Prof. Davide Manca – Politecnico di Milano

Dynamics and Control of Chemical Processes

Solution to Lab #8

Dynamic simulation of a C4-C5 separation column

RUN A DISTILLATION COLUMN USING HYSYS/UNISIM IN DYNAMIC MODE

Data

Fluid package: Peng-Robinson

Feed: composition: 0.5 i-butane, 0.5 n-pentane.

molar flow: 113.4 kmol/h

temperature: 327.3K

pressure: 441 kPa

feed tray: 5

Column type: trays with partial condenser

#stages: 8

Top column pressure: 437 kPa

Bottom column pressure: 444 kPa

<u>Specify:</u>

Molar component fraction: i-butane in the distillate 0.925

n-pentane in the bottom 0.95

Reflux rate: 69 kmol/h

Column Size

Diameter: 0.9144 m

Tray space: 0.6096 m

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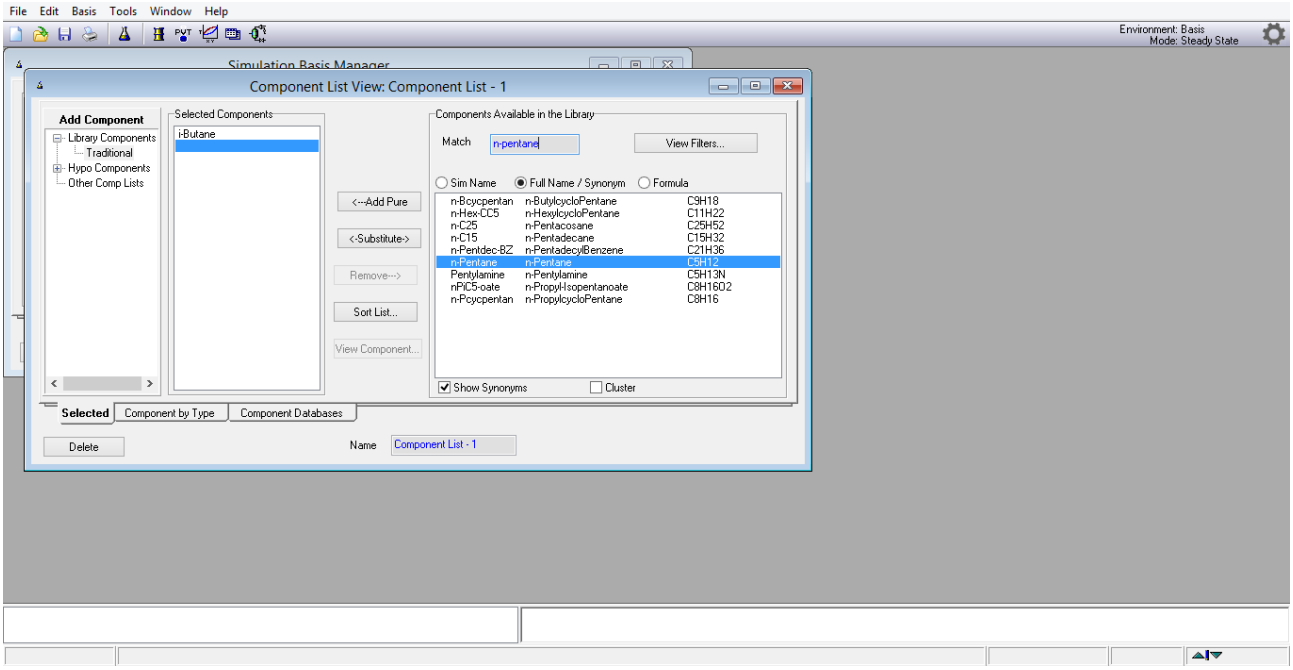
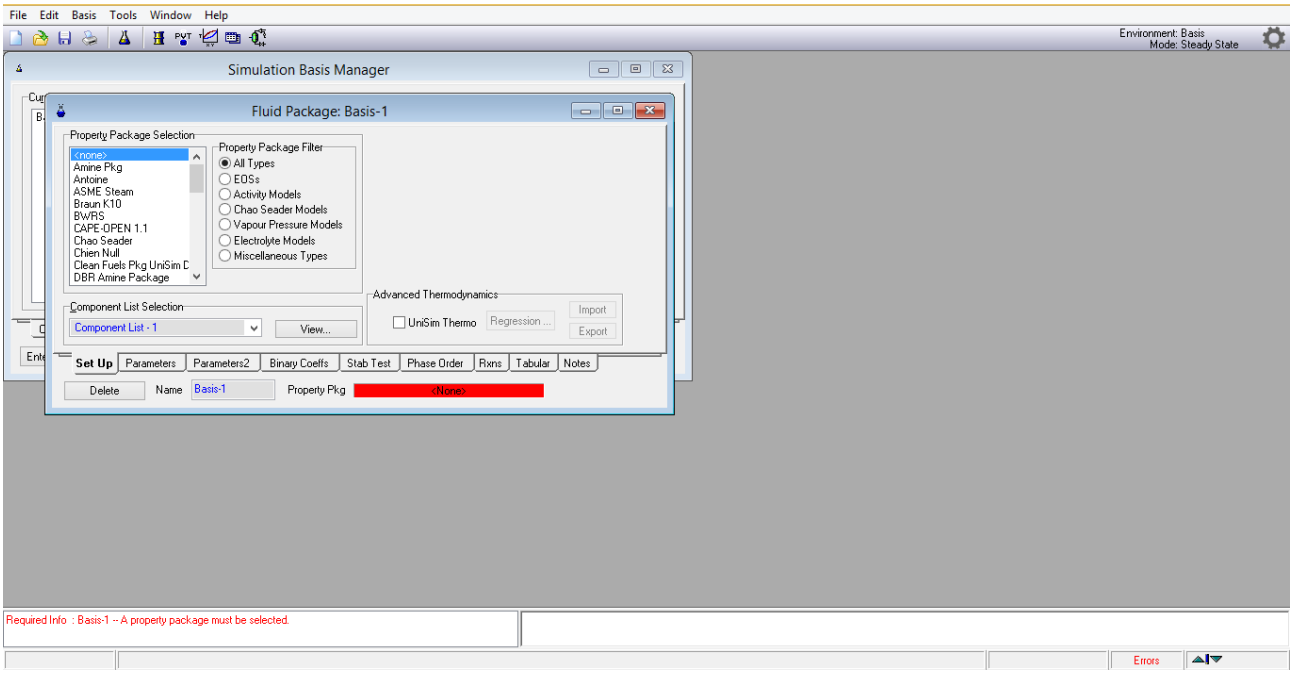
Solution

