energy is a powerful tool to evaluate technical or process circumstances. Although the use cases are sometimes very different, we often find similar coherences between the single kinds of energy. Just to give an example: the energy that can be stored in a mechanical spring is defined as ½ by the spring rate value by the square of the elongation. The energy that can be stored in an electrical capacitor is defined as ½ by the capacitance value by the square of the voltage. Things that seem quite different on the first view can be sometimes very similar to each other. So it is obvious, that it can make sense to compare the different kinds of energy and to use the law of conservation of energy for practical evaluations. In every case we must be aware that the energy can never be converted from one kind to another to hundred percent. Parts of the energy will convert into other kinds, too. This is what we call losses, but the energy is only lost in reference to the considered process. In many cases these losses are converted into thermal energy. The energy input minus the energy losses is the energy output. The energy output in relation to the energy input is the efficiency rate, which is an important measure to be taken into consideration for the law of conservation of energy.

Energy can be stored as potential energy in a spring for example. Therefore the elongation of the spring has to be changed in relation to the length it has in an unstressed condition. To change the elongation it is required to stress the string by force. Hereby the square of the elongation is relevant. In this situation energy is stored inside the spring as potential energy, which can be released again.

For the calculation one of the following variables can be selected as output variable: spring rate, elongation, potential energy. The output variable will be calculated. The residual two variables are given input variables.

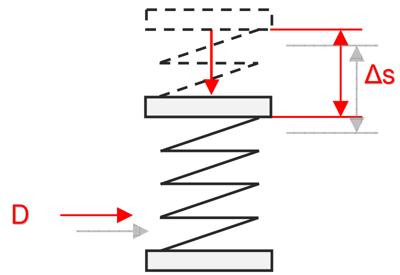



Figure 82: sketch energy balance – potential spring energy

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

**spring rate**

It is the spring rate of the system that is considered. The spring rate is a measure for the force that occurs, if the position for at least a part of the system is changed. The behavior of a stressed spring can be progressive, digressive or linear. The program provides a linear calculation, only.

The variable type is Input or Output.
The unit is kilo-joule per millimeter.
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**elongation**

If the system is stressed by force at least a part of it will change its position. A measure for this is the elongation.

The variable type is Input or Output.
The unit is millimeter [mm].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**potential energy**

It is the potential energy for the considered system. The energy is stored in the spring. The energy is released, if the stress disappears.

The variable type is Input or Output.
The unit is kilo-joule [kJ].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

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

**<u>Step 5:</u>**
**Check result**
After clicking the Calculate-Button I can check the result.

**<u>Step 1:</u>**
**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.

**<u>Step 4:</u>**
**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.

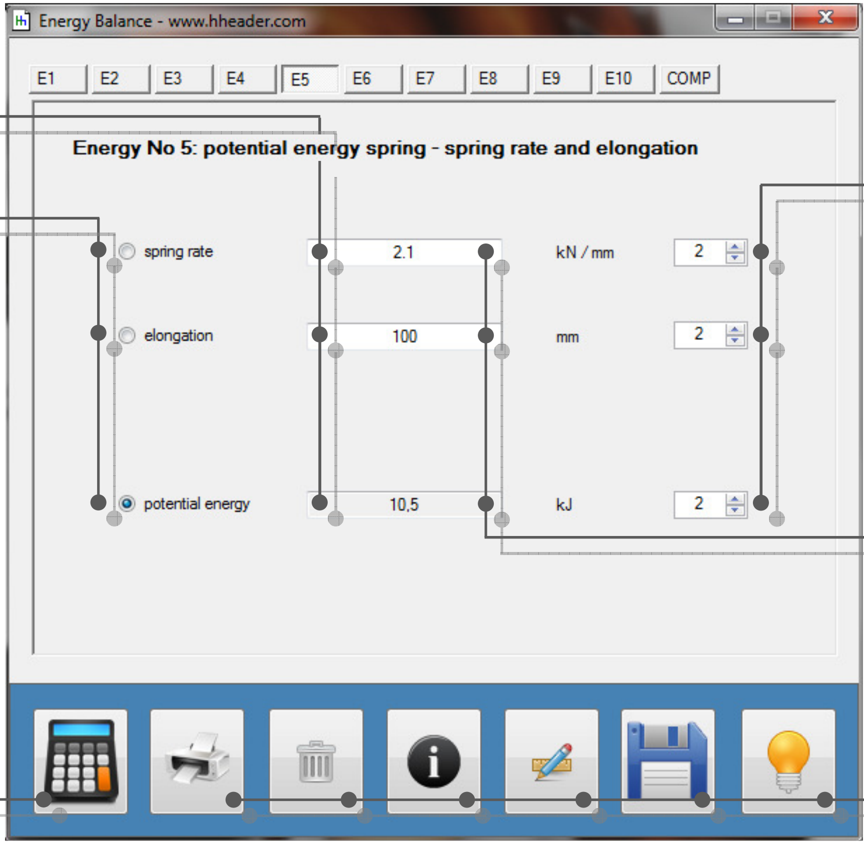



Figure 83: form energy balance – potential energy spring

**<u>Step 2:</u>**
**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.

**<u>Step 3:</u>**
**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.

**<u>Step 6:</u>**
**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.

## 9.8. Energy Balance – Electrical Capacitive Energy

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

The program is part of category 4 – energy. Energy cannot get lost - energy can be converted from one kind to another kind. There are many different kinds of energy. Energy can appear, can be stored and can be converted. Some of these kinds, which are often relevant for technical processes, are: position energy, kinetic energy, thermal energy, pressure volume work, potential energy spring, electrical capacitive energy, electro-magnetic energy, electric term energy, radiant energy, kinetic gas energy. The program provides the corresponding calculations for the mentioned energy kinds. The law of conservation of energy is a powerful tool to evaluate technical or process circumstances. Although the use cases are sometimes very different, we often find similar coherences between the single kinds of energy. Just to give an example: the energy that can be stored in a mechanical spring is defined as ½ by the spring rate value by the square of the elongation. The energy that can be stored in an electrical capacitor is defined as ½ by the capacitance value by the square of the voltage. Things that seem quite different on the first view can be sometimes very similar to each other. So it is obvious, that it can make sense to compare the different kinds of energy and to use the law of conservation of energy for practical evaluations. In every case we must be aware that the energy can never be converted from one kind to another to hundred percent. Parts of the energy will convert into other kinds, too. This is what we call losses, but the energy is only lost in reference to the considered process. In many cases these losses are converted into thermal energy. The energy input minus the energy losses is the energy output. The energy output in relation to the energy input is the efficiency rate, which is an important measure to be taken into consideration for the law of conservation of energy.

Energy can be stored as electrical energy in a capacitor for example. Relevant is the capacity and the peak value of the voltage that supplies the capacitor.
Hereby the square of the voltage is relevant.

For the calculation one of the following variables can be selected as output variable: capacity, voltage, electrical energy. The output variable will be calculated. The residual two variables are given input variables.

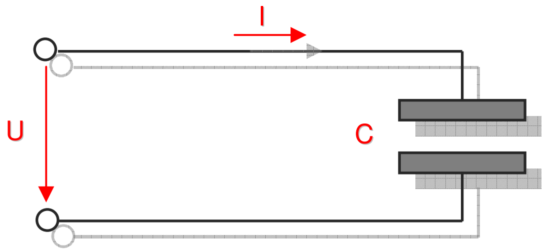



Figure 84: sketch energy balance – electrical capacitive energy

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

**capacity**

It is the electric capacity of the capacitor. The electric capacity is the ability to store electric energy. The capacitor will charge to the maximum voltage value. Remember: the unit Farad [F] is equal 1 Ampere by 1 second over 1 Volt [As / V].

The variable type is Input or Output.
The unit is Farad [F].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**electric energy**

It is the electric energy that is stored inside the capacitor.

The variable type is Input or Output.
The unit is kilo-joule [kJ].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**voltage**

It is the supply voltage for the capacitor. The capacitor will charge to the peak value of the voltage. It is spare root of 2 (1.41) as factor in an AC-system. In a three phase system the voltage between the phases needs to be considered.

The variable type is Input or Output.
The unit is volt [V].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

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

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

**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 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.

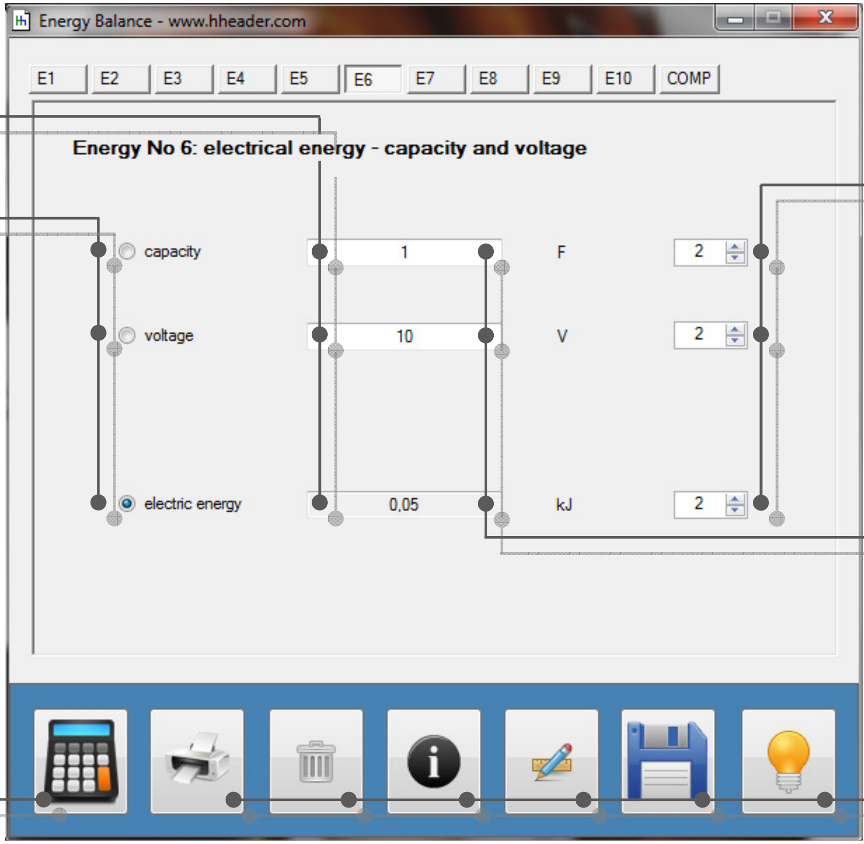



Figure 85: form energy balance - electrical capacitive energy

**Step 2:**
**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 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 6:**
**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.

