

**PROSIMPLUS APPLICATION EXAMPLE**

**NATURAL GAS DEHYDRATION UNIT**

**WITH TRIETHYLENE GLYCOL**

**EXAMPLE PURPOSE**

This example illustrates a process to remove water from natural gas using Triethylene Glycol (TEG) as dehydration solvent. The interesting points of this example lie in the use of the “absorption” module for the contactor model and in the representation of two columns connected in series (the TEG regenerator and the TEG stripper) by a single ProSimPlus “stripper” module. Additionally, the Windows Script module is used in different parts of the flowsheet to perform specific calculations (gas water dew point, TEG losses for make-up calculation).

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**CORRESPONDING PROSIMPLUS FILES**

[PSPS\\_EX\\_EN-TEG-Gas-Dehydration.pmp3](#)

*Il est rappelé au lecteur que ce cas d'utilisation est un exemple et ne doit pas être utilisé à d'autres fins. Bien que cet exemple soit basé sur un cas réel il ne doit pas être considéré comme un modèle de ce type de procédé et les données utilisées ne sont pas toujours les plus exactes disponibles. ProSim ne pourra en aucun cas être tenu pour responsable de l'application qui pourra être faite des calculs basés sur cet exemple*

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# 1. PROCESS MODELING

## 1.1. Process description

This process is the “traditional” Triethylene Glycol (TEG) based dehydration process and represents a unit with gas absorption and extraction solvent regeneration. The objective is to reduce the amount of water in the natural gas with TEG, used as the extraction solvent. This process is required to prevent hydrates formation at low temperatures or corrosion problems due to the presence of carbon dioxide or hydrogen sulfide (regularly found in natural gas).

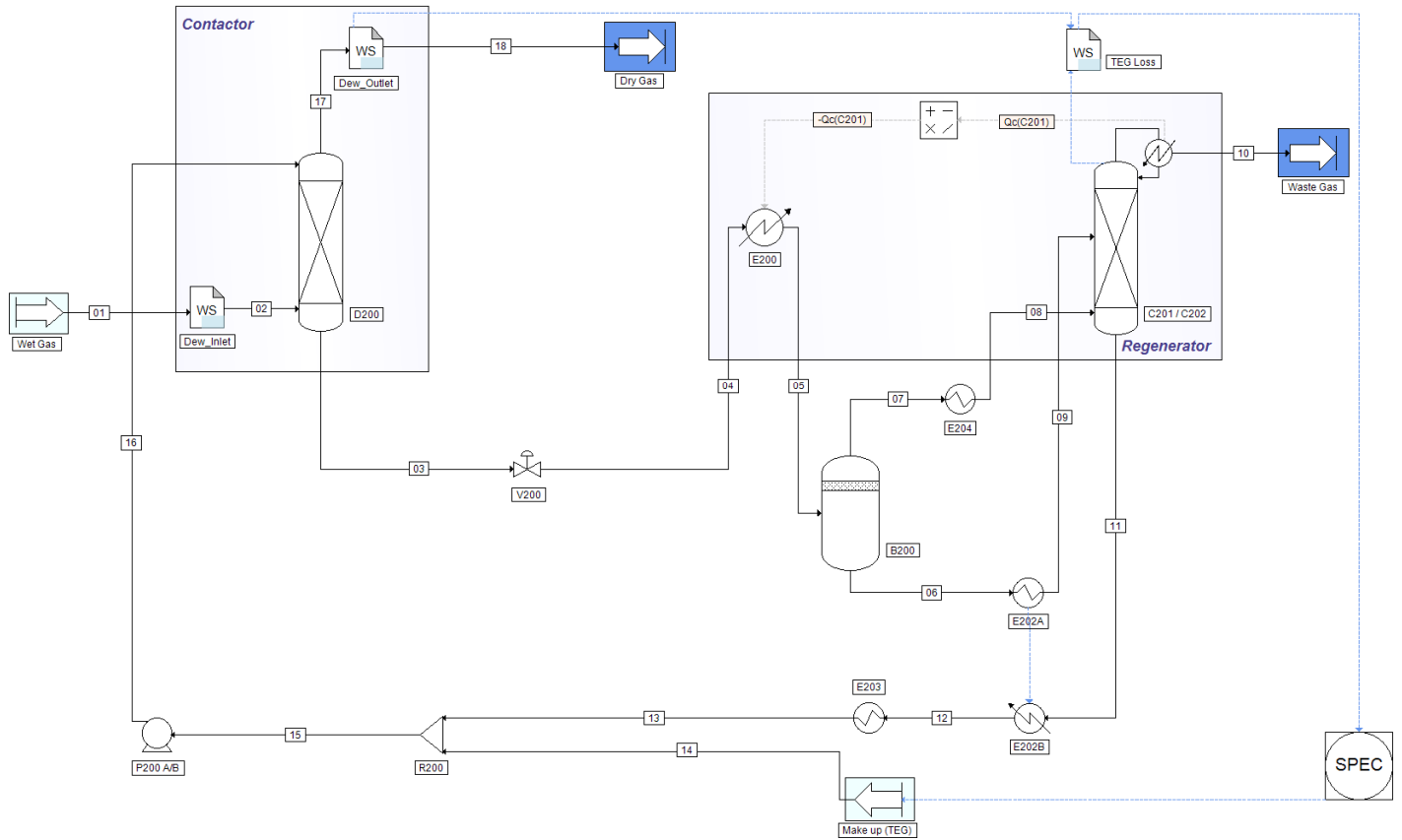
The wet gas feeds the contactor D200 (stream 01) at 71 barg. This column absorbs a part of the water in the gas in the Triethylene Glycol (TEG) mixture. At the end of the regeneration loop, the lean TEG feeds the top part of the contactor (stream 16) and absorbs water. Rich TEG leaves the bottom (stream 03) by level control and is depressurized to 5 barg (valve V200). The rich stream flows through a cartridge filter (F200 A/B) to remove solid particles coming from corrosion or TEG degradation. These solid particles and degradation are not taken into account in this model and consequently, the filtration does not have any impact in terms of simulation and is not represented. Once filtered, this flow is used as cold fluid of the condenser (E200) of the TEG regeneration column (C201). It is to be noted that in the simulation this condenser is represented separately from the column. The amount of heat to be removed in the C201 column condenser is transferred through an information stream in the heat exchanger module E200.

