PROSIMPLUS APPLICATION EXAMPLE

GAS GATHERING SYSTEM

INTEREST OF THIS EXAMPLE
This example mainly illustrates the use of the pipe segment module included in the standard version of ProSimPlus through the modeling of a small gas condensate gathering system consisting of three wells connected to a gas plant via a network of pipelines. It also illustrates the creation of pseudo-compound and the estimation of hypothetical component properties to model C7+ cut. Besides, this example shows how the pressure at the nodes of the gas network can be automatically adjusted when the wellhead rates and output delivery pressure are fixed ("pressure driven" simulation). Finally modeling of wellhead performance curves is used to show how to add features to existing unit operations thanks to "Windows Script" feature allowed by ProSimPlus.

ACCESS	☑ Free-Internet	☐ Restricted to clients	☐ Restricted	☐ Confidential

CORRESPONDING PROSIMPLUS FILES	PSPS_EX_EN – Gas Gathering System1.pmp3 PSPS_EX_EN – Gas Gathering System2.pmp3 PSPS_EX_EN – Gas Gathering System3.pmp3 PSPS_EX_EN – Gas Gathering System4.pmp3

Reader is reminded that this use case is only an example and should not be used for other purposes. Although this example is based on actual case it may not be considered as typical nor are the data used always the most accurate available. Fives ProSim shall have no responsibility or liability for damages arising out of or related to the use of the results of calculations based on this example.

TABLE OF CONTENTS

1. INTRODUCTION

1.1. Sources

This example is taken from a document called "PIPESYS™ Tutorials" [1] to illustrate how with ProSimPlus standard version it is possible to perform the same simulations than using HYSYS™ with the PIPESYS™ extension when modeling pipelines and gas gathering systems.

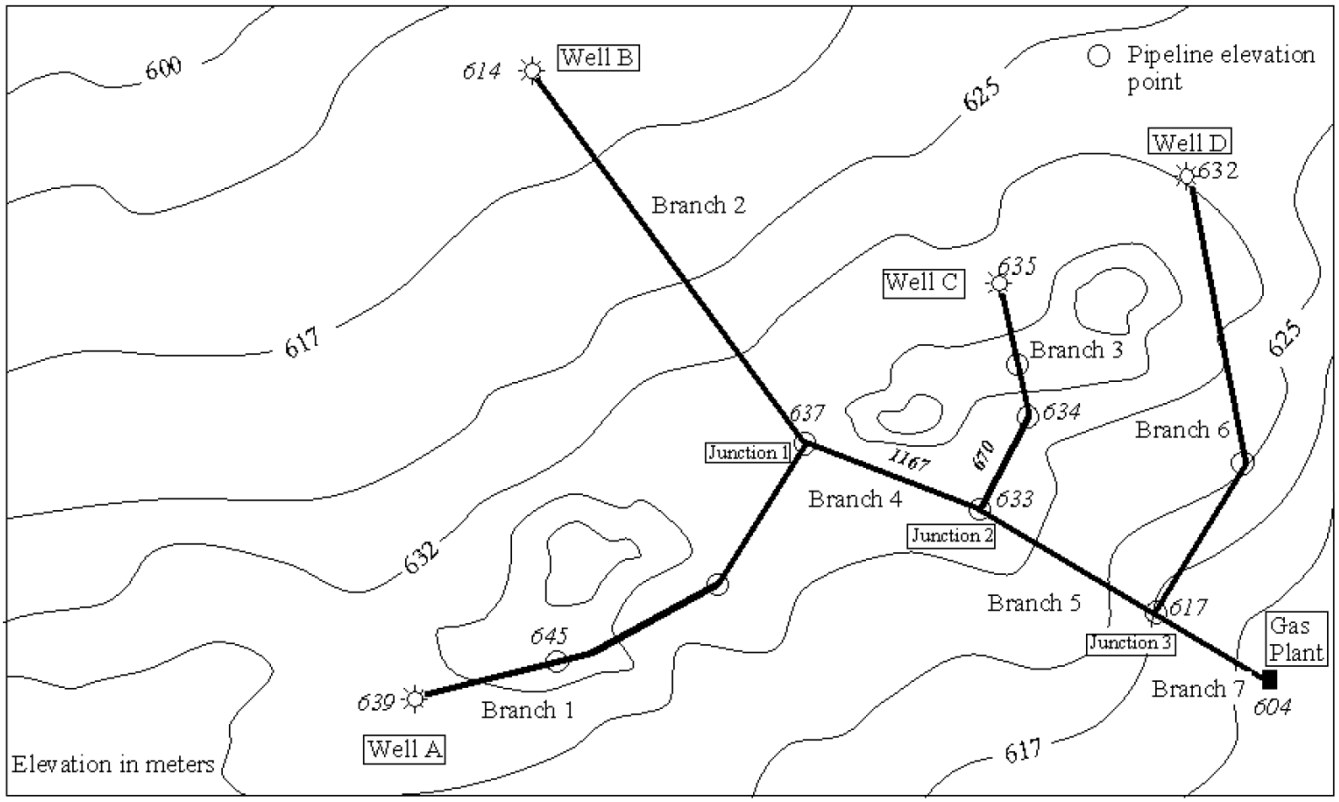
PIPESYS™ is a registered product of SPT Group (www.sptgroup.com).

HYSYS™ is a registered product of AspenTech (www.aspentech.com).

1.2. Example

The performance of a small gas condensate gathering system is modeled.

The following figure shows the physical configuration of this system superimposed on a topographic map. The system consists of three wells distributed over an area of approximately 1.0 square mile connected to a gas plant via a network of pipelines.



Well D will be supposed to be closed and Gas Plant located at the point named "Junction 3" on the previous topographic map (branch 6 and branch 7 are not modeled here).

Wells have the following depths (in ft):

Well	**Depth** (ft)
A	2095
B	2015
C	2085

Branches that traverse undulating terrain have been subdivided into a number of segments with elevation points assigned at locations where there is a significant slope change. The following table summarizes the pipe diameters and the elevation data for each of the branches. The elevation given for the pipe units is for the endpoint of the pipe (i.e. the downstream end). Rise of each pipe unit is calculated and recorded here.

Branch	**Diameter** (in)	**Unit**	**Length** (ft)	**Elevation** (ft)	**Rise** (ft)
Branch 1	3"	Pipe Unit 1	945	2110	2110 – 2085 = 15
		Pipe Unit 2	1110	2089	2089 – 2110 = - 21
		Pipe Unit 3	1056	2090	2090 – 2089 = 1
Branch 2	3"	Pipe Unit 1	2822	2090	2090 – 2015 = 75
Branch 3	3"	Pipe Unit 1	528	2125	2125 – 2085 = 40
		Pipe Unit 2	334	2080	2080 – 2125 = - 45
		Pipe Unit 3	670	2077	2077 – 2080 = - 3
Branch 4	4"	Pipe Unit 1	1167	2077	2077 – 2090 = - 13
Branch 5	6"	Pipe Unit 1	2110	1980	1980 – 2077 = - 97

A schedule 40 steel pipe is used throughout.

All branches are buried at a depth of 3 feet. All pipes are uninsulated.

The ambient temperature is supposed to be 40 °F.

This example will show the different steps: from a simple model of the unit to an optimization of the gas gathering condensate system including wellhead delivery curves.

2. FLUID PROPERTIES

2.1. Gas condensate data

All the three wells have the same composition.

The compositional analysis of the gas condensate resulted in the following information:

Component	**Composition** (mole-fractions)
Methane	0.623
Ethane	0.280
Propane	0.0163
i-Butane	0.00433
n-Butane	0.00821
i-Pentane	0.00416

Component	**Composition** (mole-fractions)
n-Pentane	0.00405
n-Hexane	0.00659
C7+	0.00992
Nitrogen	0.00554
Carbon Dioxide	0.0225
Hydrogen Sulfide	0.0154

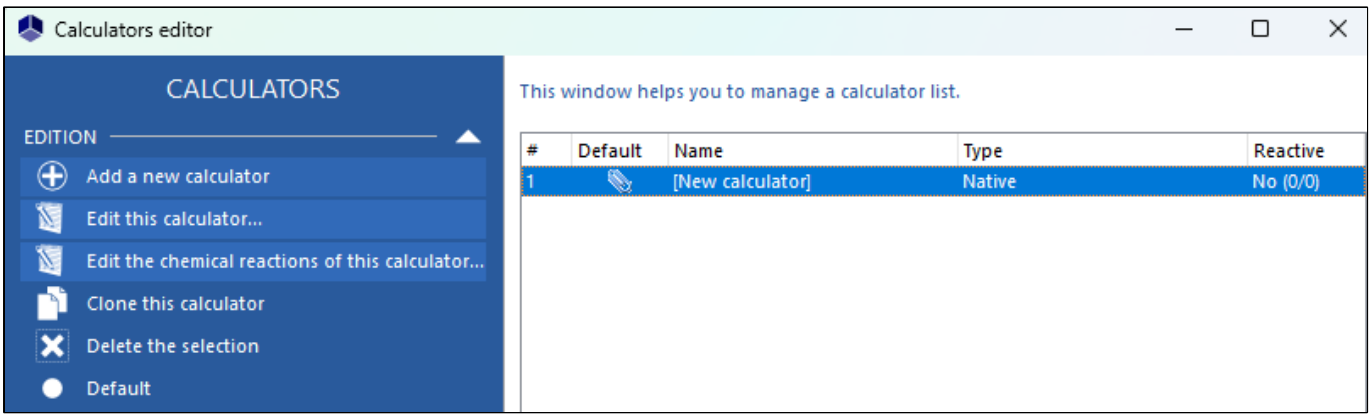
2.2. Fluid properties modeling

Start ProSimPlus (*ProSimPlus Standard* environment is adequate for all the simulation cases presented in this example) and create a new file using "File" menu and then "New".

Give a title and all the information you estimate useful in the "Project Synopsis" window and click OK to validate.

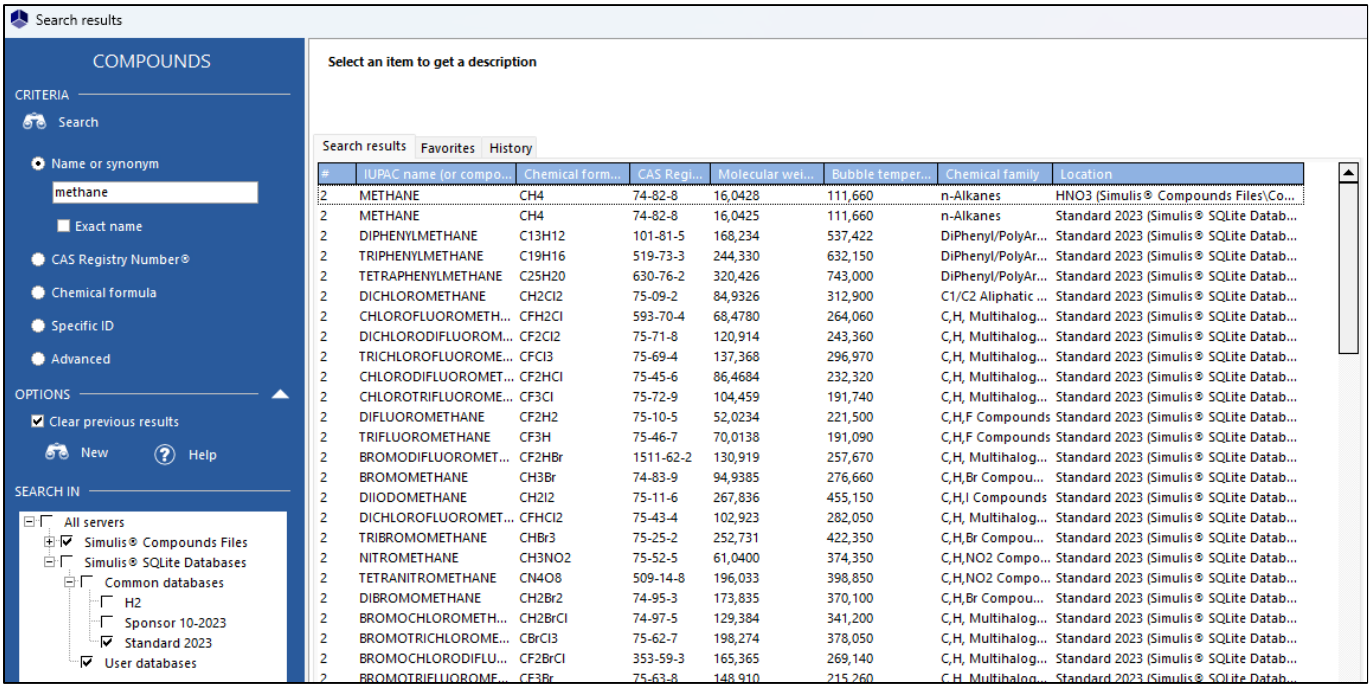
Click the "Thermodynamic and compounds" button to access the fluid properties definition windows (Thermodynamic calculators editor).

Click "Edit this calculator..." (or double click the line [New calculator]) to enter the compounds in the gas condensate.



Click "Select compounds", select the databases from which you want to import the compounds properties on the upper left part of the window (here "Standard 2023"), enter the name of the compound you want to import in the appropriate field and then click the "Search" button.

In the list of compounds that appear in the "Search results" window, double-click the compound you want to have in your simulation project. To reduce the compounds number appearing in the "Search results", select "Exact name" in the "Search criteria" window (provided that you know the exact name of your compound).



#	IUPAC name (or compo...	Chemical form...	CAS Regi...	Molecular wei...	Bubble temper...	Chemical family	Location
2	METHANE	CH4	74-82-8	16,0428	111,660	n-Alkanes	HNO3 (Simulis® Compounds Files\Co...
2	METHANE	CH4	74-82-8	16,0425	111,660	n-Alkanes	Standard 2023 (Simulis® SQLite Datab...
2	DIPHENYLMETHANE	C13H12	101-81-5	168,234	537,422	DiPhenyl/PolyAr...	Standard 2023 (Simulis® SQLite Datab...
2	TRIPHENYLMETHANE	C19H16	519-73-3	244,330	632,150	DiPhenyl/PolyAr...	Standard 2023 (Simulis® SQLite Datab...
2	TETRAPHENYLMETHANE	C25H20	630-76-2	320,426	743,000	DiPhenyl/PolyAr...	Standard 2023 (Simulis® SQLite Datab...
2	DICHLOROMETHANE	CH2Cl2	75-09-2	84,9326	312,900	C1/C2 Aliphatic ...	Standard 2023 (Simulis® SQLite Datab...
2	CHLOROFLUOROMETH...	CFH2Cl	593-70-4	68,4780	264,060	C,H, Multihalog...	Standard 2023 (Simulis® SQLite Datab...
2	DICHLORODIFLUOROM...	CF2Cl2	75-71-8	120,914	243,360	C,H, Multihalog...	Standard 2023 (Simulis® SQLite Datab...
2	TRICHLOROFLUOROME...	CFCl3	75-69-4	137,368	296,970	C,H, Multihalog...	Standard 2023 (Simulis® SQLite Datab...
2	CHLORODIFLUOROMET...	CF2HCl	75-45-6	86,4684	232,320	C,H, Multihalog...	Standard 2023 (Simulis® SQLite Datab...
2	CHLOROTRIFLUOROME...	CF3Cl	75-72-9	104,459	191,740	C,H, Multihalog...	Standard 2023 (Simulis® SQLite Datab...
2	DIFLUOROMETHANE	CF2H2	75-10-5	52,0234	221,500	C,H,F Compounds	Standard 2023 (Simulis® SQLite Datab...
2	TRIFLUOROMETHANE	CF3H	75-46-7	70,0138	191,090	C,H,F Compounds	Standard 2023 (Simulis® SQLite Datab...
2	BROMODIFLUOROMET...	CF2HBr	1511-62-2	130,919	257,670	C,H, Multihalog...	Standard 2023 (Simulis® SQLite Datab...
2	BROMOMETHANE	CH3Br	74-83-9	94,9385	276,660	C,H,Br Compou...	Standard 2023 (Simulis® SQLite Datab...
2	DIIODOMETHANE	CH2I2	75-11-6	267,836	455,150	C,H,I Compounds	Standard 2023 (Simulis® SQLite Datab...
2	DICHLOROFLUOROMET...	CFHCl2	75-43-4	102,923	282,050	C,H, Multihalog...	Standard 2023 (Simulis® SQLite Datab...
2	TRIBROMOMETHANE	CHBr3	75-25-2	252,731	422,350	C,H,Br Compou...	Standard 2023 (Simulis® SQLite Datab...
2	NITROMETHANE	CH3NO2	75-52-5	61,0400	374,350	C,H,NO2 Compo...	Standard 2023 (Simulis® SQLite Datab...
2	TETRANITROMETHANE	CN4O8	509-14-8	196,033	398,850	C,H,NO2 Compo...	Standard 2023 (Simulis® SQLite Datab...
2	DIBROMOMETHANE	CH2Br2	74-95-3	173,835	370,100	C,H,Br Compou...	Standard 2023 (Simulis® SQLite Datab...
2	BROMOCHLOROMETH...	CH2BrCl	74-97-5	129,384	341,200	C,H, Multihalog...	Standard 2023 (Simulis® SQLite Datab...
2	BROMOTRICHLOROME...	CBrCl3	75-62-7	198,274	378,050	C,H, Multihalog...	Standard 2023 (Simulis® SQLite Datab...
2	BROMOCHLORODIFLU...	CF2BrCl	353-59-3	165,365	269,140	C,H, Multihalog...	Standard 2023 (Simulis® SQLite Datab...
2	BROMOTRIFLUOROME...	CF3Br	75-63-8	148,910	215,260	C,H, Multihalog...	Standard 2023 (Simulis® SQLite Datab...