## 9.9. Energy Balance – Electro-magnetic Energy

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

The program is part of category 4 – energy. Energy cannot get lost - energy can be converted from one kind to another kind. There are many different kinds of energy. Energy can appear, can be stored and can be converted. Some of these kinds, which are often relevant for technical processes, are: position energy, kinetic energy, thermal energy, pressure volume work, potential energy spring, electrical capacitive energy, electro-magnetic energy, electric term energy, radiant energy, kinetic gas energy. The program provides the corresponding calculations for the mentioned energy kinds. The law of conservation of energy is a powerful tool to evaluate technical or process circumstances. Although the use cases are sometimes very different, we often find similar coherences between the single kinds of energy. Just to give an example: the energy that can be stored in a mechanical spring is defined as ½ by the spring rate value by the square of the elongation. The energy that can be stored in an electrical capacitor is defined as ½ by the capacitance value by the square of the voltage. Things that seem quite different on the first view can be sometimes very similar to each other. So it is obvious, that it can make sense to compare the different kinds of energy and to use the law of conservation of energy for practical evaluations. In every case we must be aware that the energy can never be converted from one kind to another to hundred percent. Parts of the energy will convert into other kinds, too. This is what we call losses, but the energy is only lost in reference to the considered process. In many cases these losses are converted into thermal energy. The energy input minus the energy losses is the energy output. The energy output in relation to the energy input is the efficiency rate, which is an important measure to be taken into consideration for the law of conservation of energy.

Energy can be stored as electrical-magnetic energy inside an inductor for example. Important is the inductance and the current that is going through the inductor. Hereby the square of the current is relevant.

For the calculation one of the following variables can be selected as output variable: inductance, current, electro-magnetic energy. The output variable will be calculated. The residual two variables are given input variables.

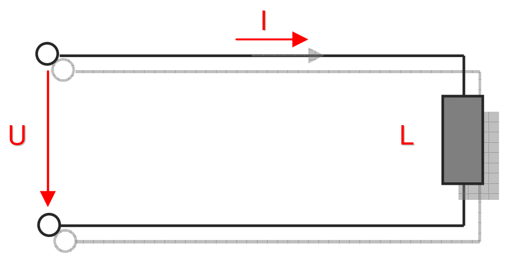



Figure 86: sketch energy balance – electro-magnetic energy

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

**inductance**

It is the inductance of the inductor. The inductance will try to hold the current and keep it constant. Remember: the unit Henry [H] is equal 1 Volt by 1 second over 1 Ampere [Vs / A].

The variable type is Input or Output.
The unit is Henry [H].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**current**

It is the current that is going through the inductance. The inductance will try to hold the current and keep it constant.

The variable type is Input or Output.
The unit is ampere [A].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**electric energy**

It is the electric energy that is stored inside the inductor.

The variable type is Input or Output.
The unit is kilo-joule [kJ].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

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

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

**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 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.

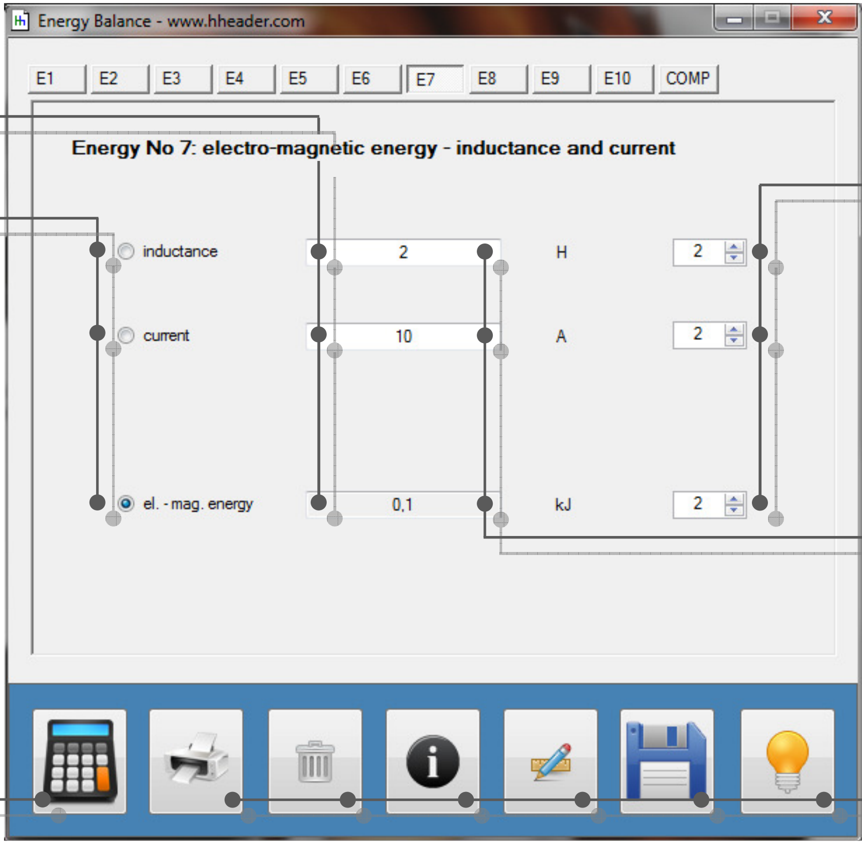



Figure 87: form energy balance – electro-magnetic energy

**Step 2:**
**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 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 6:**
**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.

## 9.10. Energy Balance – Electric Term Energy

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

The program is part of category 4 – energy. Energy cannot get lost - energy can be converted from one kind to another kind. There are many different kinds of energy. Energy can appear, can be stored and can be converted. Some of these kinds, which are often relevant for technical processes, are: position energy, kinetic energy, thermal energy, pressure volume work, potential energy spring, electrical capacitive energy, electro-magnetic energy, electric term energy, radiant energy, kinetic gas energy. The program provides the corresponding calculations for the mentioned energy kinds. The law of conservation of energy is a powerful tool to evaluate technical or process circumstances. Although the use cases are sometimes very different, we often find similar coherences between the single kinds of energy. Just to give an example: the energy that can be stored in a mechanical spring is defined as ½ by the spring rate value by the square of the elongation. The energy that can be stored in an electrical capacitor is defined as ½ by the capacitance value by the square of the voltage. Things that seem quite different on the first view can be sometimes very similar to each other. So it is obvious, that it can make sense to compare the different kinds of energy and to use the law of conservation of energy for practical evaluations. In every case we must be aware that the energy can never be converted from one kind to another to hundred percent. Parts of the energy will convert into other kinds, too. This is what we call losses, but the energy is only lost in reference to the considered process. In many cases these losses are converted into thermal energy. The energy input minus the energy losses is the energy output. The energy output in relation to the energy input is the efficiency rate, which is an important measure to be taken into consideration for the law of conservation of energy.

Energy can occur or be consumed as electric term energy. It is the electrical power rate multiplied by the operation time. The electrical power rate is at least the product of voltage and current.

For the calculation one of the following variables can be selected as output variable: voltage, current, time, electric term energy. The output variable will be calculated. The residual three variables are given input variables.

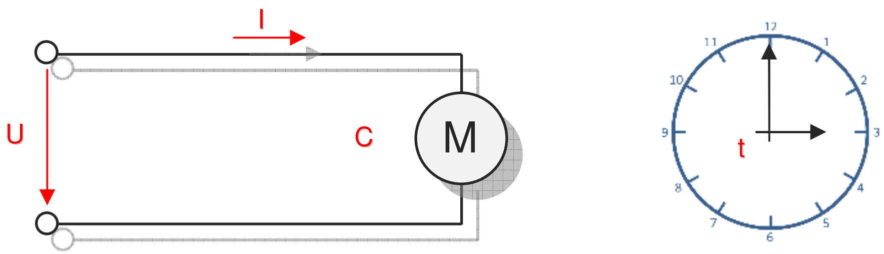



Figure 88: sketch energy balance – electric term energy

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

**voltage**

It is the voltage that is power supply for the system.

The variable type is Input or Output.
The unit is volt [V].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**current**

It is the current that is going through the conductors of the system.

The variable type is Input or Output.
The unit is ampere [A].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**time**

It is the operation time.

The variable type is Input or Output.
The unit is second [s].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**electric term energy**

It is the electric term energy that is consumed or transmitted by time.

The variable type is Input or Output.
The unit is kilo-joule [kJ].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

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

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

**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 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.

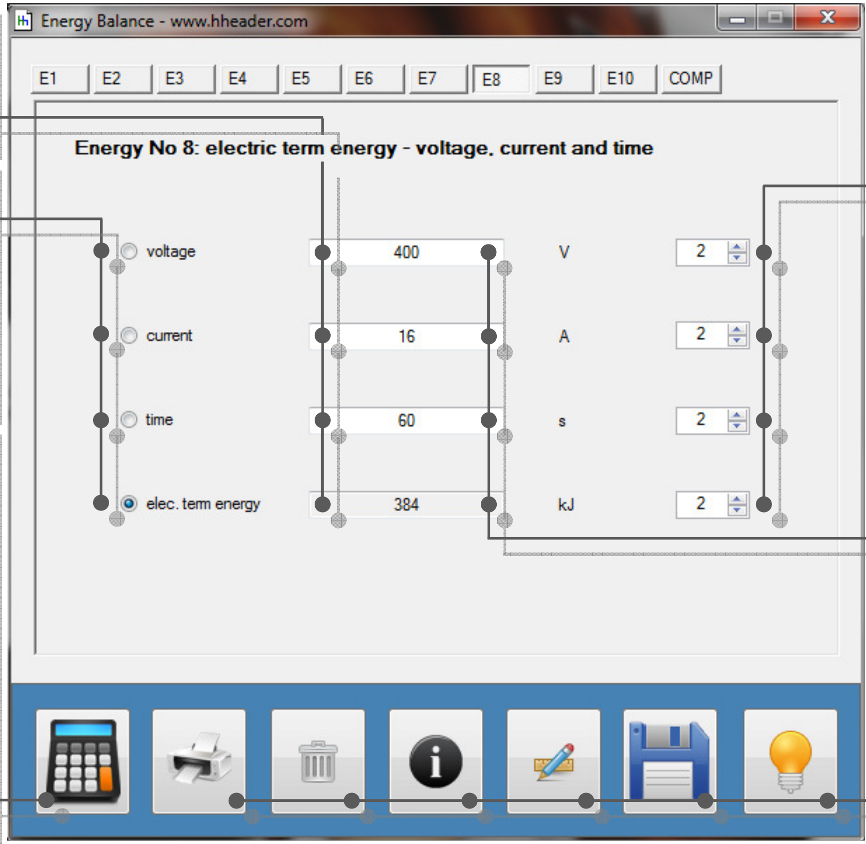



Figure 89: form energy balance – electric term energy

**Step 2:**
**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 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 6:**
**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.

