PROSIMPLUS APPLICATION EXAMPLE

ABSORPTION HEAT PUMPS

EXAMPLE PURPOSE
This document presents the simulations of different absorption heat pump cycles. Two types of absorption heat pump are presented: an absorption heat transformer and an absorption refrigerator. A industrial example is also presented to illustrate the utilization of absorption heat pump.

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CORRESPONDING PROSIMPLUS FILES	*PSPS_EX_EN-Absorption-Heat-Pump-Transformer.pmp3* *PSPS_EX_EN-Absorption-Heat-Pump-Refrigerator.pmp3* *PSPS_EX_EN-Absorption-Heat-Pump-Process.pmp3*

Energy

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1. PROCESSES MODELLING

1.1. Processes description

This document presents several simulations of the absorption heat pump. In general, the absorption heat pump (AHP) differs from the “traditional” heat pump by its capacity to compress a fluid without mechanical compression. Another interest of using the absorption heat pump comparing to the “traditional” heat pump is the absence of chlorofluorocarbons (CFC) as working fluid which has negative impacts to the environment. Furthermore, this technology is considered as an efficient and economically reasonable way for low temperature waste heat recovery.

In order to use an absorption heat pump, three heat sources at different temperatures must be available: at cold temperature (Q_C), medium temperature (Q_M) and hot temperature (Q_H). The system is made up of some main units such as generator, condenser, evaporator, absorber, internal heat exchanger, pump(s), and expansion valve(s). AHP uses a pair of working fluid consisting of a refrigerant and an absorbent (the refrigerant is the most volatile component).

Two solutions commonly employed in the industry:

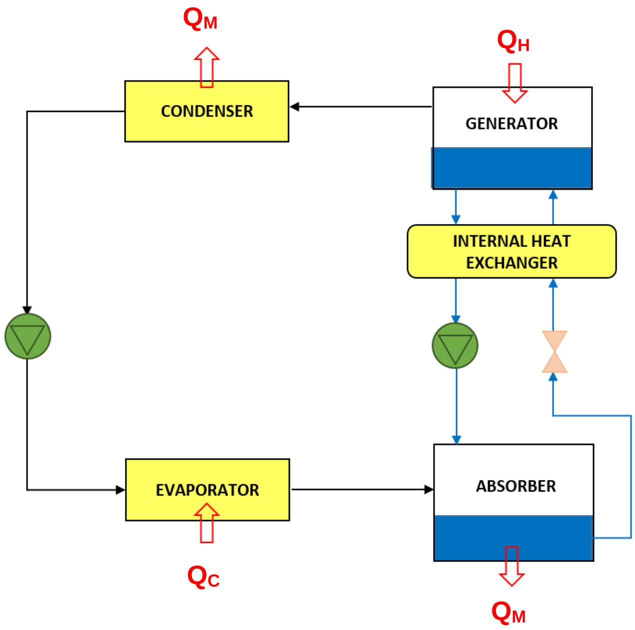
- Water/NH_3, ammonia is the refrigerant, water is the absorbent. This working fluid is used for cooling purposes.
- Water/LiBr, water as the refrigerant, lithium bromide as the absorbent. This working fluid ensure the production of cold water (> 5°C) for cooling purposes and/or the production of hot water at the condenser.

The working system H_2O-LiBr is employed in this example, in which water is the refrigerant and LiBr is the absorbent.

The compression of the refrigerant is performed by the absorption system: the refrigerant is absorbed by the absorbent in the weak liquid, and then desorbed using a heat source. The solution rich in working fluid is heated in the generator. The working fluid evaporates and separates from the absorbent and is then sent to the classic cycle of condenser/throttling valve/evaporator. The solution weak in working fluid returns to the absorber. The working fluid is absorbed by the weak solution in the absorber and is sent back to the generator to complete the cycle.

Three examples of absorption heat pump are presented: the absorption heat transformer, the absorption refrigerator and finally an industrial example that presents the use of an absorption heat pump.

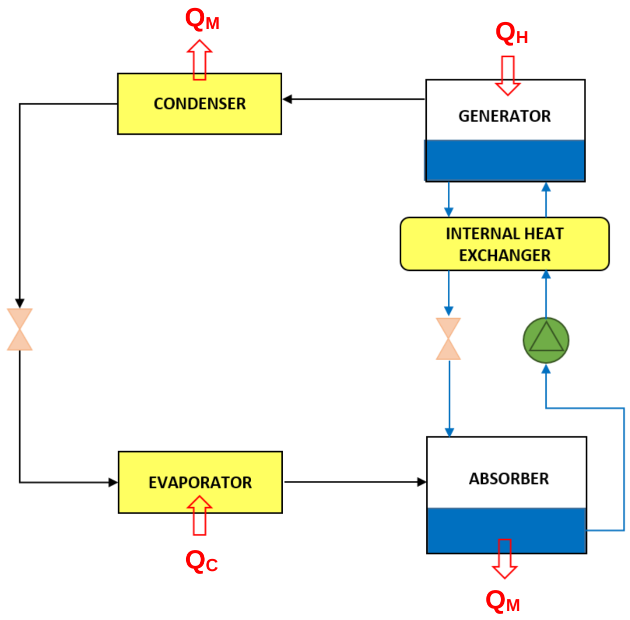
1.1.1. Absorption heat transformer



Schematic of an absorption heat transformer

An absorption heat transformer uses the heat of the medium-temperature waste (Q_M) to produce an output high temperature heat medium (hot water steam) and an output close to ambient temperature heat medium (ambient heated water). The above illustration shows the schematic of the absorption heat transformer where the working pair refrigerant-absorbent flow is illustrated in blue colour. In this example, the absorption heat transformer achieves a COP of 0.58.

1.1.2. Absorption refrigerator



Schematic of an absorption refrigerator

An absorption refrigerator is also capable to absorb the heat of a medium temperature. The illustration above shows the schematic of the absorption refrigerator where the working pair refrigerant-absorbent flow is illustrated in blue colour. In this example, the absorption refrigerator achieves a COP of 0.56.