Repeat this for all the compounds of this example (except C7+). At the end of this step you must have the following list of compounds appearing at the bottom of the window:

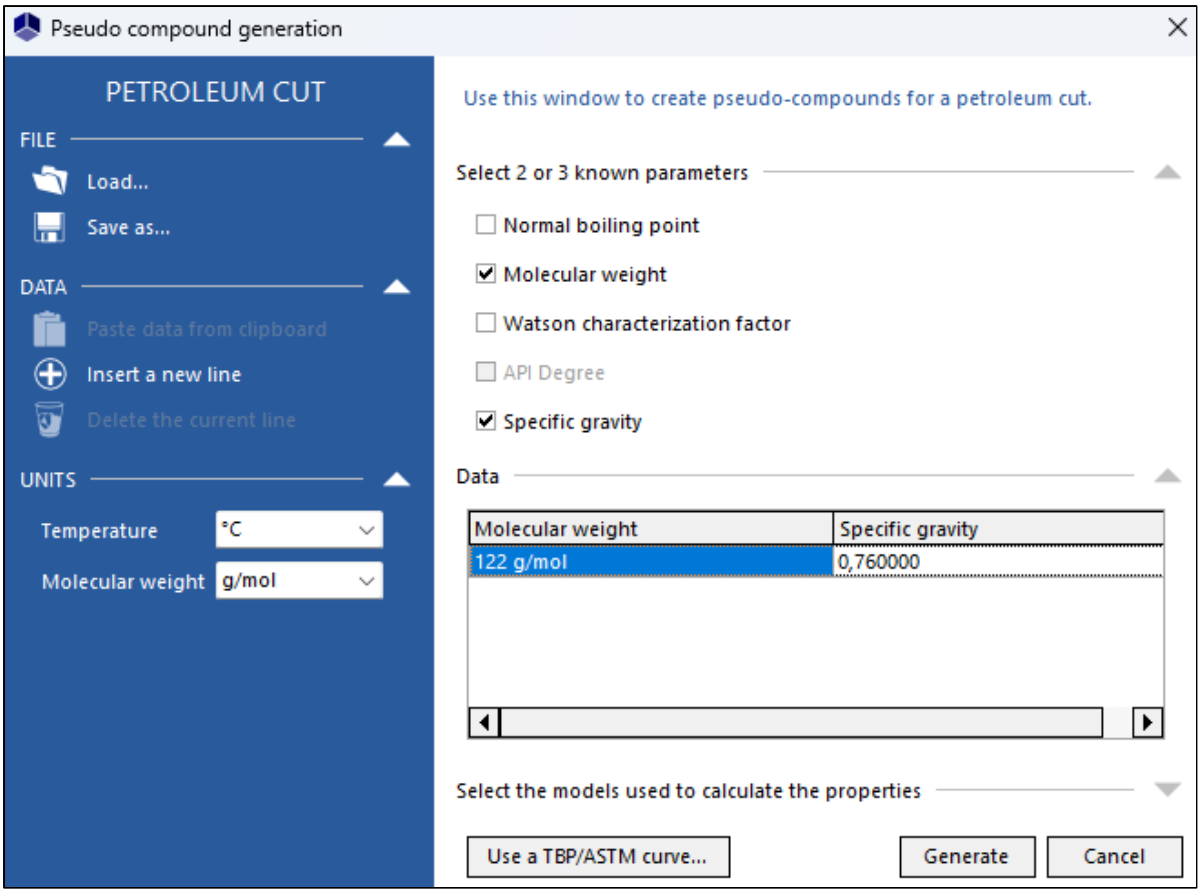
Selected compounds:

Name
METHANE
ETHANE
PROPANE
ISOBUTANE
n-BUTANE
ISOPENTANE
n-PENTANE
n-HEXANE
C7+
NITROGEN
CARBON DIOXIDE
HYDROGEN SULFIDE

Now C7+ pseudo-compound must be created.

Click "Create pseudo-compounds..." from the "Thermodynamic calculator editor" window.

Then select the properties you know for the C7+ cut, here *Molecular weight* and *Specific Gravity* and enter the values in the appropriate fields:



And then click the "Generate" button.

In this case default models are used to generate C7+ pseudo-compounds properties, but you can select other models, using the models tab of the window. To learn more about available models, press F1 key to open the User Guide dedicated to pseudo-compound properties generation.

A new compound named "NBP-417(K)" appears now in the compounds list.

COMPOUNDS | MODEL | BINARIES | PARAMETERS

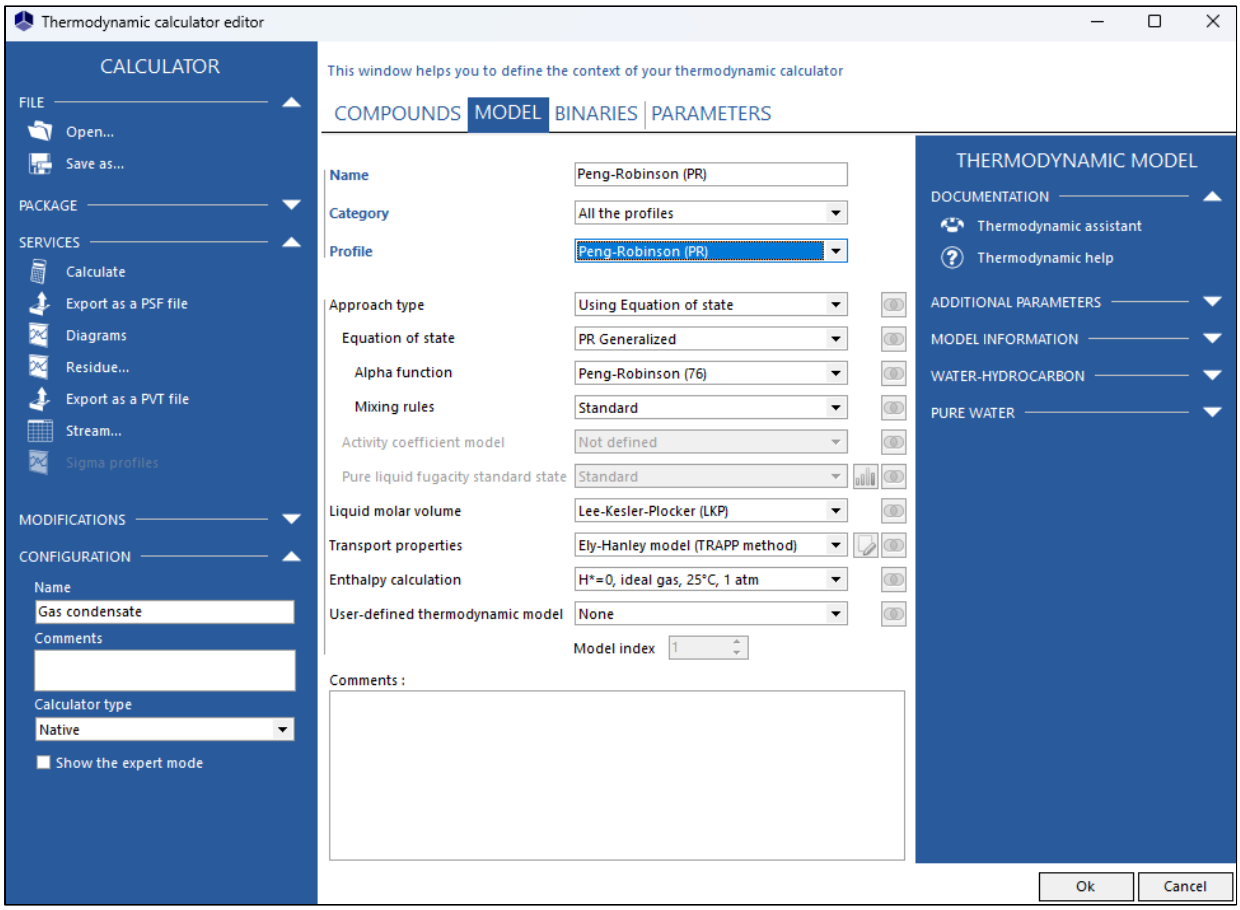
#	IUPAC Name	CAS Registry Number®
1	METHANE	74-82-8
2	ETHANE	74-84-0
3	PROPANE	74-98-6
4	ISOBUTANE	75-28-5
5	n-BUTANE	106-97-8
6	ISOPENTANE	78-78-4
7	n-PENTANE	109-66-0
8	n-HEXANE	110-54-3
9	C7+	
10	NITROGEN	7727-37-9
11	CARBON DIOXIDE	124-38-9
12	HYDROGEN SULFIDE	7783-06-4

You can now edit this compound to change its name into C7+ and change the order of compounds in the list to have the same order as in the compounds analysis data table.

You can also change the name of this calculator to "Gas condensate" for instance.

You must now select a thermodynamic model to compute phase equilibrium and physical properties of the fluid.

Select "Peng Robinson (PR)" model in the list of predefined models available in the "Profile" field.



Enthalpy calculation option is also changed from the default option in order to have the same that the enthalpy calculation used in the reference document: H* = 0 for ideal gas at 25°C and 1 atm, but H-H* is computed from LK (Lee Kesler model).

In this example we will not make use of "Binary Interaction Parameters" (BIP) with this Peng-Robinson Equation of State to reproduce the results obtained in the source document (see paragraph 1). If needed, those parameters can be automatically loaded from the BIP database supplied with ProSimPlus.

You can now close the "Thermodynamic calculator editor" by clicking the "OK button (just closing the window will not validate your last modifications). You are now back to ProSimPlus main screen.

3. SIMULATION CASE 1

3.1. Introduction

In this simulation case of the gas gathering pipeline network, the flow rate of each well is specified and is independent of the flow rate of each of the other wells. The temperature of each wellhead is also fixed.

Wellhead delivery pressure of each well is supposed here to be independent of the well flow rate. Delivery pressure of Well A is fixed here and ProSimPlus will compute the pressure everywhere else.

The following parameters for the wells are used:

Well A	Temperature (F)	105
	Pressure (psia)	1060
	Molar flow (MMSCFD)	8.6
Well B	Temperature (F)	115
	Molar flow (MMSCFD)	7.4
Well C	Temperature (F)	110
	Molar flow (MMSCFD)	10.1

3.2. Building the case

3.2.1. Select the unit set

To change the unit set to the units you want to use in this simulation project, click the "Unit systems" button in the tool bar and go to "Unit system for edition…".

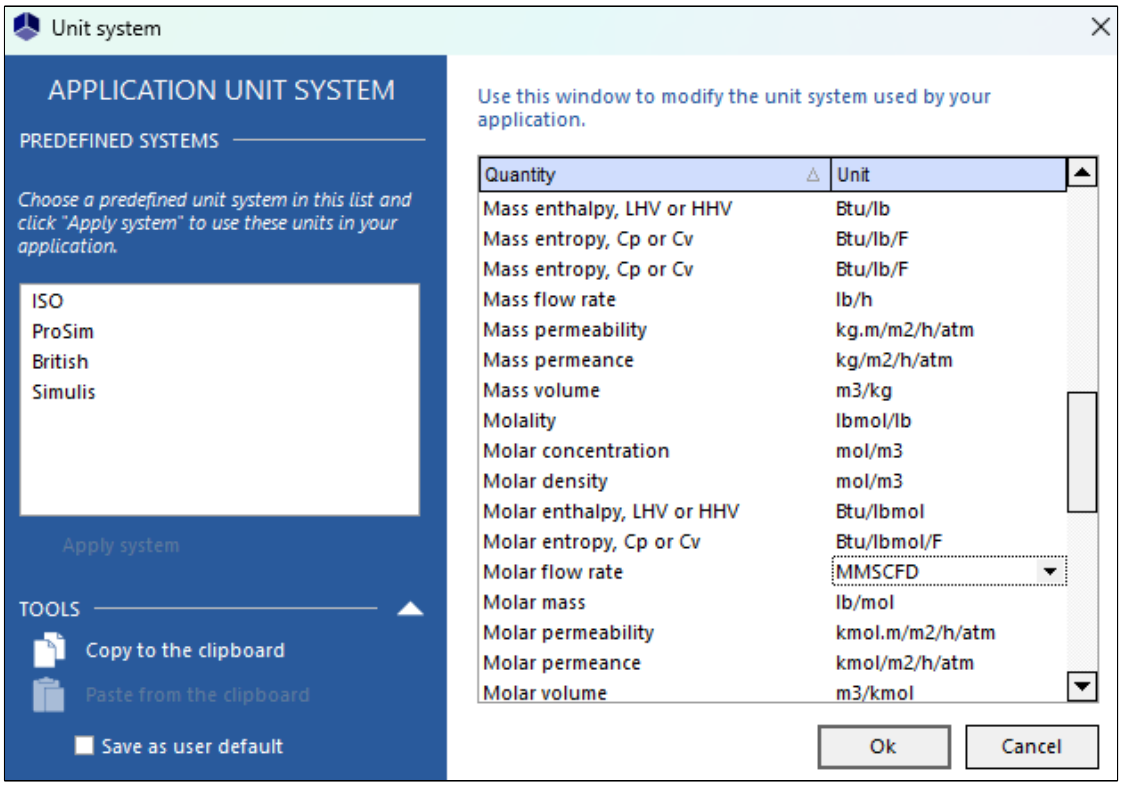
Then select "British" in the "Predefined systems" area and click "Apply system".

The units to be used for each kind of data can also be selected individually.

For instance here, for the molar flow rate, the unit is changed from "lbmol/h" to "MMSCFD".

The same can be done for the "Unit system for report…" to get the same unit set in the simulation report.

Clicking "Apply the unit system for edition everywhere" makes the data specification easier..

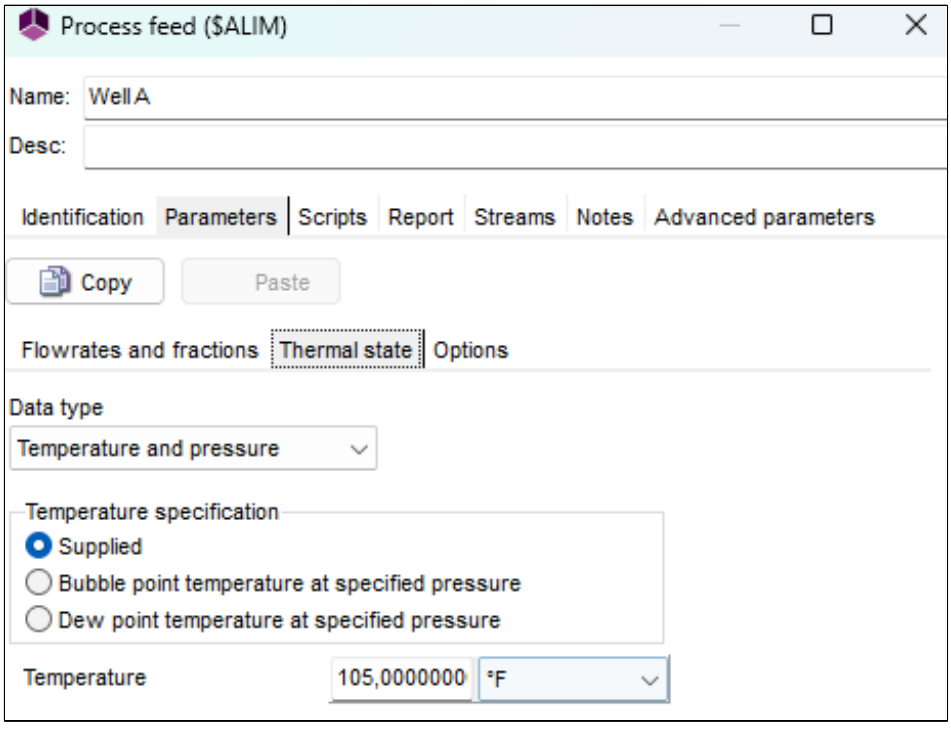


3.2.2. Wells

The wells are placed first on the "flowsheet" (PFD). They are in fact process feed streams.

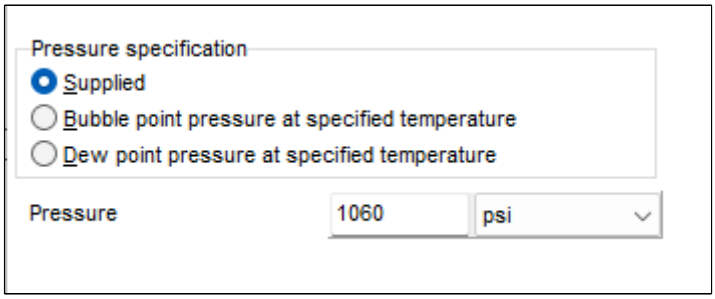
Start with the first (Well A) by placing on the white sheet a "Feed stream" module.

Then double click the module to enter its parameters. First enter the temperature (105 F):

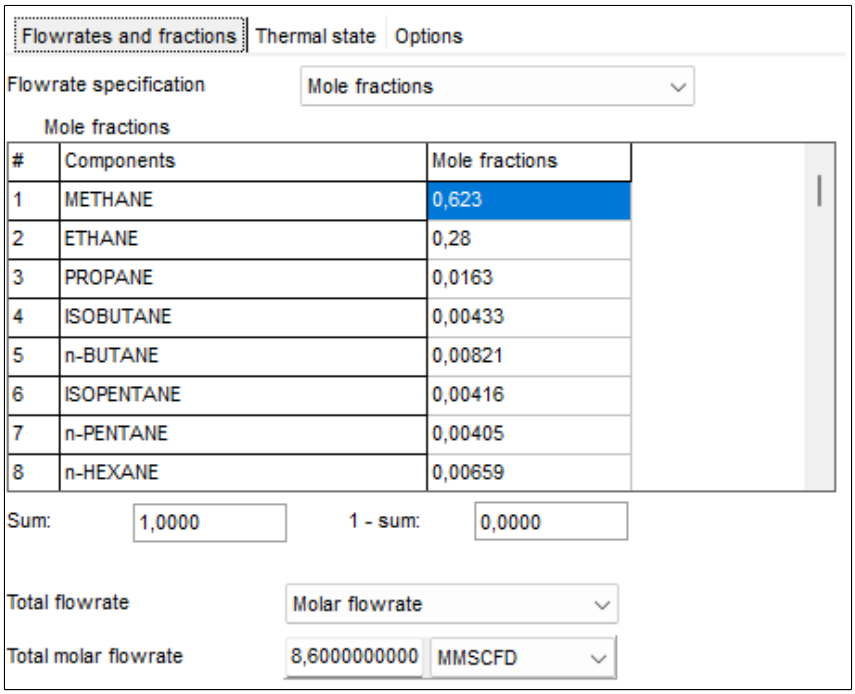


Then the pressure (1060 psia) can be entered.

The physical state of the stream can also be set to "Vapor stream" or "Liquid stream". However, if you are not sure what could be this physical state, we recommend unselecting the "Stream physical state" option, and ProsimPlus will compute it.



Finally, the stream composition and flow rate are specified:



Click the OK button to validate your entries and to close the window.

Since the gas composition is the same for the three wells, and in order to avoid re-entering this information twice more, you can duplicate the "Well A" module (*Copy* and *Paste*) to create Well B and the same for Well C.

At the level of Well B and Well C you just now have to change the name, the temperature and the flow rate.

Pressures of Well B and Well C (copied from Well A) will be used as initial values for computing the pressures since these pressures needs to be adjusted.