## 9.11. Energy Balance – Radiant Energy

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

The program is part of category 4 – energy. Energy cannot get lost - energy can be converted from one kind to another kind. There are many different kinds of energy. Energy can appear, can be stored and can be converted. Some of these kinds, which are often relevant for technical processes, are: position energy, kinetic energy, thermal energy, pressure volume work, potential energy spring, electrical capacitive energy, electro-magnetic energy, electric term energy, radiant energy, kinetic gas energy. The program provides the corresponding calculations for the mentioned energy kinds. The law of conservation of energy is a powerful tool to evaluate technical or process circumstances. Although the use cases are sometimes very different, we often find similar coherences between the single kinds of energy. Just to give an example: the energy that can be stored in a mechanical spring is defined as ½ by the spring rate value by the square of the elongation. The energy that can be stored in an electrical capacitor is defined as ½ by the capacitance value by the square of the voltage. Things that seem quite different on the first view can be sometimes very similar to each other. So it is obvious, that it can make sense to compare the different kinds of energy and to use the law of conservation of energy for practical evaluations. In every case we must be aware that the energy can never be converted from one kind to another to hundred percent. Parts of the energy will convert into other kinds, too. This is what we call losses, but the energy is only lost in reference to the considered process. In many cases these losses are converted into thermal energy. The energy input minus the energy losses is the energy output. The energy output in relation to the energy input is the efficiency rate, which is an important measure to be taken into consideration for the law of conservation of energy.

Energy can occur as radiant energy. Therefore the number of radiant particles as multiple of one mol and the frequency are relevant. One mol is equal 1.6022 by 10^23 particles as amount of particles.

For the calculation one of the following variables can be selected as output variable: amount of radiant particles, frequency and radiant energy. The output variable will be calculated. The residual two variables are given input variables.

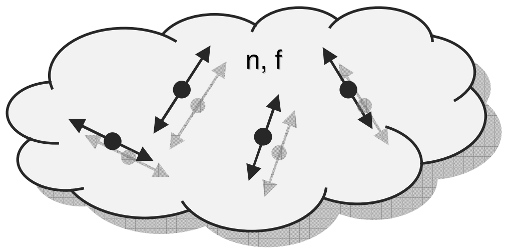



Figure 90: sketch energy balance - radiant energy

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

**radiant particles**

It is the amount of radiant particles. The unit is mol. 1 mol is equal 1.6022 by 10^23 particles.

The variable type is Input or Output.
The unit is mol [mol].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**radiant energy**

It is the radiant energy that is provided by the system.

The variable type is Input or Output.
The unit is kilo-joule [kJ].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**frequency**

It is the actual frequency for the radiant particles. The unit is multiple of 10^12 Hertz [Hz], which is 10^12 per second [10^12 / s].

The variable type is Input or Output.
The unit is multiple of 10^12 Hertz [Hz].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

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

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

**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 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.

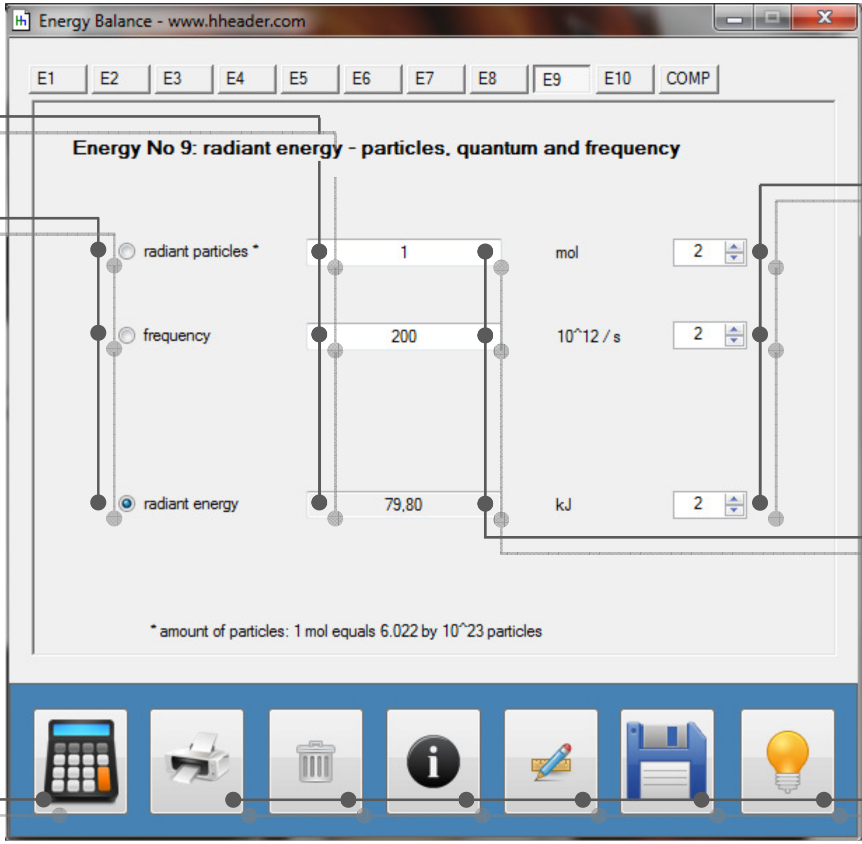



Figure 91: form energy balance – radiant energy

**Step 2:**
**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 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 6:**
**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.

## 9.12. Energy Balance – Kinetic Gas Energy

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

The program is part of category 4 – energy. Energy cannot get lost - energy can be converted from one kind to another kind. There are many different kinds of energy. Energy can appear, can be stored and can be converted. Some of these kinds, which are often relevant for technical processes, are: position energy, kinetic energy, thermal energy, pressure volume work, potential energy spring, electrical capacitive energy, electro-magnetic energy, electric term energy, radiant energy, kinetic gas energy. The program provides the corresponding calculations for the mentioned energy kinds. The law of conservation of energy is a powerful tool to evaluate technical or process circumstances. Although the use cases are sometimes very different, we often find similar coherences between the single kinds of energy. Just to give an example: the energy that can be stored in a mechanical spring is defined as ½ by the spring rate value by the square of the elongation. The energy that can be stored in an electrical capacitor is defined as ½ by the capacitance value by the square of the voltage. Things that seem quite different on the first view can be sometimes very similar to each other. So it is obvious, that it can make sense to compare the different kinds of energy and to use the law of conservation of energy for practical evaluations. In every case we must be aware that the energy can never be converted from one kind to another to hundred percent. Parts of the energy will convert into other kinds, too. This is what we call losses, but the energy is only lost in reference to the considered process. In many cases these losses are converted into thermal energy. The energy input minus the energy losses is the energy output. The energy output in relation to the energy input is the efficiency rate, which is an important measure to be taken into consideration for the law of conservation of energy.

The kinetic theory of gas refers at least to the consideration of the kinetic energy of a single gas particle with a specific mass moving with a certain speed. Therefore the speed is increasing with the temperature of the gas. Beyond this the universal gas constant has to be taken into consideration. The universal gas constant is a differential heat capacity. It is the difference between the pressure related heat capacity and the volume related heat capacity of a gas. The result is constant at 8.144598 Joule per mol and Kelvin. It is at least the energy that can be stored in one mol per Kelvin.

For the calculation one of the following variables can be selected as output variable: amount of particles, temperature, kinetic gas energy. The output variable will be calculated. The residual two variables are given input variables.

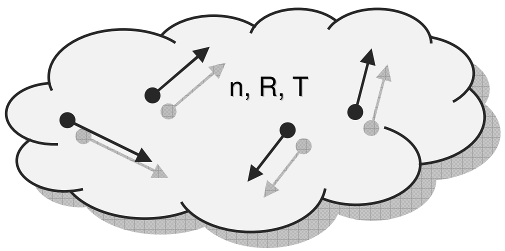



Figure 92: sketch energy balance – kinetic gas energy

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

**amount**

It is the amount of gas particles. The unit is mol. 1 mol is equal 1.6022 by 10^23 particles.

The variable type is Input or Output.
The unit is mol [mol].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**kin. gas energy**

It is the energy of the gas according to the kinetic gas theory.

The variable type is Input or Output.
The unit is kilo-joule [kJ].
The minimum limit is 0.0001.
The maximum limit is 999999999.
The replacement value is 100.
The number of digits is 10.

**temperature**

It is the actual gas temperature.

The variable type is Input or Output.
The unit is degree Celsius [°C].
The minimum limit is -200.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 10.

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

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

**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 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.

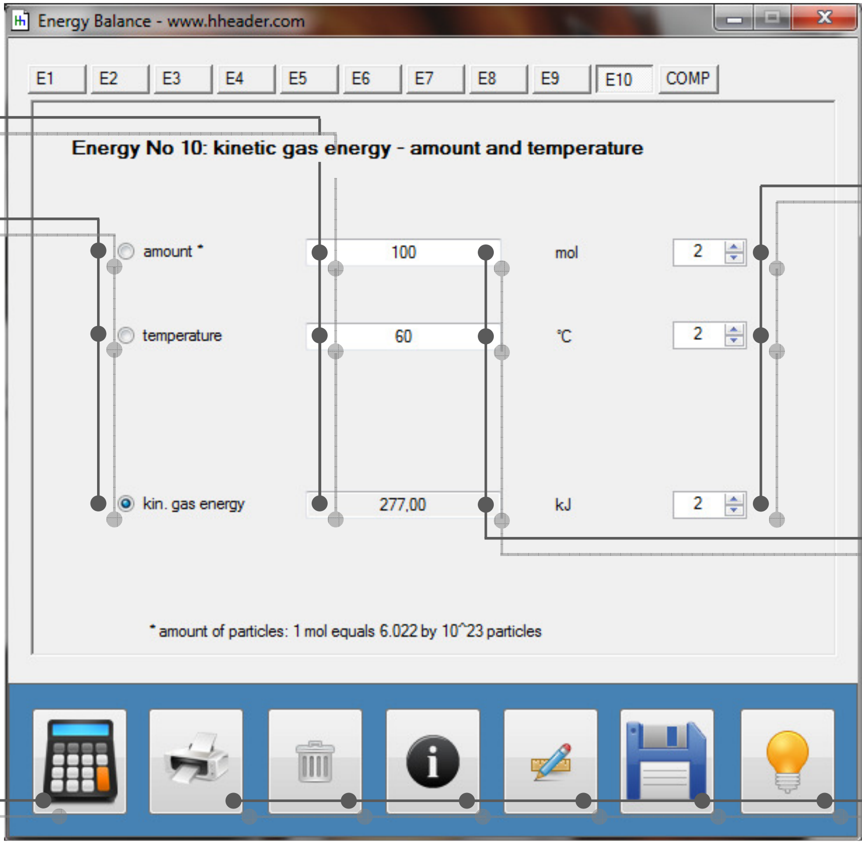



Figure 93: form energy balance – kinetic gas energy

**Step 2:**
**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 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 6:**
**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.