The wet TEG then enters a flash tank B200 (stream 05) in which gaseous hydrocarbons that were absorbed along with the water in the contactor are vaporized. These hydrocarbons are heated in heat exchanger E204 (stream 07) and used as stripping fluid in the stripper C202 (stream 08). The liquid phase heated in the heat exchanger E202 (stream 06) then feeds the regenerator C201 head (stream 09). This column is used to strip water from the TEG and operates at atmospheric pressure. Waste gases consisting of water and the hydrocarbons dissolved in the TEG, leave the regenerator at the top. The liquid bottom stream feeds the stripping column C202. This column decreases of the TEG water concentration by stripping using hydrocarbons vapors from B200. Lean TEG (stream 11) is then sent from the bottom of the column to storage tank R200. This storage tank has no meaning in terms of steady-state simulation but allows the regulation of the TEG flow. Consequently, it is represented by a mixer module. The TEG make-up (stream 14) is required to compensate the losses due to gas entrainment or degradation. Lean TEG is then pumped in P200 A/B and feed the contactor D200 head (stream 16).



### 1.3. Simulation flowsheet

#### TEG Dehydration Unit



## 1.4. 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 [ROW11].

Component name	Chemical formula	CAS number
Methane	CH <sub>4</sub>	74-82-8
Ethane	C <sub>2</sub> H <sub>6</sub>	74-84-0
Propane	C <sub>3</sub> H <sub>8</sub>	74-98-6
n-butane	C <sub>4</sub> H <sub>10</sub>	106-97-8
Isobutane	C <sub>4</sub> H <sub>10</sub>	75-28-5
n-pentane	C <sub>5</sub> H <sub>12</sub>	109-66-0
Isopentane	C <sub>5</sub> H <sub>12</sub>	78-78-4
n-hexane	C <sub>6</sub> H <sub>14</sub>	110-54-3
n-heptane	C <sub>7</sub> H <sub>16</sub>	142-82-5
n-octane	C <sub>8</sub> H <sub>18</sub>	111-65-9
n-nonane	C <sub>9</sub> H <sub>20</sub>	111-84-2
n-decane	C <sub>10</sub> H <sub>22</sub>	124-18-5
n-undecane	C <sub>11</sub> H <sub>24</sub>	1120-21-4
n-dodecane	C <sub>12</sub> H <sub>26</sub>	112-40-3
Nitrogen	N <sub>2</sub>	7727-37-9
Carbon dioxide	CO <sub>2</sub>	124-38-9
Water	H <sub>2</sub> O	7732-18-5
Triethylene glycol	C <sub>6</sub> H <sub>14</sub> O <sub>4</sub>	112-27-6

## 1.5. Thermodynamic model

Considering the temperatures and pressures of the contactor, an equation of state approach has been chosen, allowing the accurate calculation of the thermodynamics functions (fugacities, enthalpies, entropies...) at conditions close to critical conditions. As polar components are also present (water and TEG in particular), a complex mixing rule has been used in order to use an equation of state approach with this type of components. The equation of state selected is the **Peng-Robinson** equation of state [PEN76] with the mixing rule **MHV2** proposed by [DAH90], [MIC90]. The model for the activity coefficient calculations is **UNIQUAC** [ABR75], [AND78].

The binaries interaction parameters have been regressed in MS-Excel using Simulis Thermodynamics.