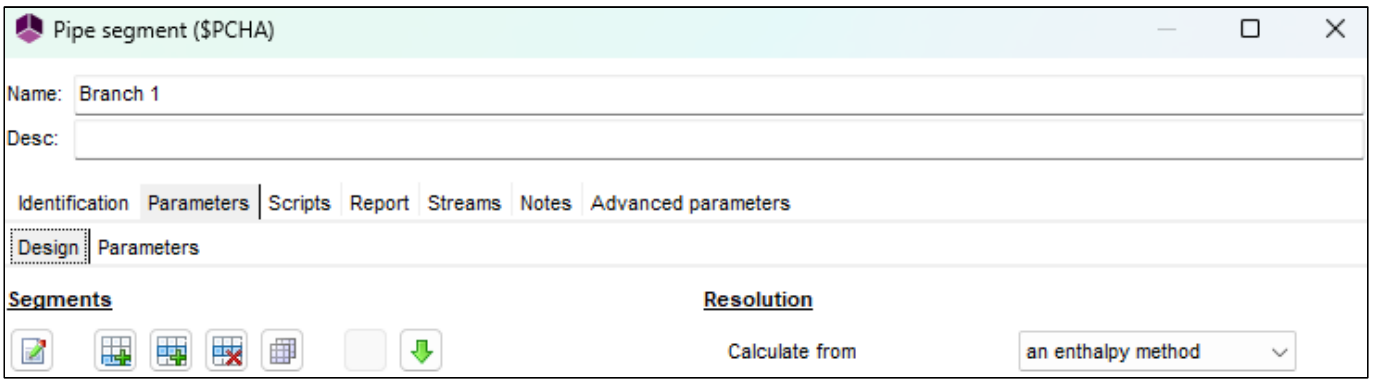
3.2.3. Pipes

The pipes are then placed on the PFD. "Pipe segment" modules are used.

Since each pipe can be divided into several segments, only one module will be used for each branch (5 modules will be placed on the PFD) and at the level of each module (each branch) each segment will be described.

After placing the first "Pipe segment" module on the PFD, description of "Branch 1" is as follows.

First the name is changed to "Branch 1":

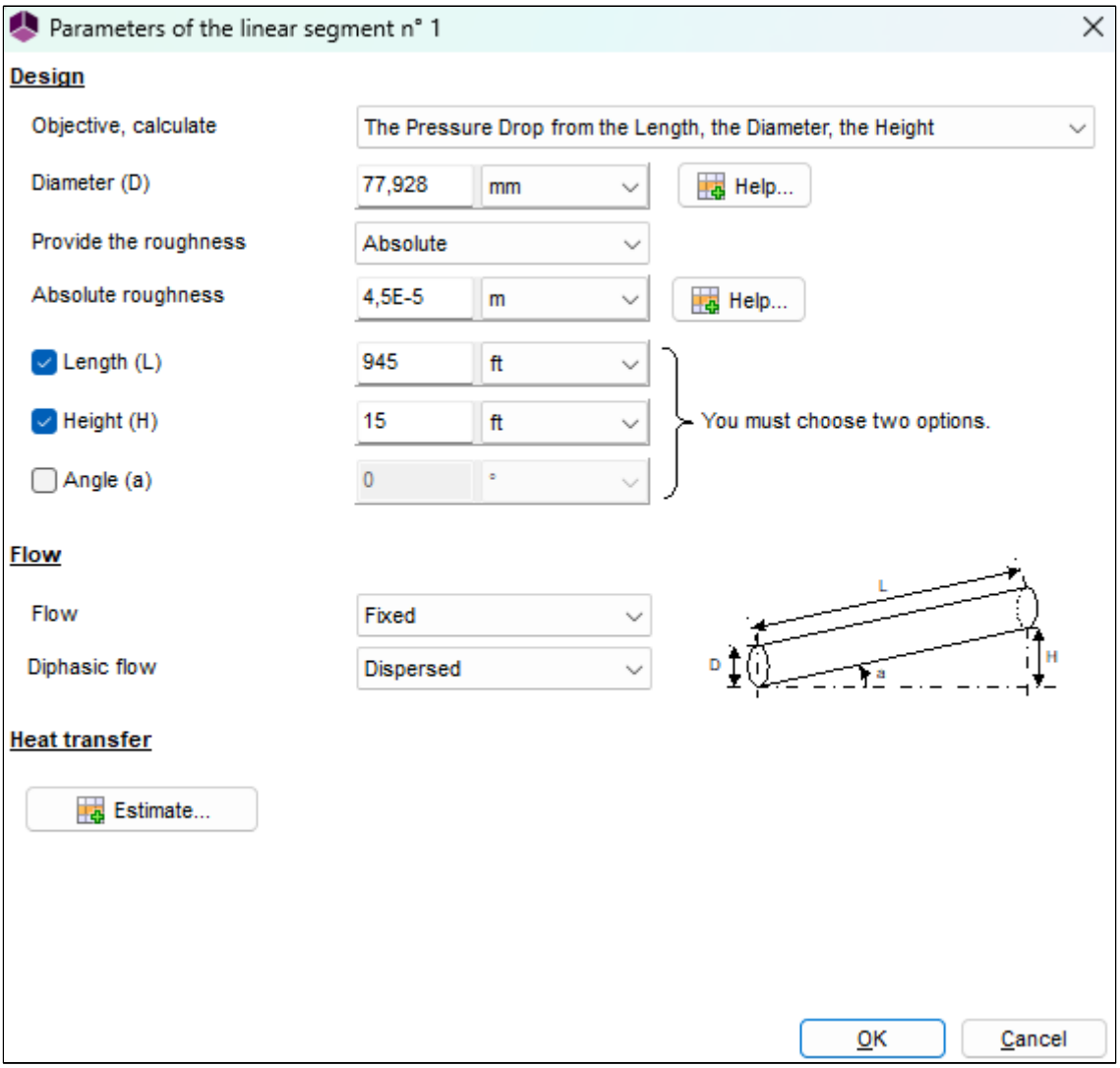


Then click the "Add" button to add the first pipe segment and enter its parameters by clicking "Edit" (it is a "Linear" segment, default option).

Here the design option to select is to calculate "The Pressure Drop from the Length, the Diameter, the Height" (default option). Other design options are available at this level, for instance to calculate the diameter of the pipe in order to have a given pressure drop (at pipe length and rise given), but they are not used in this example.

Then, enter the parameters of this first pipe segment:

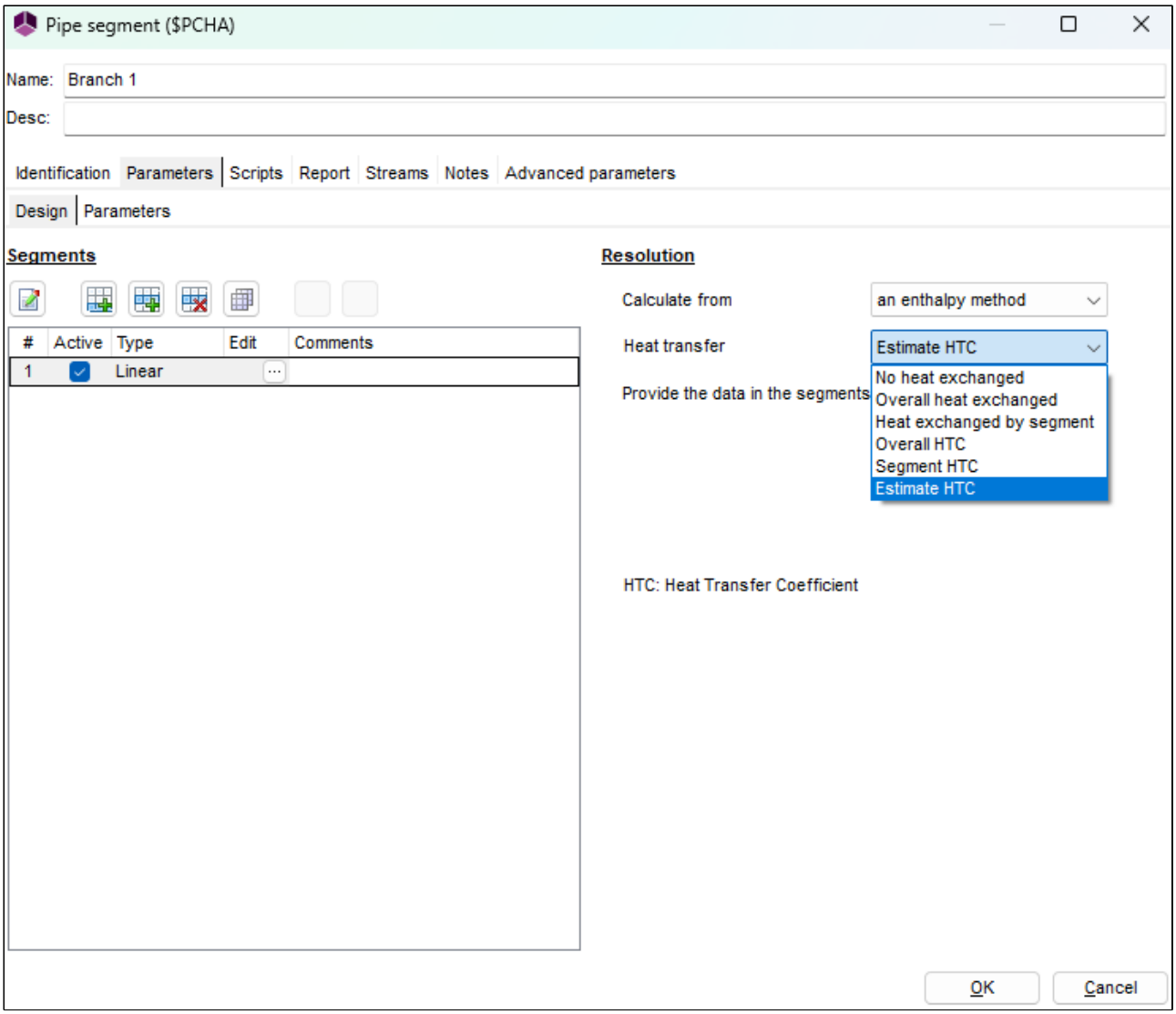
- Pipe inside diameter: 77.928 mm (3 in, schedule 40)
- Absolute roughness: 0.045 mm (database of main material roughness is accessible through the "Help" button: when selecting the material, the corresponding roughness is automatically entered)
- Length: 945 ft
- Height (rise): 15 ft
- Flow pattern: dispersed. The flow pattern can be fixed (selected among several possibilities: dispersed, annular, plug,..as in our example) or calculated from several available methods (Beggs & Brill,...).



Heat transfer data can also be entered for this pipe segment.

To do this, you must first specify that you want to calculate from an enthalpy method (non isothermal) and select "Estimate HTC" to estimate the heat transfer coefficients. These options are accessible from the "Pipe Segment" module main window.

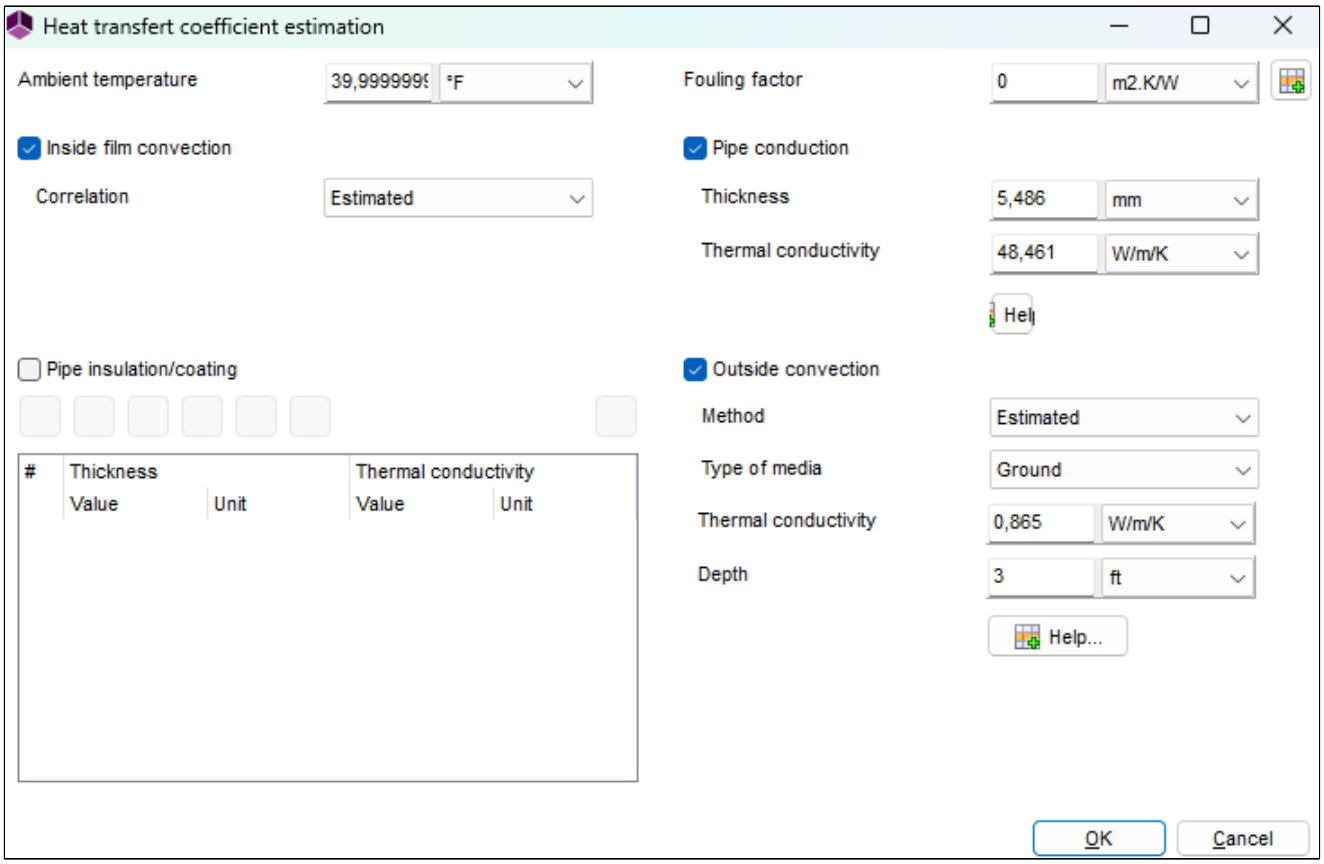
Then the parameters to use in order to estimate the heat transfer coefficients required to calculate the temperature downstream the pipe segment are given in each segment window.



Enter the parameters used to compute the heat transfer coefficient in the appropriate fields:

- Ambient temperature: 40 °F
- Inside film coefficient: estimated
- Pipe conduction:
    - Wall thickness: 5.486 mm
    - Wall thermal conductivity: 48.461 W/m/K
- Outside convection (estimated):
    - Type of media: ground
    - Thermal conductivity: 0.865 W/m/K
    - Depth: 3 ft

Databases of main material properties are available when appropriate and accessible through the "Help" buttons.



To enter the other pipe segments of this branch (Branch 1), use the "Clone" button and just change the following parameters:

- Length
- Height (rise)

using the values provided in the table presented in paragraph 1.2.

To add "Branch 2":

- Duplicate the "Branch 1" module on the PFD (Copy and Paste)
- Open its description window and change the following:
  - Module name: "Branch 2"
  - Delete Segment 2 and Segment 3 to keep only one segment for this Branch 2
  - Length: 2822 ft
  - Height (rise): 75 ft

To add "Branch 3":

- Duplicate the "Branch 1" module on the PFD (Copy and Paste)

- Open its description window and change the following:
    - Module name: "Branch 3"
    - For segment 1:
        - Length: 528 ft
        - Height (rise): 40 ft
    - For segment 2:
        - Length: 334 ft
        - Height (rise): -45 ft
    - For segment 3:
        - Length: 670 ft
        - Height (rise): -3 ft

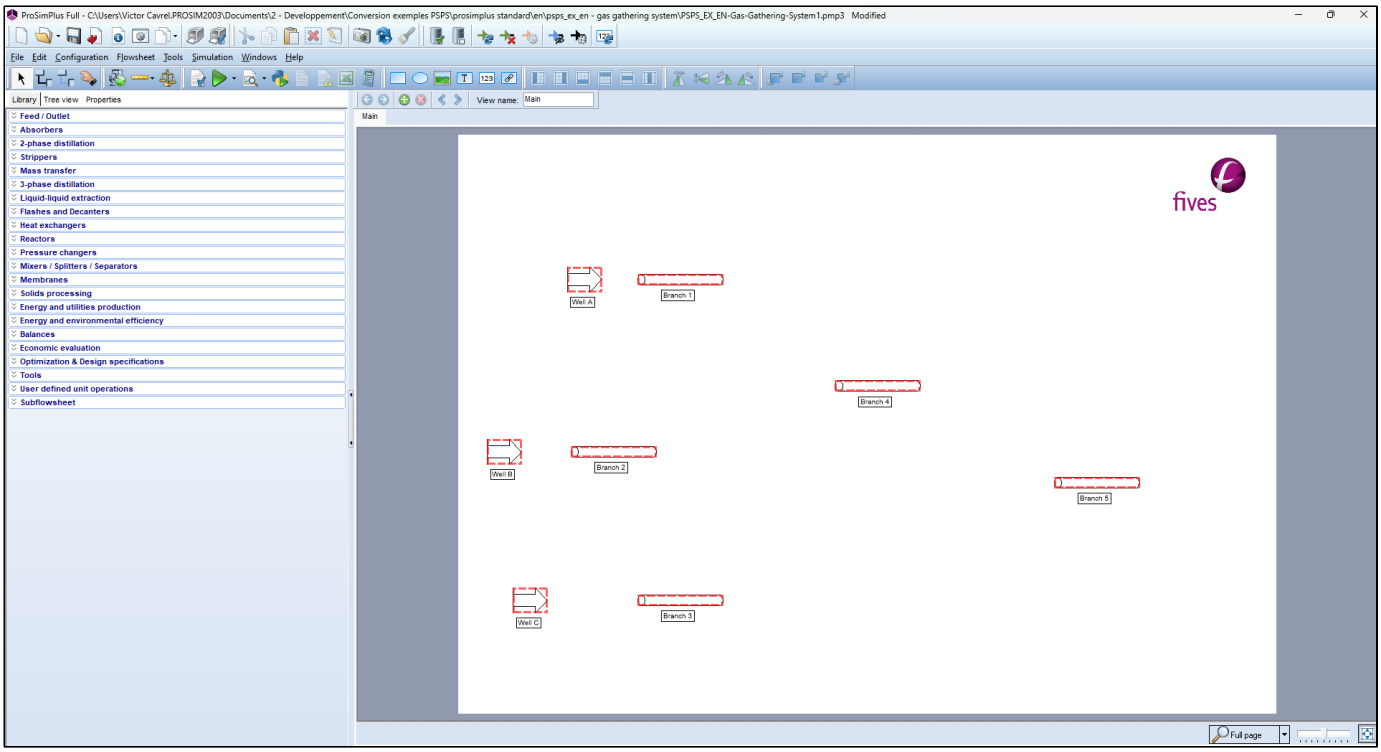
To add "Branch 4":

- Duplicate the "Branch 2" module on the PFD (Copy and Paste)
- Open its description window and change the following:
    - Module name: "Branch 4"
    - Pipe inside diameter: 102.26 mm (4 in, schedule 40)
    - Length: 1167 ft
    - Height (rise): -13 ft
    - Pipe thickness: 6.020 mm (from the "Heat transfer coefficient estimation" window).