## 9.13. Energy Balance – Comparison of Energies

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

The program is part of category 4 – energy. Energy cannot get lost - energy can be converted from one kind to another kind. There are many different kinds of energy. Energy can appear, can be stored and can be converted. Some of these kinds, which are often relevant for technical processes, are: position energy, kinetic energy, thermal energy, pressure volume work, potential energy spring, electrical capacitive energy, electro-magnetic energy, electric term energy, radiant energy, kinetic gas energy. The program provides the corresponding calculations for the mentioned energy kinds. The law of conservation of energy is a powerful tool to evaluate technical or process circumstances. Although the use cases are sometimes very different, we often find similar coherences between the single kinds of energy. Just to give an example: the energy that can be stored in a mechanical spring is defined as ½ by the spring rate value by the square of the elongation. The energy that can be stored in an electrical capacitor is defined as ½ by the capacitance value by the square of the voltage. Things that seem quite different on the first view can be sometimes very similar to each other. So it is obvious, that it can make sense to compare the different kinds of energy and to use the law of conservation of energy for practical evaluations. In every case we must be aware that the energy can never be converted from one kind to another to hundred percent. Parts of the energy will convert into other kinds, too. This is what we call losses, but the energy is only lost in reference to the considered process. In many cases these losses are converted into thermal energy. The energy input minus the energy losses is the energy output. The energy output in relation to the energy input is the efficiency rate, which is an important measure to be taken into consideration for the law of conservation of energy.

In order to be able to compare the different kinds of energy due to the law of conservation of energy the program provides a corresponding *TabPage*. Via two *ComboBoxes* the first and the second kind of energy can be selected. The results are displayed accordingly. The results refer to the corresponding calculations for the energy kinds E1 to E10. It is obvious that the energies can only be compared sensible if the results for the energies are equal. In the first it has to be taken care for this. Afterwards the confrontation of energies can take place.

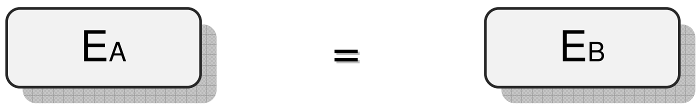



Figure 94: sketch energy balance – comparison of energies

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

The variables and the results refer to the corresponding calculations for the energy kinds E1 to E10.

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

**Step 1:**
**Select first Energy kind**
I can select one of the provided energy calculations in order to compare it with another one. The results will be shown according to the selected energy kind. The results refer to the corresponding calculations for the energy kinds E1 to E10.

**Step 2:**
**Select second Energy kind**
I can select one of the provided energy calculations in order to compare it with another one. The results will be shown according to the selected energy kind. The results refer to the corresponding calculations for the energy kinds E1 to E10.

**Step 3:**
**Check result**
After clicking the Calculate-Button I can check the result.

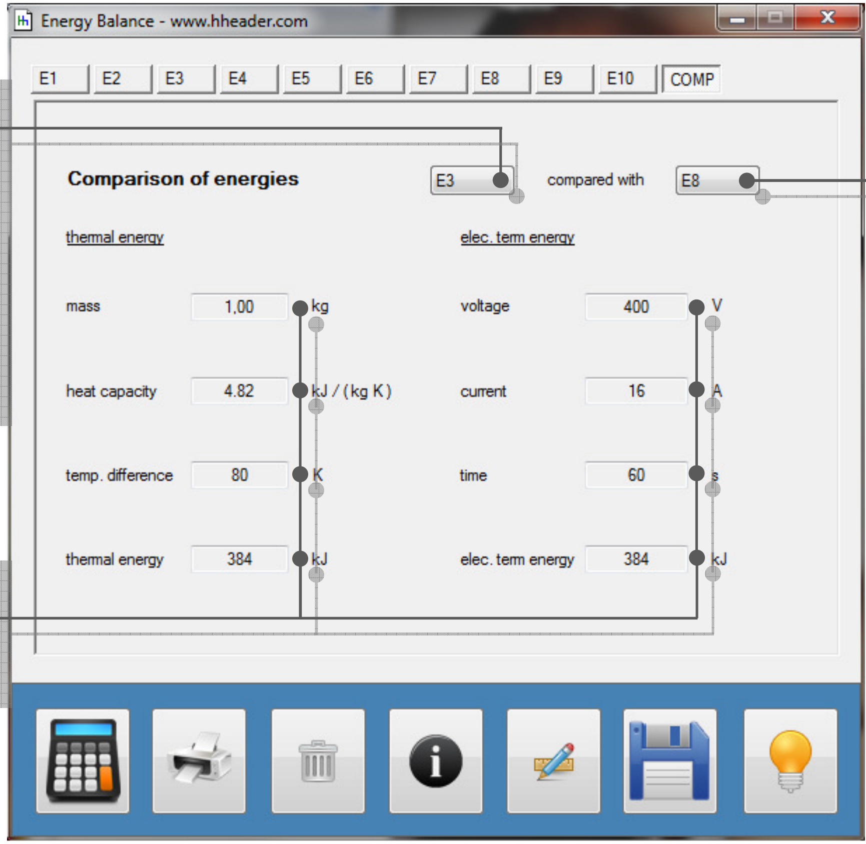



Figure 95: form energy balance – comparison of energies

## 9.14. Heat Capacity

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

The program is part of category 4 – energy. Part of many processes is a direct or indirect heating up of different fluids. That means at least a defined volume of a fluid with a specified heat capacity and density is heated up from a start temperature to an end temperature. Therefore the temperature difference is relevant. Regarding this it is important to know which amount of thermal energy is required for increasing the temperature, how long this procedure will last and which power rate is required, accordingly.

By the way: it is obvious that the required thermal energy will be negative, if the start temperature is greater than the end temperature. A negative thermal energy means at least, that there will be no energy intake into the system but a removal of energy from the system.

In practice on site there will be power losses like convectional losses beside others. This even if the system (piping, tanks and compounds) has a proper insulation. Anyway the program provides a selection by which the consideration of energy losses can be activated or deactivated. Beside the design and the used materials, many different coefficients depending on the operation mode and other process circumstances have to be taken into consideration. On site many parameters which are taking influence on the heat transfer are not constant. On site the required coefficients are not always available. The target of the program is to provide a calculation tool with a minimum of required variables that is useful in practice. The losses are defined by the factor for heat transmission, the total lateral area of all the included piping, tanks and compounds and the ambient temperature outside the system (piping, tanks and compounds).

By the way: it is obvious that the losses will be negative, if the ambient temperature outside the system is greater than the end temperature. A negative energy loss means at least, that there is an energy intake. Consequently the total required energy will be reduced in this case.

Auxiliary methods for determining the heat capacity and the density for a selection of liquids and gases (fluids) are also provided on a separate *TabPage*. In the first there is a selection of different fluids. The corresponding values for the heat capacity and the density will be displayed, accordingly. In addition to that there is a general method provided for determining the heat capacity for gases. This refers to the corresponding number of atoms of the used gas.

It can be chosen between the following items:

- gases with one atom,
- gases with two atoms,
- inflexible gases with three atoms,
- flexible gases with three atoms.

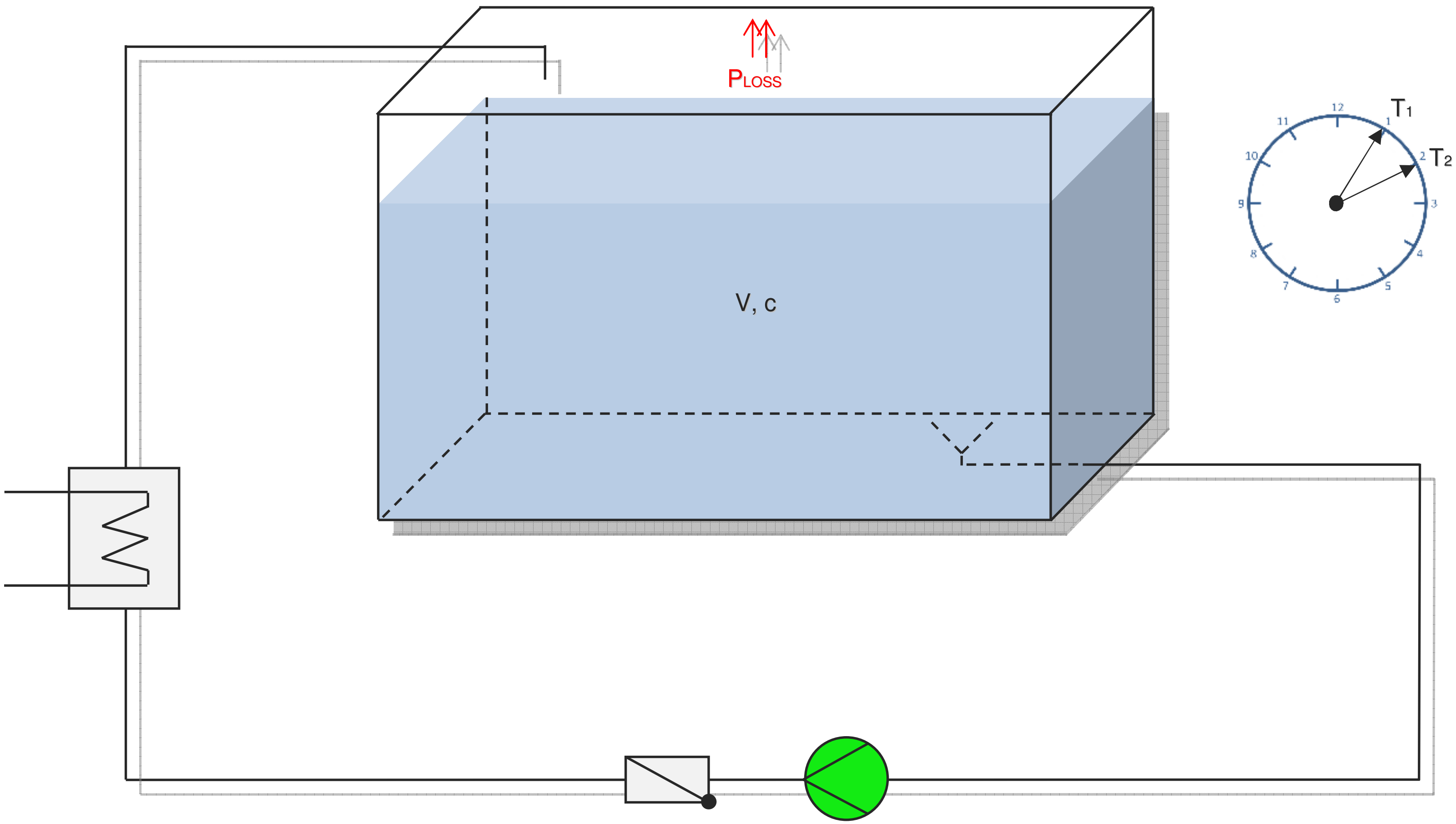



Figure 96: sketch heat capacity

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

**capacity**

It is the specific heat capacity of the matter that is heated up. The specific heat capacity is a measure for the ability of a material to store thermal energy. At least it is the thermal energy that can be stored inside the material per kilogram and Kelvin. The specific heat capacity of a material depends on different parameters. One of these is the temperature. If not otherwise stated usually the values belong to a temperature of 20°C.

