ProSimPlus Application Example

Operating Balance Optimization of a Natural Gas Liquids Plant

Example purpose
This example presents the optimization of an existing natural gas liquids plant operating balance with ProSimPlus. This example especially illustrates the combined use of the "Economic evaluation" and the "SQP Optimization" modules of ProSimPlus.

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Corresponding ProSimPlus file	*PSPS_EX_EN-NGL-Plant-OPEX-Optimization.pmp3*

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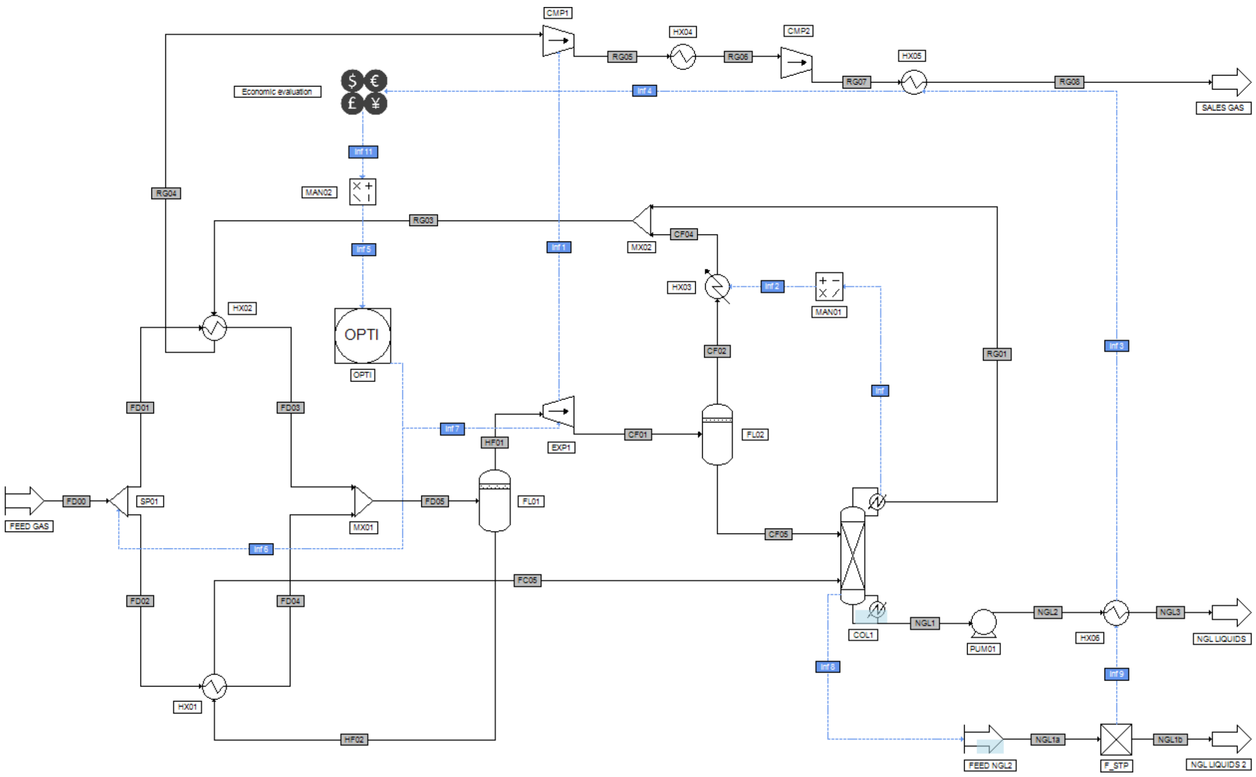
1. PROCESS MODELING

1.1. Process presentation

This example presents the simulation of a natural gas liquids plant. This process extracts the liquids contained in the natural gas while maintaining a residue gas heating value close to 1000 Btu/SCF for residual sales gas. The gas feed is cooled in two parts, one with the gas stream coming from the second flash FL02 mixed with the vapor distillate of the deethanizer, and the other with the condensate coming from the first flash FL01. The cooled feed is flashed a first time. The gas stream is expanded before being flashed again. The liquid streams coming from these two flashes are sent to the deethanizer distillation column. The bottom product is the natural gas liquids. The vapor distillate mixed with the vapor stream coming from the second flash is compressed and cooled to form the residual sales gas. The objective of this study is to maximize the profit generated by an existing plant (cost of the feed and utilities compared to the cost of the products). The optimization variables are the feed splitting ratio and the expander discharge pressure.

The input data of this problem is available in [PRO95].

1.2. Process flowsheet



1.3. Compounds

The compounds used in this example are listed in the table below. The order of the components is to be kept given that some scripts use this predefined order.

Name	Chemical formula	CAS number
Nitrogen	N_2	7727-37-9
Methane	CH_4	74-82-8
Ethane	C_2H_6	74-84-0
Propane	C_3H_8	74-98-6
Isobutane	iC_4H_{10}	75-28-5
n-Butane	nC_4H_{10}	106-97-8
Isopentane	iC_5H_{12}	78-78-4
n-Pentane	nC_5H_{12}	109-66-0
n-Hexane	C_6H_{14}	110-54-3
n-Heptane	C_7H_{16}	142-82-5

1.4. Thermodynamic model

This process deals with hydrocarbons and nitrogen. The operating pressure never exceeds 100 bars. As a consequence, the SRK model has been chosen. The binary interaction parameters come from the ProSim database have been used. The liquid molar volume is calculated using the Lee-Kesler method.

1.5. Operating conditions

The operating conditions required to define the process are gathered in this part. The data in orange corresponds to initial values that will be modified by the optimization module:

- ✓ Feed gas

		Feed gas
Molar percentage	N_2	0.62
	CH_4	89.23
	C_2H_6	6.96
	C_3H_8	2.23
	iC_4H_{10}	0.29
	nC_4H_{10}	0.47
	iC_5H_{12}	0.09
	nC_5H_{12}	0.07
	nC_6H_{14}	0.03
	nC_7H_{16}	0.01
Total molar flowrate (lbmol/h)		1646.98
Temperature (°F)		120
Pressure (psi)		510

- ✓ Separators

Operating parameters	*Flash FL01*
Separator type	Liquid-vapor separator
Pressure (psi)	505
Heat duty (Btu/h)	Adiabatic

Operating parameters	*Flash FL02*
Separator type	Liquid-vapor separator
Temperature (°F)	Feeds adiabatic mixing temperature
Pressure (psi)	The lowest of the feed streams

✓ Columns

Operating parameters	*Distillation column COL1*
Column type	Distillation column with partial condenser
Number of theoretical stages	16
Feed stages	6 and 12
Vapor distillate flowrate (lbmol/h)	65
Reflux flowrate (lbmol/h)	40
Reboiler heat duty (kcal/h)	Calculated
Overhead pressure (and at the stage 2) (psi)	“EXP1” expander pressure - 5 psi
Bottom pressure (psi)	“EXP1” expander pressure
Stage efficiencies	1

To obtain the specified column pressure profile, the following script has been used:

```
' Loading of the library containing the unit conversion tool
with CreateObject("Scripting.FileSystemObject")
  ExecuteGlobal .OpenTextFile(Project.ApplicationPath & "Scripts\UnitConversion.vbs", 1).ReadAll()
end with

' Creation function of the column pressure profile
Sub OnCalculationStart()

' Recovery of the "EXP1" expander pressure value
P1 = Project.Modules("TUR1").PressureSpecValue

' Pressure drop (value: 5 psi) conversion into ProSim units (atm)
DP = ConvertToProSim("Pressure drop", 5, "psi")

with Module
   ' 1st stage pressure
   .OverheadPressure               = P1 - DP
   ' Stage 2
   .IntermediatePressuresStages(1) = 2
   ' Pressure of the previously entered stage (stage 2)
   .IntermediatePressuresValues(1) = P1 - DP
end with

End Sub
```

COL1 column further specifications:

Specification		Product type	Compound	Value	Action
1:	Partial flowrate	Bottom liquid product	ETHANE	0.1137 lbmol/h	Vapor distillate flowrate
2:	Partial flowrate	Vapor distillate	PROPANE	1.62 lbmol/h	Reflux flowrate

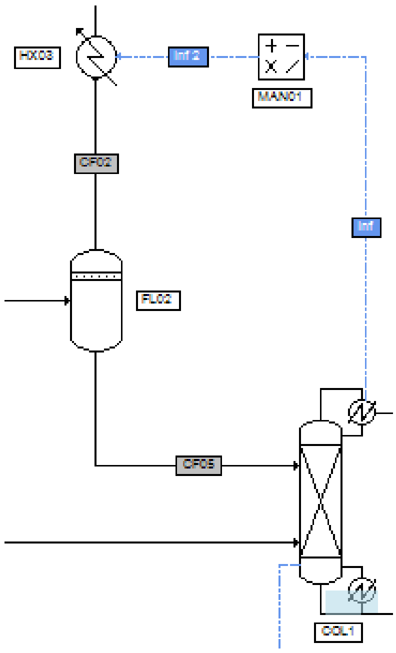
✓ Generalized heat exchangers

Name	*Specification type*	*Specification value*	*Pressure drop (psi)* *1st stream / 2nd stream*
HX01	Other: UA Product	2 666.3 Btu / h / °F	0 / 0
HX02	Cold stream: Outlet temperature	110 °F	0 / 0