## 1.6. Operating conditions

- ✓ Process feeds

	Wet gas	Make up (TEG) Initialization
Temperature (°C)	25	28.7
Pressure (barg)	71	0
Total mass flowrate	37.208 t/h	0.150 kg/h
<b>Mass fraction</b>		
Methane	0.8227	0
Ethane	0.0592	0
Propane	0.0476	0
n-butane	0.0188	0
Isobutane	0.0109	0
n-pentane	0.0063	0
Isopentane	0.0074	0
n-hexane	0.0065	0
n-heptane	0.0042	0
n-octane	0.0014	0
n-nonane	0.000217	0
n-decane	4.27x10 <sup>-5</sup>	0
n-undecane	3.80x10 <sup>-6</sup>	0
n-dodecane	1.01x10 <sup>-6</sup>	0
Nitrogen	0.0045	0
Carbon dioxide	0.0095	0
Water	0.000622	0
Triethylene glycol	0	1

- ✓ Absorber - Contactor D200

Operating parameters	Value
Type of column	Absorber
Number of theoretical tray	4
Overhead pressure (barg)	70.75

## ✓ Valve V200

Operating parameters	Value
Type of valve	Expansion valve
Pressure (barg)	5

## ✓ Heat exchanger E200

Operating parameters	Value
Type of exchanger	Simple heat exchanger
Information stream specification	-

## ✓ Liquid-vapor separator B200

Operating parameters	Value
Type of separator	Diphasic L-V separator
Type of flash	Pressure and heat duty fixed
Heat duty exchanged	Adiabatic
Pressure	The lowest of the feed streams

## ✓ Heat exchanger E204

Operating parameters	Value
Type of exchanger	Cooler / heater
Outlet temperature (°C)	175

## ✓ Heat exchanger E202

## ○ Heat exchanger E202A

Operating parameters	Value
Type of exchanger	Cooler / heater
Outlet temperature (°C)	150

## ○ Heat exchanger E202B

Operating parameters	Value
Type of exchanger	Simple heat exchanger
Information stream specification	-



## ✓ Columns C201/ C202

Operating parameters	Value
Type of column	Stripper with partial condenser
Number of theoretical trays	7
Feed tray	2
Heat duty to be removed from the condenser (kW)	3
Overhead pressure (bar)	1.05
Intermediate boiler	At tray 4, with 10 kW heat input

## Objectives / Constraints:

Specification	Value
Tray 1 temperature (°C)	100
Tray 4 temperature (°C)	204
Adjusted variable	Value
Tray 4 heat input	
Condenser heat duty	

## Initialization:

Variable	Value
Initialization : top temperature (°C)	100

## ✓ Heat exchanger E203

Operating parameters	Value
Type of exchanger	Cooler / heater
Outlet temperature (°C)	28.7

## ✓ Mixer R200

Operating parameters	Value
Type of mixer	Other mixer
Outlet pressure	The lowest of the feed streams

## ✓ Pump P200 A/B

Operating parameters	Value
Type of mixer	Centrifugal pump
Outlet pressure (barg)	70.75
Volumetric efficiency	0.65

## 1.7. Initialization

The TEG flowrate in the loop is fixed by initializing the flash drum B200 inlet stream (stream 05). From the knowledge of this flowrate, it is possible to calculate B200, C201/C202 and the TEG feed to contactor D200. Initialization is set in order to obtain a dry gas dew point at  $-27^{\circ}\text{C}$ .

## 1.8. “Tips and tricks”

Windows Script modules (“Dew\_Inlet” and “Dew\_Outlet”) located on the wet gas stream and on the dry gas stream calculate the water dew point of their respective streams. The calculation is performed using the correlation of [BUC59].

Another Windows Script module (“TEG loss”) is used to calculate the required TEG make-up from the TEG losses in the dry gas and the waste gas.

Additionally, the top column C201 condenser has been separated in the simulation flowsheet: the heat duty removed from the condenser is transferred through an information stream to the heat exchanger module E200. The required conversion is made by information stream handler.

C201 and C202 columns are represented with a unique column module as they are installed in series. C201 reboiler is set in this module as an intermediate tray boiler. This simplifies the simulation flow scheme but it's not mandatory. Using a distillation column module for C201 and a stripper module for C202 connected in series would have provided the same results.

Heat exchanger E202 is modeled using a cooler / heater unit operation (E202A) fixing the cold side outlet temperature, linked with a simple exchanger (E202B). E202B heat duty is provided by E202A, which avoids the creation of a tear stream.