The variable type is Input.
The unit is kilo-joule per kilogram and Kelvin [kJ / (kg K)].
The minimum limit is 0.001.
The maximum limit is 500.
The replacement value is 4.82.
The number of digits is 10.

**density**

It is the density of the matter that is heated up. Be aware that the density depends on different parameters as temperature and pressure for example. At least it is the mass that is relevant. The mass results from the density multiplied by the volume using the compatible units.

The variable type is Input.
The unit is kilogram per liter [kg / l].
The minimum limit is 0.001.
The maximum limit is 99.
The replacement value is 1.
The number of digits is 10.

**volume**

It is the total volume of the matter that is heated up. At least it is the mass that is relevant. The mass results from the density multiplied by the volume using the compatible units.

The variable type is Input or Output.
The unit is 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 10.

**temperature start**

It is the temperature at the beginning of the heat up process. The matter should be heated up from the start temperature to the end temperature. The temperature difference is the value that is relevant for the energy calculation.

The variable type is Input or Output.
The unit is degree Celsius [°C].
The minimum limit is -200.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 10.

**temperature end**

It is the temperature at the end of the heat up process. The matter should be heated up from the start temperature to the end temperature. The temperature difference is the value that is relevant for the energy calculation.

The variable type is Input or Output.
The unit is degree Celsius [°C].
The minimum limit is -200.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 10.

**thermal energy**

It is the thermal energy that is required to heat up the total matter volume. In this case all losses are disregarded. So it is equal to the energy that is absorbed by the matter capacity.

The variable type is Input.
The unit is kilo-joule [kJ].
The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

**factor heat transition**

It is the heat transition factor for the total lateral piping, tank and compound area. Whenever a construction or a unit handles with thermal energy and fluid flows, it is obvious, that there will be losses according to convection and similar mechanism. This is axiomatic however the insulation and the walls of the unit will be designed. Regarding the evaluation of the losses and the heat transition, there are many formulas and coefficients known. In case if the circumstances are always equal: always equal temperatures inside and outside the unit, always equal properties and thicknesses for the insulation, always equal flow rates with equal compositions, always equal pressures, etc., the calculations meet the real conditions. On site usually the conditions and circumstances change by time. Due to this it has been seen, that a rough base calculation and further an observation of the average energy balances, is at least more close to the real behavior of the plant than a conservative calculation. According to this the factor for heat transition considers the power rate of losses in relation to a defined area and the differential temperature.

The variable type is Input.
The unit is watt per meter square and Kelvin [W / ($m^2$ K)].
The minimum limit is 1.
The maximum limit is 9999.
The replacement value is 5.
The number of digits is 10.

**total lateral area**

It is the total lateral area of all the included piping, tanks and compounds. Anyhow thermal energy will get lost via this area. The area has to be considered for a rough calculation of losses by convection and similar mechanism. These losses can be estimated by multiplying the factor for heat transition and the total lateral area.

The variable type is Input.
The unit is meter square [$m^2$].
The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

**temperature outside**

It is the temperature outside the system or unit. For the evaluation of the convection losses the temperature difference between matter and the outer temperature is relevant.

The variable type is Input.
The unit is degree Celsius [°C].
The minimum limit is -200.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 10.

**primary energy loss**

It is the primary energy loss that is resulting from the power rate for the losses and the operation time. This energy has to be additionally taken into the system by the main aggregate. Be aware that the power rate for the losses has to be less than the power rate of the main aggregate.

The variable type is Output.
The unit is kilo-joule [kJ].
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.

**power rate loss**

It is the power rate for the losses that is calculated by the factor for heat transition, total lateral area and the temperature difference between matter and the outer temperature. The power rate will disappear via the total lateral area of all the included piping, tanks and compounds. Be aware that the power rate for the losses has to be less than the power rate of the main aggregate.

The variable type is Output.
The unit is kilowatt [kW].
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 power rate**

It is the total power rate that is required to heat up the matter and additionally to provide the power rate that disappears as losses via the total lateral area. The total power rate is the power rate of the main aggregate that is taking the thermal energy into the system. Be aware that the power rate for the losses has to be less than the power rate of the main aggregate.

The variable type is Input or Output.
The unit is kilowatt [kW].
The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

**time**

It is the time that the main aggregate has to be operated in order to heat up the total matter volume and to provide the power rate that disappears as losses via the total lateral area. Be aware that the power rate for the losses has to be less than the power rate of the main aggregate.

The variable type is Input or Output.
The unit is hour [h].
The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

**total required energy**

It is the total energy that is required to heat up the matter and additionally to provide the power rate that disappears as losses via the total lateral area. The total required energy is consumed after the main aggregate that operated for the determined operation time.

The variable type is Output.
The unit is kilo-joule [kJ].
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. mol mass**

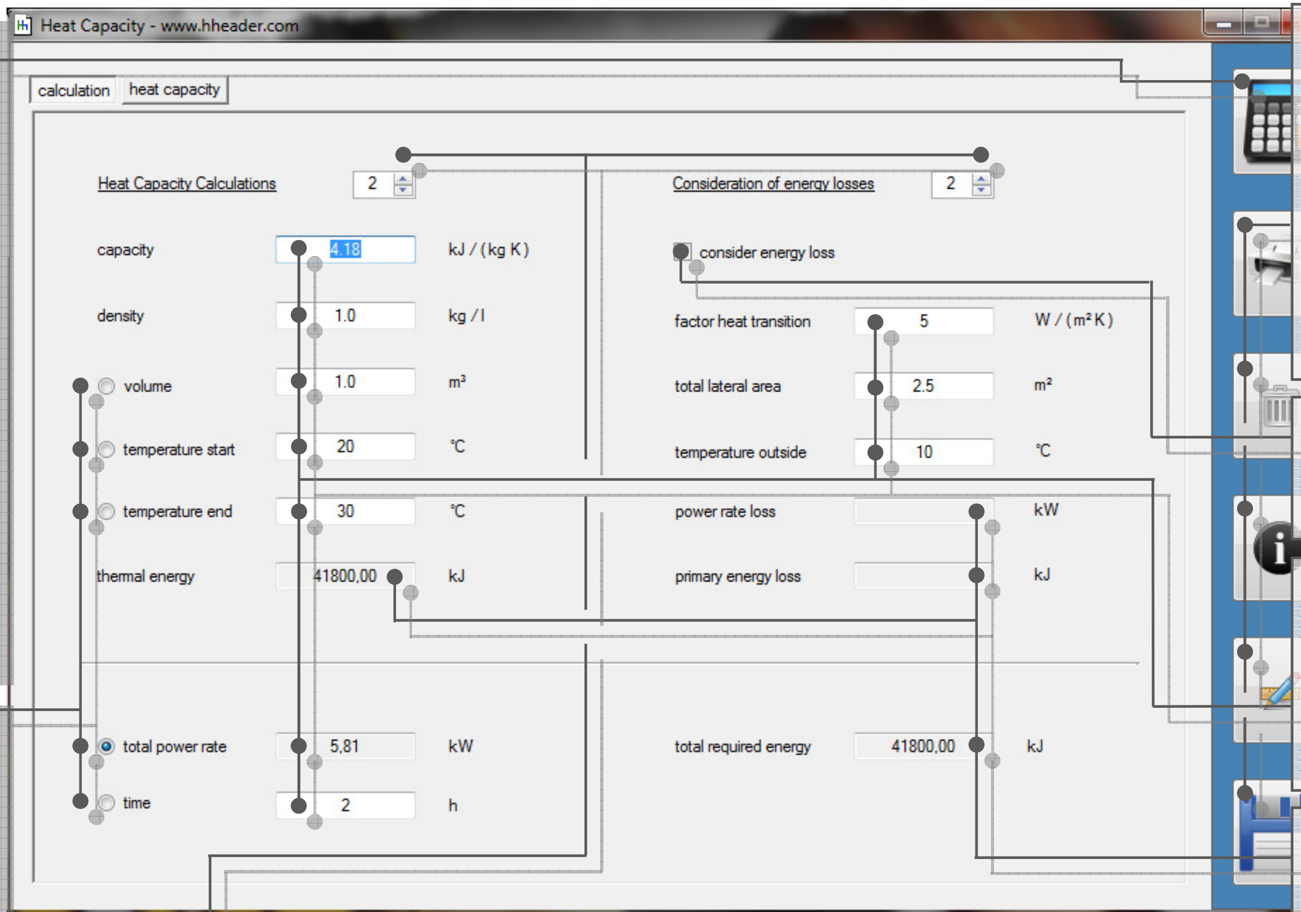
It is specific molar mass of the used gas. In case if a gas is involved in the process and the heat capacity is unknown, it can be calculated by the number of atoms and the molar mass of the gas. The molar mass can be determined easily by using the Periodic Table of Elements.

The variable type is Input.
The unit is gram per mol [g / mol].
The minimum limit is 1.
The maximum limit is 1000.
The replacement value is 16.
The number of digits is 10.

### 9.14.3. 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 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 4:**
**Decimal places**
I can select the number of decimal places.

Figure 97: form heat capacity - calculation

**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.

**Step 2:**
**Consider energy loss**
I can select, if the energy loss is considered or 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 6:**
**Check results**
After clicking the Calculate-Button I can check the results.

**Step 1:** (matter)
**Select medium**
I can select the used medium. The density and the heat capacity are displayed in the *TextBox* below, accordingly. By using the transfer button the value will be transferred to the corresponding calculation variable in the main sheet.

**Step 2:** (matter)
**Calculate and transfer**
The Transfer-Button will calculate the result and transfer the value to the corresponding calculation variable in the main sheet.