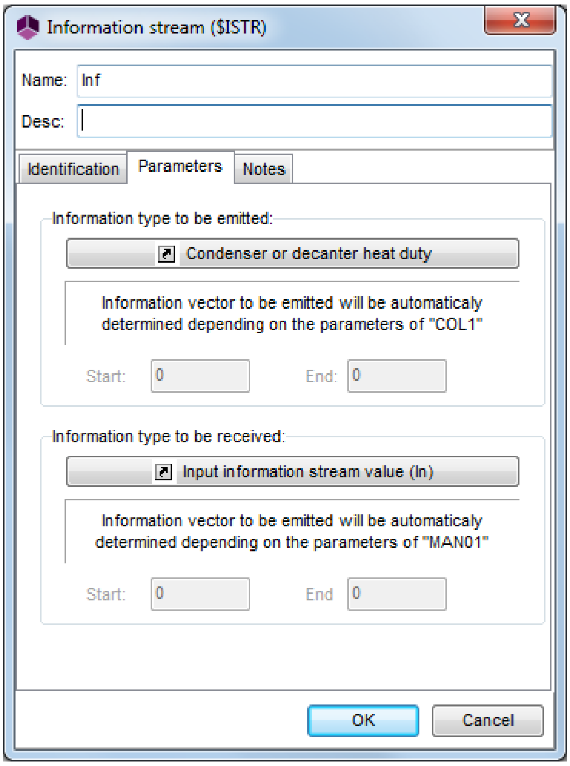
✓ Simple heat exchanger

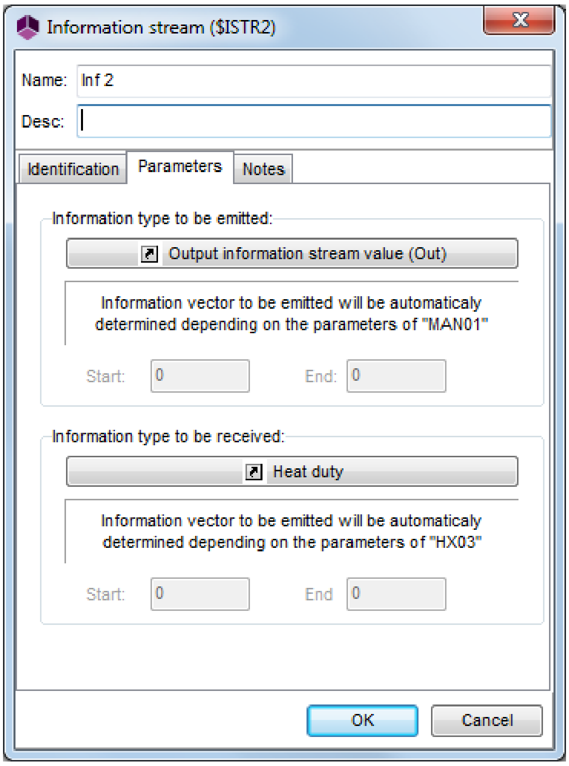
Name	*Heat duty (Btu/h)*	*Pressure drop (psi)*
HX03	- COL 1 condenser heat duty (heating)	0

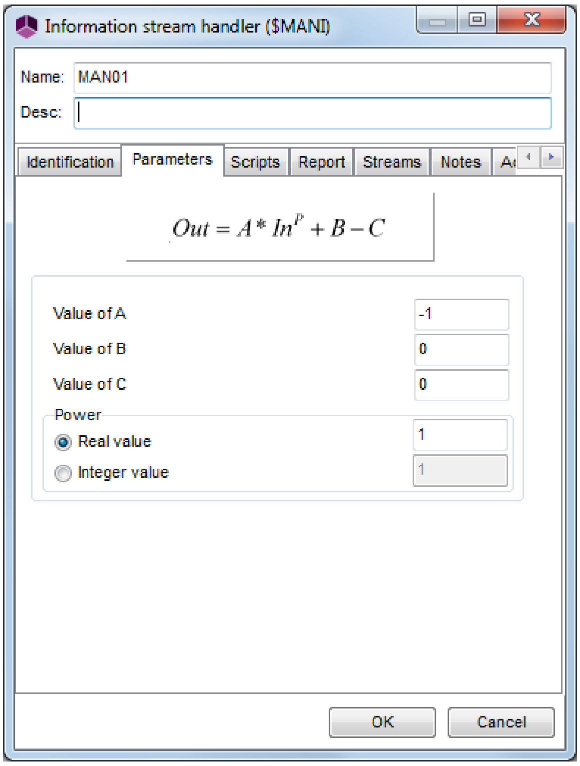
The “HX03” heat duty has to be of opposite sign than the COL1 condenser heat duty in order to respect ProSimPlus heat duty convention. Thus, an information stream handler and two information streams have been used to connect “COL1” to “HX03 as presented below:



The configuration windows of the “Inf” and “Inf2” information streams and of the “MAN01” information stream handler are the following ones:







✓ Coolers/Heaters

Name	***Outlet temperature (°F)***	***Pressure drop (bar)***
HX04	115	0
HX05	115	0
HX06	115	0

✓ *Expander*

Operating parameters	***Expander EXP1***
Specification	Outlet pressure supplied by user: 200 psi
Isentropic efficiency	0.95
Mechanical efficiency	1
Electrical efficiency	1

✓ *Compressors*

Operating parameters	***Compressor CMP1***	***Compressor CMP2***
Supplied specification	Actual supplied pressure: “EXP1” expander mechanical power *	Exhaust pressure: 510 psi
Isentropic efficiency	0.6519	0.7025
Mechanical efficiency	1	1
Electrical efficiency	1	1

*: supplied by an information stream

Remark: the “EXP1” expander - “CMP1” compressor ensemble forms a turbo-compressor.

✓ *Pump*

Operating parameters	*Pump* *PUM01*
Exhaust pressure (psi)	275
Volumetric efficiency	0.65
Mechanical efficiency	1
Electrical efficiency	1

✓ *Mixers*

Operating parameters	*Mixer* *MX01*	*Mixer* *MX02*
Outlet pressure (psi)	Equal to the lowest of the feeds	Equal to the lowest of the feeds

✓ *Stream splitter*

Operating parameters	*Stream splitter* *SP01*
FD02 stream splitting ratio	0.06
Outlet pressure (bar)	Equal to the feed pressure

1.6. NGL liquids volume flowrate calculation in Volume Standard Liquid

In [PRO95], the “NGL liquids” outlet flowrate is given in Volume Standard Liquid. To convert the calculated value of the “NGL liquids” flowrate into Volume Standard Liquid, the following method has been used.

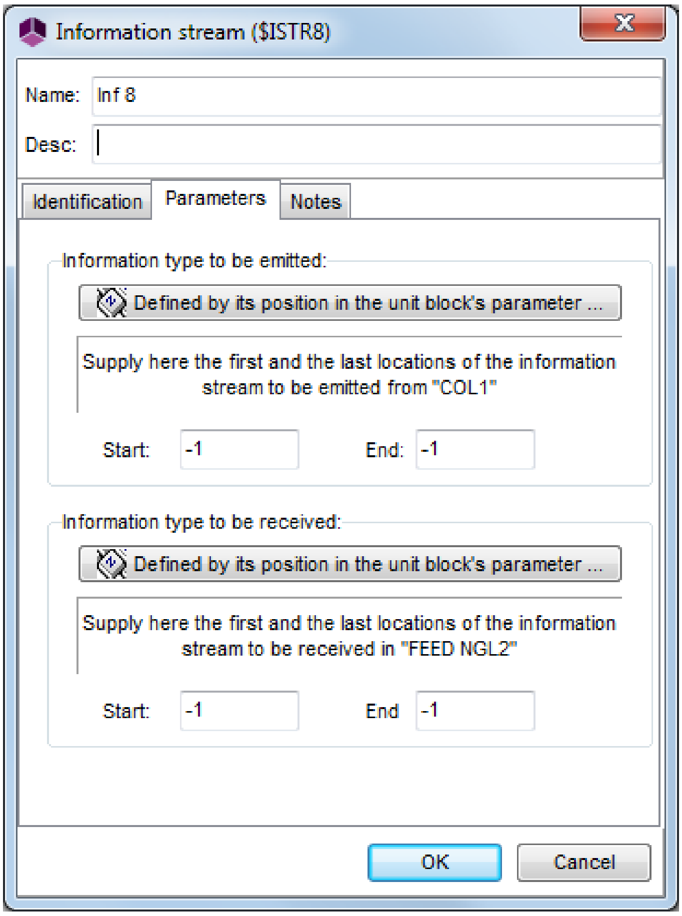
The value of the “NGL1” bottom liquid product stream leaving the “COL1” column is recovered and injected in the “FEED NGL2” feed module. To do so, the following script has been written in the “FEED NGL2” feed module.

```
' Recovery of the "COL1" column bottom liquid product parameters (stream "NGL1")
Sub OnCalculationEnd()
   Module.OutputStream(1).Copyfrom(Project.Streams("GNL1"))
End Sub
```

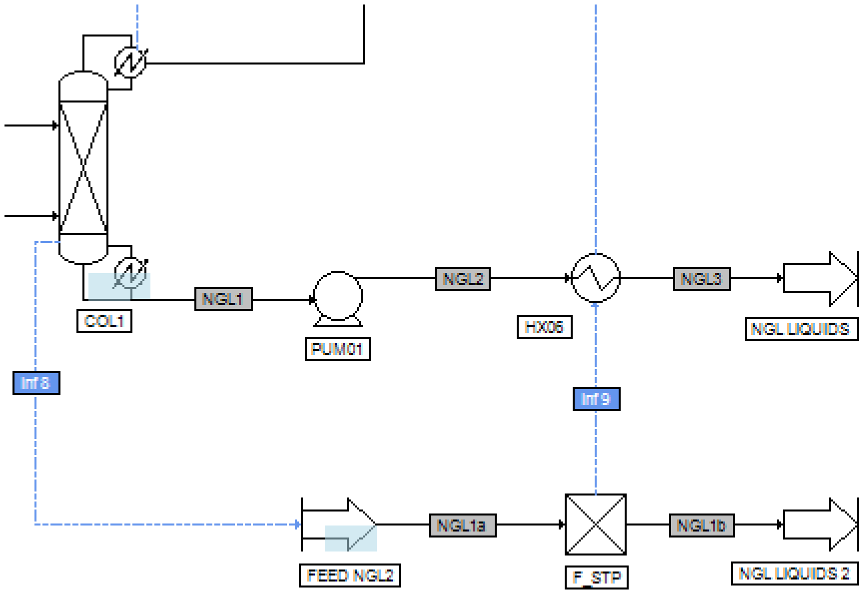

The “FEED NGL2” feed module is connected to a “2-phase separator with one outlet stream” named here “F_STP”. In this separator, the standard conditions have been imposed: temperature of 60 °F and bubble pressure. The volume flowrate calculated at the outlet of the separator thus corresponds to the flowrate in Volume Standard Liquid.

This calculation has to be done just after the one of the “COL1” column in the calculation sequence. To do so, an information stream has been added between the “COL1” and the “FEED NGL2” modules.

This stream is only used to impose the calculation sequence and is configured as presented in the following figure. In the rest of this document a so configured information stream will be called “-1/-1”.



The connection diagram used to modify the calculation sequence (with the “Inf8” information stream) can be seen on the following figure:



2. Process operating balance calculation

The ProSimPlus economic evaluation module allows to determine the operating balance of a process that is to say the difference between the operating gain and the operating cost of the process.

Before configuring the economic evaluation module, it is required to well define the inventory of the operating gains and costs of the studied process.

2.1. Operating gains inventory

The operating gains of the process correspond to:

- the gas sale

- the natural gas liquids sale

The required data to calculate these gains is gathered in the table below [PRO95].