1.1.3. Industrial example

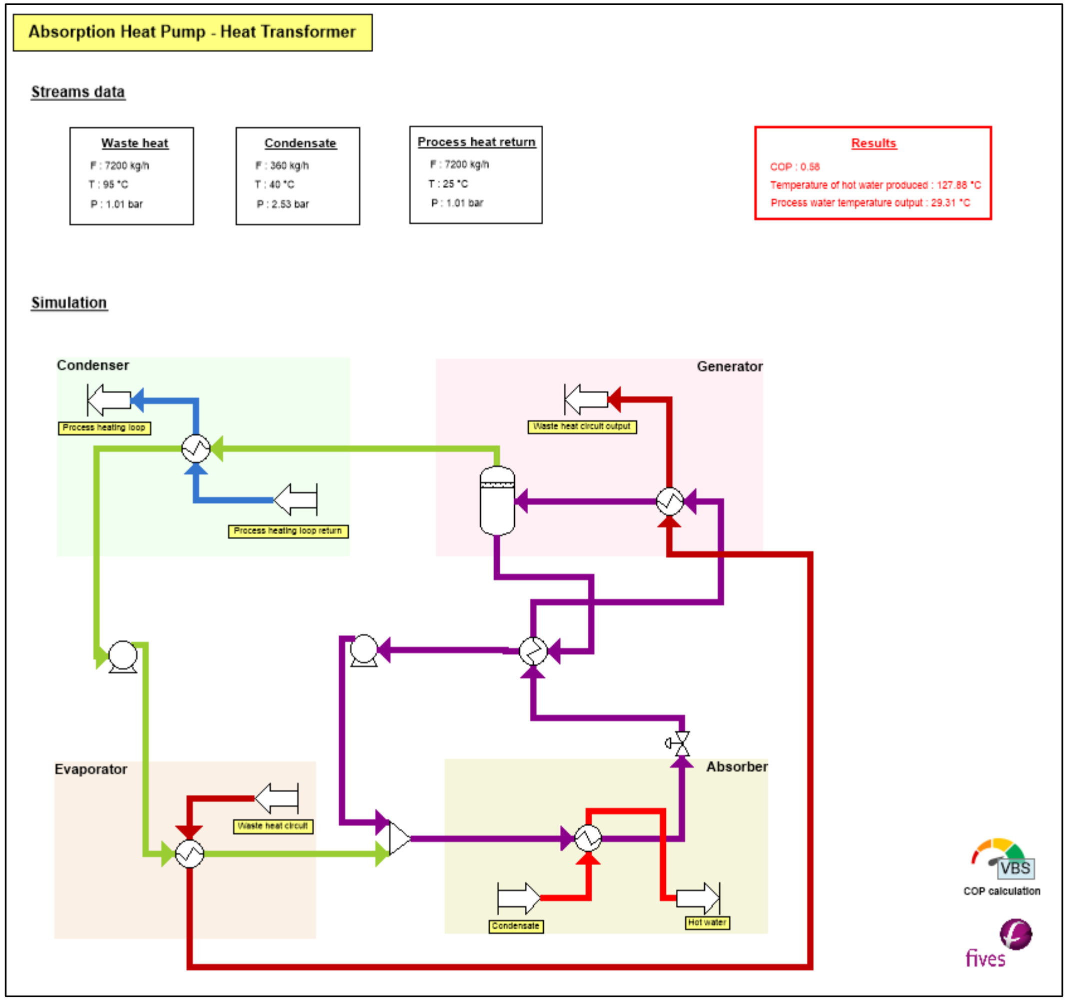
An industrial example is presented to illustrate the use of an absorption heat pump for industrial waste heat recovery. The waste heat is produced by a high-pressure boiler. The steam generated by the boiler drives 2 steam turbines in series to produce electricity. In order to supply hot water for district heating, steam is extracted from the turbines to heat the return water from the heating station (the heating station is not presented in this example). The return water at 45°C is heated up to 100°C through the absorption heat pump. In this example, the process achieves a COP of 1.5.

This example is inspired by an industrial process referenced in the literature [XU18].