To add "Branch 5":

- Duplicate the "Branch 4" module on the PFD (Copy and Paste)
- Open its description window and change the following:
    - Module name: "Branch 5"
    - Pipe inside diameter: 154.056 mm (6 in, schedule 40)
    - Length: 2110 ft
    - Height (rise): -97 ft
    - Pipe thickness: 7.112 mm (from the "Heat transfer coefficient estimation" window).

At this step, your main screen should look like the following one:



3.2.4. Links between pipes

The pipelines must now be connected together and connections to the wells must also be added.

First, you must connect ("Create a material stream" button, and successively click the two modules you want to connect) "Well A" to "Branch 1" module, "Well B" to "Branch 2", and "Well C" to "Branch 3".

Material streams "1", "2" and "3" are created.

To connect "Branch 2" and "Branch 3" to "Branch 4", a mixer is used to merge streams.

An "Other mixer" module is added to the PFD (other ProSimPlus operations can be used to merge streams but this one is the simplest to use and the most suitable for this example).

It is the same to connect "Branch 3" and "Branch 4" to "Branch 5", another mixer module is placed on the PFD.

There is no parameter to enter for these mixer modules except their name: "Junction 1" and "Junction 2" for instance.

"Branch 1" and "Branch 2" are connected to "Junction 1" (material streams "4" and "5" are created) and "Junction 1" is connected to "Branch 4" (material stream "6" is created).

Then "Branch 4" and "Branch 3" are connected to "Junction 2" (material streams "7" and "8" are created) and "Junction 2" is connected to "Branch 5" (material stream "9" is created).

Finally, an output stream of the process is added to the PFD. There is no parameter needed for this module, only its name can be changed to "To gas plant" for instance. "Branch 5" is now connected to this module (material stream "10" is created).

In such process, pressures are continuous throughout the network. However, here, at the level of each mixer module, if the pressure of the streams entering the module is not the same, the pressure of the merged stream will be set "Equal to the lowest of the feeds", resulting in non-equilibrated pressures at this node of the network. In fact, in the actual plant, the pressures of all three streams are equal at any node of the network.

To model the actual plant behavior, we will apply the following reasoning which may appear as complex but which is in fact very easy to implement with ProSimPlus.

Let us take the example of "Junction 1": mixer merging stream from "Branch 1" and stream from "Branch 2" into stream entering "Branch 4".

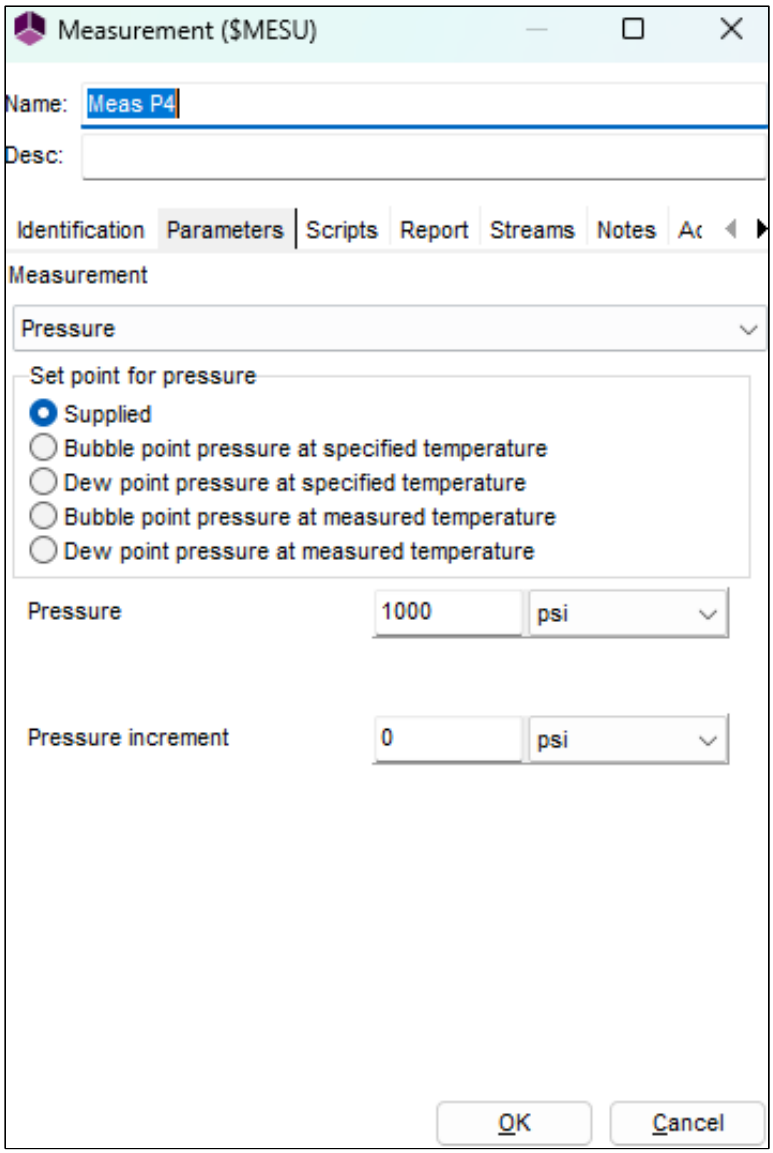
The aim is to equalize pressures of "Branch 1" and "Branch 2", that way, the merged stream will also have the same pressure ("Equal to the lowest of the feeds") and the pressures will be equilibrated at this node. To do this, we will measure pressure downstream "Branch 1", measure pressure downstream "Branch 2" and put as a "Specification" that we want both pressures to be equal by adjusting pressure of "Well B" (pressure of "Well A" is fixed in this case).

First, a "Measurement" module is placed on the PFD between "Branch 1" and "Junction 1". Stream "4" is reconnected by right-clicking it and by selecting the "Reconnect…" option. Then the measurement module is connected to "Junction 1". The name of this new stream is changed to "4b".

Parameters of this measurement module are entered as follows:

- Name given: "Meas P4"
- Pressure set point: 1000 psia.

  Note: any value can be given at this level because our objective is not to fix the pressure at this point, but to equalize it to pressure of stream "5" (material stream downstream "Branch 2"). With this measurement module, we are interested in getting the actual value of the pressure and not the difference between a set point and the actual value: this will be selected when connecting the information stream emitted by this measurement module (see hereafter).



A second "Measurement" module is placed on the PFD between "Branch 2" and "Junction 1". Stream "5" is reconnected and the measurement module is connected to "Junction 1". The name of this new stream is changed to "5b".

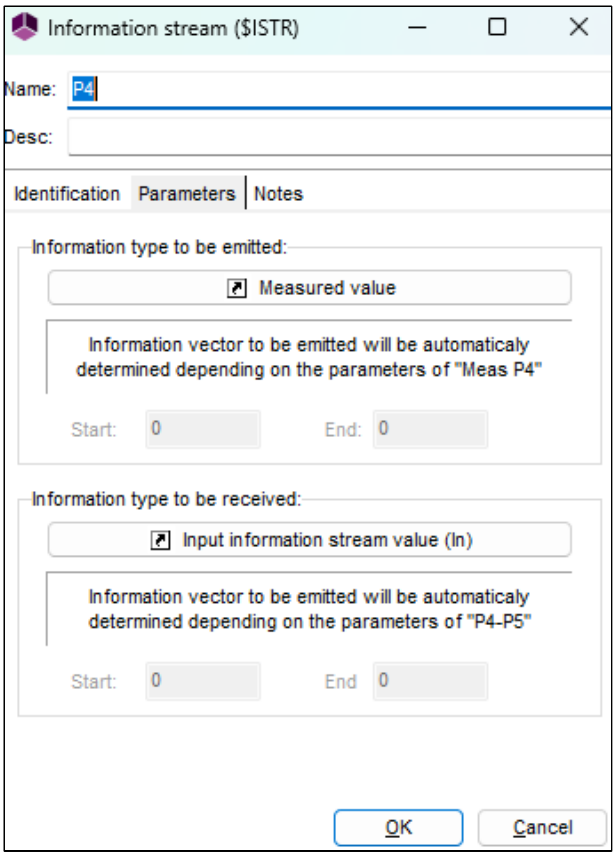
Parameters of this measurement module are entered as follows:

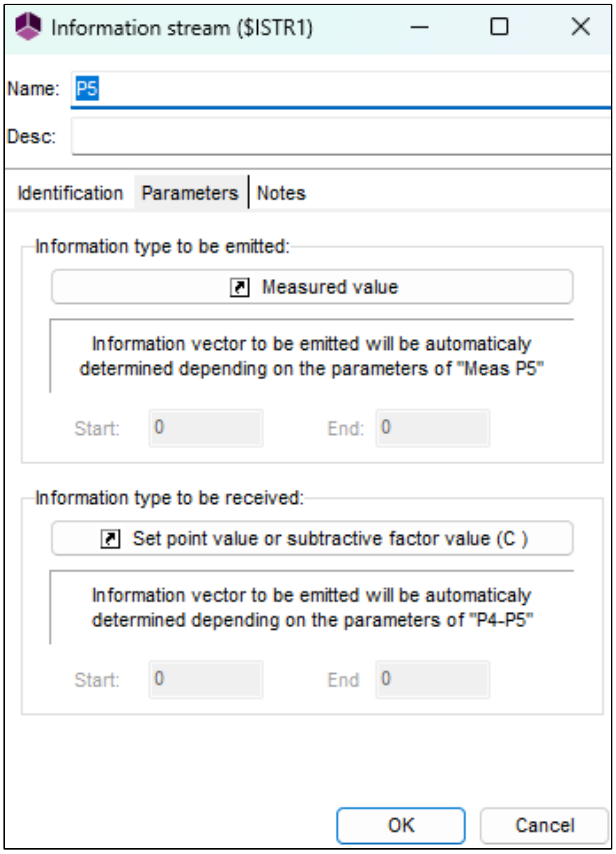
- Name given: "Meas P5"
- Pressure set point: 1000 psia (same remark as previously).

An "Information stream handler" module is now added to calculate the difference between both pressures (we want this difference to be zero).

"Meas P4" is connected to this "Information stream handler" module by an information stream ("Create an information stream button"). Double click this information stream to change its name into "P4" and the "Information type to be emitted" into "Measured value" (by default the information stream emitted is the difference between the set point given in the measurement module and the actual value).

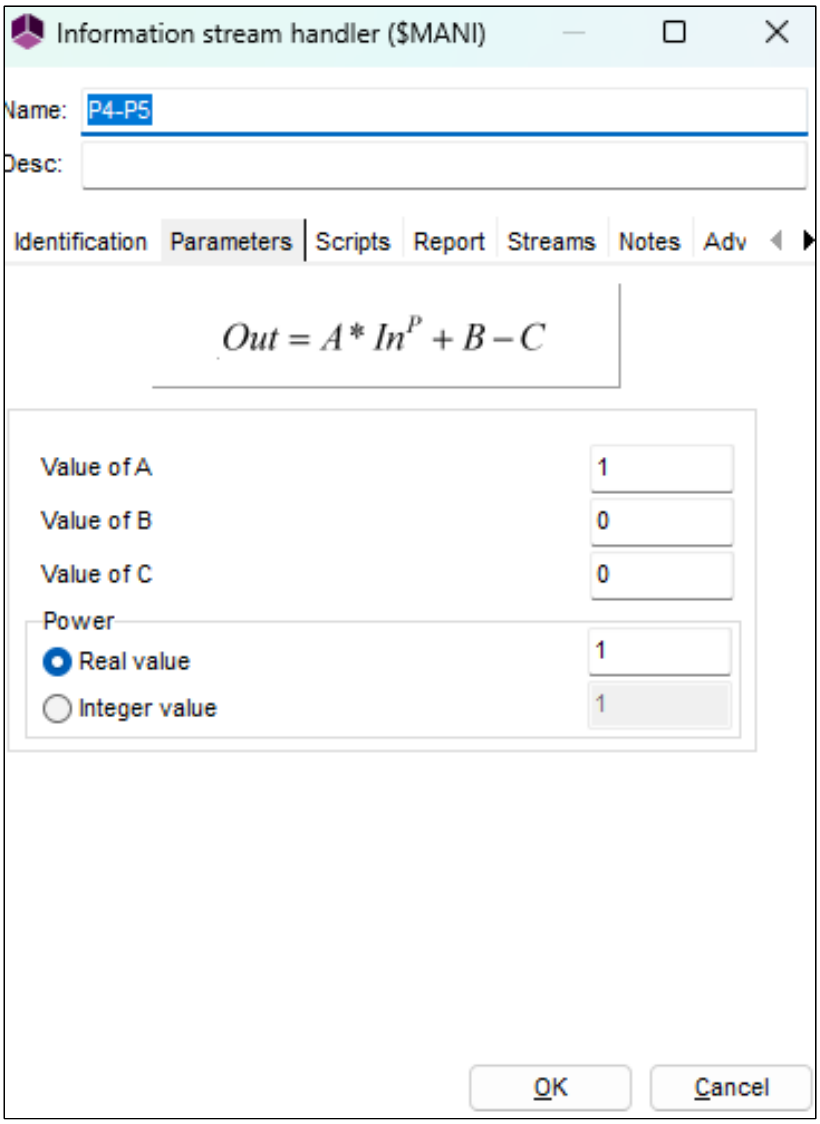
In the same way, "Meas P5" is connected to the "Information stream handler" module and the name of the corresponding information stream name is changed into "P5". Also, the "Information type to be emitted" is changed into "Measured value" and the "Information type to be received" into "Set point (C)".





Parameters can now be entered in the "Information stream handler" module. In fact, the only thing to do is to change default name to: "P4-P5".

For more information on the use of "Measurement" modules and "Information stream handler" modules, refer to Chapter 5 of ProSimPlus User Manual.



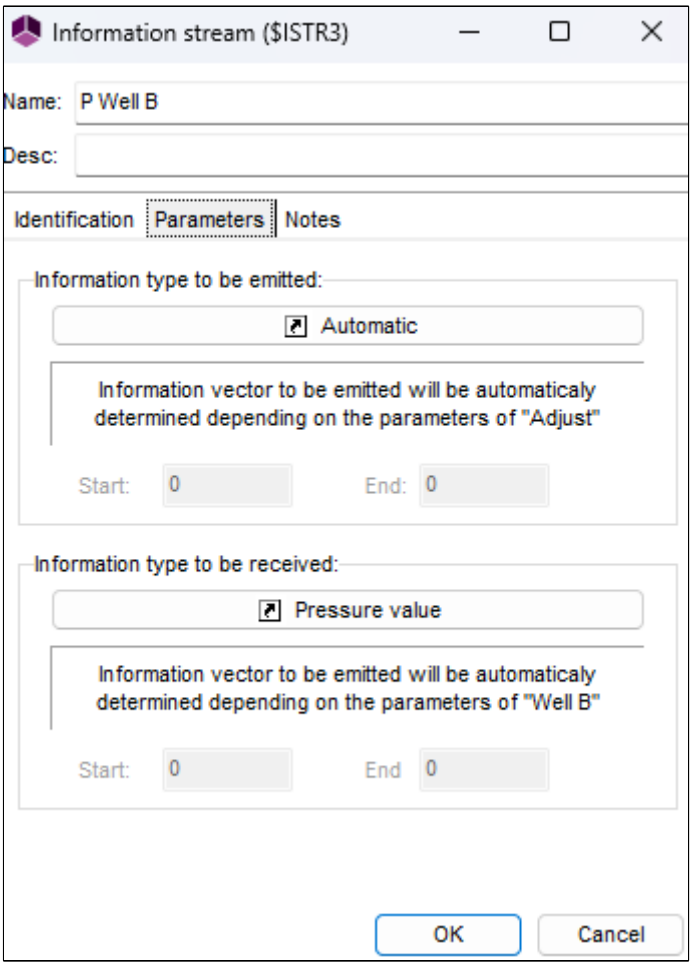
Add now a "Constraints and Recycles" module. It will be used to manage all the specifications and adjust the appropriate variables. Its default name can be changed to "Adjust".

Establish a connection between the "Information stream handler" module (now called "P4-P5") and this "Adjust" module by means of an information stream (we will change its name into "P4-P5").

Finally connect by means of an information stream the "Adjust" module to "Well B" (our objective is to adjust delivery pressure of "Well B" in order to equilibrate the pressures at the node "Junction 1").

Double click this "Information stream" to enter its parameters:

- change its default name to "P Well B"
- put "Feed pressure" as the "Information stream to be received".