Product	Gain
Feed/residue gas	3.40 $/MMBtu
Ethane liquids	0.18 $/gal
Propane liquids	0.355 $/gal
iC4 liquids	0.50 $/gal
nC4 liquids	0.505 $/gal
C5+ liquids	0.57 $/gal

The piece of data “Feed/residue gas” will allow to calculate the operating gain generated by the outlet “SALES GAS” and the 5 other pieces of data the gain generated by “NGL LIQUIDS 2”.

2.2. Operating costs inventory

The operating costs of the process correspond to:

- the gas purchase (“FEED GAS” process inlet),

- the cost of the electricity consumed by the compressor “CMP2” and the pump “PUM01”

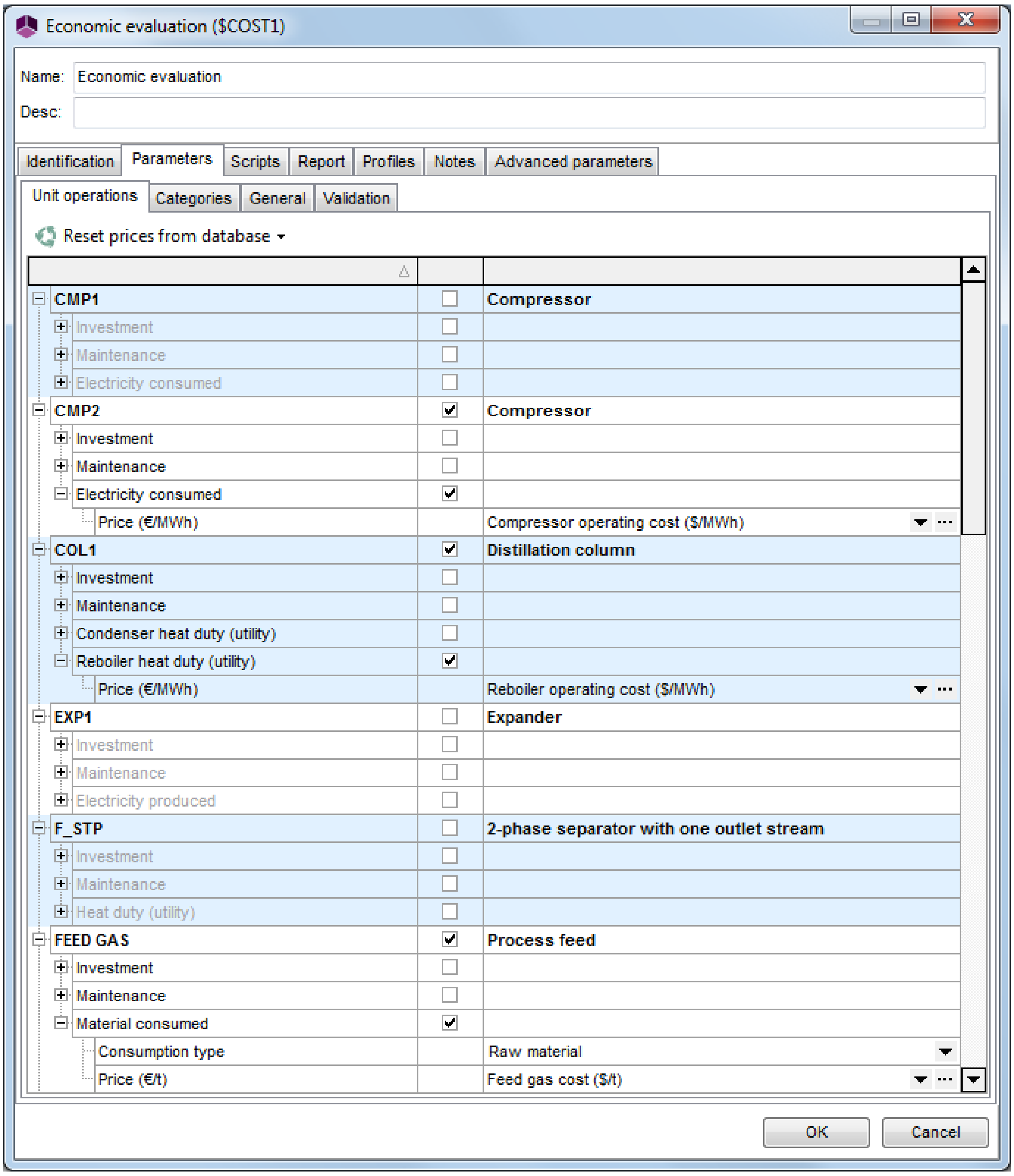
- the cost of the utility (gas) used to supply the energy required by the “COL1” column reboiler

The required data to calculate these costs are gathered in the table below [PRO95].

Piece of data	Value
Feed/residue gas	3.40 $/MMBtu
Furnace brut efficiency	65 %
Electricity	0.027 $/kWh

2.3. Input of the operating gains and costs in the economic evaluation module

The aim of this example is only to calculate the operating balance of an existing unit without taking into account neither the equipment investment nor its maintenance. To configure the economic evaluation module in order to calculate the operating balance, the sub-tab “Unit operations” in the “Parameters” tab has to be selected. The window to configure is then the following one:



The first step is to untick all the prices related to the investment and the maintenance as well as all the unit operations that are not taken into account in this example.

The following figures gather all the unit operations and the prices considered in this example.

CMP2	☑	**Compressor**
Investment	☐	
Maintenance	☐	
Electricity consumed	☑	
Price (€/MWh)		Compressor operating cost ($/MWh)

COL1	☑	**Distillation column**
Investment	☐	
Maintenance	☐	
Condenser heat duty (utility)	☐	
Reboiler heat duty (utility)	☑	
Price (€/MWh)		Reboiler operating cost ($/MWh)

FEED GAS	☑	**Process feed**
Investment	☐	
Maintenance	☐	
Material consumed	☑	
Consumption type		Raw material
Price (€/t)		Feed gas cost ($/t)

NGL LIQUIDS 2	☑	**Process outlet**
Material produced	☑	
Production type		Product
Price (€/t)		NGL price ($/t)

PUM01	☑	**Centrifugal pump**
Investment	☐	
Maintenance	☐	
Electricity consumed	☑	
Price (€/MWh)		Electricity cost ($/MWh)

SALES GAS	☑	**Process outlet**
Material produced	☑	
Production type		Product
Price (€/t)		Sales gas price ($/t)

In the following, for all module considered in the operating balance calculation, the calculation functions of the used costs are described.

Remark: the cost calculation currency of the economic evaluation is the actual € (year 2016 when this example was written). However, the costs in the reference [PRO95] are given in $. Since the year of the $ currency is not specified and the actualization rate has no influence in this example, the costs and prices have been entered in $ with a currency conversion ratio from the actual € to the $ equals to 1.

2.3.1. "FEED GAS" inlet

The cost of the process feed gas is given in [PRO95] in \$/MMBtu. The economic evaluation module required a cost in €/t for a material stream. To do this conversion, the following formula has been used:

$$\text{Feed gas cost} = (\text{Heating value})\,(\text{Molar Volume})\,(\text{Gas cost})\,(\text{Molar weight}) / 10^6$$

With: Feed gas cost in \$/t

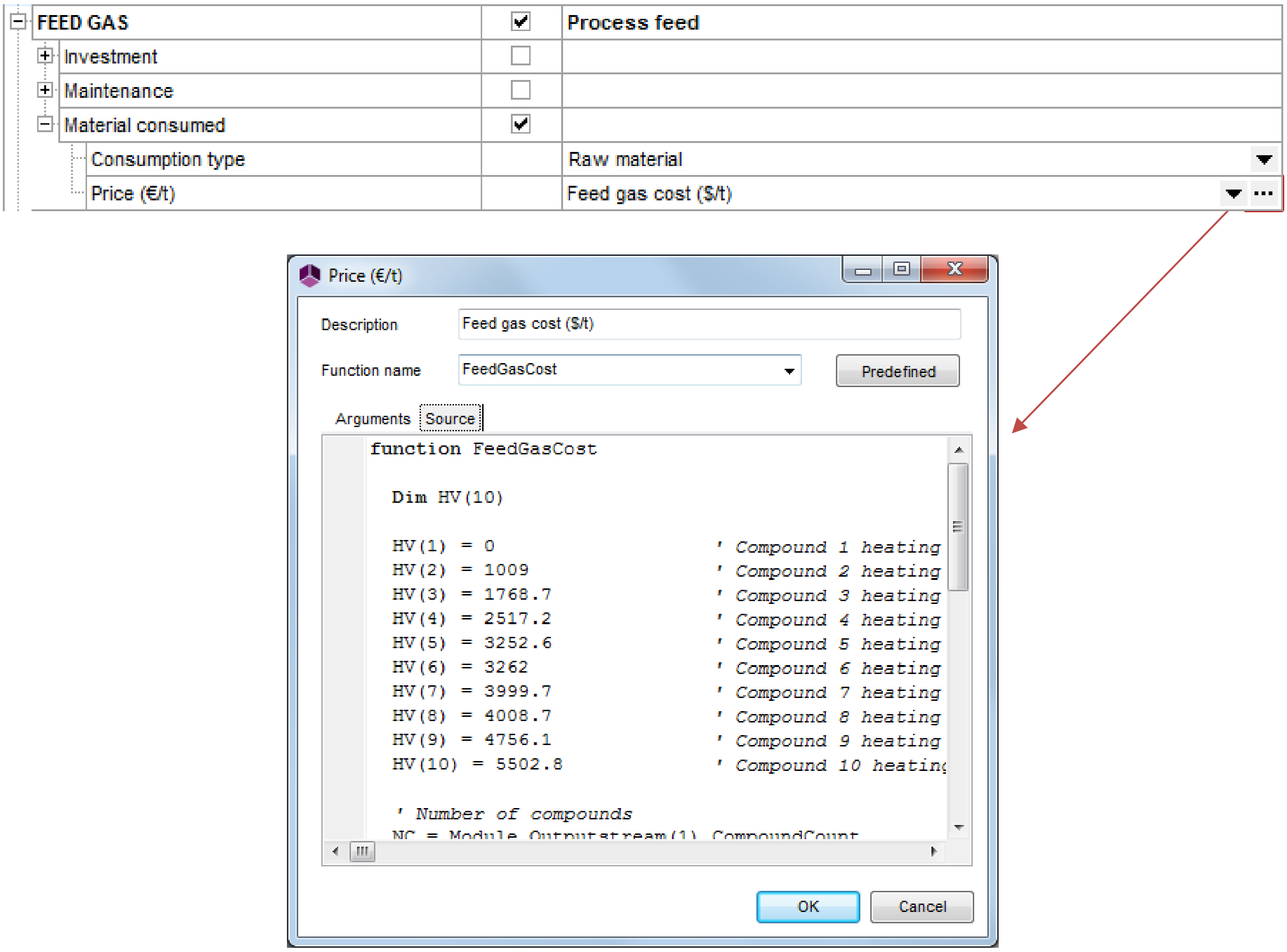
Heating value in Btu/SCF, the heating values are given for every compounds in [PRO95]. The heating value of the stream is then the sum of the heating values of the compounds weighted by the molar fractions.