1.2. Simulation flowsheets

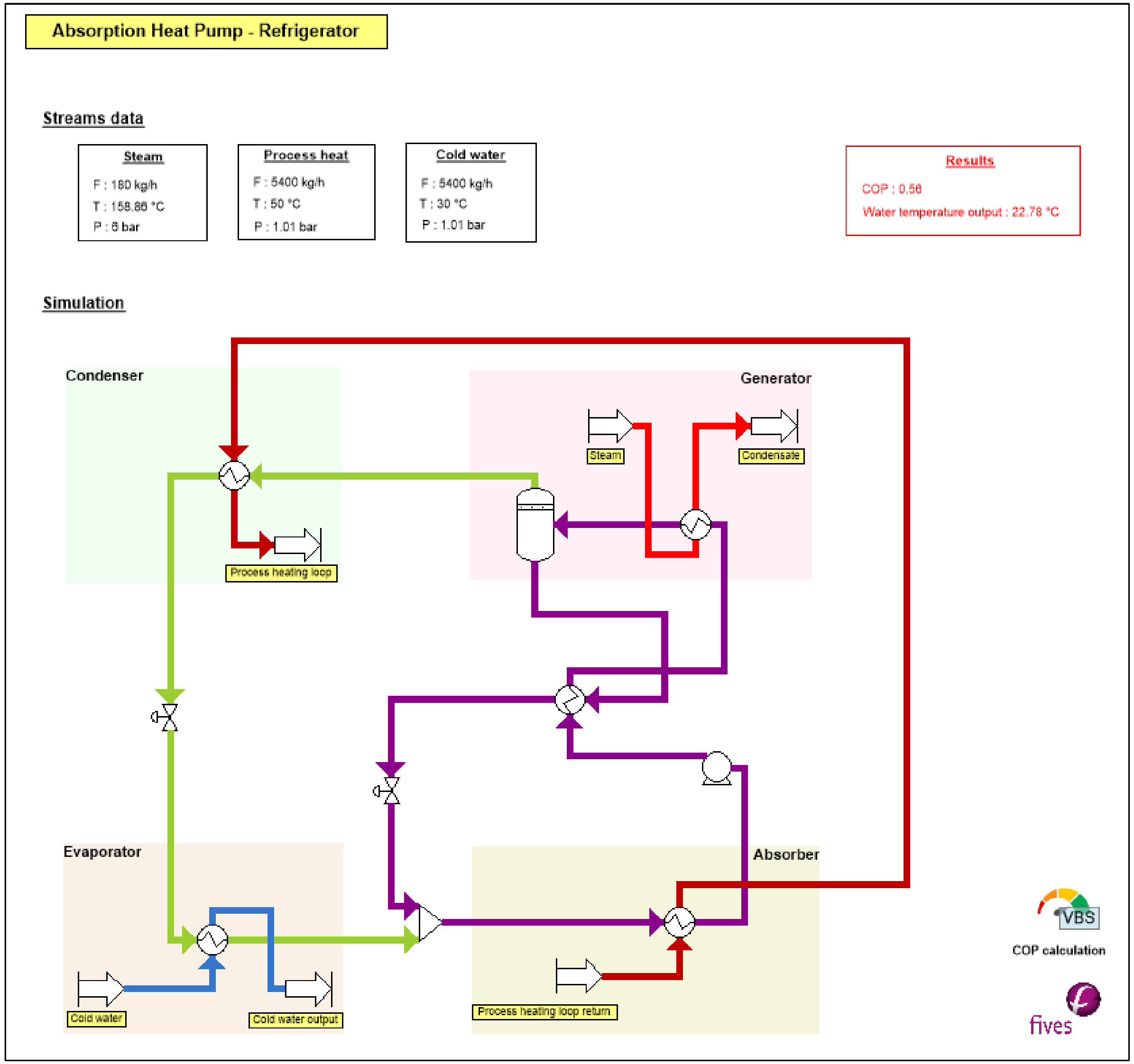
1.2.1. Absorption heat transformer

This flowsheet is presented in: “PSPS_EX_EN-Absorption-Heat-Pump-Transformer.pmp3”.



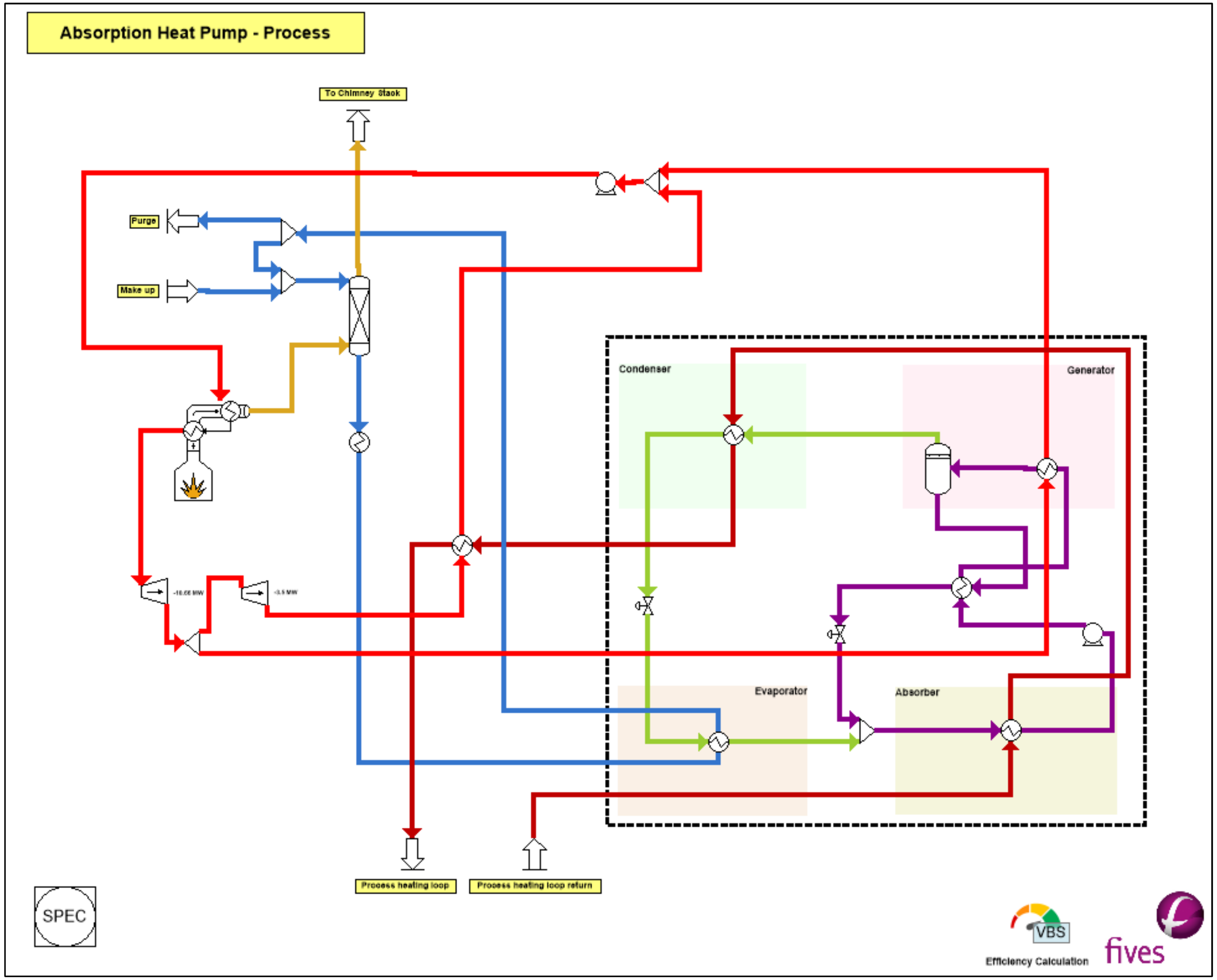
1.2.2. Absorption refrigerator

This flowsheet is presented in: “PSPS_EX_EN-Absorption-Heat-Pump-Refrigerator.pmp3”.