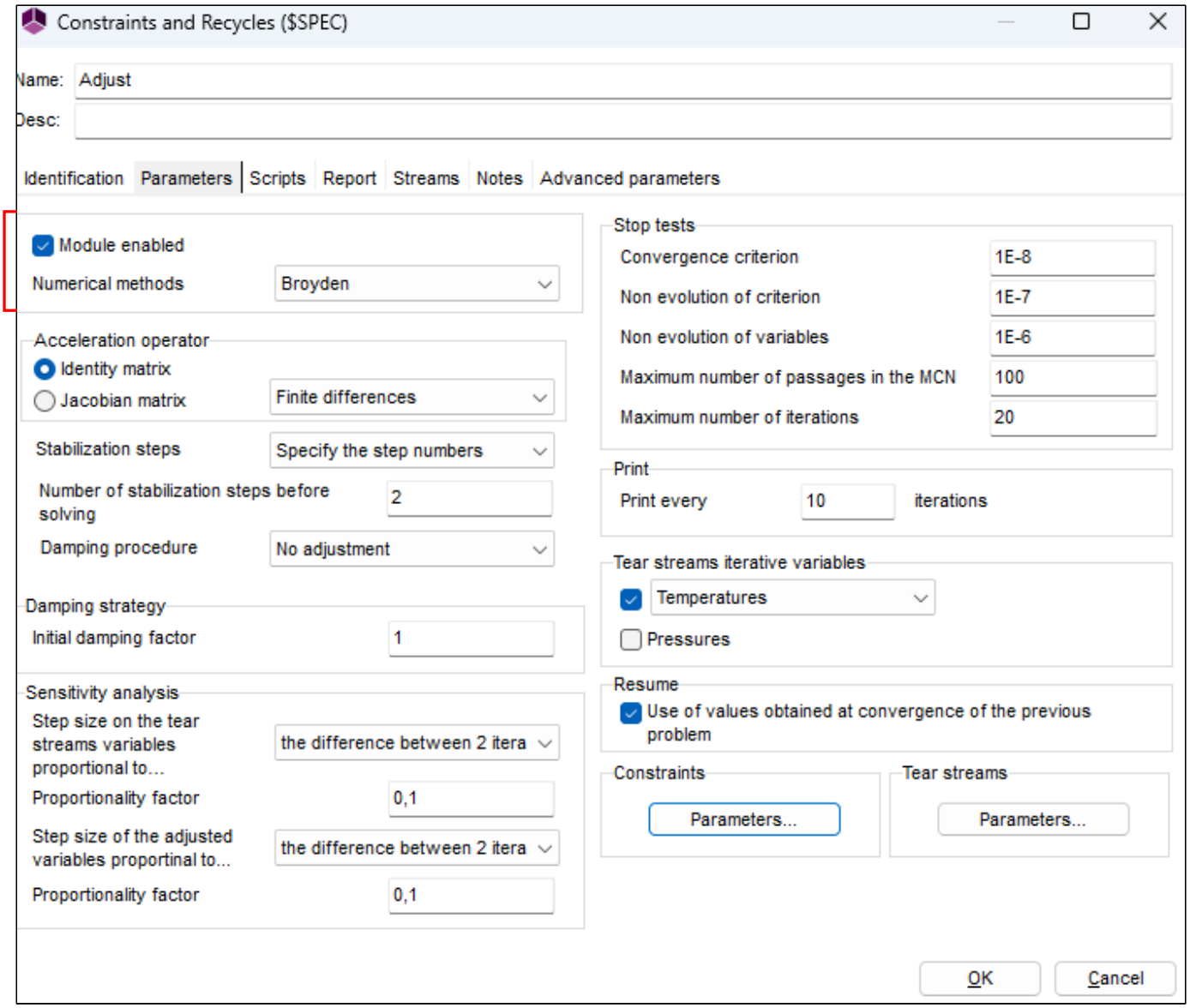


Apply exactly the same procedure to equalize pressures at "Junction 2" by adjusting pressure of "Well C".

To ease the convergence, the default value of the "Adjust" module can be changed to the following ones:

- numeric method: "Broyden"
- bounded adjusted variables:
    - pressure of Well B between 20 and 100 atm
    - pressure of Well C between 20 and 100 atm.

Areas where these parameters must be modified are highlighted in the next view.



3.3. Running the simulation and viewing the results

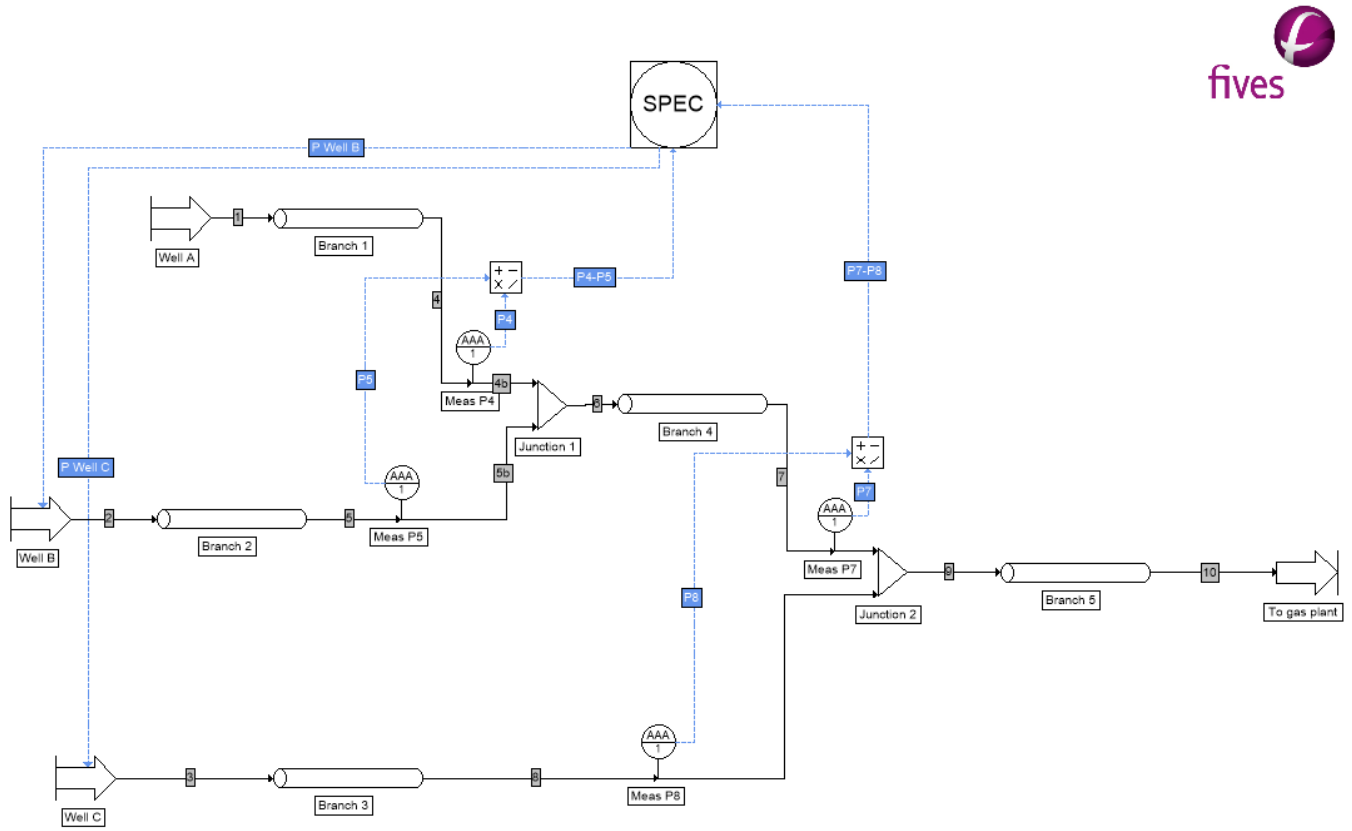
We advise you to save your simulation file prior to run a new simulation.

To run the simulation, just click the "Start the simulation" button (or F9 key). Several options are available at this level:

- "Start the simulation…" (if a previous simulation has already been run, the calculation will start from previous results which may result in faster convergence time for some complex flowsheets).
- "Start the simulation paused…": "step by step" simulation, so that you can follow step by step the calculation evolution (you select the stop points). It is particularly interesting for very complex processes or processes made up of many unit operations.
- "Start the full simulation": start the simulation without any initialization.
- "Start the full simulation paused…"

- "Verify data": just check that the data entered are satisfactory to run a simulation. It can also be used to view the calculation sequence established by ProSimPlus automatically (order of calculation of the different unit operations).

After the simulation has run, calculation results can be viewed in several ways. Here they appear in a table under the flowsheet.



Streams		1	2	3	4	5	6	7	8	9	10
From		Well A	Well B	Well C	Branch 1	Branch 2	Junction 1	Branch 4	Branch 3	Junction 2	Branch 5
Total flow	MMSCFD	8,6	7,4	10,1	8,6	7,4	16,0	16,0	10,1	26,1	26,1
Physical state		Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.
Temperature	°F	105,0	115,0	110,0	93,8	104,6	98,8	95,5	103,1	98,5	96,1
Pressure	psi	1060	1027	991	949	949	949	912	912	912	893
Enthalpic flow	kJ/h	-905 247	-601 947	-882 114	-987 476	-689 368	-1 676 844	-1 708 677	-927 495	-2 636 173	-2 701 122
Vapor molar fraction		0,96289	0,96920	0,96708	0,95818	0,96495	0,96145	0,96046	0,96498	0,96227	0,96136

More or less results can appear in this table according to the options selected by the user (right click on the table).

Main results obtained here give a pressure of "Well B" equal to 1027 psia and a pressure of "Well C" equal to 991 psia.

Results obtained here with ProSimPlus are very close to those given in the source document (see paragraph 1).

4. SIMULATION CASE 2

4.1. Introduction

This simulation case is very similar to Case 1, however here, the pressure of Well A is also adjusted in order to maintain a constant pressure of 1000 psia at gas plant.

The flow rate of each well is specified and is independent of the flow rate of each of the other wells. The temperature of each wellhead is also fixed.

Wellhead delivery pressure of each well is supposed to be independent of the well flow rate.

The following parameters for the wells are used:

Well A	Temperature (F)	105
	Molar flow (MMSCFD)	8.6
Well B	Temperature (F)	115
	Molar flow (MMSCFD)	7.4
Well C	Temperature (F)	110
	Molar flow (MMSCFD)	10.1

4.2. Building the case

Starting from Case 1 this new simulation case can be easily built.

Save the previous simulation file to " PSPS_EX_EN - Gas Gathering System2.pmp3" (for instance).

The only thing to do is to add a "Measurement" module on stream 10, in order to enter the set point on the pressure (1000 psia) at this point (gas plant). Change the default name of this new "Measurement" module to "Meas P10".

Then connect this measurement module to the "Adjust" module by means of an "Information stream". Rename this information stream into "P10". Then connect the "Adjust" module to "Well A" module by means of another "Information stream" (renamed into "P Well A"). Then, double-click this "P Well A" information stream, and specify that "Feed pressure" is the parameter you want to adjust ("Information stream to be received").

Bounds on pressure of "Well A" can also be added at the level of the "Adjust" module to keep this pressure between 20 and 100 atm during the convergence process.

With ProSimPlus, the three wellhead pressures will be adjusted simultaneously to reach the three specifications (pressure equilibrium at "Junction 1", pressure equilibrium at "Junction 2" and pressure at gas plant equal to 1000 psia).

4.3. Viewing the results

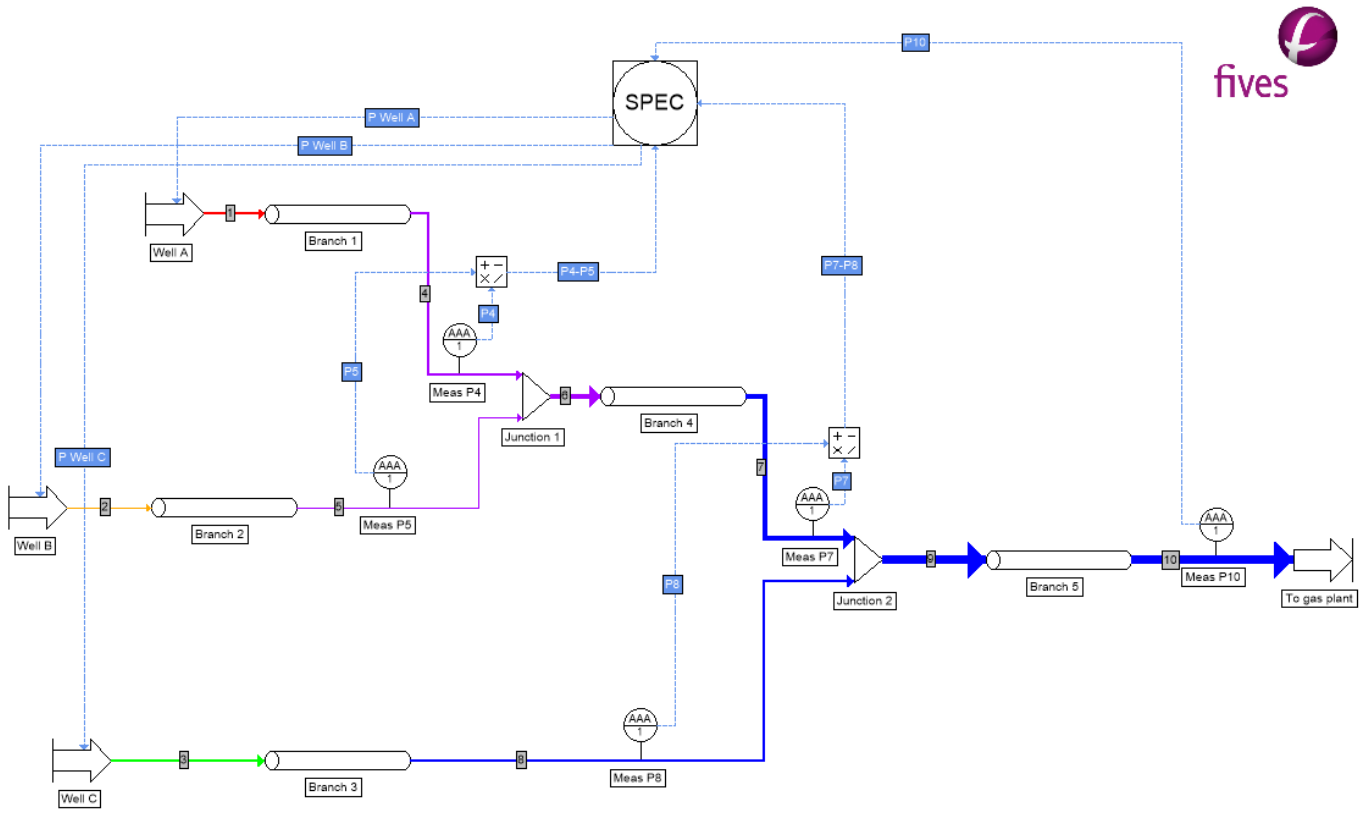
Upon convergence, the well pressure should be:

Well A	Pressure (psia)	1151
Well B	Pressure (psia)	1121
Well C	Pressure (psia)	1088

Here also, the results are very similar to those presented in the source document (see paragraph 1).

Results are presented in the PDF hereafter using a feature available in ProSimPlus:

- Streams are colored according to their pressure from blue (lowest pressure) to red (highest pressure),
- Stream lines have different thicknesses, according to their molar flow rate.



Streams		1	2	3	4	5	6	7	8	9	10
From		Well A	Well B	Well C	Branch 1	Branch 2	Junction 1	Branch 4	Branch 3	Junction 2	Branch 5
Total flow	MMSCFD	8,6	7,4	10,1	8,6	7,4	16,0	16,0	10,1	26,1	26,1
Physical state		Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.
Temperature	°F	105,0	115,0	110,0	94,7	105,3	99,5	96,6	103,7	99,3	97,1
Pressure	psi	1151	1121	1088	1050	1050	1050	1016	1016	1016	1000
Enthalpic flow	kJ/h	-996 707	-678 506	-992 285	-1 079 513	-766 338	-1 845 851	-1 878 184	-1 037 874	-2 916 059	-2 982 129
Vapor molar fraction		0,96148	0,96811	0,96554	0,95592	0,96324	0,95945	0,95821	0,96294	0,96010	0,95902

Pressure drops in each branch are as follows:

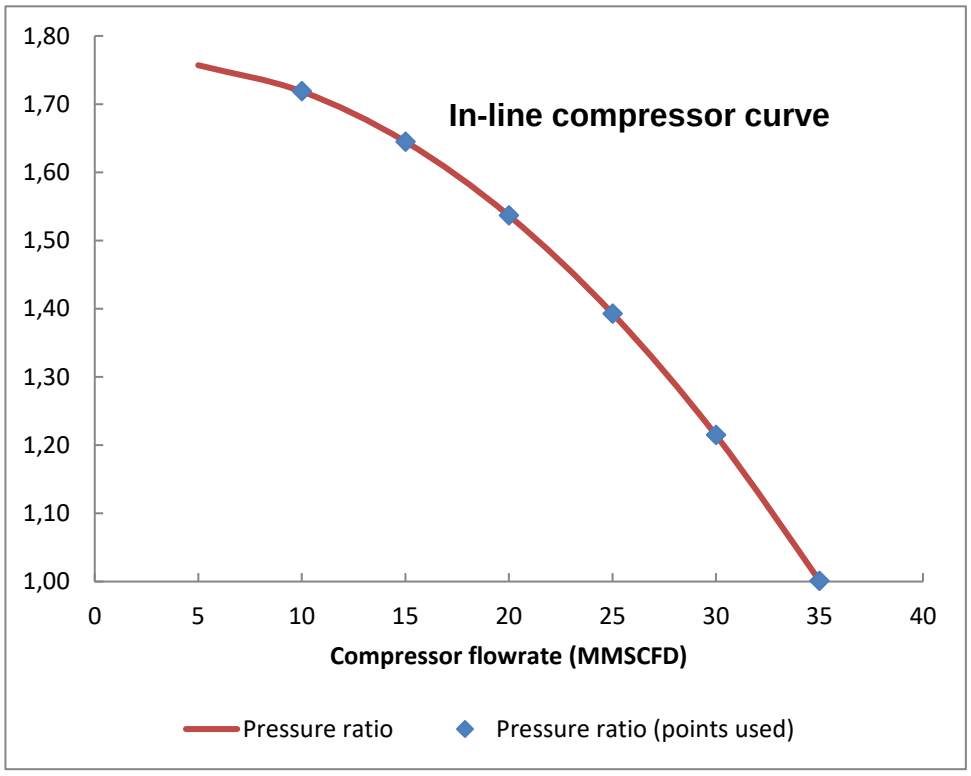
Branch	**Diameter** (in)	**Unit**	**Length** (ft)	**Rise** (ft)	**Pressure drop** (psia)	
Branch 1	3"	Pipe Unit 1	945	15	30.52	**101.67**
		Pipe Unit 2	1110	- 21	35.32	
		Pipe Unit 3	1056	1	35.83	
Branch 2	3"	Pipe Unit 1	2822	75	71.24	**71.24**
Branch 3	3"	Pipe Unit 1	528	40	25.83	**71.85**
		Pipe Unit 2	334	- 45	14.17	
		Pipe Unit 3	670	- 3	31.85	
Branch 4	4"	Pipe Unit 1	1167	- 13	33.49	**33.49**
Branch 5	6"	Pipe Unit 1	2110	- 97	16.29	**16.29**

5. SIMULATION CASE 3

5.1. Introduction

In this simulation case, an inline compressor is added at the upstream end of "Branch 5" in order to reduce the pressure at the wells to such an extent that production can be significantly increased to justify additional cost of compressor.

A one stage 750 hp compressor is selected, with the following efficiency performance curve:



Just as in Case 2, the flow rate of each well is independent of the flow rate of each of the other wells. Wellhead delivery pressure of each well is supposed to be independent of the well flow rate.