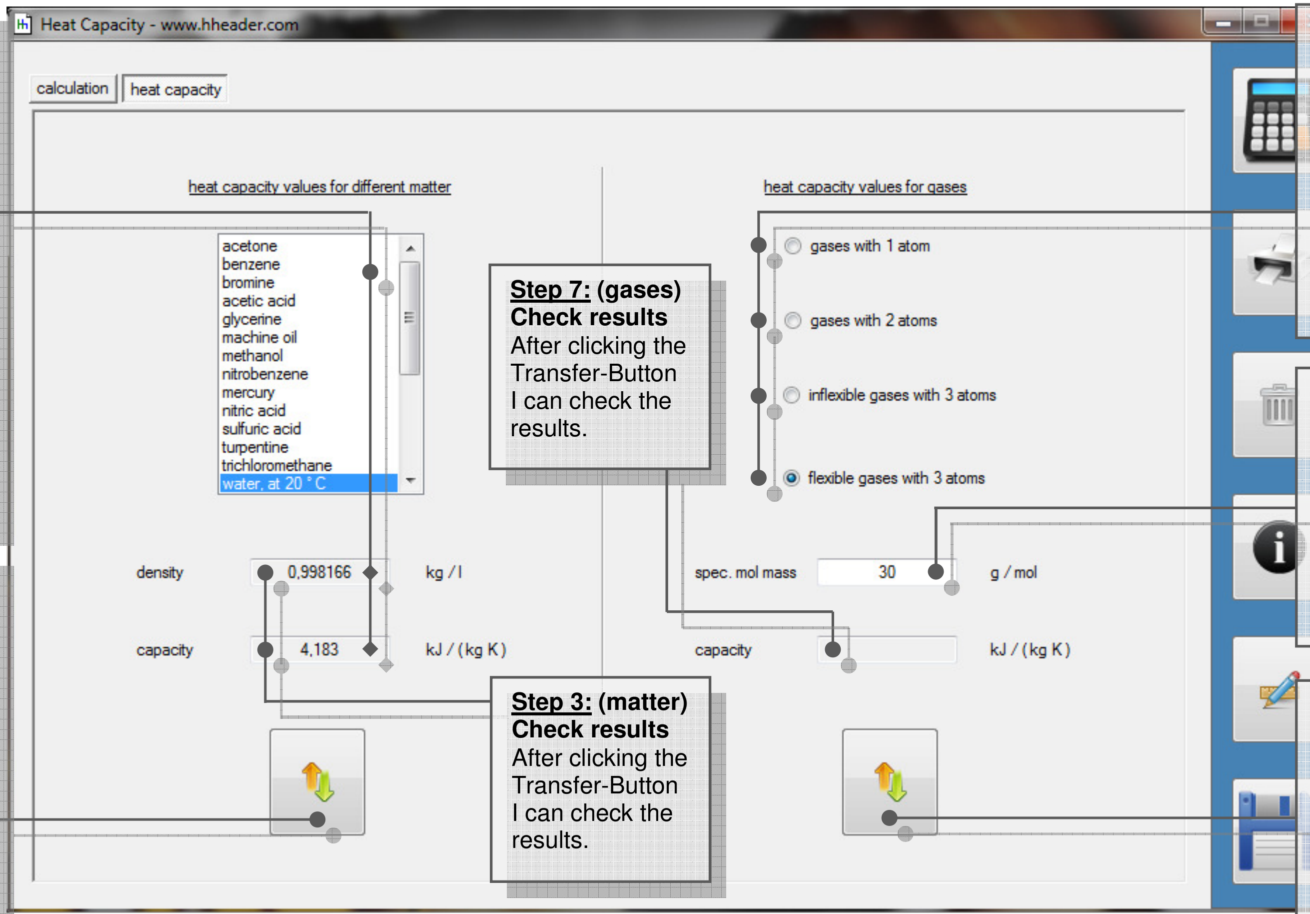



Figure 98: form heat capacity – heat capacity

**Step 3:** (matter)
**Check results**
After clicking the Transfer-Button I can check the results.

**Step 4:** (gases)
**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:** (gases)
***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:** (gases)
**Calculate and transfer**
The Transfer-Button will calculate the result and transfer the value to the corresponding calculation variable in the main sheet.

**Step 7:** (gases)
**Check results**
After clicking the Transfer-Button I can check the results.

## 9.15. ISO-Conditions

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

The program is part of category 4 – energy. Beside the specific parameters there are in general three physical values that are important for gases and which define the process circumstances significant. These are pressure, volume and temperature. They are working in coherence to each other. During the process it is often the case, that the parameters are changing slowly or that one of the parameters is constant according to the design criteria of the plant or according to a controlled process. In this case the change of the parameters can be assumed not to be isentropic, but it is either isotherm or isochore or isobar. The prefix “iso” means that the parameter is constant and it will not change during the process.

<u>That means:</u>

For the isothermal process, there is a constant temperature while volume and pressure are variable.

For the isochoric process, there is a constant volume while temperature and pressure are variable.

For the isobaric process, there is a constant pressure while volume and temperature are variable.

The program provides calculations for the three mentioned cases. For each calculation two duty points (DP1 and DP2) have to be defined. So in general there are six variables: the temperature for duty point one and two, the volume for duty point one and two and the pressure for duty point one and two. In each case one of the variables is constant for both duty points. For the corresponding calculation the constant variable has not to be taken into consideration. That means that four variables are relevant for each calculation. For each case one variable can be selected as result, the residual three are given variables.

<u>Thereby the distribution of the variables is as follows:</u>

- For the isothermal process, there are volume DP1 and volume DP2 and pressure DP1 and pressure DP2 defined as variables.
- For the isochoric process, there are temperature DP1 and temperature DP2 and pressure DP1 and pressure DP2 defined as variables.
- For the isobaric process, there are volume DP1 and volume DP2 and temperature DP1 and temperature DP2 defined as variables.

Beside the parameters pressure, volume and temperature the total and differential energies are calculated. Therefore the maximum total energy of the two duty points is displayed. The delta energy is the difference between the inner energies of the two duty points according to the ideal gas law. For all calculations of this program theoretical perfect gases are assumed to be used.

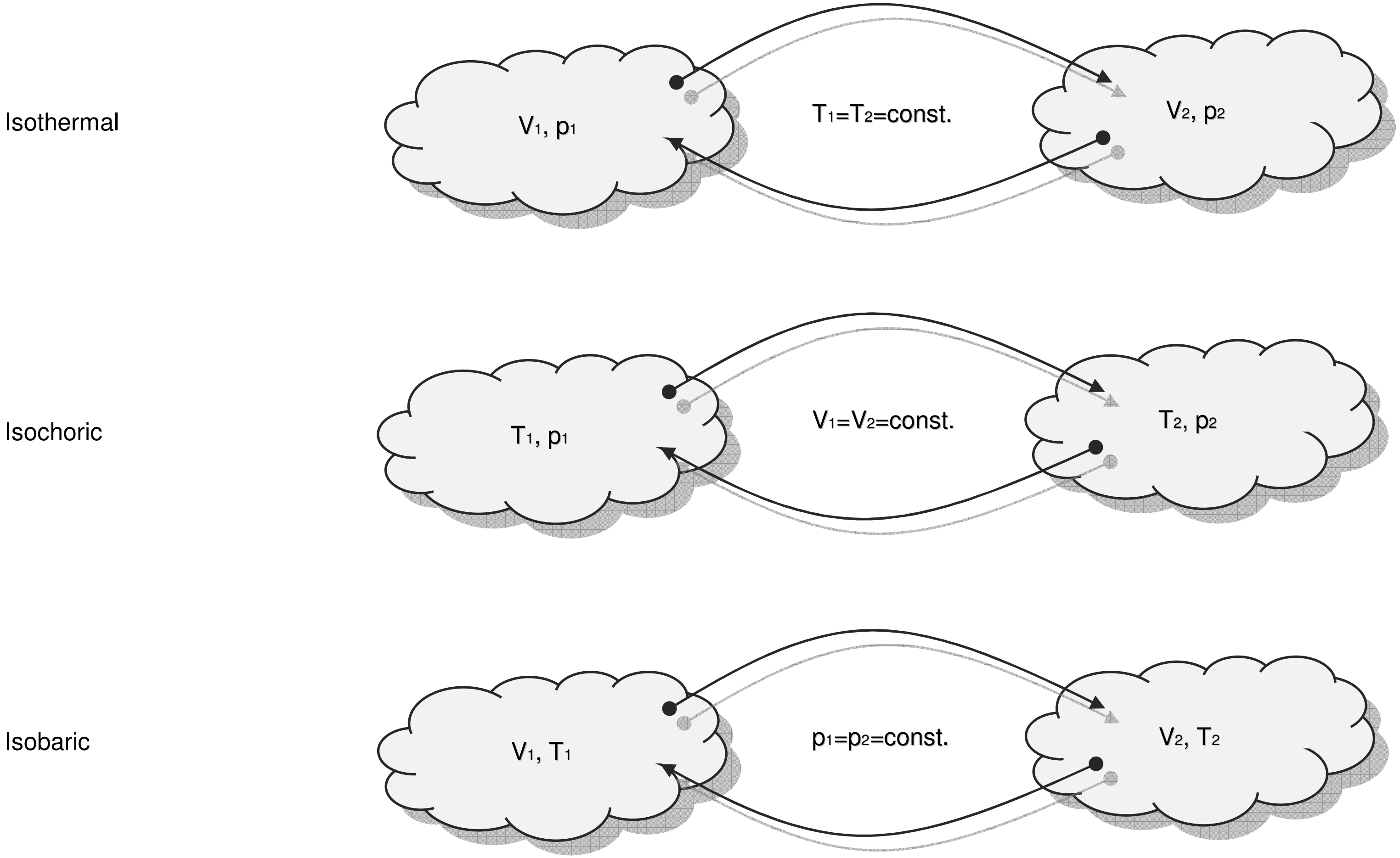



Figure 99: sketch ISO-conditions

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

**volume**

It is the volume of the gas at the corresponding duty point (DP1 – duty point one, DP2 – duty point two).

The variable type is Output.
The unit is meter cube [m³].
The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

**pressure**

It is the pressure of the gas at the corresponding duty point (DP1 – duty point one, DP2 – duty point two).

The variable type is Input.
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 10.

**temperature**

It is the temperature of the gas at the corresponding duty point (DP1 – duty point one, DP2 – duty point two).

The variable type is Output.
The unit is degree Celsius [°C].
The minimum limit is -200.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 10.

**amount of particles - mol**

It is the amount of particles that are focus for the energy calculations. The amount of particles is relevant for the energy calculations of the isochoric and isobaric conditions. One mol is equal to 6.022 by 10^23 particles.

The variable type is Input.
The unit is mol [mol].
The minimum limit is 1.
The maximum limit is 100000.
The replacement value is 1.
The number of digits is 6.

**total energy**

It is the total inner energy of the gas at the duty point with the greater energy level respectively at both duty points in case if the inner energy is equal for duty point one and duty point two. For the energy calculations of the isochoric and isobaric conditions the amount of particles is relevant. One mol is equal to 6.022 by 10^23 particles.

The variable type is Output.
The unit is kilo-joule [kJ].
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 energy**

It is differential energy that is required or released while the system conditions are changed from one duty point to the other duty point. For the energy calculations of the isochoric and isobaric conditions the amount of particles is relevant. One mol is equal to 6.022 by 10^23 particles.

The variable type is Output.
The unit is kilo-joule [kJ].
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.