## 2. RESULTS

### 2.1. Mass and energy balance

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

Streams		01	03	05	08	09
From		Wet Gas	D200	E200	E204	E202A
To		Dew_Inlet	V200	B200	C201 / C202	C201 / C202
Total flow	t/h	37.208	0.59094	0.59094	0.0017847	0.58915
Total flow	Nm3/h	46353	117.18	117.18	1.7596	115.42
Mass fractions						
METHANE		0.82279	0.0017331	0.0017331	0.5302	0.00013227
ETHANE		0.059207	0.00045565	0.00045565	0.10949	0.00012535
PROPANE		0.047605	0.00059909	0.00059909	0.11282	0.00025915
n-BUTANE		0.018802	0.00076459	0.0007646	0.066312	0.00056604
ISOBUTANE		0.010901	0.00034733	0.00034733	0.037002	0.00023629
n-PENTANE		0.0063007	0.00026066	0.00026066	0.018978	0.00020396
ISOPENTANE		0.0074008	0.00025233	0.00025234	0.021917	0.00018671
n-HEXANE		0.0065007	0.00025886	0.00025886	0.016314	0.00021023
n-HEPTANE		0.0042005	0.00016017	0.00016017	0.0087543	0.00013414
n-OCTANE		0.0014002	5.1004E-005	5.1005E-005	0.00241	4.3859E-005
n-NONANE		0.00021702	7.6687E-006	7.6688E-006	0.00030849	6.7575E-006
n-DECANE		4.2705E-005	1.4814E-006	1.4814E-006	4.9805E-005	1.335E-006
n-UNDECANE		3.8004E-006	1.3506E-007	1.3506E-007	3.6543E-006	1.244E-007
n-DODECANE		1.0101E-006	3.5111E-008	3.5112E-008	7.8962E-007	3.2826E-008
NITROGEN		0.0045005	0.00012995	0.00012995	0.024132	5.7245E-005
CARBON DIOXIDE		0.0095011	0.00034042	0.00034042	0.04929	0.00019214
WATER		0.00062207	0.041833	0.041832	0.0020117	0.041953
TRIETHYLENE GLYCOL		0	0.9528	0.95281	4.8651E-006	0.95569
Physical state		Vapor	Liquid	Liq./Vap.	Vapor	Liq./Vap.
Temperature	°C	25	25.328	37.658	175	150
Pressure	barr	71	70.75	5	5	5
Enthalpic flow	kW	-839.15	-108.36	-105.36	0.16002	-62.429
Vapor molar fraction		1	0	0.015016	1	0.00013262

Streams		10	11	13	14	16	18
From		C201 / C202	C201 / C202	E203	Make up (TE..	P200 A/B	Dew _Outlet
To		Waste Gas	E202B	R200	R200	D200	Dry Gas
Total flow	t/h	0.025465	0.56547	0.56547	0.00015148	0.56562	37.183
Total flow	Nm3/h	30.191	86.992	86.992	0.02261	87.015	46323
Mass fractions							
.....							
METHANE		0.039555	2.9854E-005	2.9854E-005	0	2.9846E-005	0.82333
ETHANE		0.0097887	3.5347E-005	3.5347E-005	0	3.5338E-005	0.05924
PROPANE		0.012965	4.2191E-005	4.2191E-005	0	4.2179E-005	0.047629
n-BUTANE		0.017187	2.5038E-005	2.5038E-005	0	2.5032E-005	0.018803
ISOBUTANE		0.0077917	1.208E-005	1.208E-005	0	1.2077E-005	0.010903
n-PENTANE		0.0058401	9.397E-006	9.397E-006	0	9.3945E-006	0.006301
ISOPENTANE		0.0056395	9.7298E-006	9.7298E-006	0	9.7272E-006	0.007402
n-HEXANE		0.0057715	1.0611E-005	1.0611E-005	0	1.0608E-005	0.0065012
n-HEPTANE		0.003563	6.9301E-006	6.9301E-006	0	6.9283E-006	0.0042009
n-OCTANE		0.0011319	2.3276E-006	2.3276E-006	0	2.327E-006	0.0014003
n-NONANE		0.00017004	3.5675E-007	3.5675E-007	0	3.5665E-007	0.00021706
n-DECANE		3.2843E-005	6.9064E-008	6.9064E-008	0	6.9046E-008	4.2711E-005
n-UNDECANE		3.0024E-006	5.9303E-009	5.9303E-009	0	5.9287E-009	3.801E-006
n-DODECANE		7.8188E-007	1.4818E-009	1.4818E-009	0	1.4814E-009	1.0103E-006
NITROGEN		0.0029286	3.9199E-006	3.9199E-006	0	3.9189E-006	0.0045016
CARBON DIOXIDE		0.0075359	1.6378E-005	1.6378E-005	0	1.6373E-005	0.0095024
WATER		0.87965	0.0041021	0.0041021	0	0.004101	2.004E-005
TRIETHYLENE GLYCOL		0.00044909	0.99569	0.99569	1	0.99569	3.7662E-006
Physical state		Vapor	Liquid	Liquid	Liquid	Liquid	Vapor
Temperature	°C	100	198.41	28.7	28.7	30.771	25.482
Pressure	barr	0.03675	0.03675	0.03675	4.0936E-012	70.75	70.75
Enthalpic flow	kW	0.95597	-30.621	-91.03	-0.024004	-89.522	-820.3
Vapor molar fraction		1	0	0	0	0	1