Molar volume in SCF/lbmol, the hypothesis of a constant gas molar volume in the process and equals to 379.941 SCF/lbmol has been made [PRO95]

Gas cost in \$/MMBtu

Molar mass in t/lbmol

The corresponding script of this cost calculation has been entered in the economic evaluation module at the following place:



The script entered in the “Source” tab is the following one:

```
Function FeedGasCost

  Dim HV(10)

  HV(1) = 0                   ' Compound 1 heating value, Btu/SCF
  HV(2) = 1009                ' Compound 2 heating value, Btu/SCF
  HV(3) = 1768.7              ' Compound 3 heating value, Btu/SCF
  HV(4) = 2517.2              ' Compound 4 heating value, Btu/SCF
  HV(5) = 3252.6              ' Compound 5 heating value, Btu/SCF
  HV(6) = 3262                ' Compound 6 heating value, Btu/SCF
  HV(7) = 3999.7              ' Compound 7 heating value, Btu/SCF
  HV(8) = 4008.7              ' Compound 8 heating value, Btu/SCF
  HV(9) = 4756.1              ' Compound 9 heating value, Btu/SCF
  HV(10) = 5502.8             ' Compound 10 heating value, Btu/SCF

  ' Number of compounds
  NC = Module.Outputstream(1).CompoundCount

  ' Molar fraction array sizing
  Redim MF(NC)

  ' Compound molar fractions
  For i = 1 to NC
    MF(i) = Module.OutputStream(1).PartialMolarFlowrate(i) / Module.OutputStream(1).MolarFlowrate
  Next

  ' Molar weight, t/lbmol
  MW = Module.OutputStream(1).MolarWeight      ' lb/lbmol
  MW = MW / 2204.62                            ' t/lbmol

  ' Feed/residue gas, $/MMBtu
  FGCost = 3.4

  ' Feed stream heating value, Btu/SCF
  HeatingValue = 0.0
  For i = 1 to NC
    HeatingValue = HeatingValue + MF(i) * HV(i)
  Next

  ' Feed gas cost, $/t
  FeedGasCost = HeatingValue * 379.491 * FGCost / 1e6 / MW

End Function
```

Remark: In the input fields of the economic evaluation module (tab “Source”), it is possible to use the properties calculation functions proper to each module. In the case of “FEED GAS”, the properties of the streams leaving the module have been used.

2.3.2. “SALES GAS” outlet

The script entered to calculate the sales gas price (“SALES GAS” module) is similar to the one used for “FEED GAS”. Only the names of the function and some variables have been replaced to improve clarity.

```
Function SalesGasPrice

  Dim HV(10)

  HV(1) = 0                    ' Compound 1 heating value, Btu/SCF
  HV(2) = 1009                 ' Compound 2 heating value, Btu/SCF
  HV(3) = 1768.7               ' Compound 3 heating value, Btu/SCF
  HV(4) = 2517.2               ' Compound 4 heating value, Btu/SCF
  HV(5) = 3252.6               ' Compound 5 heating value, Btu/SCF
  HV(6) = 3262                 ' Compound 6 heating value, Btu/SCF
  HV(7) = 3999.7               ' Compound 7 heating value, Btu/SCF
  HV(8) = 4008.7               ' Compound 8 heating value, Btu/SCF
  HV(9) = 4756.1               ' Compound 9 heating value, Btu/SCF
  HV(10) = 5502.8              ' Compound 10 heating value, Btu/SCF

  ' Number of compounds
  NC = Module.Outputstream(1).CompoundCount

  ' Molar fraction array sizing
  Redim MF(NC)

  ' Compound molar fractions
  For i = 1 to NC
    MF(i) = Module.OutputStream(1).PartialMolarFlowrate(i) / Module.OutputStream(1).MolarFlowrate
  Next

  ' Molar weight, t/lbmol
  MW = Module.OutputStream(1).MolarWeight      ' lb/lbmol
  MW = MW / 2204.62                            ' t/lbmol

  ' Feed/residue gas price, $/MMBtu
  FGPrice = 3.4

  ' Heating value, Btu/SCF
  HeatingValue = 0.0
  For i = 1 to NC
    HeatingValue = HeatingValue + MF(i) * HV(i)
  Next

  ' Sales gas price, $/t
  SalesGasPrice = HeatingValue * 379.491 * FGPrice / 1e6 / MW

End Function
```

Remark: in the economic evaluation module, each process outlet is defined at the level of the module linked to this outlet. For example, the outlet “SALES GAS” is defined at the level of the “HX05” module. Thus, to have access to an outlet property (flowrate, molar mass…), the index number of the stream linking the module to the outlet needs to be determined. For example, the outlet “SALES GAS” corresponds to the outlet 1 of the “HX05” module. The syntax to have access to the total molar flowrate of the outlet “SALES GAS” is then:

```
Module.OutputStream(1).MolarFlowrate
```


2.3.3. “NGL LIQUIDS 2” outlet

To calculate the sales price of this outlet, the given data is here the volume price of the compounds or groups of compounds in this stream. In order to respect the unit required by the economic evaluation module (€/t for the feeds/outlets), this volume price has to be converted in mass price by determining the mixture density.

The script used to determine the sales price is the following one:

```
Function NGLPrice

  Dim C(6)

  C(2) = 0.18        ' C2 liquids cost, $/gal
  C(3) = 0.355       ' C3 liquids cost, $/gal
  C(4) = 0.5         ' IC4 liquids cost, $/gal
  C(5) = 0.505       ' NC4 liquids cost, $/gal
  C(6) = 0.57        ' C5+ liquids cost, $/gal

  ' Calculator creation, copy of the F_STP outlet stream (NGL1b)
  dim calc
  set calc = Module.Outputstream(1).VBSCalculator

  ' Recovery of the NGL1 stream temperature, pressure and number of compounds
  T = Module.Outputstream(1).Temperature
  P = Module.Outputstream(1).Pressure
  NC = Module.Outputstream(1).CompoundCount

  ' Array sizing
  Redim MF(NC-1)
  Redim MFPure(NC-1)
  Redim VmLPure(NC-1)
  Redim VF(NC-1)

  ' Initialization of the volume fraction array norm
  NormVF = 0

  ' NGL1b molar fraction calculation
  For i = 1 to NC
    MF(i-1) = Module.OutputStream(1).PartialMolarFlowrate(i)/Module.OutputStream(1).MolarFlowrate
  Next

  ' NGL1b liquid molar volume calculation
  VmL = calc.PCalcVmL(T,P,MF)

  ' Calculation of the pure compound molar volumes, the not normed volume fractions
  ' and the volume fraction array norm
  For i = 1 to NC

    VmLPure(i-1) = calc.Compounds.Items(i-1).LiquidMolarVolumeAtT(T)
    VF(i-1) = MF(i-1) * VmLPure(i-1) / VmL
    NormVF = NormVF + VF(i-1)

  Next

  ' Normalization of the volume fractions (this is equivalent to calculate the volume fractions
  ' with the "ideal mixture" hypothesis)
  For i = 1 to NC
    VF(i-1) = VF(i-1) / NormVF
  Next
```



```
  ' Volume fraction of the C5+ liquids in the NGL
  VFC5plus = 0.0
  For i = 7 to NC
    VFC5plus = VFC5plus + VF(i-1)
  Next

  ' NGL volume cost, $/gal
  NGLVolumeCost = VF(2) * C(2) + VF(3) * C(3) + VF(4) * C(4) + VF(5)* C(5) + VFC5plus * C(6)

  ' Density, t/gal
  Density = Module.OutputStream(1).Density      ' kg/m3
  Density = Density / 1000                      ' t/m3
  Density = Density / 264.172                   ' t/gal

  ' NGL price, $/t
  NGLPrice = NGLVolumeCost / Density

  ' Calculator destruction
  set calc = Nothing

End Function
```

2.3.4. “CMP2” compressor

The utility used in the “CMP2” compressor is natural gas. The efficiency of the energy supply is 40 %.

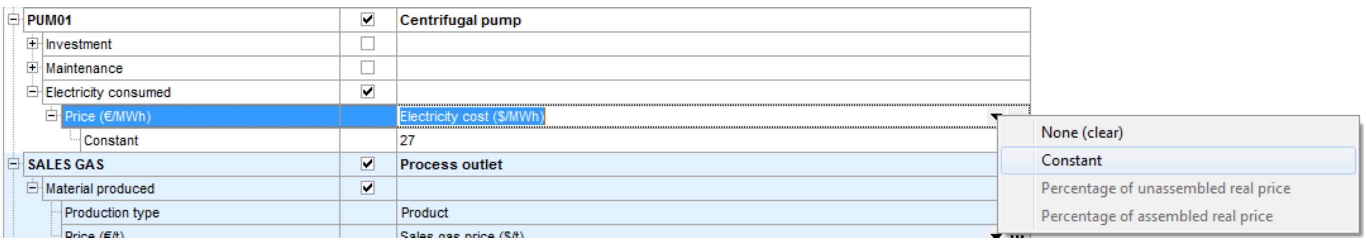
The script used to calculate the operating cost of the compressor is the following one:

```
Function CompressorOperatingCost

  ' Feed/residue gas cost, $/MMBtu
  FGCost = 3.4

  ' Compressor operating cost (efficiency: 40 %), $/MMBtu
  CompressorOperatingCost = FGCost / 0.4

  ' Compressor operating cost, $/MWh
  CompressorOperatingCost = CompressorOperatingCost * 3600 / 1054.35

End Function
```

2.3.5. “PUM01” centrifugal pump

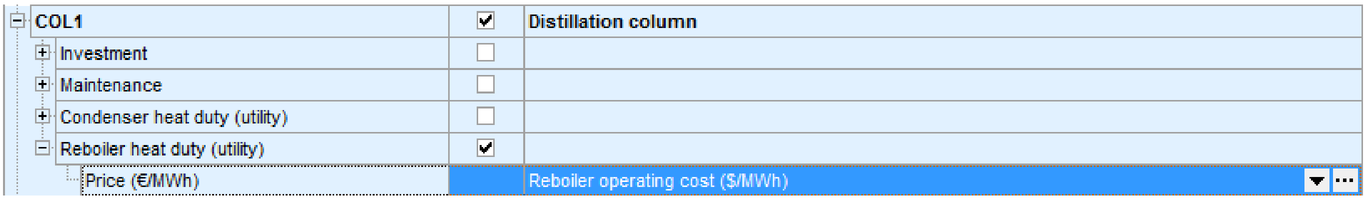
The centrifugal pump “PUM01” works with electrical energy for which cost is given in $/kWh in [PRO95]. The cost in $/MWh (unit required by the economic evaluation module) is simply this cost multiplied by 1000: 27$/MWh.