The following parameters for the wells are used:

Well A	Temperature (F)	105
	Molar flow (MMSCFD)	8.6
Well B	Temperature (F)	115
	Molar flow (MMSCFD)	7.4
Well C	Temperature (F)	110
	Molar flow (MMSCFD)	10.1

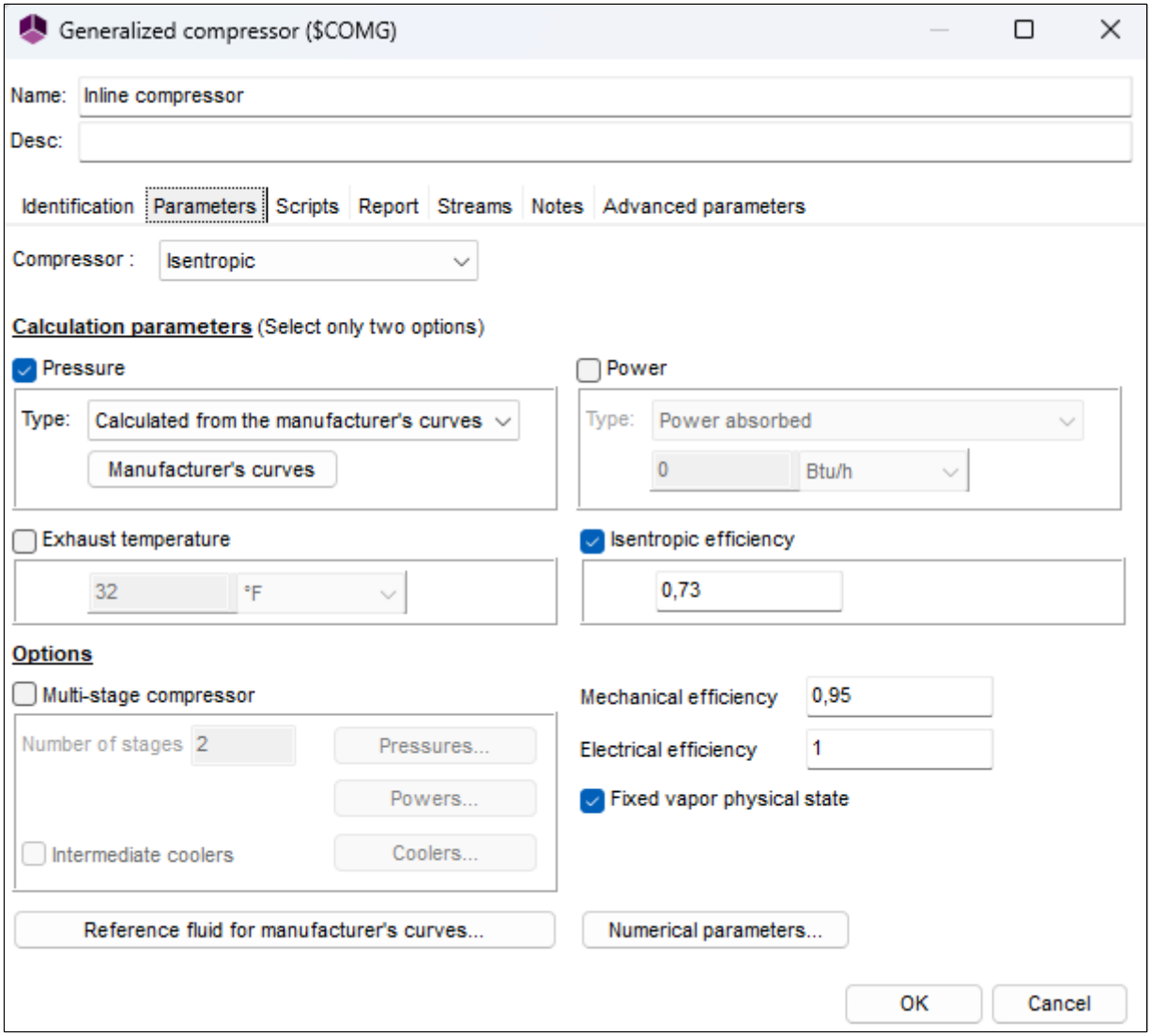
Here also the pressure of Well A is adjusted in order to maintain a constant pressure of 1000 psia at gas plant (and pressures of wells B and C are adjusted to equilibrate pressures at Junction 1 and at Junction 2).

5.2. Building the case

Save the previous simulation file to " PSPS_EX_EN - Gas Gathering System3.pmp3" (for instance).

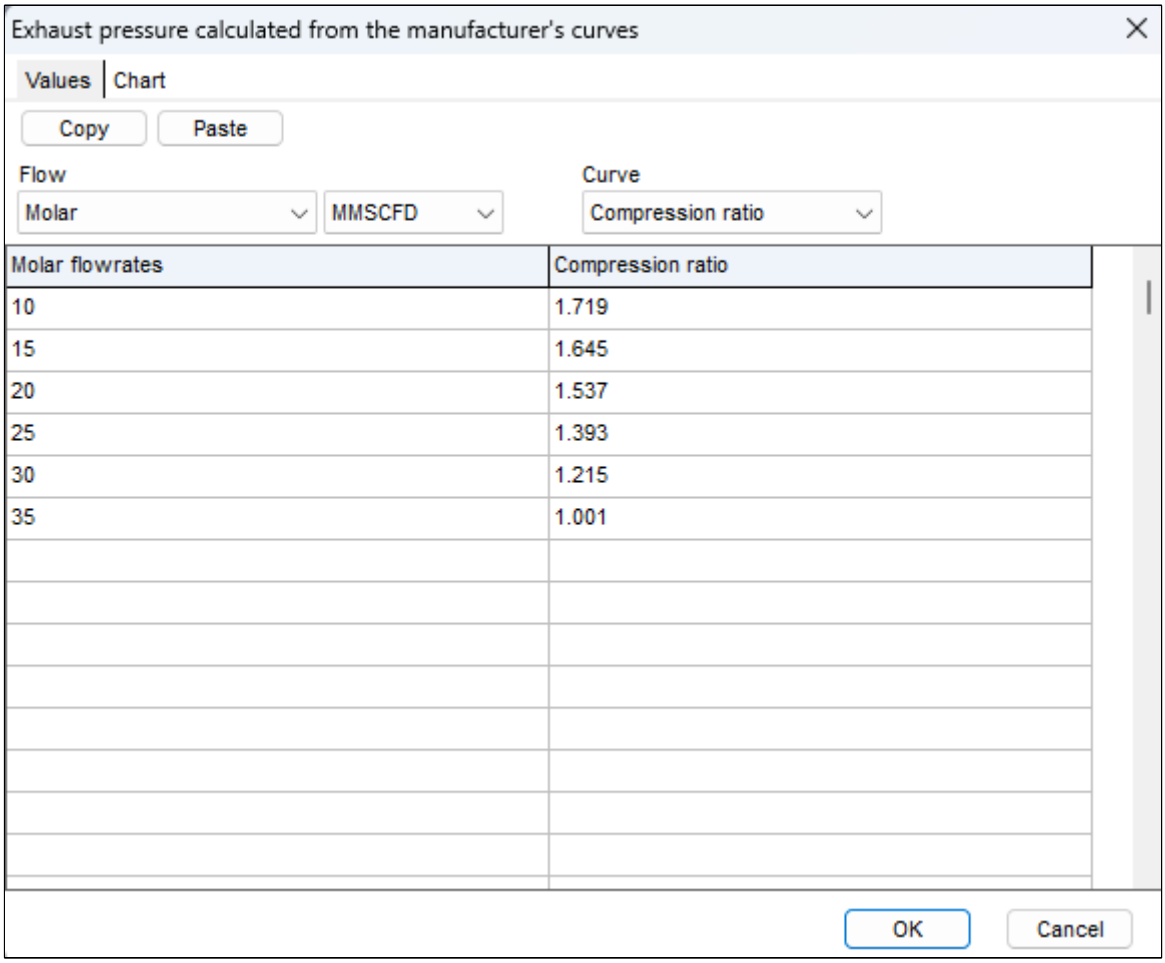
Starting from Case 2 this new simulation case can be easily built. Add a "Generalized compressor" module on the PFD and reconnect stream 9 to this new module. Then the parameters of the compressor must be entered in the corresponding view:

- Name : "Inline compressor"
- Compressor type: isentropic
- Efficiency: 0.73
- Fixed vapor physical state (to improve the simulation of this case, to be closer to the actual plant, a flash drum should be added at the compressor inlet to avoid liquid entering the compressor).

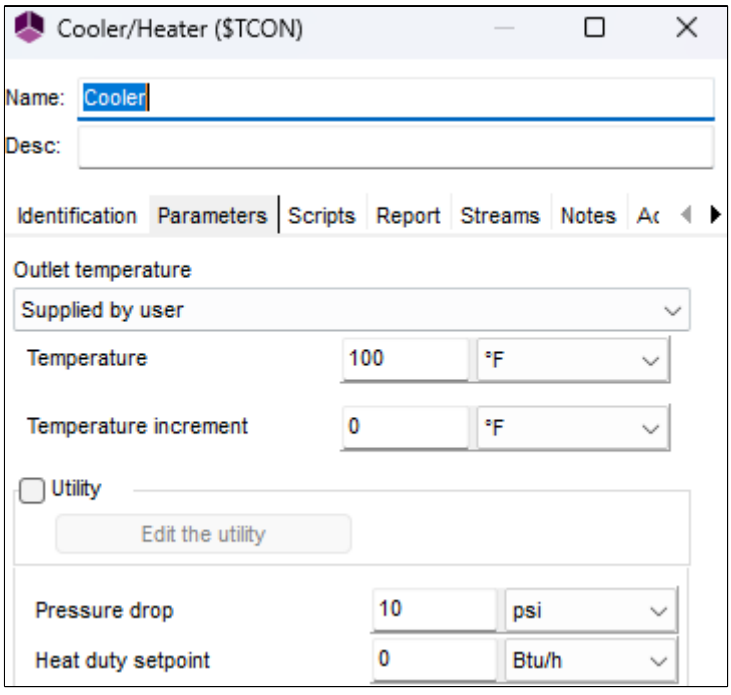


Regarding the exhaust pressure, it is here calculated from the manufacturer's curve.

Following values of pressure ratios are read on the previous graph and entered into the appropriate table:



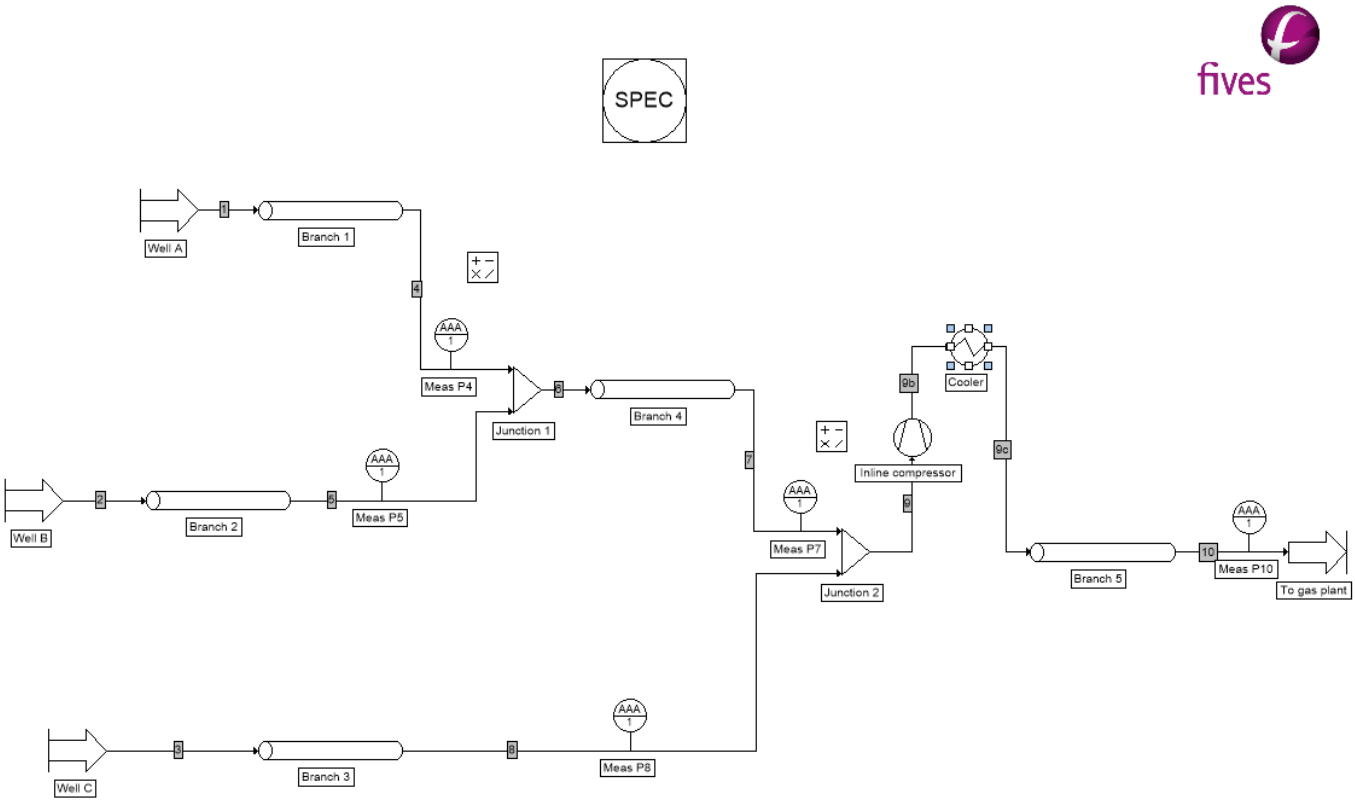
A cooler is also added to keep the exhaust temperature at 100 °F. Its pressure drop is specified to 10 psi.



Streams are also renamed around the compressor and the cooler.

5.3. Viewing the results

The resulting PFD is the following one:



Here, "Information streams" are hidden (available option in ProSimPlus).

Upon convergence, the well pressures should be:

Well A	Pressure (psia)	927.1
Well B	Pressure (psia)	888.5
Well C	Pressure (psia)	848.9

Main stream properties are given in the following table:

Streams		1	2	3	4	5	6	7	8	9	9b	9c	10
From		Well A	Well B	Well C	Branch 1	Branch 2	Junction 1	Branch 4	Branch 3	Junction 2	Inline compressor	Cooler	Branch 5
Total flow	MMSCFD	8,6	7,4	10,1	8,6	7,4	16,0	16,0	10,1	26,1	26,1	26,1	26,1
Physical state		Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Vapor	Liq./Vap.	Liq./Vap.
Temperature	°F	105,0	115,0	110,0	92,3	103,5	97,5	93,7	102,0	96,9	146,6	100,0	97,8
Pressure	psi	927	888	849	800	800	800	756	756	756	1026	1016	1000
Enthalpic flow	kJ/h	-773 116	-490 649	-721 282	-854 347	-577 363	-1 431 710	-1 462 657	-766 284	-2 228 940	-270 262	-2 880 457	-2 947 275
Vapor molar fraction		0,96566	0,97147	0,96998	0,96223	0,96815	0,96509	0,96453	0,96865	0,96618	1,00000	0,96055	0,95946

At the level of the inline compressor:

- Power: 768.02 HP
- Exhaust pressure: 1026.3 psia
- Exhaust temperature: 146.6 °F

Here, the results are somewhat different from those presented in the source document (see paragraph 1), mainly because we selected to model a real compressor (with its manufacturer's curve linking the compression ratio to the flow rate) with one stage instead of a two-stage compressor with fixed power. This will be useful in the next simulation case (see paragraph 6) where the delivery flow rates of the wells are automatically adjusted.