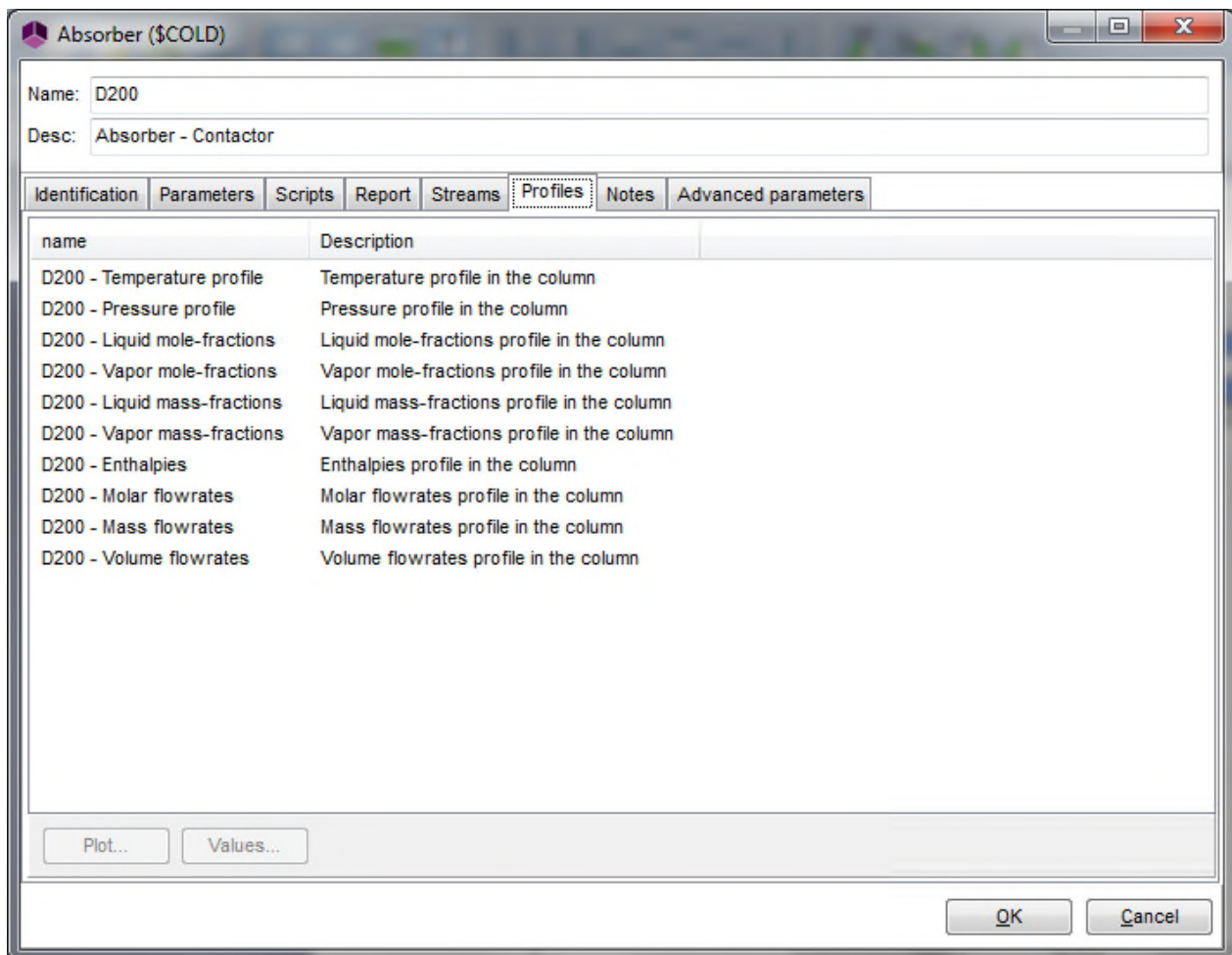
## 2.2. Dew temperatures

Dew temperatures are calculated by Windows Script modules:

Module	Inlet stream	Result (°C)
Dew_Inlet	1	24.7
Dew Outlet	17	-27.4

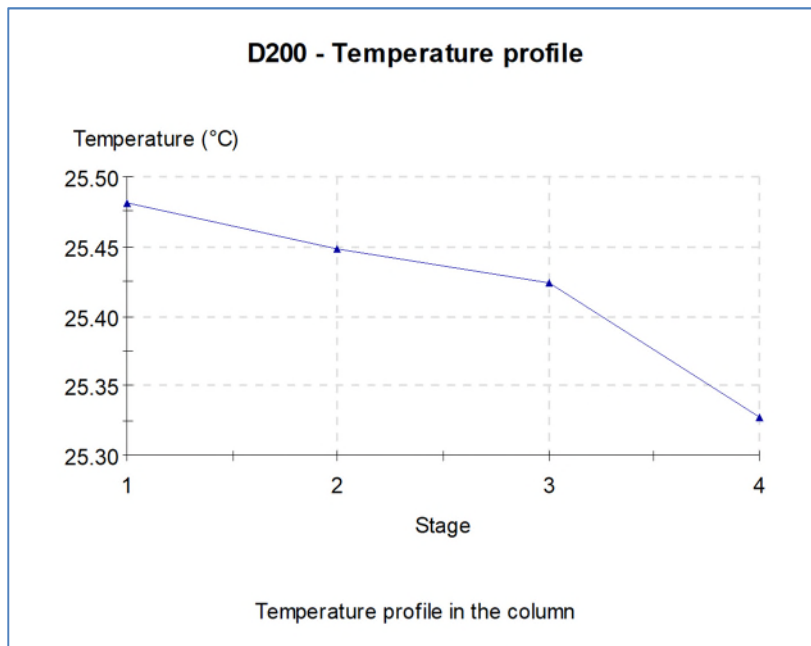
## 2.3. Columns profiles

Composition 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.