1.2.3. Industrial example

This flowsheet is presented in: "PSPS_EX_EN-Absorption-Heat-Pump-Process.pmp3".



1.3. Components

Components taken into account in the simulation, their chemical formula and CAS(*) number are presented in the following table. Pure components physical properties are extracted from the ProSimPlus standard database [WIL19].

Component	Chemical formula	CAS number
Water	H_2O	7732-18-5
Lithium bromide	LiBr	7550-35-8
Hydrogen	H_2	1333-74-0
Carbon dioxide	CO_2	124-38-9
Oxygen	O_2	7782-44-7
Carbon monoxide	CO	630-08-0
Hydrogen sulfide	H_2S	7783-06-4
Sulfur dioxide	SO_2	7446-09-5
Sulfur trioxide	SO_3	7446-11-9
Nitric oxide	NO	10102-43-9
Nitrogen	N_2	7727-37-9

1.4. Thermodynamic model

Three “calculator” were defined in order to simulate the examples of “Absorption Heat Pump”:

- “H_2O-LiBr”: this calculator contains water and lithium bromide components. It is used to simulate the primary streams of the absorption heat pumps. Given the nature of the components, the thermodynamic profile used to represent the phase’s equilibria and the enthalpy calculations is “Engels” profile.
- “H_2O”: this calculator contains only the water component. Hence it uses the “pure water” thermodynamic model. This calculator is used to model the utility fluid streams of the heat exchangers.
- “Fumes”: this calculator contains all the components listed previously, except lithium bromide. Given the nature of the components in the process, the thermodynamic model used is the “ideal” profile.

The thermodynamic models used are documented in the thermodynamic help accessible from the calculator definition window.

1.5. Operating conditions

1.5.1. Absorption heat transformer

The operating conditions of the different modules in the “Absorption heat transformer” are the following:

- ✓ Feeds

Name	Process heating loop return	Waste heat circuit	Condensate
Partial mass flowrates (kg/h):			
Water	7200	7200	360
Lithium bromide	0	0	0
Temperature (°C)	25	95	40
Pressure (atm)	1	1	2.5

- ✓ Generalized heat exchangers

Name	Evaporator	Absorber	Condenser
Exchanger type	Counter current or multipasses	Counter current or multipasses	Counter current or multipasses
Specification type	Other	Hot stream	Hot stream
Specification	Minimum temperature difference between HS and CS	Outlet temperature	Outlet molar vapor fraction
Specification value	5 °C	45 °C	0

Name	Generator	SHX
Exchanger type	Counter current or multipasses	Counter current or multipasses
Specification type	Cold stream	Cold stream
Specification	Outlet temperature	Temperature difference between output and input
Specification value (°C)	85	10

✓ Centrifugal pumps

Name	P1	P2
Specification	Supplied	Supplied
Exhaust pressure (mbar)	550	550
Isentropic efficiency	0.65	0.65
Mechanical efficiency	0.95	0.95
Electrical efficiency	0.98	0.98

✓ Expansion valve“V1”

Constraint type	Pressure specification
Pressure specification	Supplied
Pressure (mbar)	50

✓ Liquid-vapor separator “S1”

This module is defined with the default operating parameters as shown below:

Flash type	Constant pressure and enthalpy flash
Pressure specification	The lowest of the feed streams
Pressure drop (bar)	0
Heat duty specification	Adiabatic

Remark: the mixer “M1” is defined with the default operating parameters (the outlet pressure is equal to the lowest of the feeds pressures).

1.5.2. Absorption refrigerator

The operating conditions of the different modules in the “Absorption refrigerator” are the following:

✓ Feeds

Name	Cold water	Process heating loop return	Steam
Partial mass flowrates (kg/h):			
Water	5400	5400	180
Lithium bromide	0	0	0
Temperature (°C)	30	50	Dew point temperature at specified pressure
Pressure	1 atm	1 atm	6 bar

✓ Generalized heat exchangers

Name	Evaporator	Absorber	Condenser
Exchanger type	Counter current or multipasses	Counter current or multipasses	Counter current or multipasses
Specification type	Cold stream	Hot stream	Hot stream
Specification	Superheated over its dew point temperature	Subcooled below its bubble point	Outlet molar vapor ratio
Specification value	0 °C	0 °C	0

The constraints on these exchangers ("Evaporator" and "Absorber") are used to impose a vapor ratio of 0 (bubble point) for the absorber and 1 (dew point) for the evaporator. It is possible to directly use the vapor ratio constraint (used in the "condenser" heat exchanger).

Name	Generator	SHX
Exchanger type	Counter current or multipasses	Counter current or multipasses
Specification type	Cold stream	Cold stream
Specification	Outlet temperature	Outlet temperature
Specification value (°C)	155	80

✓ Centrifugal pump “P1”

Specification	Pressure specification
Exhaust pressure (mbar)	550
Isentropic efficiency	0.65
Mechanical efficiency	0.95
Electrical efficiency	0.98

✓ Expansion valves

Name	V1	V2
Constraint type	Pressure specification	Pressure specification
Pressure specification	Supplied	Supplied
Pressure (mbar)	25	25

✓ Liquid-vapor separator “S1”

This module is defined with the default operating parameters as shown below:

Flash type	Constant pressure and enthalpy flash
Pressure specification	The lowest of the feed streams
Pressure drop (bar)	0
Heat duty specification	Adiabatic

Remark: the mixer “M1” is defined with the default operating parameters (the outlet pressure is equal to the lowest of the feeds pressures).