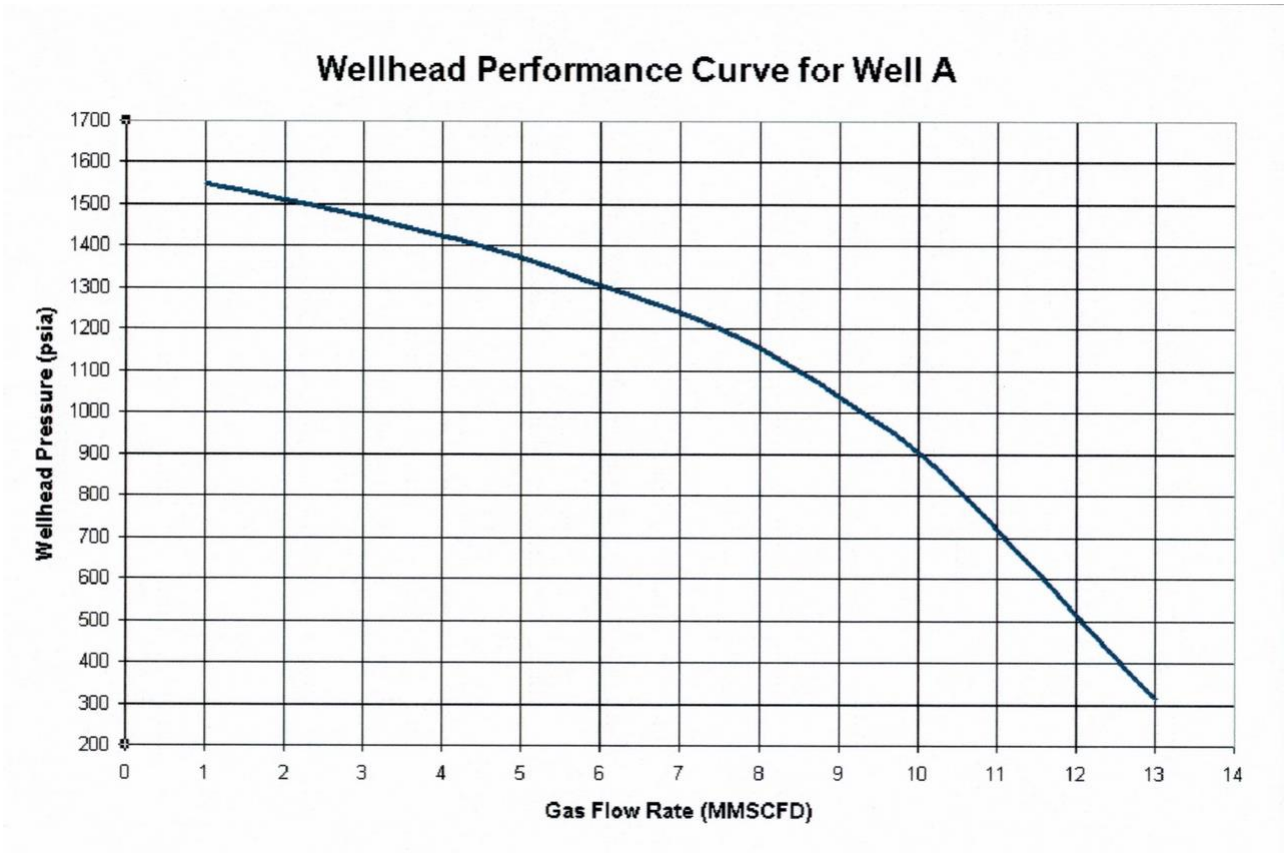
6. SIMULATION CASE 4

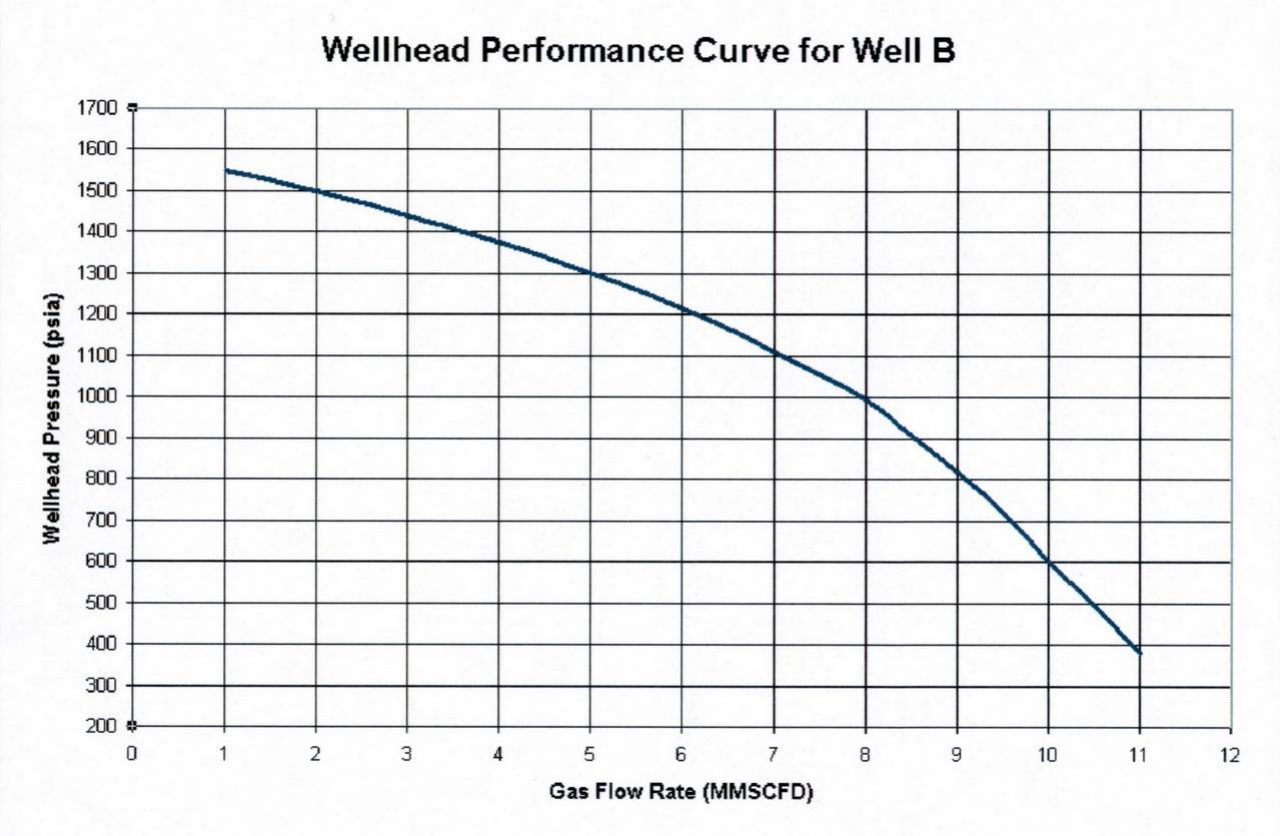
6.1. Introduction

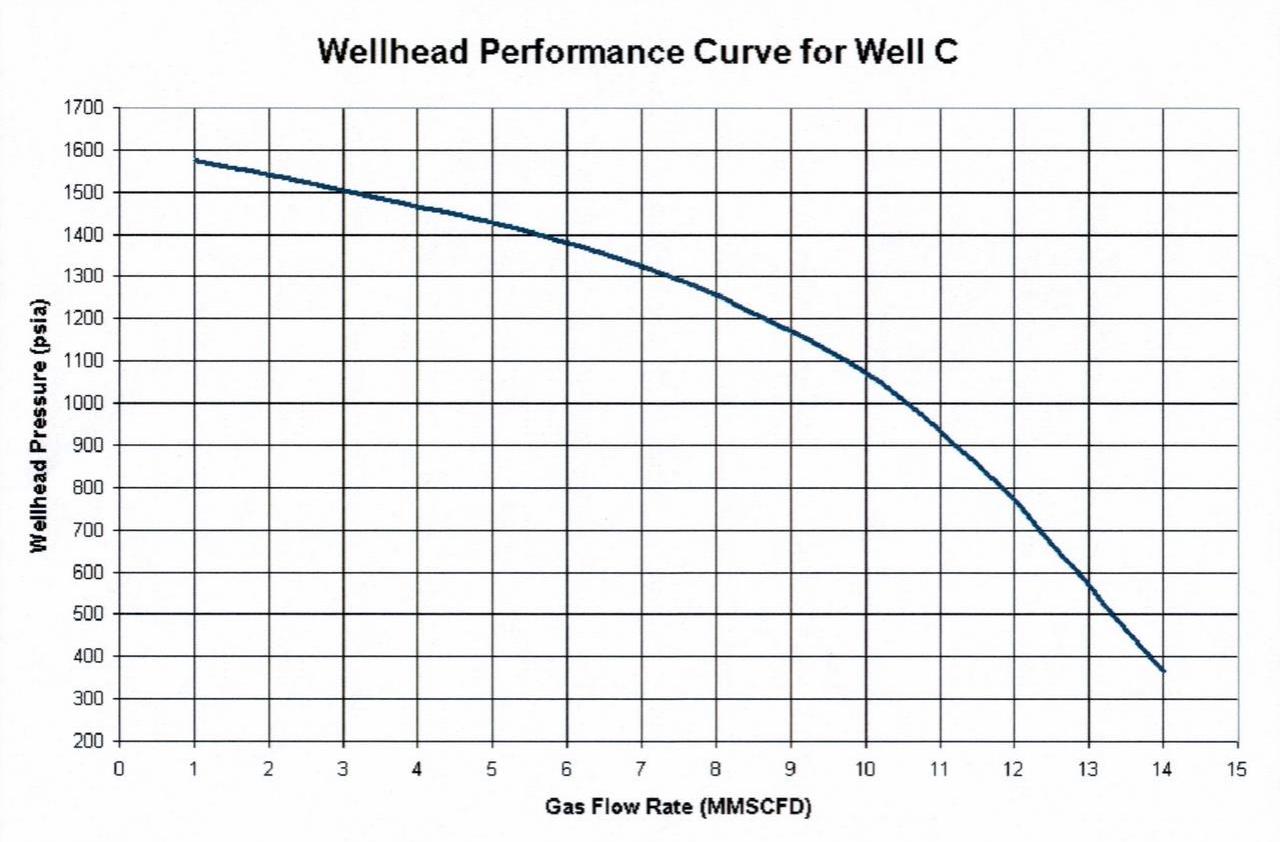
This simulation case is the same as previous case (Case 3 – see paragraph 5) but here the actual flow rates of the three wells are automatically adjusted in order to be on the wellhead delivery curves.

Process feed modules where flow rate and pressure are linked (as in the case of a wellhead delivery curve) are implemented using the Windows Script feature of ProSimPlus.

Following figures show the wellhead performances curves for Well A, Well B and Well C.







6.2. Building the case

Save the previous simulation file to "PSPS_EX_EN - Gas Gathering System4.pmp3" (for instance).

This new simulation case can be easily built by starting from Case 3.

First, the Wellhead Performance Curves are fitted with a polynomial equation where the wellhead flow rate is a function of wellhead pressure.

For Well A, following values are read on the previous curve:

Wellhead Pressure (psia)	Wellhead Flow Rate (MMSCFD)
1550	1
1510	2
1300	6
900	10
700	11
500	12
300	13

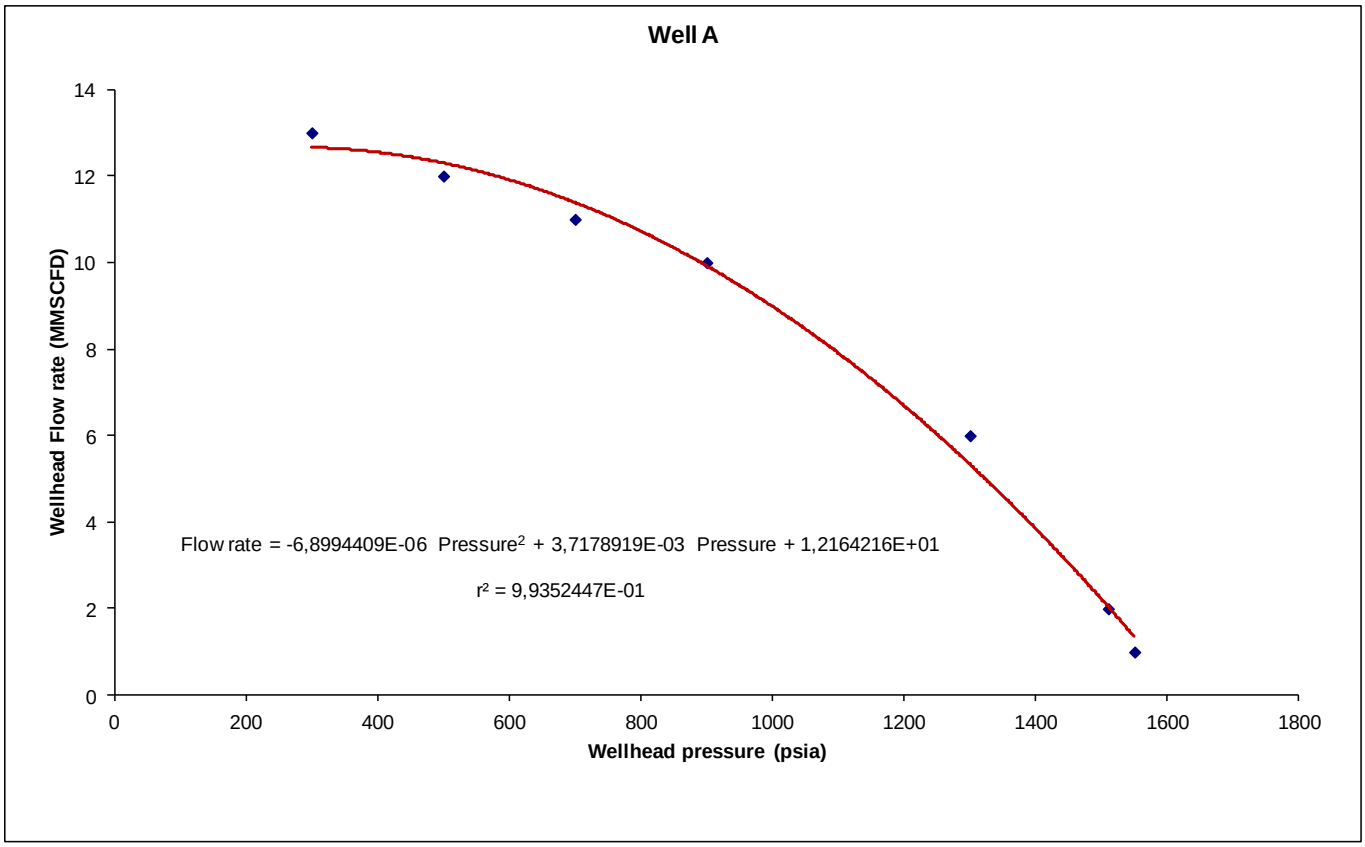
Then these values are regressed by a polynomial equation of order 2 (Microsoft© Excel can be used to do this).

The obtained equation is as follows:

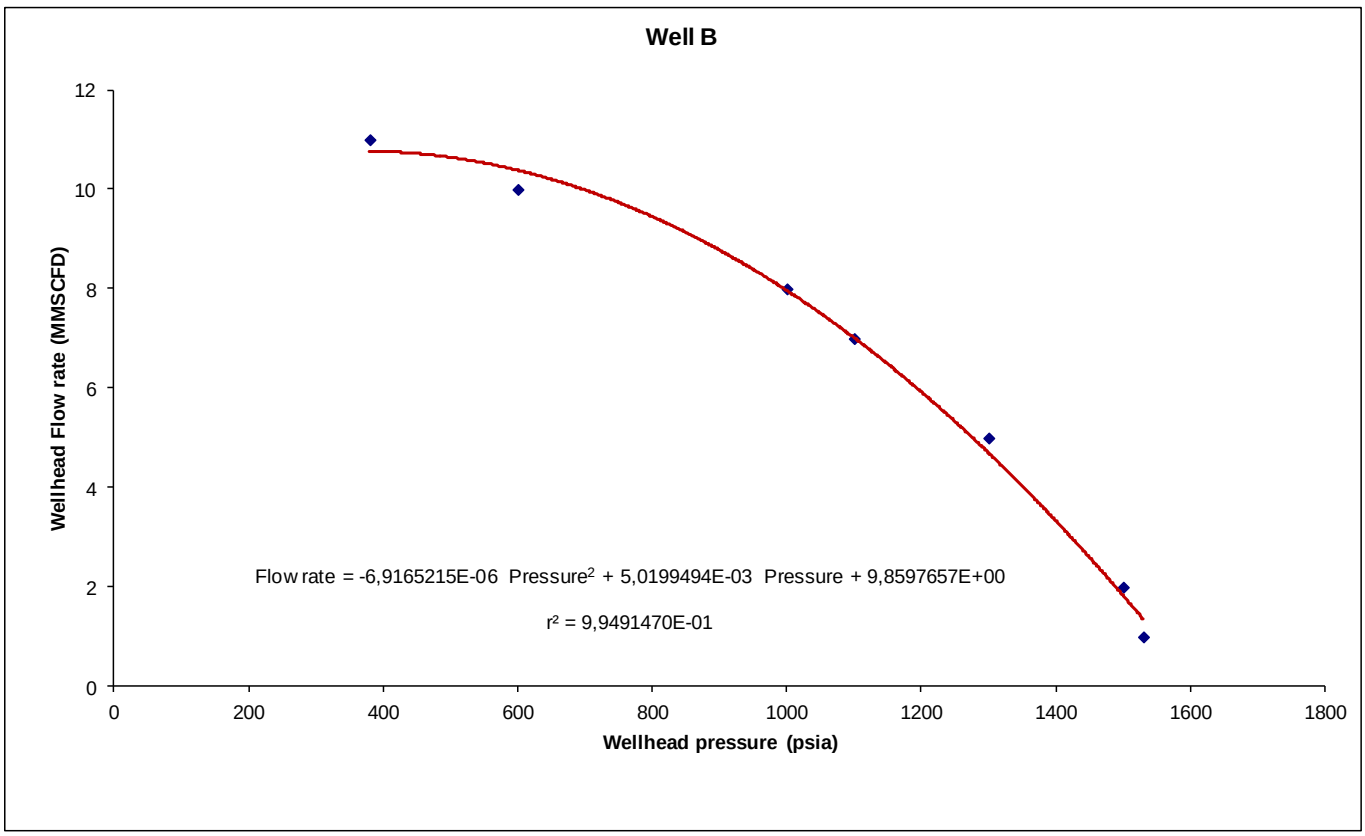
$$\text{Flow Rate} = -6.8994409\ 10^{-6} \cdot (\text{Pressure})^2 + 3.7178919\ 10^{-3} \cdot (\text{Pressure}) + 12.64216$$

With Pressure being in psia and Flow Rate in MMSCFD

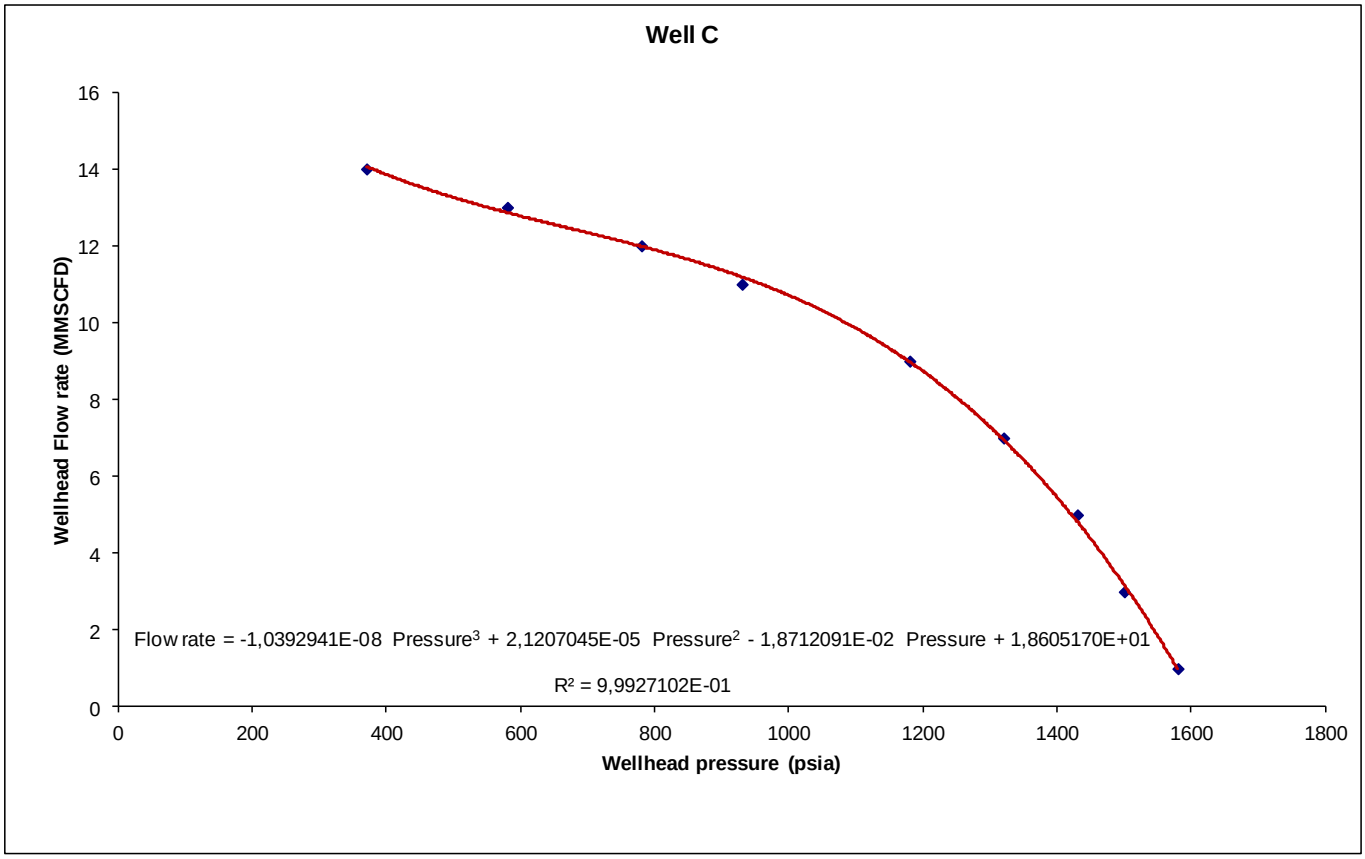
The following figure shows the values read on the curve (blue points) together with a plot of the polynomial fitting equation (red line).