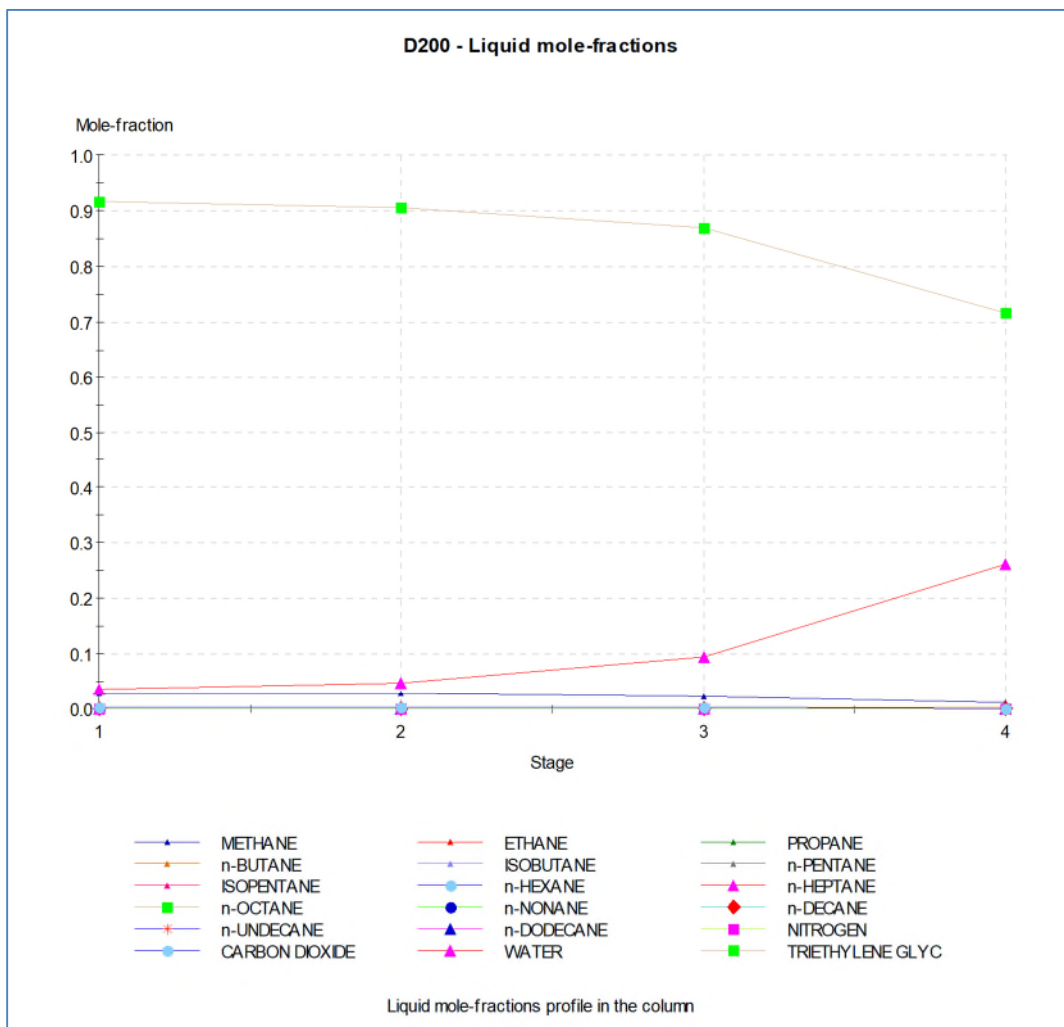


Note that in ProSimPlus the stages are numbered from top to bottom. Stage 1 is the condenser, the last stage is the boiler.

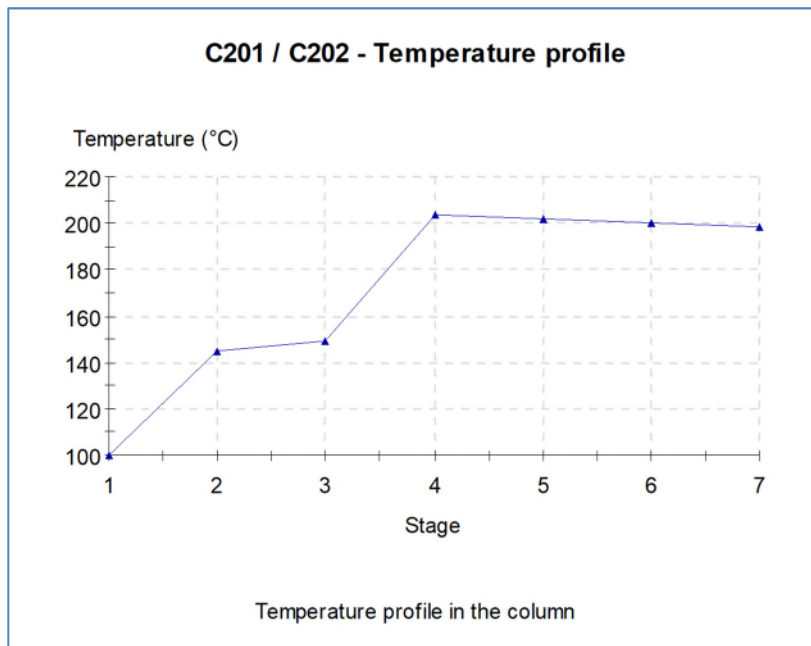
- ✓ D200 (Absorber – Contactor): Temperature profile