To enter this cost, click on the icon and select “Constant” for a constant cost. The value has to be entered in the field on the left of the field “Constant”.



2.3.6. "COL1" column reboiler

To calculate the operating cost of the "COL1" column reboiler, select the ··· icon of the blue field that can be seen on the next figure:



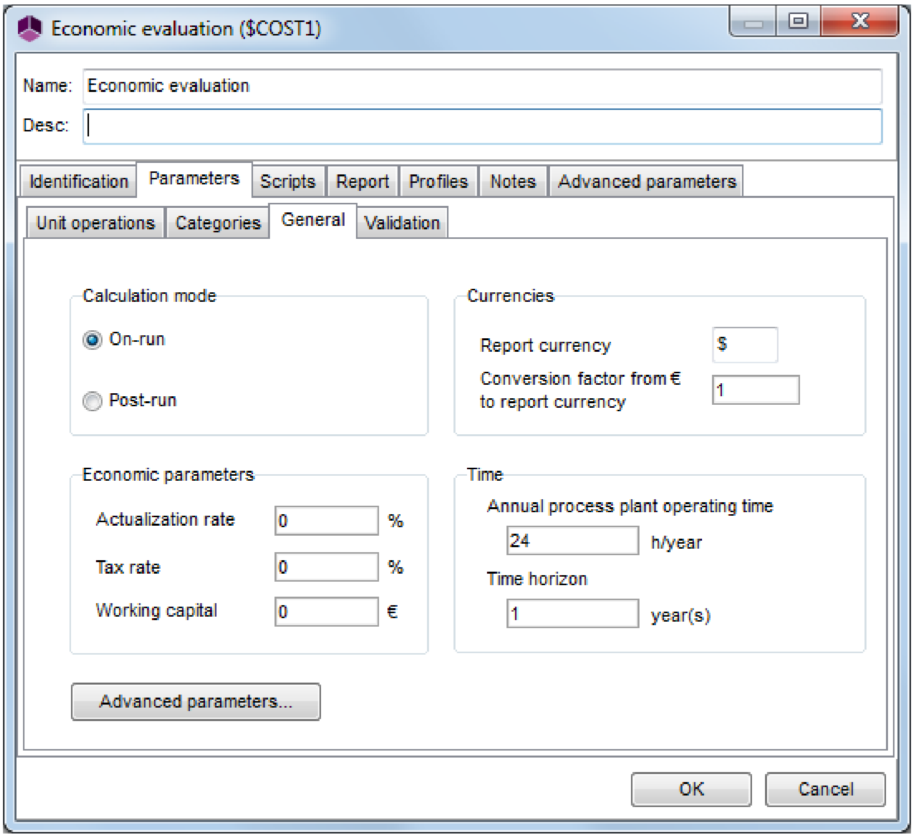
The utility used to make the reboiler work is natural gas. The efficiency of the energy supply is 65 %.

The script used to calculate the operating cost of the reboiler is the following one:

```
Function ReboilerOperatingCost

  ' Feed/residue gas cost, $/MMBtu
  FGCost = 3.4

  ' Reboiler operating cost (efficiency: 65 %), $/MMBtu
  ReboilerOperatingCost = FGCost / 0.65

  ' Reboiler operating cost, $/MWh
  ReboilerOperatingCost = ReboilerOperatingCost * 3600 / 1054.35

End Function
```


2.4. General parameters of the economic evaluation module

The general parameters to be entered in the "General" tab of the economic evaluation module can be seen in the following figure:



What follows is the explanation of the entered parameters:

Calculation mode:

The "On-run" calculation mode allows to carry out the economic evaluation during the simulation. That is here mandatory since the economic evaluation module is coupled to an optimization module in this example.

Economic parameters:

In this example, only the operating balance has to be determined. The actualization rate, the tax rate and the working capital are used to elaborate the repayment schedule and are so not used in this example. That is why the default values have been left to 0.

Currencies:

As specified in a previous remark, the prices have been entered in $ of the [PRO95] reference. The conversion factor has then been fixed to 1 and the currency symbol that will appear in the report fixed to "$".

Time:

By default the annual operating time of the plant corresponds to a nonstop operation of the plant 24/24 and 7/7. In this example, the daily operating balance has to be calculated. To do so, the chosen solution was to enter an annual process plant operating time of 24 hours (that means a day).

The time horizon is only used to elaborate the repayment schedule which is not considered in this example. Its value by default (1 year) has then been left.

Remark: the configuration of the “Categories” tab is not evocated here since it is only used for the investment calculation.

2.5. Position of the economic evaluation module in the calculation sequence

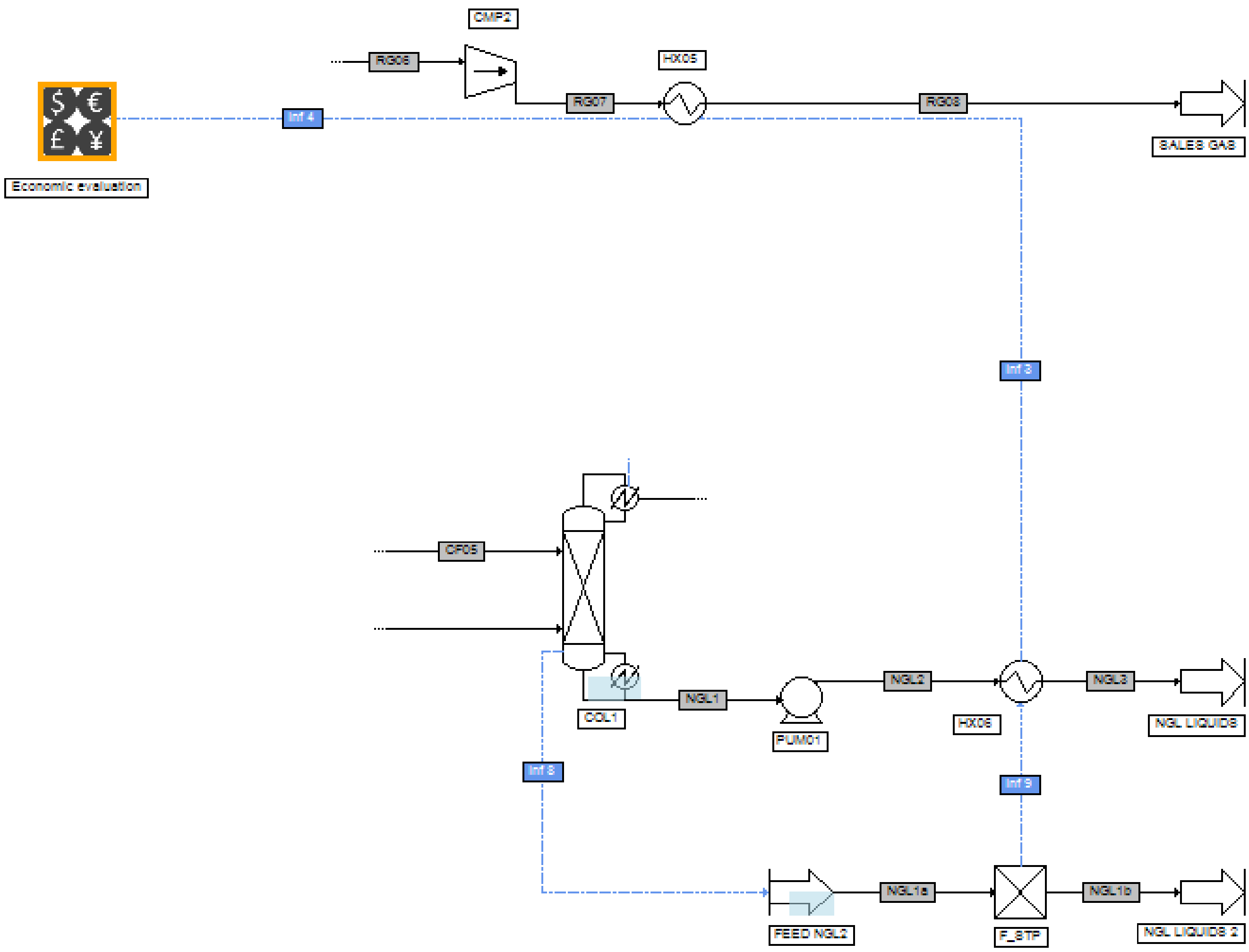
To correctly calculate the operating gains and costs, the economic evaluation module has to be placed in the right position in the calculation sequence that is to say after the following modules:

- “F_STP”

- “PUM01”

- “HX05”

The chosen solution to obtain this result is to link the previous modules (or the one placed after in the calculation sequence) to the economic evaluation module with “-1/-1” information streams. For readability reasons, the following configuration has been used:



Remark: the “Inf9”, “Inf3” and “Inf4” information streams are “-1/-1” ones.