1.5.3. Industrial example

The operating conditions of the different modules in the "Industrial example" are the following:

- ✓ Feeds

Name	Process heating loop return	Make up
Partial mass flowrates (t/h):		
Water	1440	200
Lithium bromide	0	0
Hydrogen	0	0
Carbon dioxide	0	0
Oxygen	0	0
Carbon monoxide	0	0
Hydrogen sulfide	0	0
Sulfur dioxide	0	0
Sulfur trioxide	0	0
Nitric oxide	0	0
Nitrogen	0	0
Temperature (°C)	45	15
Pressure (atm)	1	1

- ✓ Boiler

Constraint	Useful power imposed
Useful power (MW)	100
Operating mode	Nominal useful operating

- o Operating parameters of the internal exchanger

Exchanger type	Pure counter current
Fumes temperature at the outlet of the unit provided (°C)	130

- o Operating parameters of the combustion

COMBUSTIVE			
Type		Air	
Constraint: “Air excess” (%)		20	
Inlet pressure (atm)		1	
FUEL			
Type		Liquid/solid	
LHV (kJ/kg)		10000	
Inlet pressure (atm)		1	
Definition		On raw	
Name	**Mass fractions (%)**	**Name**	**Mass fractions (%)**
C	20	H	5
O	15	N	1
S	0.2	H_2O	38.8
Heat losses		5% of combustion power	

The stoichiometric coefficients of the reactions of combustion are obtained by clicking on the button “Calculate the stoichiometric coefficients of conventional reactions”.

Note: The button “Load the compound of fumes” of the module is used to import the fumes calculator and define this calculator as the boiler’s calculator. A new calculator “Fumes-Biogas” is added to the list of calculators.

✓ Absorber “Scrubber”

Number of stages	10
Pressure (bar)	Equal to the pressure of the first feed
Plate efficiencies	1

✓ Generalized heat exchangers

Name	**Evaporator**	**Absorber**	**Condenser**
Exchanger type	Counter current or multipasses	Counter current or multipasses	Counter current or multipasses
Specification type	Cold stream	Hot stream	Hot stream
Specification	Superheated over its dew point temperature	Subcooled below its bubble point	Outlet molar vapor fraction
Specification value	0 °C	0 °C	0

Name	**Generator**	**SHX**	**Heating condenser**
Exchanger type	Counter current or multipasses	Counter current or multipasses	Counter current or multipasses
Specification type	Cold stream	Cold stream	Other
Specification	Outlet temperature	Outlet temperature	Minimal internal temperature approach
Specification value (°C)	142.2	80	10

✓ Cooler/Heater “Heat loss”

Outlet temperature	Equal to the feed stream temperature
Temperature increment (°C)	-5

✓ Turbines

Name	HT Steam Turbine	LT Steam Turbine
Specification	Outlet pressure supplied by user	Outlet pressure supplied by user
Outlet pressure (bar)	6	2
Isentropic efficiency	0.68	0.71
Mechanical efficiency	0.96	0.97
Electrical efficiency	0.99	0.99

✓ Centrifugal pumps

Name	P1	P2
Specification	Supplied	Supplied
Exhaust pressure	550 mbar	35 bar
Volumetric efficiency	0.75	0.75
Mechanical efficiency	0.95	0.95
Electrical efficiency	0.98	0.98

✓ Expansion valves

Name	V1	V2
Constraint type	Pressure specification	Pressure specification
Pressure specification	Supplied	Supplied
Pressure (mbar)	25	25

✓ Stream splitters

Name	Stream	Splitting ratio	Outlet pressure
Stream splitter	11 (to the generator)	0.4	Equal to the feed pressure
Purge	23 (process purge)	0.15	Equal to the feed pressure

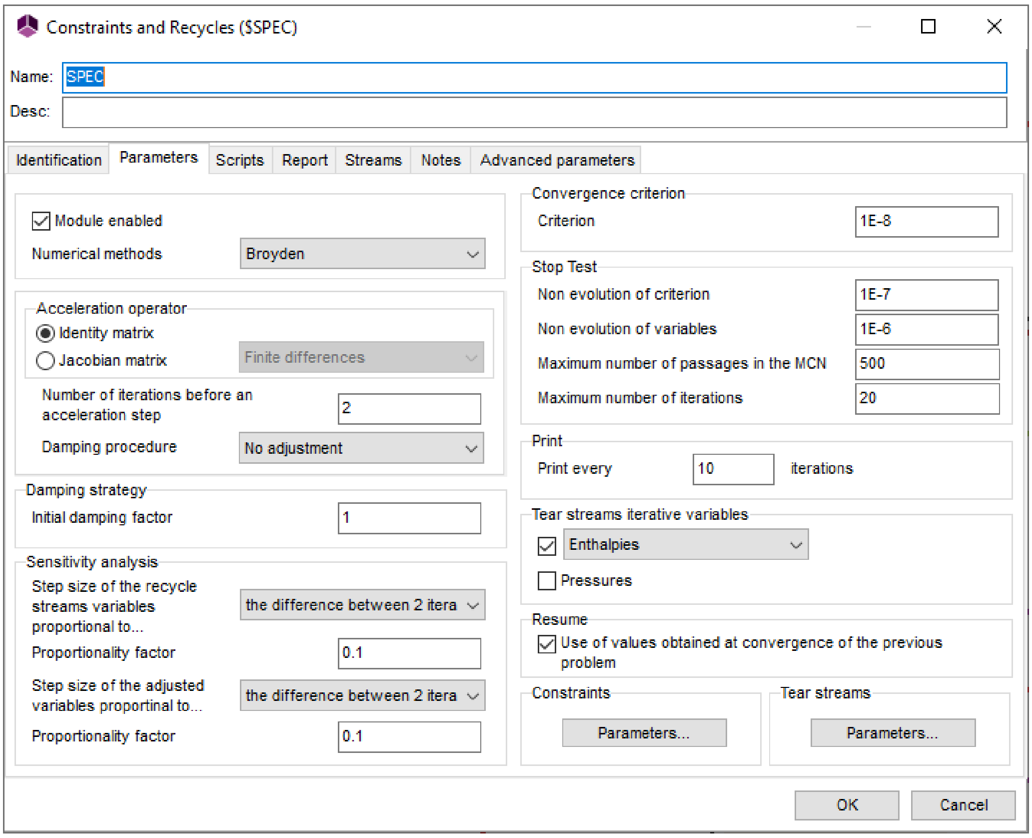
✓ Liquid-vapor separator “S1”

This module is defined with the default operating parameters as shown below:

Flash type	Constant pressure and enthalpy flash
Pressure specification	The lowest of the feed streams
Pressure drop (bar)	0
Heat duty specification	Adiabatic

✓ Constraints and Recycles “SPEC ”

The module Constraints and Recycles is necessary to solve the process recycles equations, in order to increase the maximum number of passages in the RCM, the default number not being sufficient. Enthalpy is specified as a tear streams iterative variable to manage energy balances. The parameters of the module are as shown below:



Remark: all of the mixers (“M1”, “M2” and “M3”) are defined with the default operating parameters (the outlet pressure is equal to the lowest of the feeds pressures).