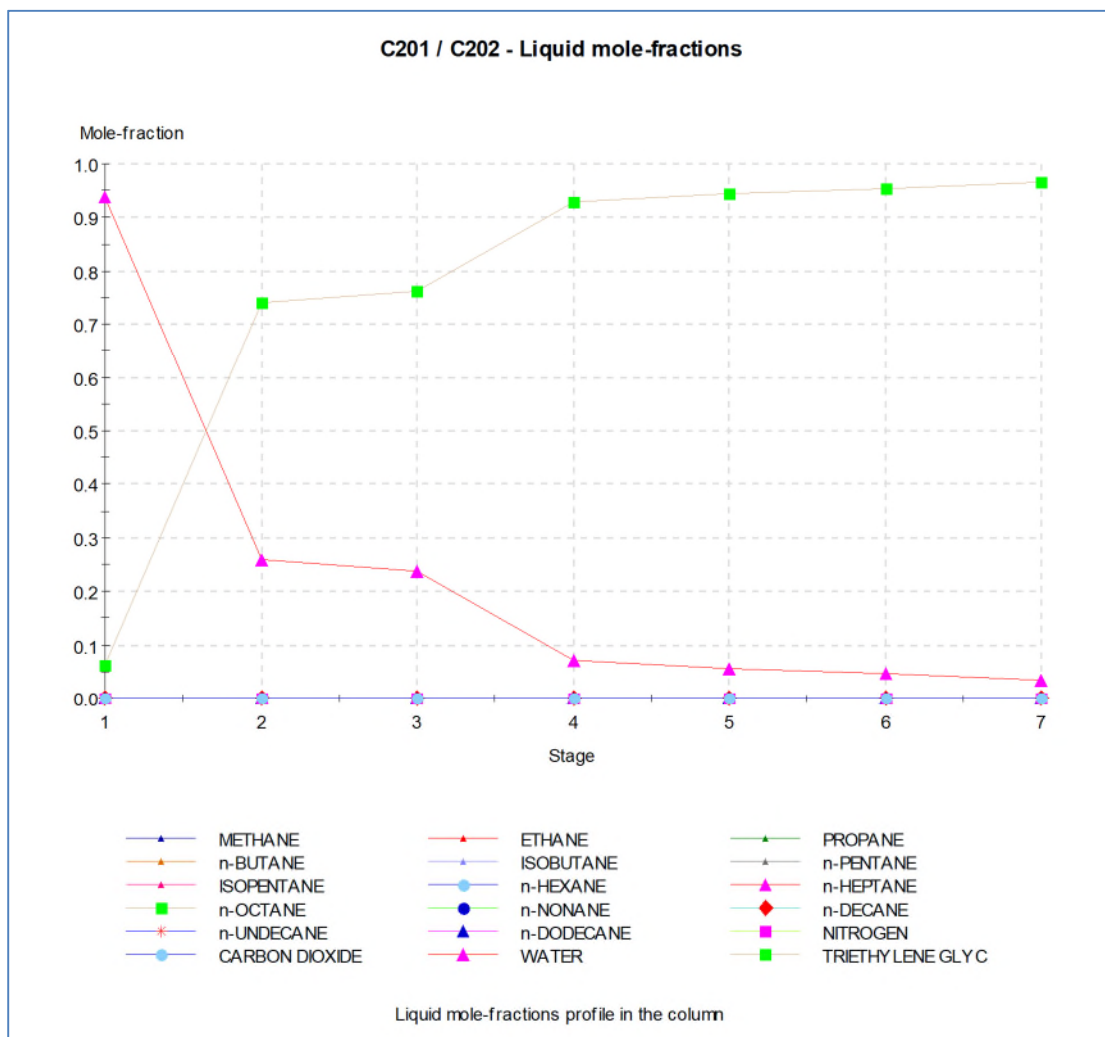
- ✓ D200 (Absorber – Contactor): Liquid mole fractions profiles