3. Process operating balance optimization

3.1. Description of the optimization problem

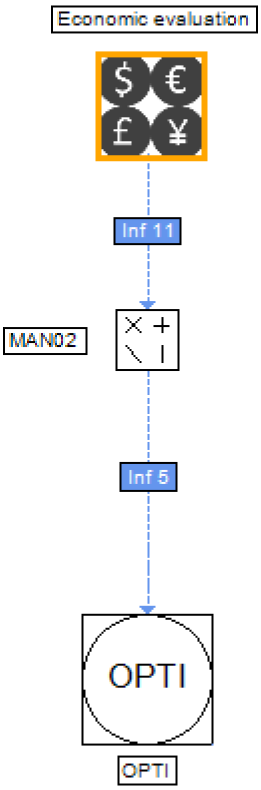
The aim is to maximize the operating balance by adjusting two process parameters:

- the splitting ratio of the stream “FD02” leaving the stream splitter “SP01”

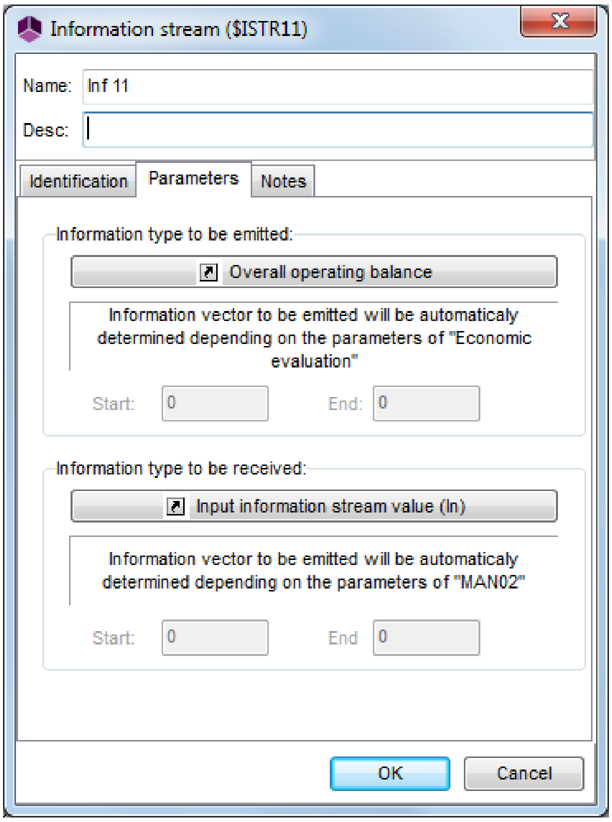
- the outlet pressure of the “EXP1” expander

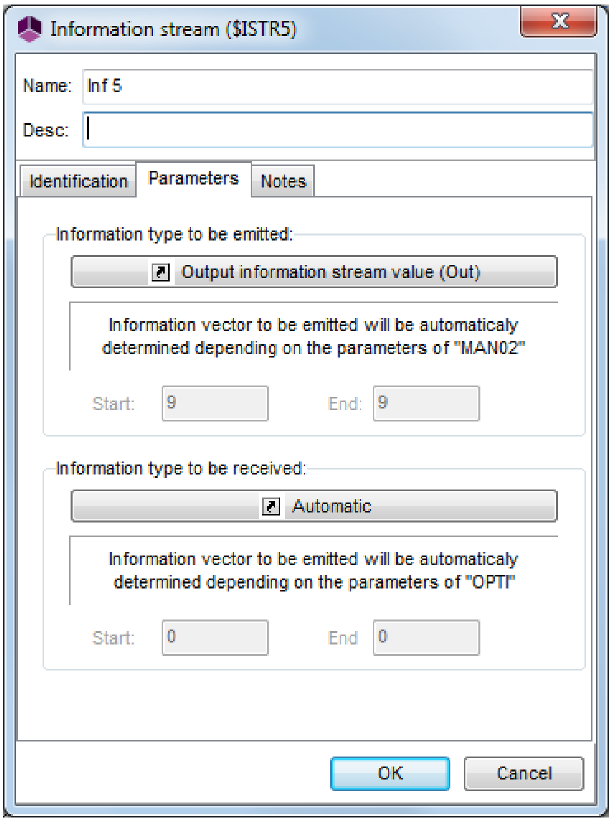
3.2. Optimization module configuration

The optimization module minimizes the parameter defined as its criterion function. Here the aim is to maximize the operating balance so the criterion to be defined is “minus operating balance”. To do so the economic evaluation module is connected to the optimization module with an information stream handler as illustrated below:

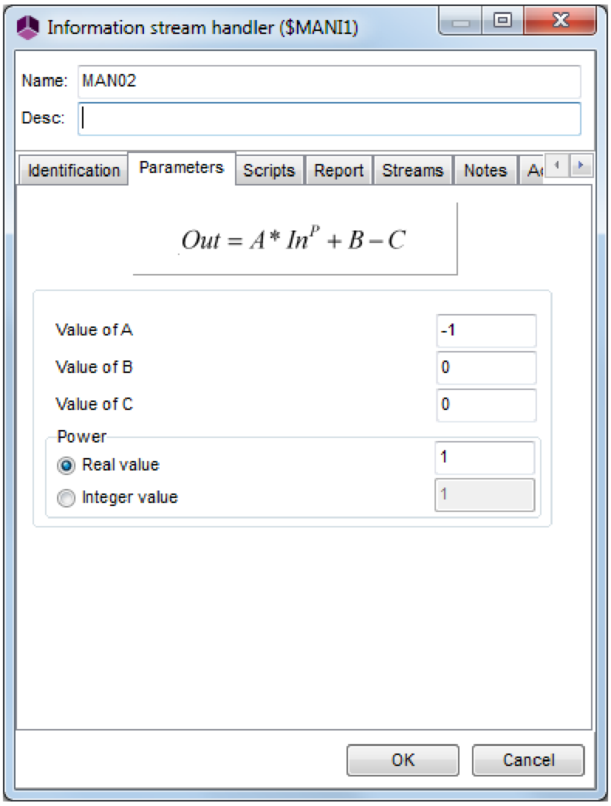


The information streams entering and leaving the “MAN02” stream handler are configured as follows:

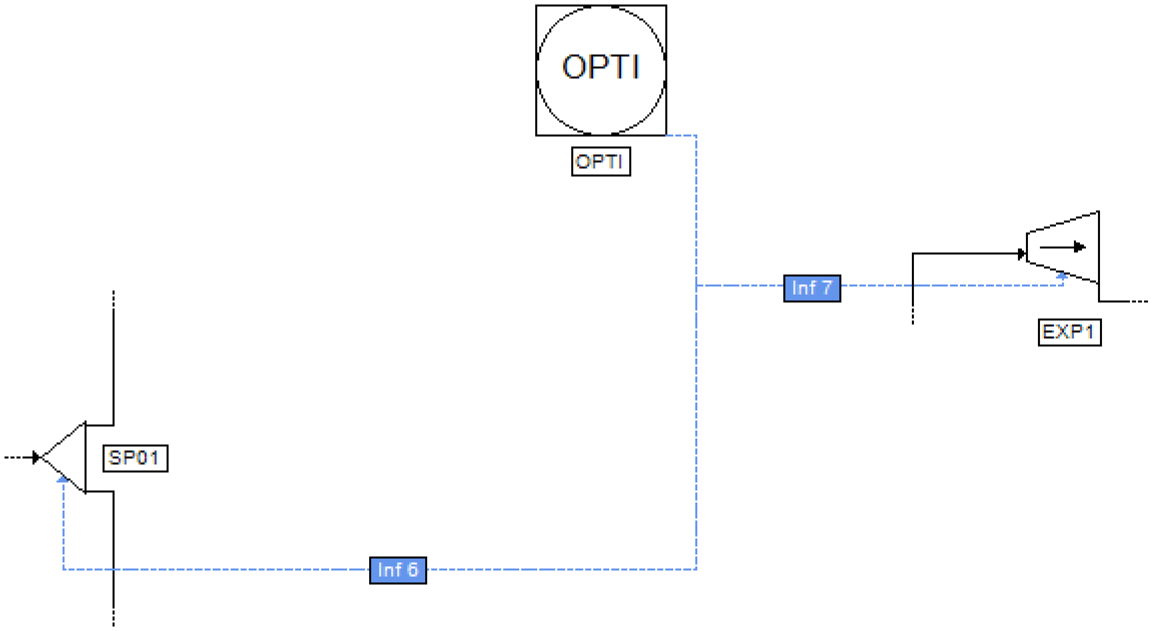




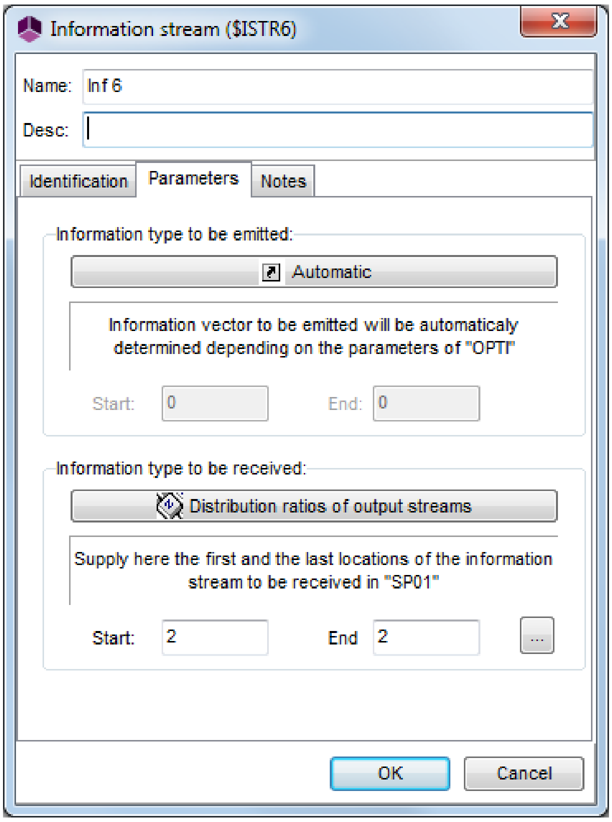
In order to send the criterion function ‘Minus operating balance” to the optimization module, the information stream handler has been configured as follows:

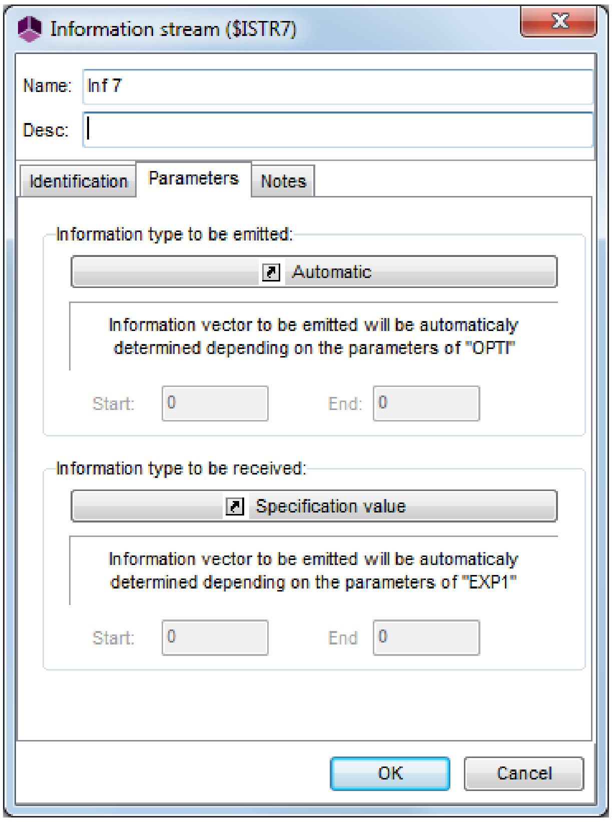


To adjust the two parameters of the optimization problem, the “OPTI” module has to be connected to the “SP01” stream splitter and to the “EXP1” expander as illustrated below:

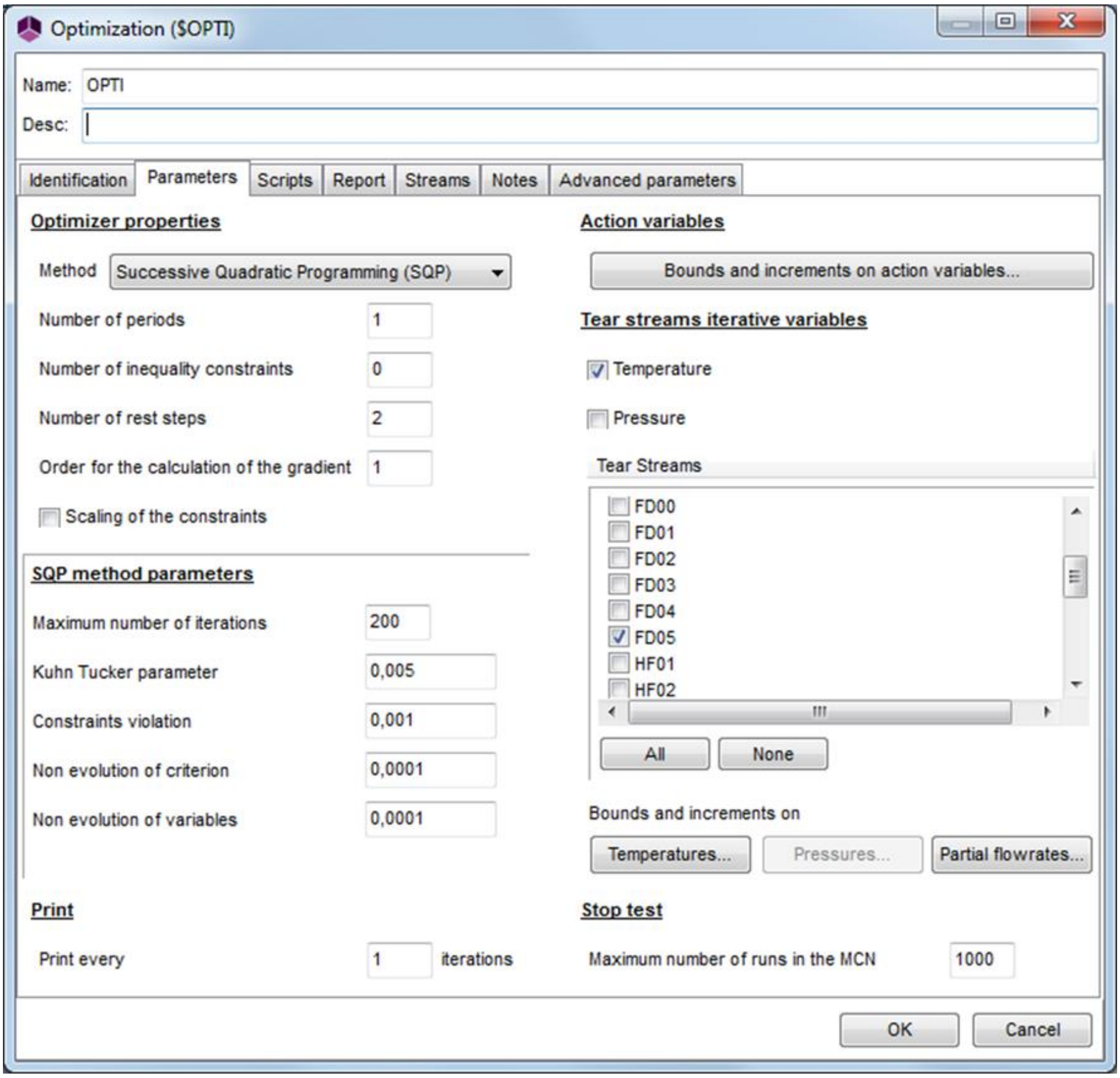


The information streams used are configured as follows:





The parameters to be entered in the definition window of the optimization module are partially visible on the following figure:



Remark: the Kuhn Tucker parameter depends on the order of magnitude of the derivative of the criterion function with respect to the different variables. It is so important to adjust the value of this parameter depending on this order of magnitude as it was done here.

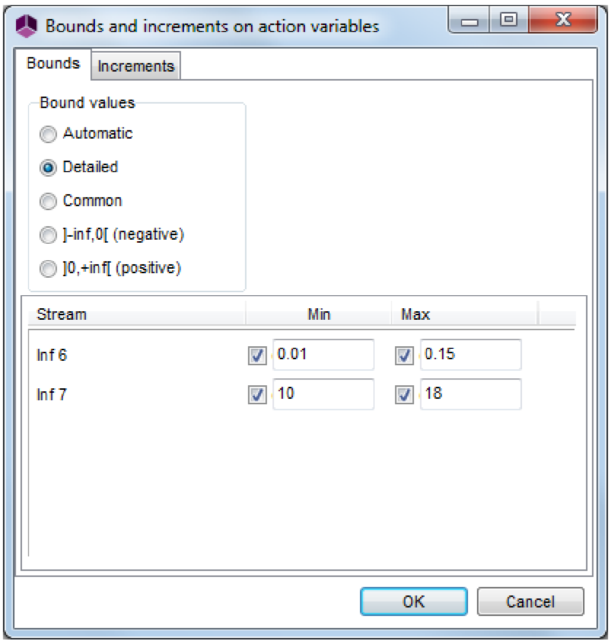
In the optimization module, it is important to specify the tear streams of the simulation.

The stream “FD05” has been chosen here as a tear stream. It is initialized with the following characteristics:

		Tear stream “FD05”
Molar flowrate (lbmol/h)	**N_2**	10.2112
	CH_4	1469.6
	C_2H_6	114.63
	C_3H_8	36.7276
	iC_4H_{10}	4.77623
	nC_4H_{10}	7.74079
	iC_5H_{12}	1.48228
	nC_5H_{12}	1.15288
	nC_6H_{14}	0.494093
	nC_7H_{16}	0.164698
Temperature (°F)		-40
Pressure (psi)		510

The partial molar flowrates of the stream “FD05” have been initialized with the ones of the feed stream “FD01” since a simple mass balance shows that these flowrates are equal.

The bounds of the action variables are presented in the figure below:



4. Simulation results

4.1. Comments on the results

The optimization gives an optimal operating balance of **661.534 $/day** for a **“FD02” stream splitter ratio of 0.15** and an **“EXP1” expander outlet pressure of 15.92 atm (233.92 psi)**.

Remark: the warning message related to the economic evaluation module that appears at the end of the simulation informs the user that a calculation could not be done in the economic evaluation module. In this example, the calculation of the rate of return could not be achieved since the process investment and the repayment schedule have not been considered.

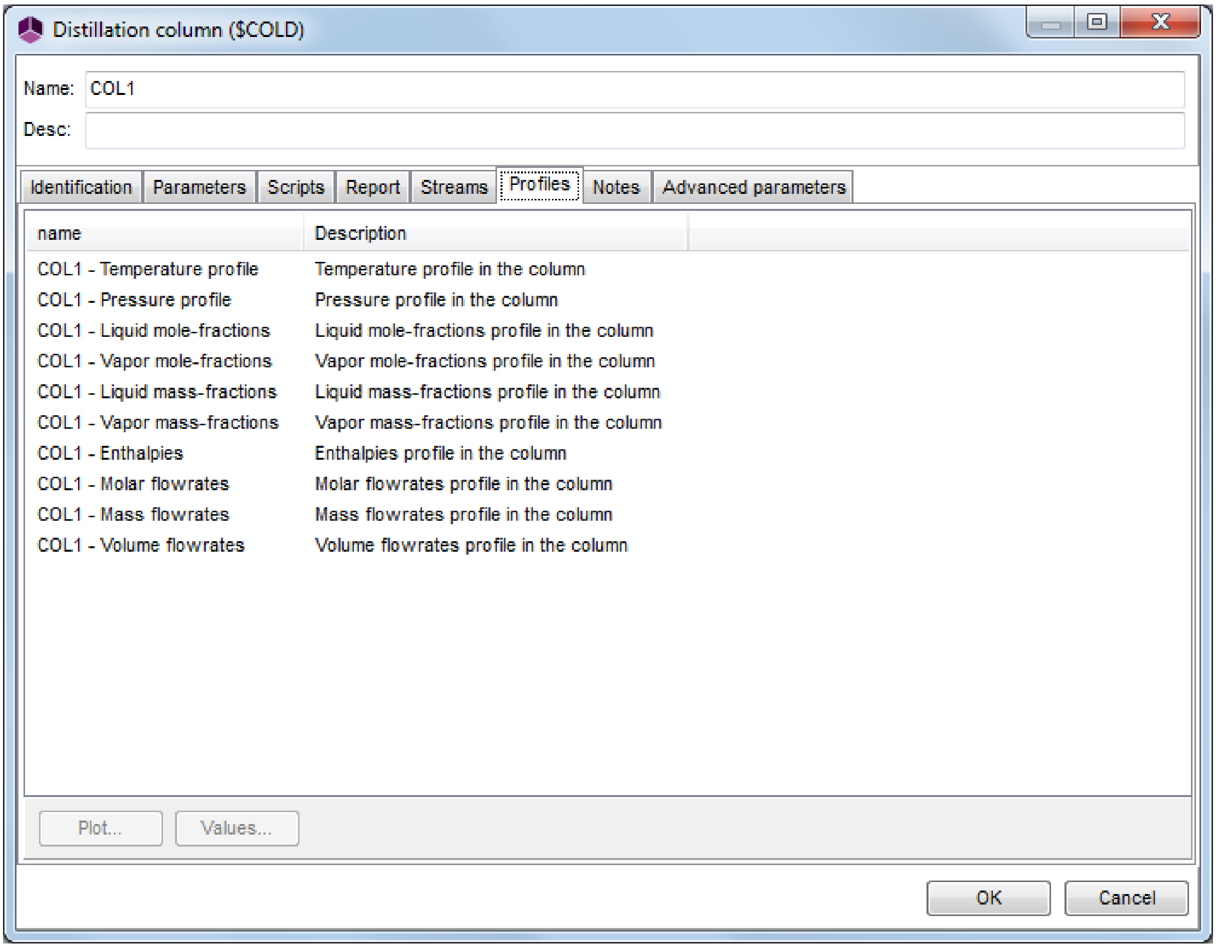
4.2. Mass and energy balances

This document only presents the most relevant stream results. In ProSimPlus, mass and energy balances are provided for all streams. Results are also available at the unit operation level (result tab in the configuration window).