Same is done for Well B:



And also for Well C (where a polynomial function of order 3 is used to better fit the values read on the curve).



Then, at the level of each Well modules (Process feed streams), a script is added to extend the functionality of the standard module in order to link the flow rate to the pressure.

This "scripting" feature makes it possible to quickly and simply add new functions to existing modules (unit operation or other type of modules) in the ProSimPlus simulation environment. Windows Script is described (programmed) directly in the ProSimPlus graphical user interface using a simple but powerful language. This language, Microsoft VBScript, is a simplified version of Microsoft Visual Basic. It allows writing the source code of a module extension in a few minutes. No further compilation is required.

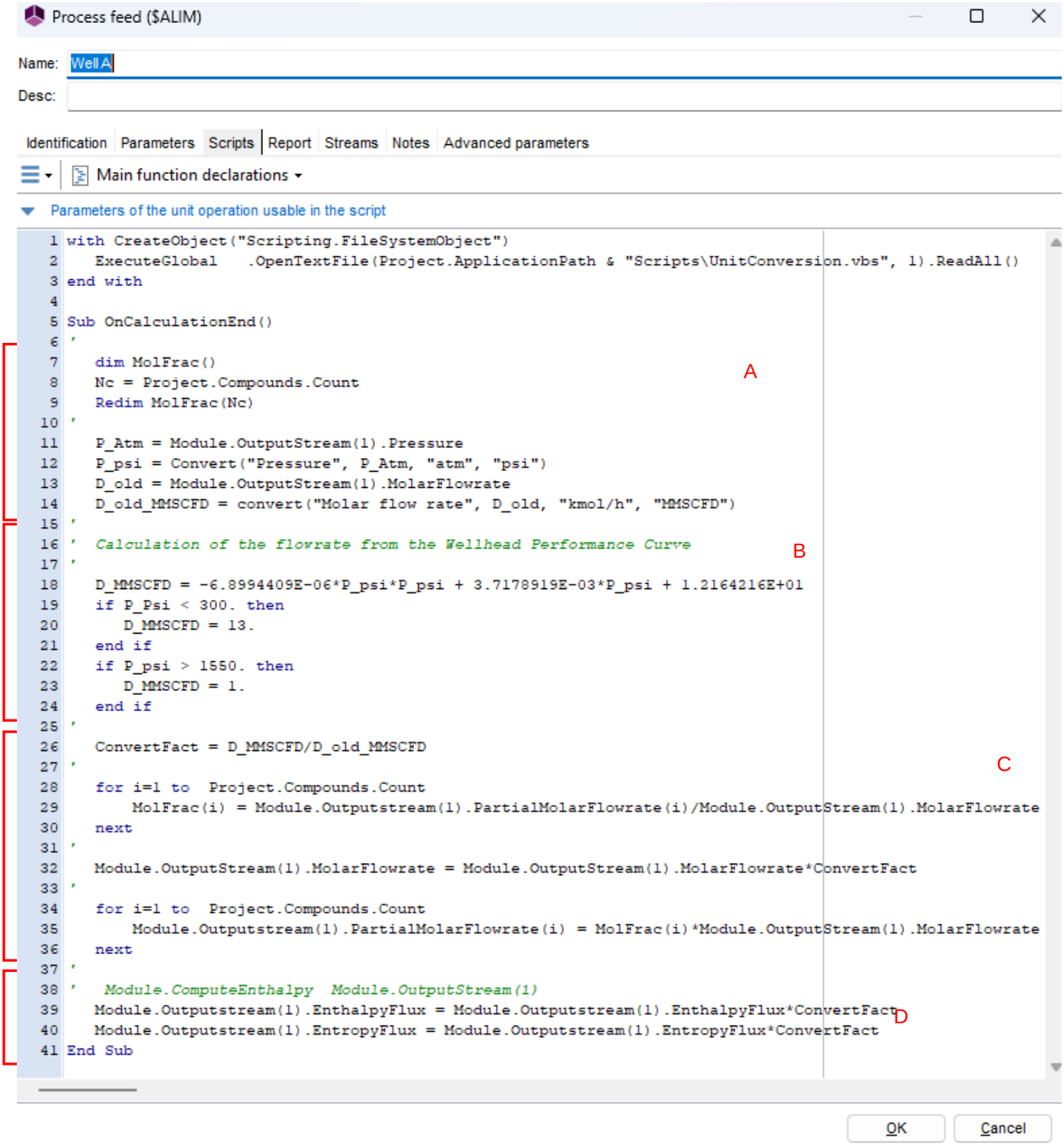
To learn more about scripting feature in ProSimPlus, refer to chapter 4 of ProSimPlus user guide.

For "Well A" module, a code is added to the script window in order to link the well flow rate to the wellhead pressure with the following equation:

$$\text{Flow Rate} = -6.8994409\ 10^{-6} \cdot (\text{Pressure})^2 + 3.7178919\ 10^{-3} \cdot (\text{Pressure}) + 12.64216$$

With Pressure being in psia and Flow Rate in MMSCFD

The VBScript code to be entered in the script window of Well A is relatively simple for people having some knowledge in programming. The code is as follows:



Main parts of this code are as follows:

A – Unit conversions. ProSimPlus predefined functions are used.

B – Calculation of the global flow rate from the pressure given by the "Adjust" module (polynomial equation fitting the wellhead delivery curve.

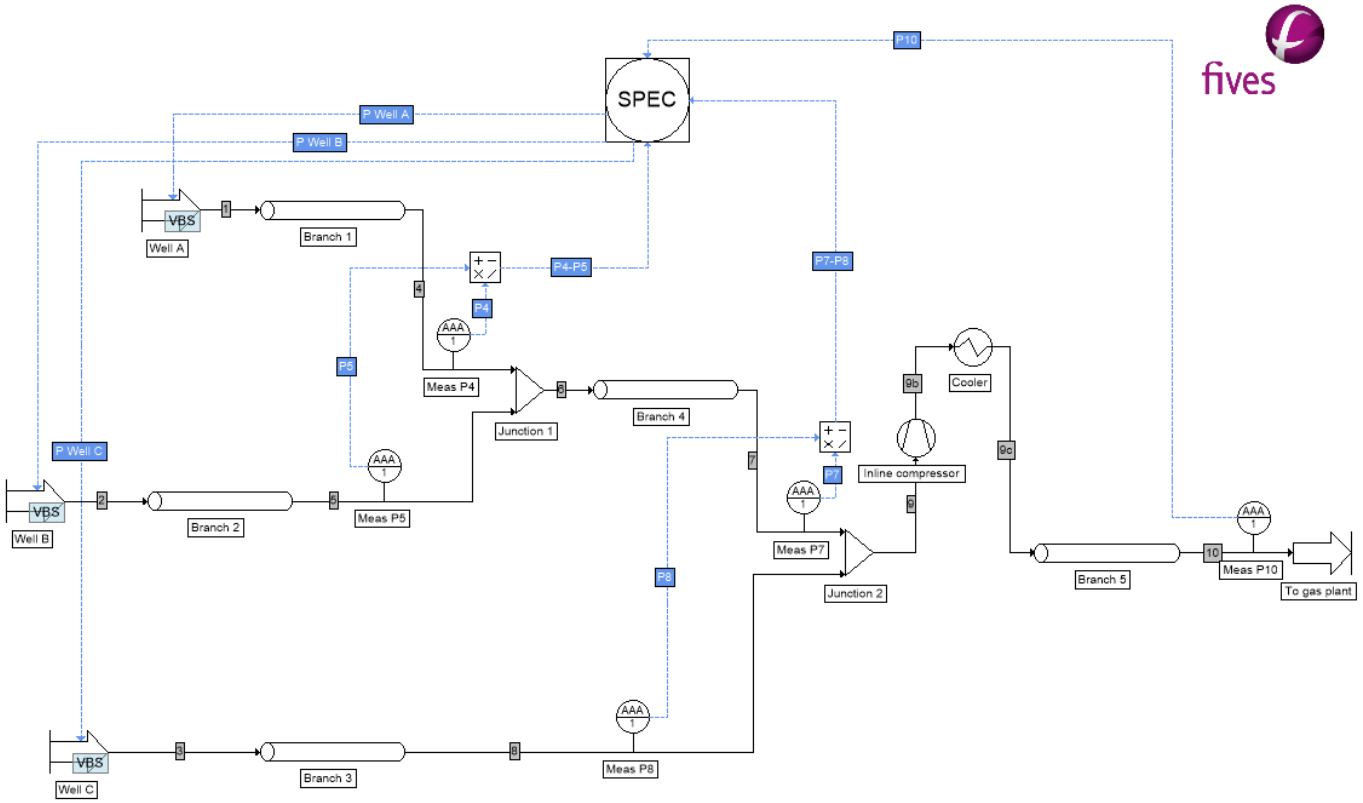
C – Calculation of partial flow rates. These flow rates are required by ProSimPlus. They are calculated from total flow rate and mole fractions (not modified here).

D – Calculation of stream enthalpy and entropy using ProSimPlus thermodynamic functions.

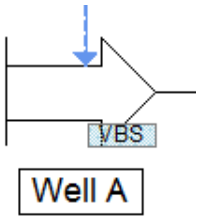
Such scripts are also added to Well B and Well C modules. Script written for Well A is in fact copied to Well B and Well C and only the coefficients of the equation are changed. You can save the script in order to load it in another module using the corresponding buttons at the top of the window:

6.3. Viewing the results

The resulting PFD can be the following one:



With regards to the previous PFD (Case 3), the only visual difference is that icons representing "Well A", "Well B" and "Well C" are somewhat different to show that they have VBScript code added:



Convergence is rapidly reached. We can check that all the constraints are obtained:

- Pressure at gas plant : 1000 psia
- Equilibrium of pressures at "Junction 1"
- Equilibrium of pressures at "Junction 2"

Main results are as follows:

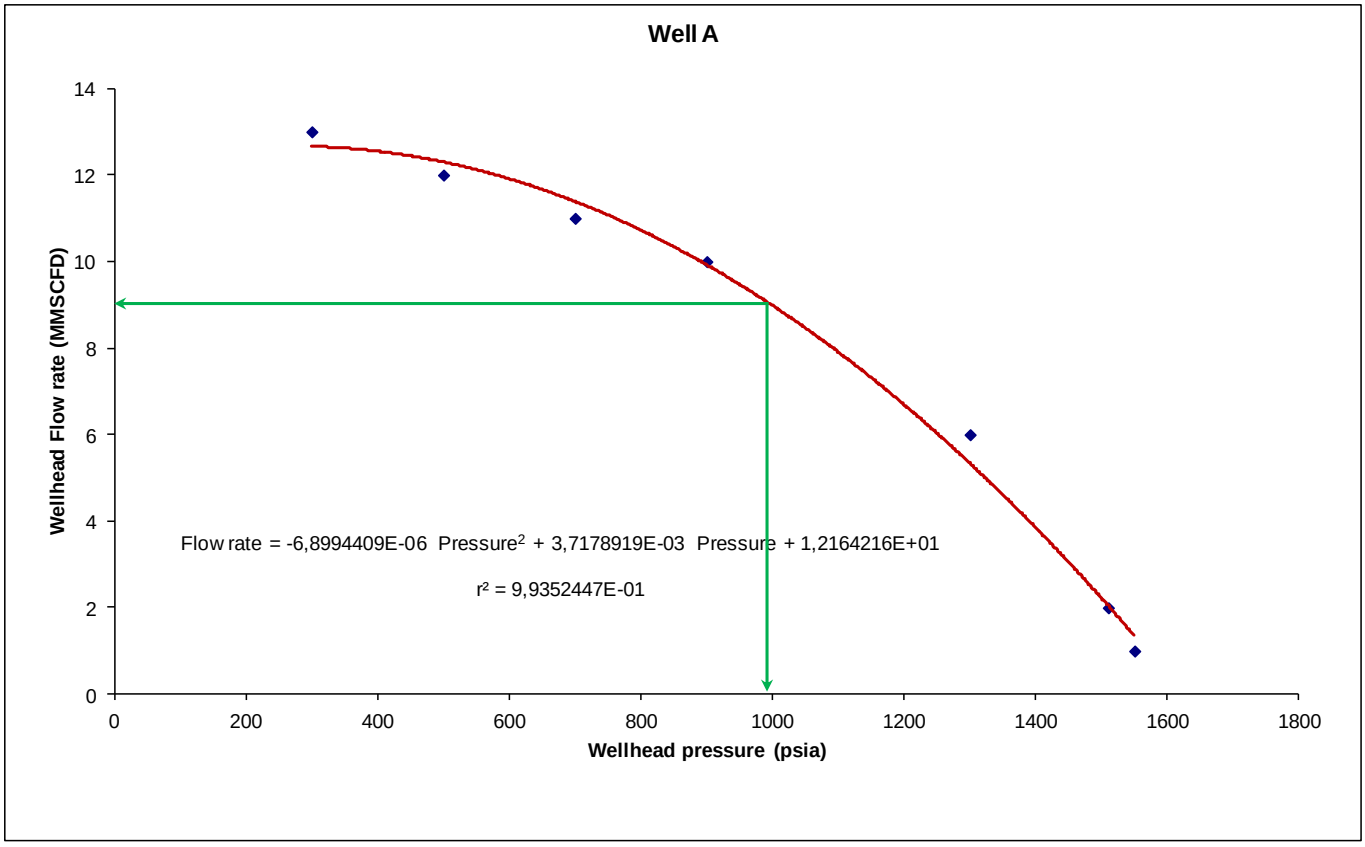
Streams		1	2	3	4	5	6	7	8	9	9b	9c	10
From		Well A	Well B	Well C	Branch 1	Branch 2	Junction 1	Branch 4	Branch 3	Junction 2	Inline compressor	Cooler	Branch 5
Total flow	MMSCFD	9,06	8,28	11,25	9,06	8,28	17,34	17,34	11,25	28,60	28,60	28,60	28,60
Physical state		Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Liq./Vap.	Vapor	Liq./Vap.	Liq./Vap.
Temperature	°F	105,0	115,0	110,0	92,5	103,6	97,8	93,9	101,5	96,9	136,2	100,0	97,7
Pressure	psi	992	963	919	860	860	860	812	812	812	1030	1020	1000
Enthalpic flow	kJ/h	-882 595	-616 036	-891 640	-963 967	-702 818	-1 666 785	-1 697 856	-936 492	-2 634 349	-825 626	-3 169 057	-3 235 807
Vapor molar fraction		0,96422	0,97017	0,96848	0,96024	0,96657	0,96339	0,96269	0,96682	0,96437	1,00000	0,96046	0,95939

At the level of the three wellheads:

Well A	Pressure (psia)	992.2
	Molar flow (MMSCFD)	9.06
Well B	Pressure (psia)	962.7
	Molar flow (MMSCFD)	8.28
Well C	Pressure (psia)	918.9
	Molar flow (MMSCFD)	11.25

We can check that these points are on the curves given in paragraph 6.1.

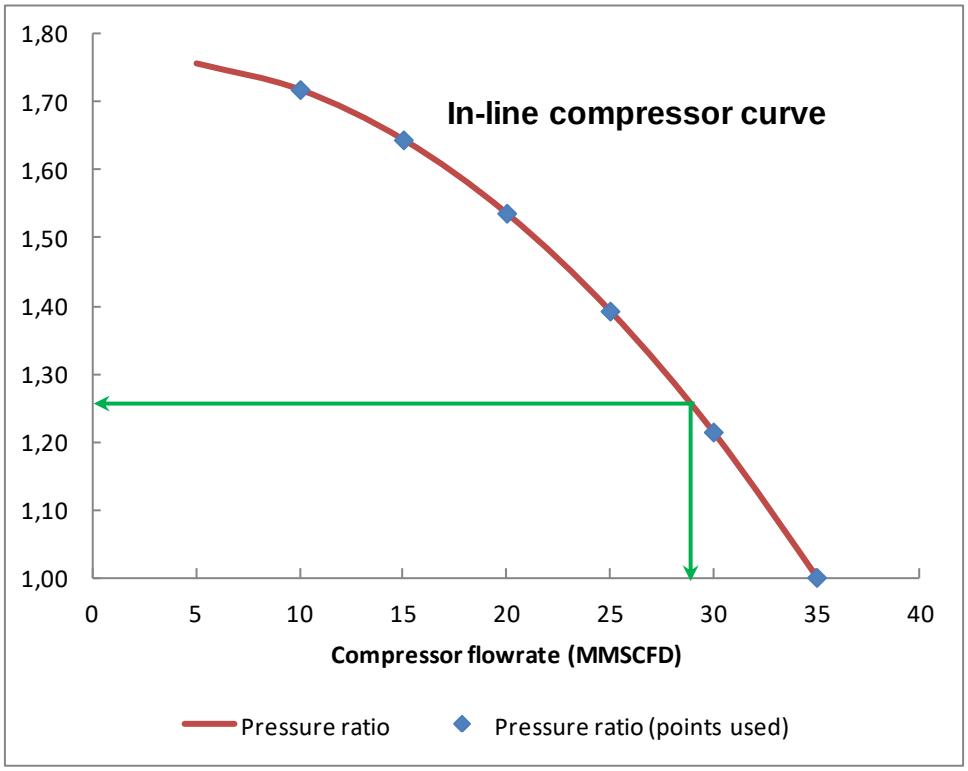
For instance for Well A:



At the level of the inline compressor:

- Power: 709.22 HP
- Exhaust pressure: 1030.1 psia
- Exhaust temperature: 136.2 °F
- Pressure ratio: 1.269
- Molar flow rate: 28.5966 MMSCFD

We can also check that this point is on the compressor manufacturer's curve given in paragraph 5.1.



7. REFERENCES

[1] "PIPESYS™ Tutorials" (Ref PIPESYS1.60-OCT03-O)