### 9.15.3. 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 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.

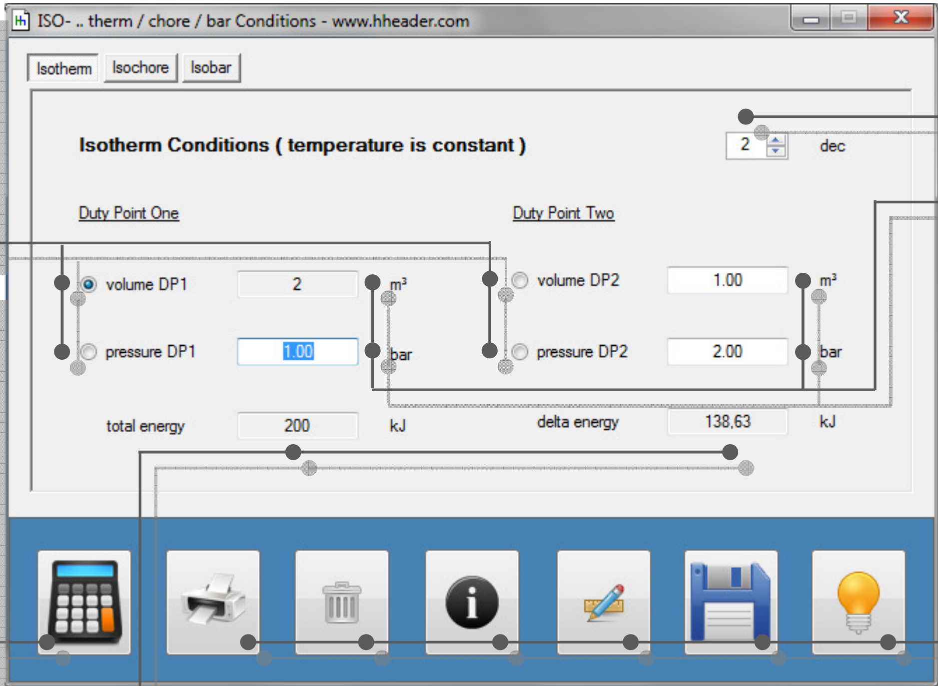



Figure 100: form ISO-Conditions – isotherm conditions

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

**Step 3:**
**Decimal places**
I can select the number of decimal places.

**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:**
**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:**
**Define the amount of gas**
I can define the amount of gas by entering the number of mol.

**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 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.

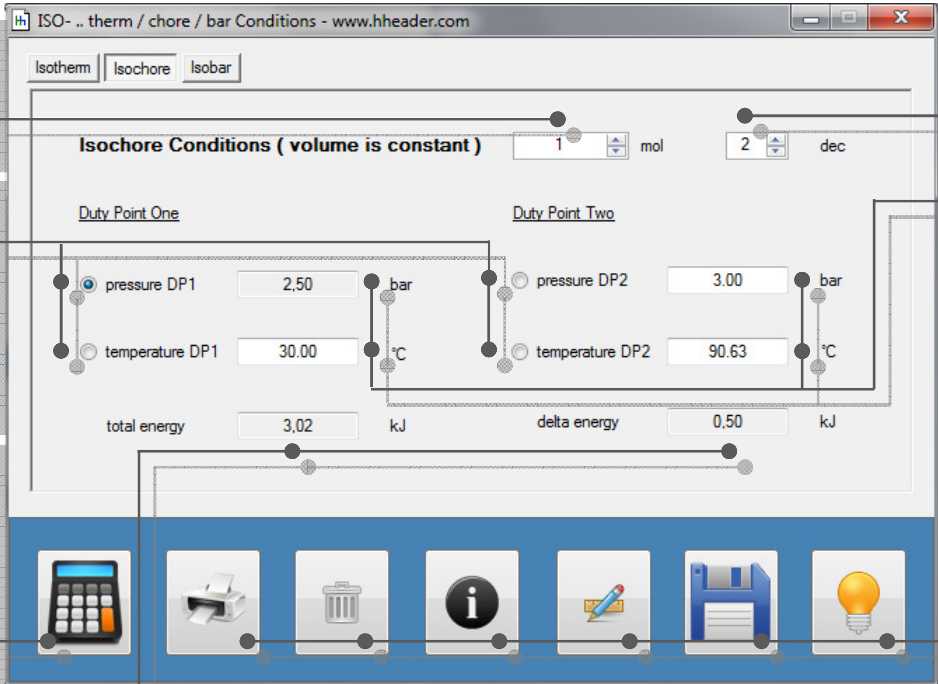



Figure 101: form ISO-Conditions – isochore conditions

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

**Step 4:**
**Decimal places**
I can select the number of decimal places.

**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 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.

**Step 1:**
**Define the amount of gas**
I can define the amount of gas by entering the number of mol.

**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 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.

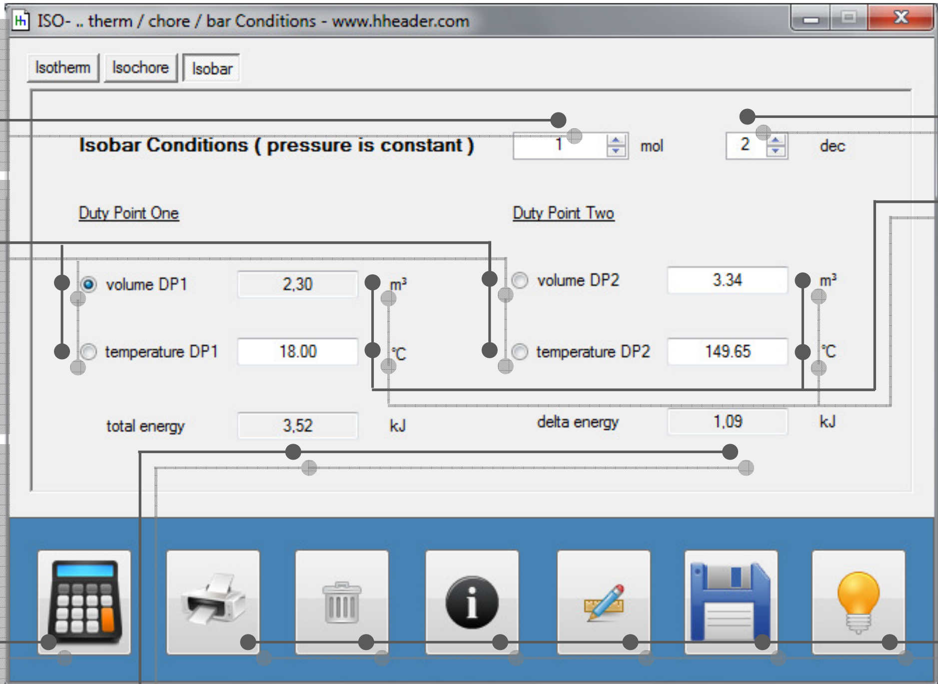



Figure 102: form ISO-Conditions – isobar conditions

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

**Step 4:**
**Decimal places**
I can select the number of decimal places.

**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 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.

## 9.16. ISEN-Condotions

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

The program is part of category 4 – energy. Beside the specific parameters there are in general three physical values that are important for gases and which define the process circumstances significant. These are pressure, volume and temperature. They are working in coherence to each other. During the process it is sometimes the case, that the parameters are changing rapidly or none of the parameters is constant. In this case the change of the parameters cannot be assumed to be either isotherm or isochore or isobar, but it is to be isentropic. Isentropic means that there is no heat transfer while the change of parameters and circumstances takes place.

The program provides calculations for this case. For the calculation two duty points (DP1 and DP2) have to be defined. So in the first there are six variables: the temperature for duty point one and two, the volume for duty point one and two and the pressure for duty point one and two. Because of the isentropic process, also the isentropic exponent kappa has to be taken into consideration. Two different methods for determining the isentropic exponent kappa for the used gas are provided. In the first there is a method for determining the isentropic exponent kappa provided for gases in general, which refers to the corresponding number of atoms. It can be chosen between the following items:

- gases with one atom,
- gases with two atoms,
- inflexible gases with three atoms,
- flexible gases with three atoms.

In addition to that there is a selection of different gases at defined temperatures. The corresponding value for the isentropic exponent kappa will be displayed, accordingly. The actual value for kappa can be transferred by the corresponding transfer buttons.

Beside the parameters pressure, volume and temperature the total energy, the volume dilatation energy and the differential energy are calculated. Therefore the maximum total energy of the two duty points is displayed. The delta energy is the difference between the inner energies of the two duty points according to the ideal gas law. For all calculations of this program theoretical perfect gases are assumed to be used.

Regarding the procedure of calculation four of the six variables for the duty points (DP1 and DP2) have to be selected as given variables. Thereby minimum one of each physical variable (volume, pressure and temperature) has to be checked. The residual two variables will be calculated. Refer to the Instruction- and the Infoticker-TextBoxes in the form! In every case the isentropic exponent kappa is a given variable for the main calculation.

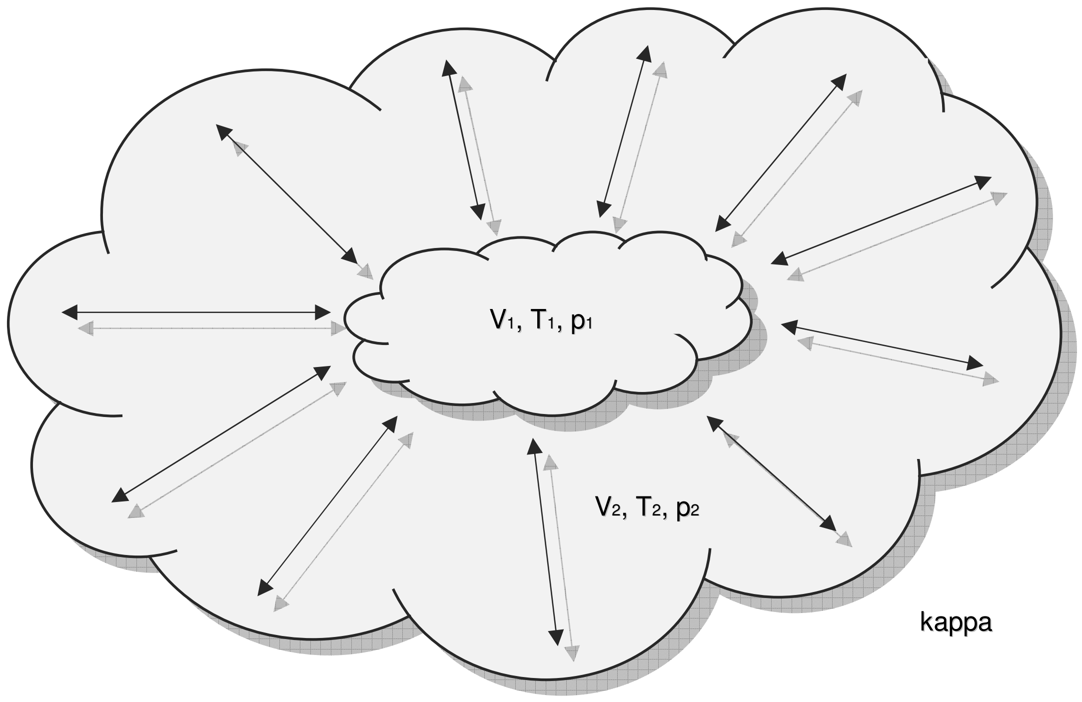



Figure 103: sketch ISEN-conditions

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

**volume**

It is the volume of the gas at the corresponding duty point (DP1 – duty point one, DP2 – duty point two).

The variable type is Input or Output.
The unit is meter cube [m³].
The minimum limit is 0.0001.
The maximum limit is 9999999999.
The replacement value is 100.
The number of digits is 10.