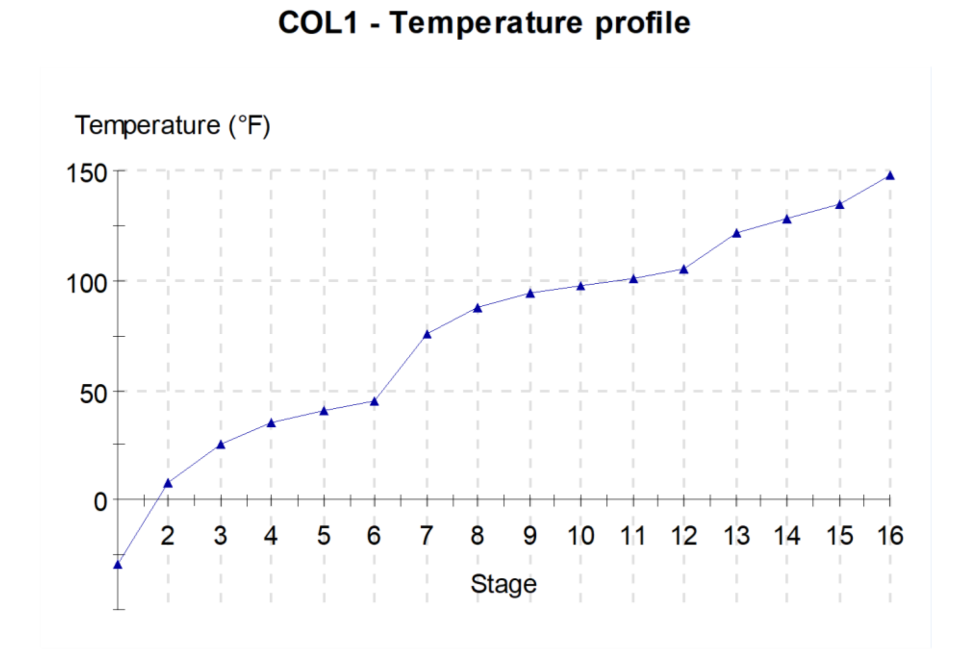
Streams		**FD00**	**NGL1b**	**RG08**
From		**FEED GAS**	**F_STP**	**HX05**
To		**DIV01**	**NGL LIQUIDS 2**	**SALES GAS**
Partial flows		**lbmol/h**	**lbmol/h**	**lbmol/h**
NITROGEN		10.21	1E-08	10.21
METHANE		1469.60	3E-04	1469.60
ETHANE		114.63	0.11	114.52
PROPANE		36.73	24.09	12.64
ISOBUTANE		4.78	4.48	0.30
n-BUTANE		7.74	7.49	0.26
ISOPENTANE		1.48	1.48	0.01
n-PENTANE		1.15	1.15	3E-03
n-HEXANE		0.49	0.49	2E-05
n-HEPTANE		0.16	0.16	4E-07
Total flow	**lbmol/h**	1646.98	39.45	1607.52
Total flow	**bbl/h**	3376.36	10.61	3281.83
Temperature	**°F**	120	60	115
Pressure	**psi**	510.0	75.1	510.0

4.3. Column profiles

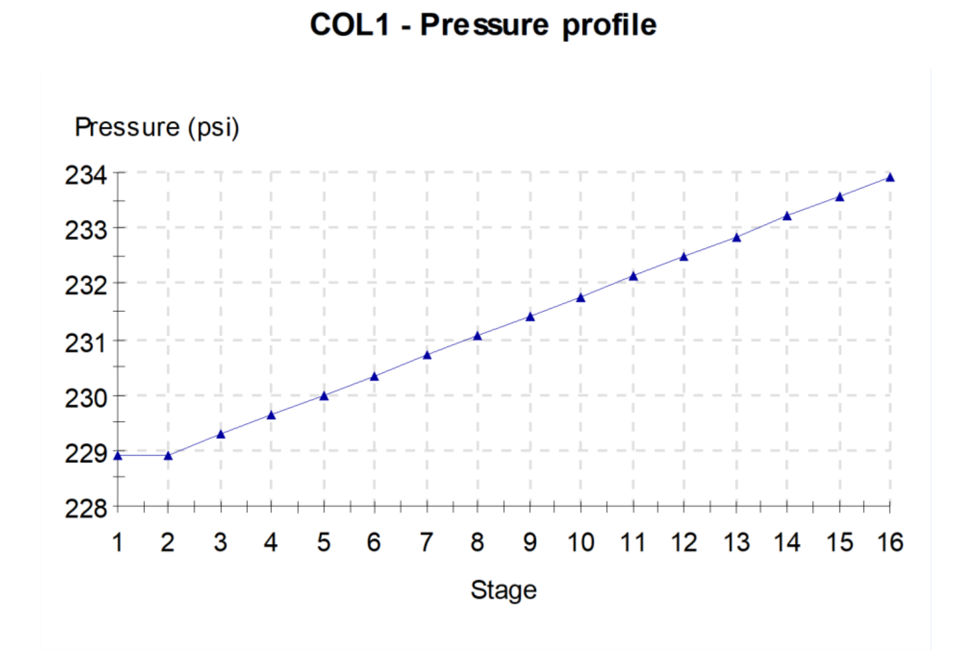
Profiles can be accessed after the simulation in each column configuration window, in the "Profiles" tab. Double clicking on the profile will generate the corresponding graph. It is important to note that, in ProSimPlus, the first stage corresponds to the top stage and the last stage to the bottom stage (respectively the condenser and the reboiler in the case of a distillation column).



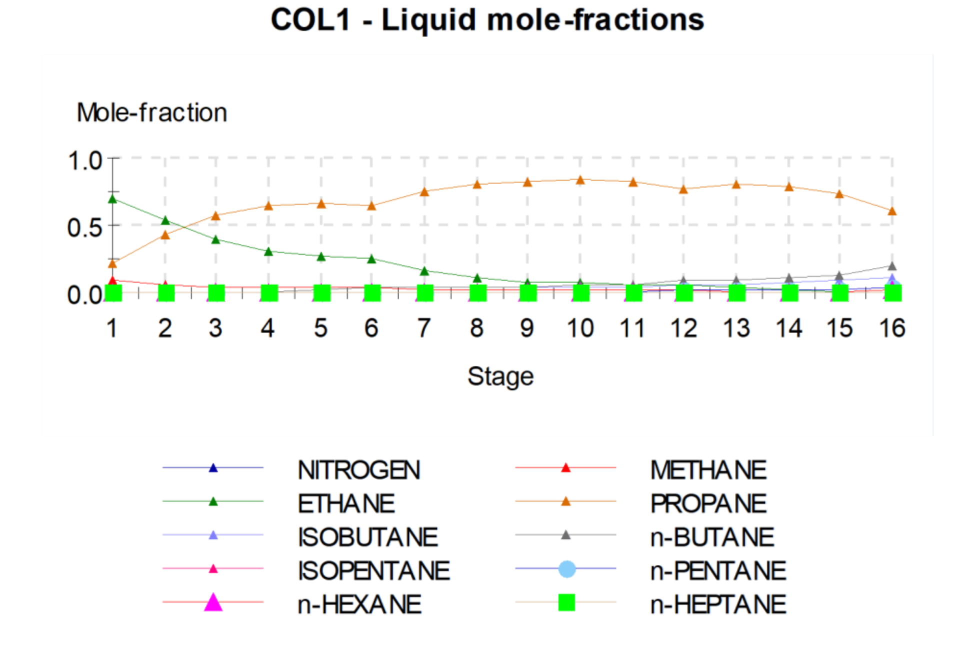
“COL1” column



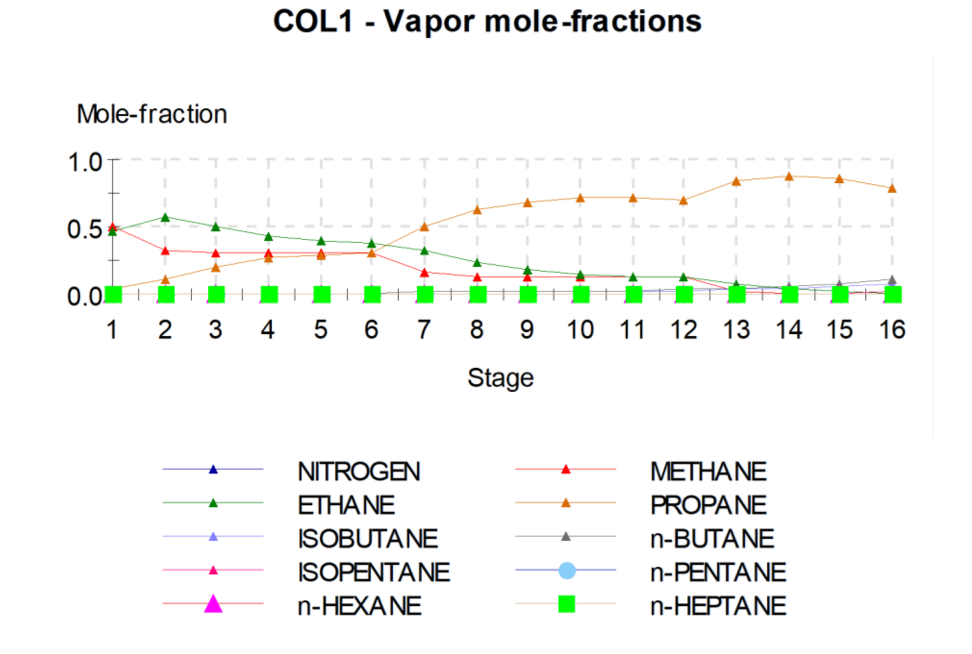
Temperature profile in the column



Pressure profile in the column



Liquid mole-fractions profile in the column



Vapor mole-fractions profile in the column

5. REFERENCES

[PRO95] Turbo-Expander Gas Plant Optimization

PRO/II Application Briefs (August 1995)