1.6. Initializations

The calculation sequence is automatically determined by ProSimPlus. Two tear streams are detected in the first two examples: the "1-1" stream of the outlet of the mixer "M1" and “3” or”3-1” of the “Generator” module. The following initializations are used:

	Absorption heat transformer	
Stream	1-1	3 or 3-1
Partial molar flowrates (kmol/h)		
Water	12,0298	12,0298
Lithium bromide	3,30796	3,30796
Temperature (°C)	136,39	85
Pressure (mbar)	550	50

	Absorption refrigerator	
Stream	1-1	3 pr 3-1
Partial molar flowrates (kmol/h)		
Water	12,0298	12,0298
Lithium bromide	3,30796	3,30796
Temperature (°C)	82,38	80
Pressure (mbar)	25	550

In the case of the “Industrial example”, several tear streams were detected: the stream “1-1” (outlet of the mixer “M1”), the stream “3” (inlet of the heat exchanger “Generator”), the stream “26” (inlet of the mixer “M3”) and the stream “19” (outlet of the pump “P2”). The following initializations are used:

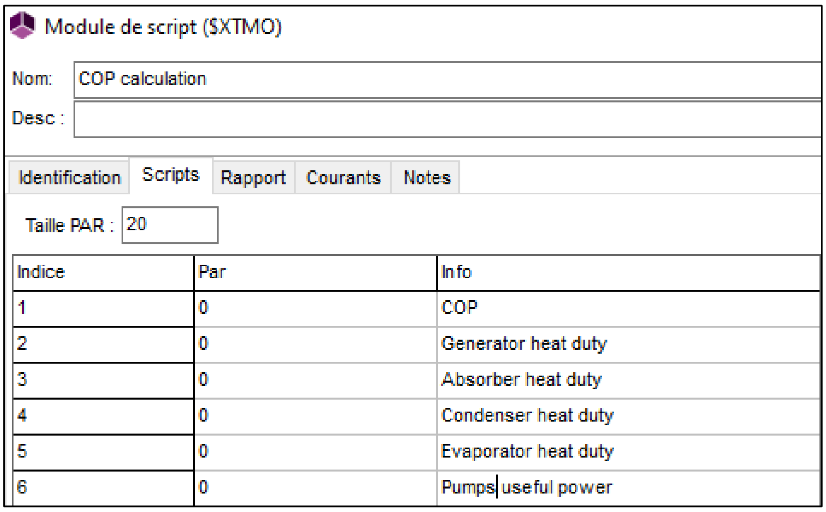
Stream	1-1	3	26	19
Partial molar flowrates (kmol/h):				
Water	7733.44	7733.44	72553.4	6938.55
Lithium bromide	2126.55	2126.55	0	0
Hydrogen	0	0	0	0
Carbon dioxide	0	0	102.131	0
Oxygen	0	0	1.02684	0
Carbon monoxide	0	0	0	0
Hydrogen sulfide	0	0	0	0
Sulfur dioxide	0	0	5.81298	0
Sulfur trioxide	0	0	0	0
Nitric oxide	0	0	0	0
Nitrogen	0	0	4.94618	0
Temperature (°C)	72.61	80	26.33	116.79
Pressure (bar)	0.025	0.55	1.01325	35

2. RESULTS

2.1. Results summary

In the first two examples, a Windows script module called “COP Calculation” is used to calculate the COP of the absorption heat pump. In the industrial example, a Windows script module called “Efficiency Calculation” is used to calculate the COP of the absorption heat pump and the process global performances.