**pressure**

It is the pressure of the gas at the corresponding duty point (DP1 – duty point one, DP2 – duty point two).

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 10.

**temperature**

It is the temperature of the gas at the corresponding duty point (DP1 – duty point one, DP2 – duty point two).

The variable type is Input or Output.
The unit is degree Celsius [°C].
The minimum limit is -200.
The maximum limit is 1400.
The replacement value is 20.
The number of digits is 10.

**amount of particles - mol**

It is the amount of particles that are focus for the energy calculations. The amount of particles is relevant for the energy calculations of the isochoric and isobaric conditions. One mol is equal to 6.022 by 10^23 particles.

The variable type is Input.
The unit is mol [mol].
The minimum limit is 1.
The maximum limit is 100000.
The replacement value is 1.
The number of digits is 6.

**factor kappa**

It is the isentropic exponent which is specific for each gas. On the left side of the form there are two possibilities provided to determine the isentropic exponent.

The variable type is Input.
The variable has no unit [-].
The minimum limit is 1.
The maximum limit is 2.
The replacement value is 1.4.
The number of digits is 10.

**volume dilatation energy**

It is the energy that is used for changing the volume while the system conditions are changed from one duty point to the other duty point. For the energy calculations the amount of particles is relevant. One mol is equal to 6.022 by 10^23 particles.

The variable type is Output.
The unit is kilo-joule [kJ].
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 energy**

It is the total inner energy of the gas at the duty point with the greater energy level respectively at both duty points in case if the inner energy is equal for duty point one and duty point two. For the total energy the amount of particles is relevant. One mol is equal to 6.022 by 10^23 particles.

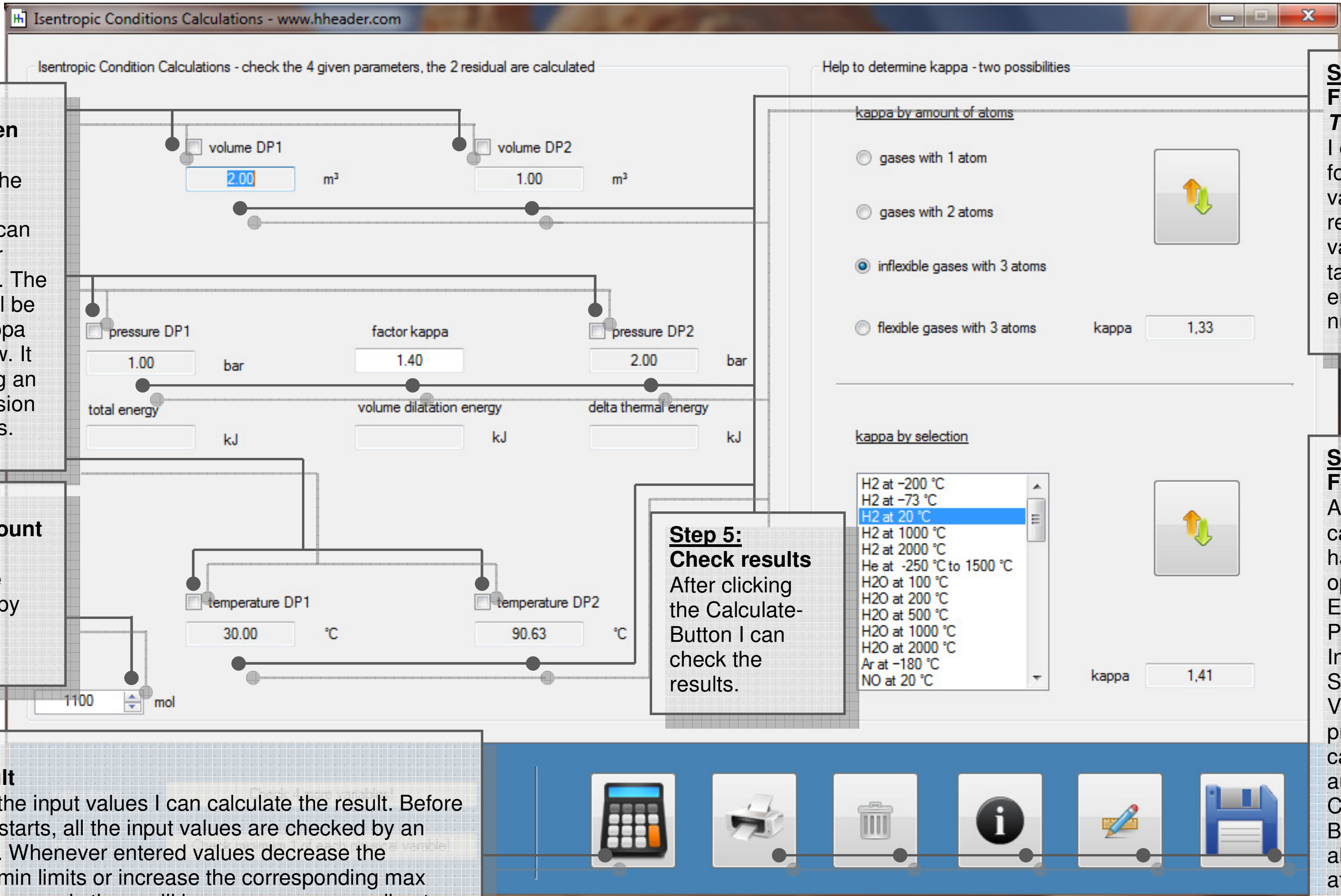
The variable type is Output.
The unit is kilo-joule [kJ].
There is no defined minimum limit for output variables.
There is no defined maximum limit for output variables.
There is no defined replacement value for output variables.
There is no defined number of digits for output variables.

**delta thermal energy**

It is differential thermal energy that between the system conditions of the two different duty points. For the energy calculations of the isochoric and isobaric conditions the amount of particles is relevant. One mol is equal to 6.022 by 10^23 particles.

The variable type is Output.
The unit is kilo-joule [kJ].
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.

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




**Step 2:**
**Select the given variables**
By clicking on the corresponding *CheckButton* I can choose the four given variables. The residual two will be calculated. Kappa is given anyhow. It is like executing an internal conversion of the equations.

**Step 1:**
**Define the amount of gas**
I can define the amount of gas by entering the number of mol.

**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 results**
After clicking the Calculate-Button I can check the results.

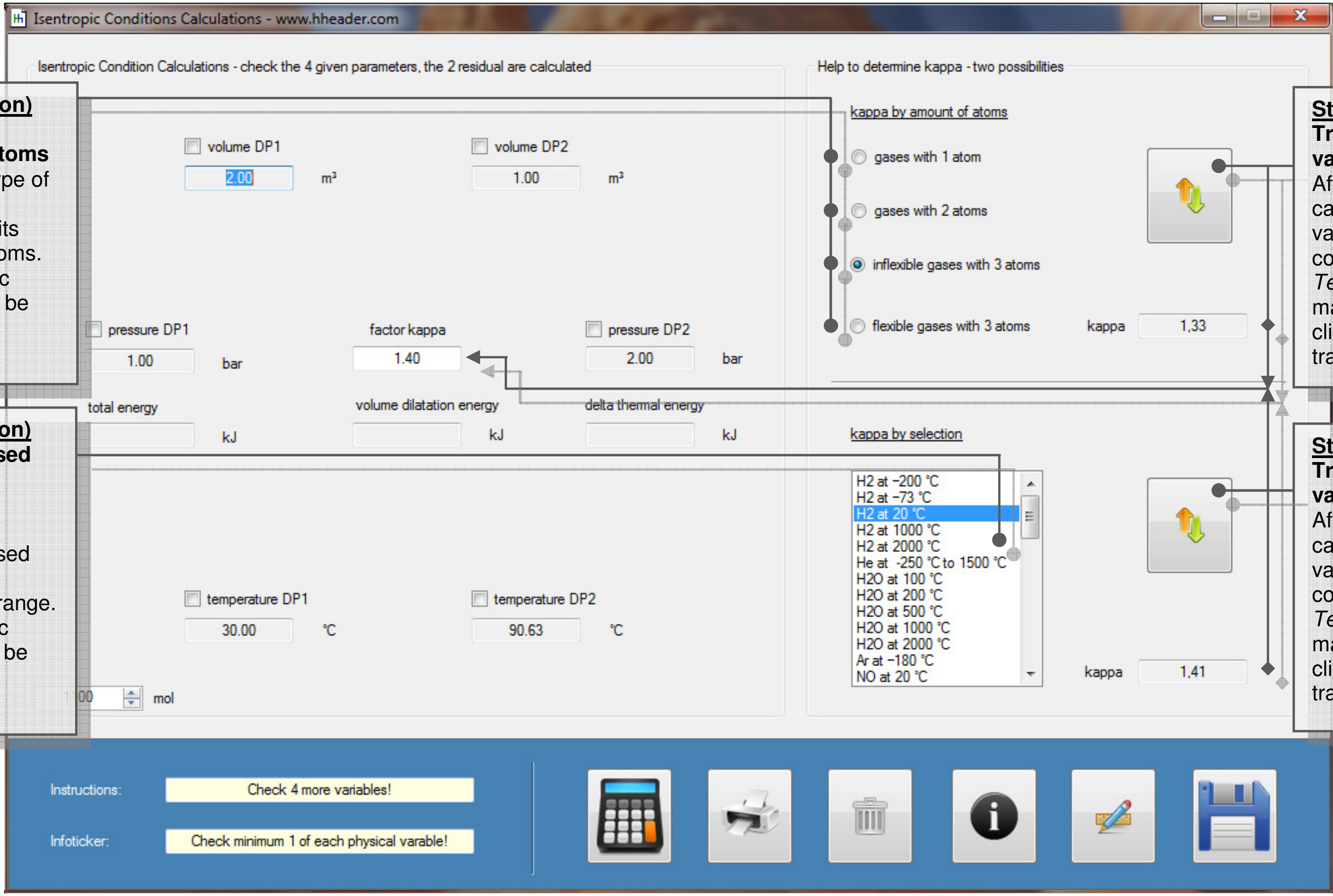
**Step 4:**
**Calculate result**
After I entered the input values I can calculate the result. Before the calculation starts, all the input values are checked by an internal routine. Whenever entered values decrease the corresponding min limits or increase the corresponding max limits or are not numeric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

**Step 6:**
**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.

Figure 104: form ISEN-conditions

**Step 1: (option)**
**Select the number of atoms**
I select the type of the used gas according to its number of atoms. The isentropic exponent will be displayed accordingly.

**Step 1: (option)**
**Select the used gas and the temperature range**
I select the used gas and the temperature range. The isentropic exponent will be displayed accordingly.




**Step 2: (option)**
**Transfer the value**
After the selection I can transfer the value into the corresponding *TextBox* for the main calculation by clicking the transfer button.

**Step 2: (option)**
**Transfer the value**
After the selection I can transfer the value into the corresponding *TextBox* for the main calculation by clicking the transfer button.

Figure 105: form ISEN-conditions