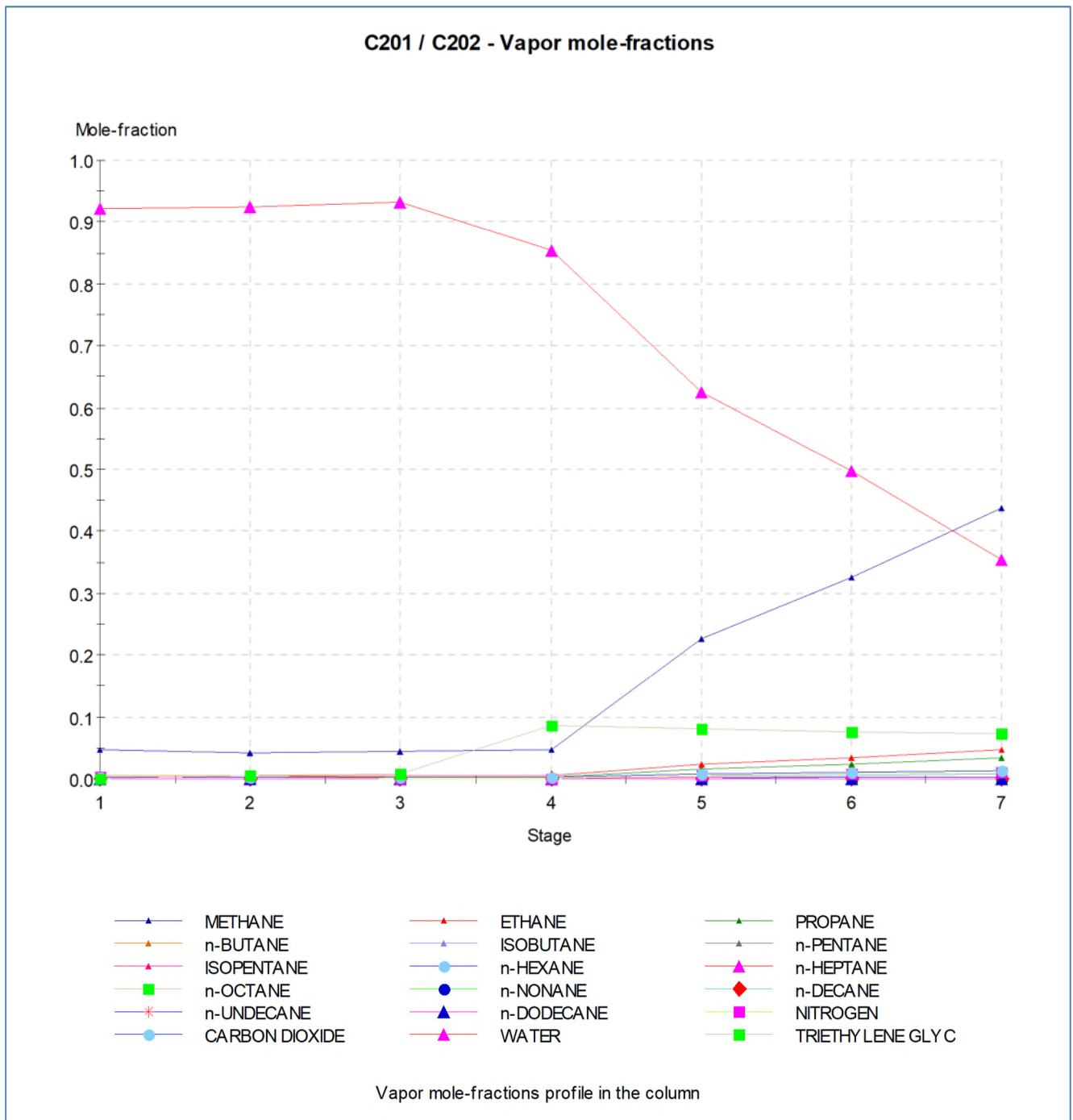
- ✓ C201/C202 (Regenerator and stripper): Temperature profile



- ✓ C201/C202 (Regenerator and stripper): Liquid mole-fractions profiles



✓ C201/C202 (Regenerator and stripper): Vapor mole fractions profiles





### 3. Process analysis and optimization

When optimizing the design of dehydration unit, the impact of the following parameters can be easily evaluated using the simulation model presented in this document:

- ✓ The number of contactor D 200 theoretical trays,
- ✓ TEG circulation rate,
- ✓ Temperature of the reboiler in the regenerator,
- ✓ Pressure of B200 flash drum.

In particular, it can be noted that the reboiler TEG temperature is limited by the degradation temperature of the glycol. B200 pressure acts on the stripping gas flow and therefore on the regenerator performance. These two parameters act on the water content of the lean TEG.

Other parameters may have also a limited impact. The number of theoretical trays of the TEG regenerator has a little impact on lean TEG content. Heat exchanger recovery E 202 outlet temperature has an impact on the reboiler duty.

Lean TEG temperature at the top of the contactor affects the water partial pressure at the top stage. Consequently, lower TEG temperatures will result in reduced amount of water in the overhead lean gas. This will also increase the amount of gas absorbed in the TEG and consequently, increase the gas losses. This temperature is controlled by the temperature controller located at E202 outlet.

## 4. REFERENCES

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