2.1.1. Absorption heat transformer



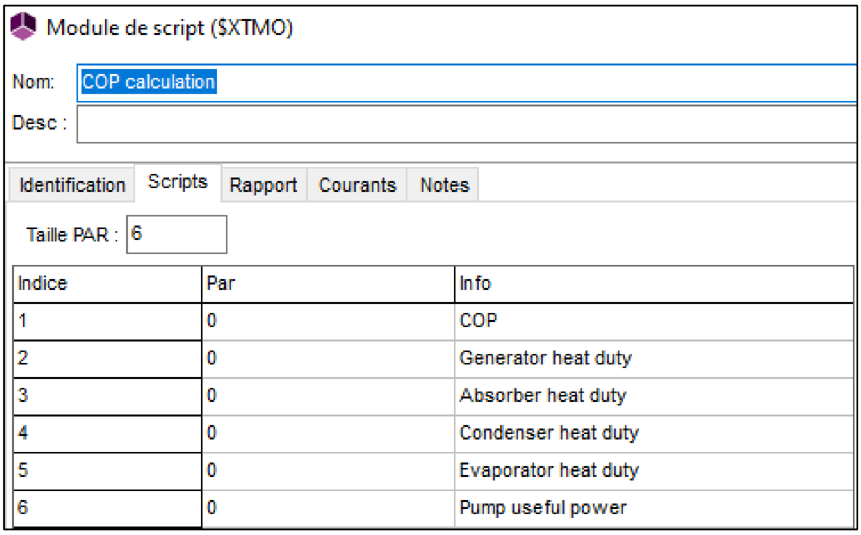
The following script is used to compute the COP and print the results in the “Report” tab of the “COP calculation” module:

```
'------------------------------------------------------------------------------'
' CALL OF "UNIT CONVERSION" SCRIPT
'------------------------------------------------------------------------------'
with CreateObject("Scripting.FileSystemObject")
    ExecuteGlobal .OpenTextFile(Project.ApplicationPath & "Scripts\UnitConversion.vbs",
1).ReadAll()
    ExecuteGlobal .OpenTextFile(Project.ApplicationPath & "Scripts\FormatDouble.vbs", 1).ReadAll()
    ExecuteGlobal .OpenTextFile(Project.ApplicationPath & "Scripts\StreamProperties.vbs",
1).ReadAll()
end with


Function OnCalculation()

'------------------------------------------------------------------------------'
' CALCULATION OF COEFFICIENT OF PERFORMANCE OF HEAT PUMP
'------------------------------------------------------------------------------'
Module.parameter(2) = Project.Modules("Generator").HeatDuty
Module.parameter(3) = Project.Modules("Absorber").HeatDuty
Module.parameter(4) = Project.Modules("Condenser").HeatDuty
Module.parameter(5) = Project.Modules("Evaporator").HeatDuty
Module.parameter(6) = Project.Modules("P1").UsefulPower + Project.Modules("P2").UsefulPower

COP = Project.Modules("Absorber").HeatDuty / (Project.Modules("Generator").HeatDuty +
Project.Modules("Evaporator").HeatDuty + Module.parameter(6))

Module.parameter(1) = COP

OnCalculation = true

End Function
```



```
Sub OnPrintResults()
'-------------------------------------------------------------------------------
' PRINT RESULTS
'-------------------------------------------------------------------------------

  Module.PrintReport "Generator heat duty  = " & NiceFloat(ConvertFromProSim("Power",
Module.parameter(2), "kW")) & "(kW)"
  Module.PrintReport "Absorber heat duty   = " & NiceFloat(ConvertFromProSim("Power",
Module.parameter(3), "kW")) & "(kW)"
  Module.PrintReport "Condenser heat duty  = " & NiceFloat(ConvertFromProSim("Power",
Module.parameter(4), "kW")) & "(kW)"
  Module.PrintReport "Evaporator heat duty = " & NiceFloat(ConvertFromProSim("Power",
Module.parameter(5), "kW")) & "(kW)"
  Module.PrintReport "Pumps useful power   = " & NiceFloat(ConvertFromProSim("Power",
abs(Module.parameter(6)), "kW")) & "(kW)"
  Module.PrintReport ""
  Module.PrintReport "COP                  = " & FormatNumber(Module.parameter(1),3) & "  (-)"
End Sub
```

2.1.2. Absorption refrigerator

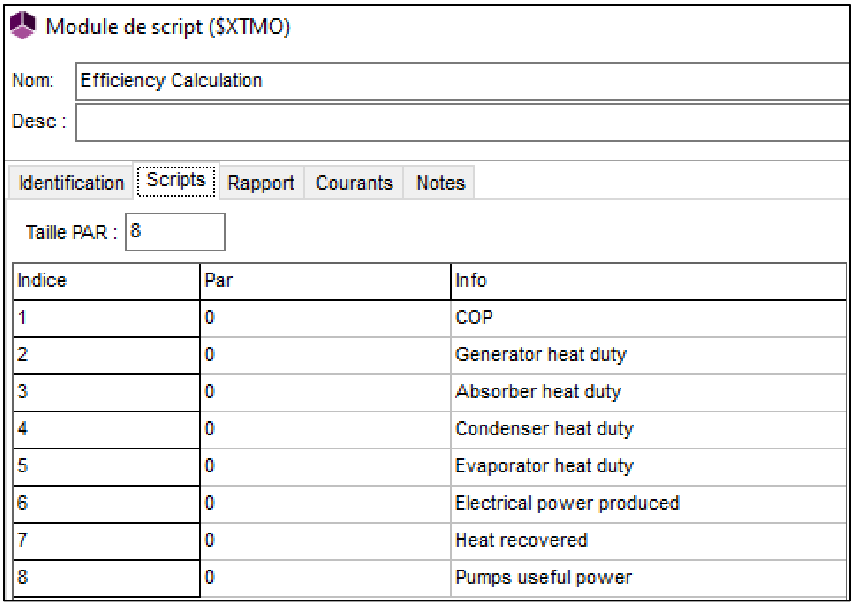


The following script is used to compute the COP and print the results in the “Report” tab of the “COP calculation” module:

```
'-----------------------------------------------------------------------------'
' CALL OF "UNIT CONVERSION" SCRIPT
'-----------------------------------------------------------------------------'
with CreateObject("Scripting.FileSystemObject")
    ExecuteGlobal .OpenTextFile(Project.ApplicationPath & "Scripts\UnitConversion.vbs",
1).ReadAll()
    ExecuteGlobal .OpenTextFile(Project.ApplicationPath & "Scripts\FormatDouble.vbs", 1).ReadAll()
    ExecuteGlobal .OpenTextFile(Project.ApplicationPath & "Scripts\StreamProperties.vbs",
1).ReadAll()
end with


Function OnCalculation()

'-----------------------------------------------------------------------------'
' CALCULATION OF COEFFICIENT OF PERFORMANCE OF HEAT PUMP
'-----------------------------------------------------------------------------'
Module.parameter(2) = Project.Modules("Generator").HeatDuty
Module.parameter(3) = Project.Modules("Absorber").HeatDuty
Module.parameter(4) = Project.Modules("Condenser").HeatDuty
```

```
Module.parameter(5) = Project.Modules("Evaporator").HeatDuty
Module.parameter(6) = Project.Modules("P1").UsefulPower

COP = Project.Modules("Evaporator").HeatDuty / (Project.Modules("Generator").HeatDuty +
Module.parameter(6))

Module.parameter(1) = COP

OnCalculation = true

End Function

Sub OnPrintResults()
'--------------------------------------------------------------------------------
' PRINT RESULTS
'--------------------------------------------------------------------------------

  Module.PrintReport "Generator heat duty  = " & NiceFloat(ConvertFromProSim("Power",
Module.parameter(2), "kW")) & "(kW)"
  Module.PrintReport "Absorber heat duty   = " & NiceFloat(ConvertFromProSim("Power",
Module.parameter(3), "kW")) & "(kW)"
  Module.PrintReport "Condenser heat duty  = " & NiceFloat(ConvertFromProSim("Power",
Module.parameter(4), "kW")) & "(kW)"
  Module.PrintReport "Evaporator heat duty = " & NiceFloat(ConvertFromProSim("Power",
Module.parameter(5), "kW")) & "(kW)"
  Module.PrintReport "Pump useful power    = " & NiceFloat(ConvertFromProSim("Power",
abs(Module.parameter(6)), "kW")) & "(kW)"
  Module.PrintReport ""
  Module.PrintReport "COP                  = " & FormatNumber(Module.parameter(1),3) & "  (-)"
End Sub
```

2.1.3. Industrial example


Module de script ($XTMO)

Nom: Efficiency Calculation

Desc :

Identification | Scripts | Rapport | Courants | Notes

Taille PAR : 8

Indice	Par	Info
1	0	COP
2	0	Generator heat duty
3	0	Absorber heat duty
4	0	Condenser heat duty
5	0	Evaporator heat duty
6	0	Electrical power produced
7	0	Heat recovered
8	0	Pumps useful power

The following script is used to compute the COP, the total electricity produced and the thermal heat recovered. This script is also used to print these results in the “Report” tab of the “Efficiency Calculation” module:

```
'-----------------------------------------------------------------------------'
' CALL OF "UNIT CONVERSION" SCRIPT
'-----------------------------------------------------------------------------'
with CreateObject("Scripting.FileSystemObject")
    ExecuteGlobal .OpenTextFile(Project.ApplicationPath & "Scripts\UnitConversion.vbs",
1).ReadAll()
    ExecuteGlobal .OpenTextFile(Project.ApplicationPath & "Scripts\FormatDouble.vbs", 1).ReadAll()
    ExecuteGlobal .OpenTextFile(Project.ApplicationPath & "Scripts\StreamProperties.vbs",
1).ReadAll()
end with


Function OnCalculation()

' Calculation of coefficient of performance of absorption heat pump
COP = (Project.Modules("Absorber").HeatDuty + Project.Modules("Condenser").HeatDuty) /
(Project.Modules("Generator").HeatDuty + Project.Modules("P1").UsefulPower)

Module.parameter(1) = COP
Module.parameter(2) = Project.Modules("Generator").HeatDuty
Module.parameter(3) = Project.Modules("Absorber").HeatDuty
Module.parameter(4) = Project.Modules("Condenser").HeatDuty
Module.parameter(5) = Project.Modules("Evaporator").HeatDuty
Module.parameter(8) = Project.Modules("P1").UsefulPower

' Calculation of total electrical power produced
Module.parameter(6) = Project.Modules("HT Steam Turbine").Power + Project.Modules("LT Steam
Turbine").Power

' Calculation of amount of heat recovered
Module.parameter(7) = Project.Modules("Heating condenser").OutputStream(1).EnthalpyFlux -
Project.Modules("Absorber").InputStream(2).EnthalpyFlux

OnCalculation = true

End Function

Sub OnPrintResults()
'-------------------------------------------------------------------------------
' PRINT RESULTS
'-------------------------------------------------------------------------------

  Module.PrintReport "ABSORPTION HEAT PUMP"
  Module.PrintReport ""
  Module.PrintReport "Generator heat duty              = " & NiceFloat(ConvertFromProSim("Power",
Module.parameter(2), "MW")) & "(MW)"
  Module.PrintReport "Absorber heat duty               = " & NiceFloat(ConvertFromProSim("Power",
Module.parameter(3), "MW")) & "(MW)"
  Module.PrintReport "Condenser heat duty              = " & NiceFloat(ConvertFromProSim("Power",
Module.parameter(4), "MW")) & "(MW)"
  Module.PrintReport "Evaporator heat duty             = " & NiceFloat(ConvertFromProSim("Power",
Module.parameter(5), "MW")) & "(MW)"
Module.PrintReport "--------------------------------------------------------"
  Module.PrintReport "COP                              =  " & FormatNumber(Module.parameter(1),3)
& "        (-)"
  Module.PrintReport ""
  Module.PrintReport ""
  Module.PrintReport "Electrical power produced        =  " &
abs(NiceFloat(ConvertFromProSim("Power", Module.parameter(6), "MW"))) & "      (MW)"
  Module.PrintReport ""
  Module.PrintReport "Amount of heat recovered         = " & NiceFloat(ConvertFromProSim("Power",
Module.parameter(7), "MW")) & "(MW)"

End Sub
```


2.2. Coefficient of performance (COP) and process global performance

In order to evaluate the thermodynamic performance of the absorption heat pump, the coefficient of performance (COP) of the cycle was calculated. COP is defined as the ratio of useful heating or cooling provided outside of the cycle to work required.

2.2.1. Absorption heat transformer

Simulation results	Notation	Value
Generator (kW)	A	49.0
Absorber (kW)	B	49.2
Condenser (kW)	C	36.1
Evaporator (kW)	D	36.2
Centrifugal pumps (kW)	E	0.01
COP	F (=B/(A+D+E))	0.58
Hot water temperature produced (°C)	G	127.9
Water temperature at the condenser outlet (°C)	H	29.3

2.2.2. Absorption refrigerator

Simulation results	Notation	Value
Generator (kW)	I	81.0
Absorber (kW)	J	9.1
Condenser (kW)	K	50.6
Evaporator (kW)	L	45.3
Centrifugal pumps (kW)	M	0.01
COP	N (=L/(I+M))	0.56
Water temperature at the evaporator outlet (°C)	O	22.8

2.2.3. Industrial example

Simulation results	Notation	Value
Generator (MW)	P	33.1
Absorber (MW)	Q	31.5
Condenser (MW)	R	17.4
Evaporator (MW)	S	15.7
Centrifugal pumps (MW)	T	0.01
COP	U (=(Q+R)/(P+T))	1.48
HT Steam Turbine (MW)	V	10.6
LT Steam Turbine (MW)	W	3.5
Electrical power produced (MW)	X (=V+W)	14.1
Heat recovered (MW)	Y	101.1

Remark: the amount of heat recovered is obtained by subtracting the enthalpy flux of the water stream leaving the process (stream "27") with the enthalpy flux of the water stream entering the process (stream "17"). This heat could supply an urban heating network, not represented in this example.

3. REFERENCES

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