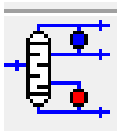
First of all, we have to create the column in steady state.

Create a **new** file, and **add** the components in a new component list



Then choose the fluid package and **enter in the simulation environment**.

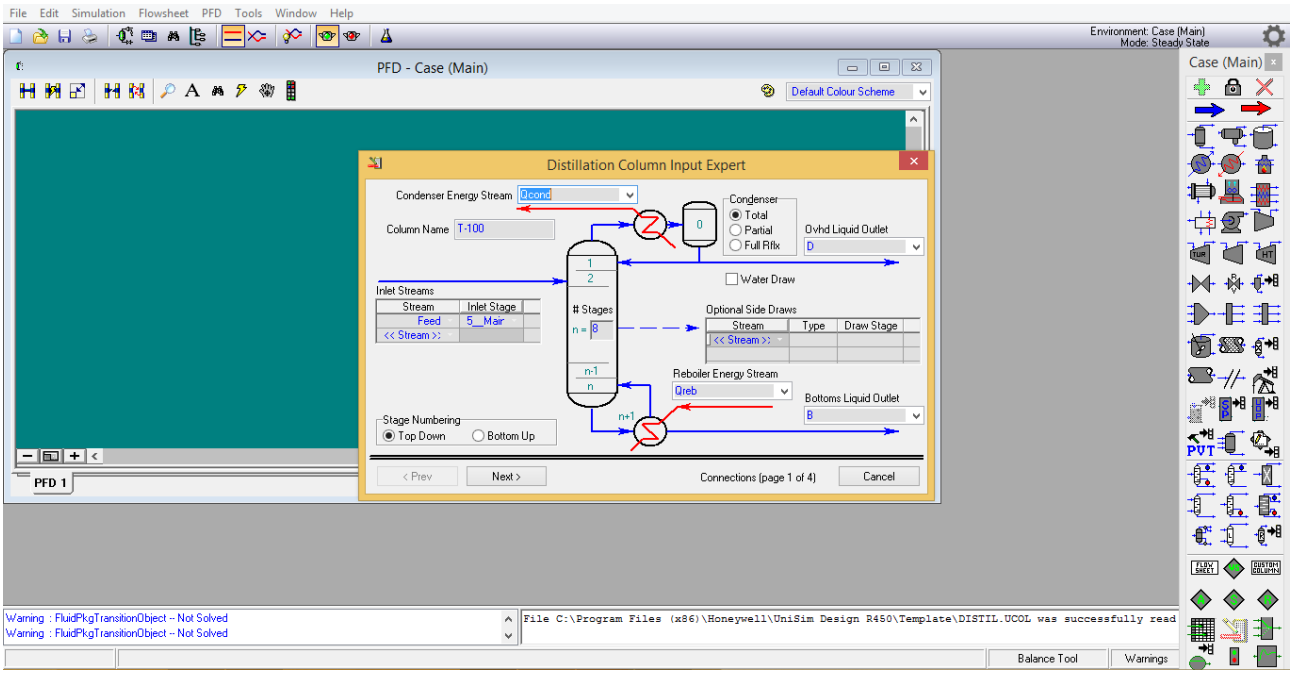


Add the distillation column by choose it in the palette (press **f4** to see it) 

or in the workbook (press **ctrl + W** go on **untit ops** and press **add unitop**, choose distillation).

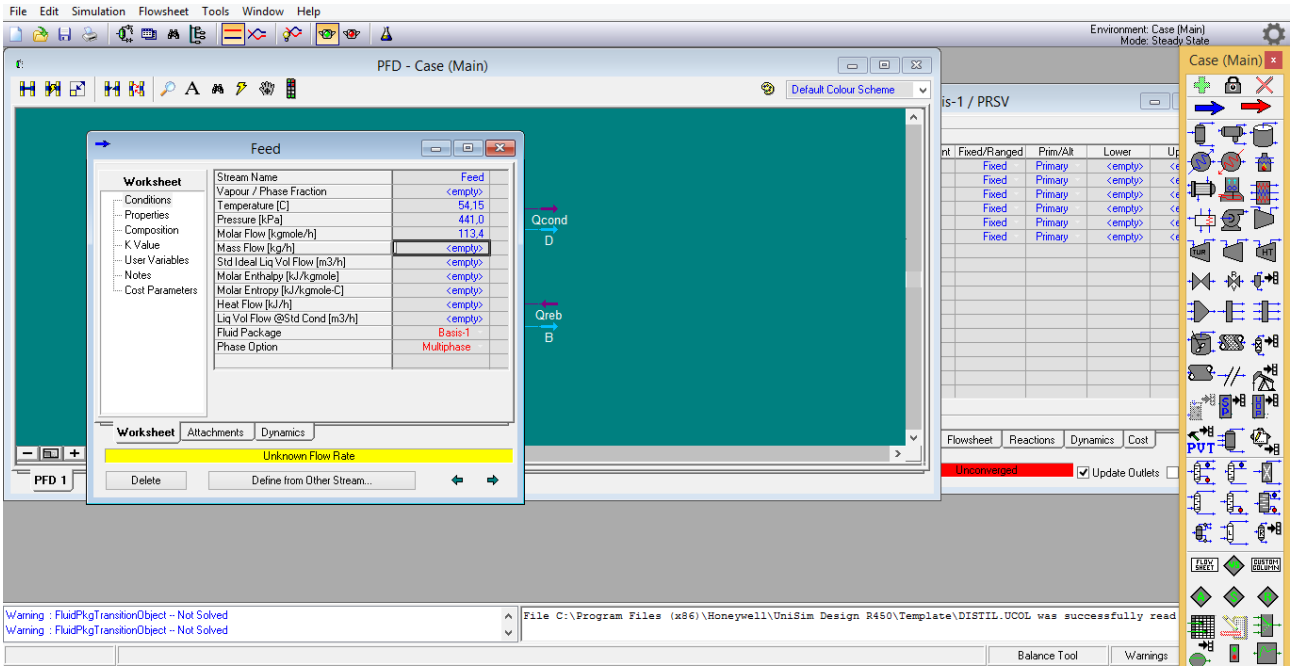
In the distillation column window you can add all the streams, material and heat: feed, distillate, bottom and the heat duty of the reboiler and condenser.

Select the number of the stages and the feed tray. Use a partial condenser. Then press **next**.



Insert the top and the bottom pressure (usually if it is not reported the pressure drop it is about 1kPa/tray) press **next** and then **done**.

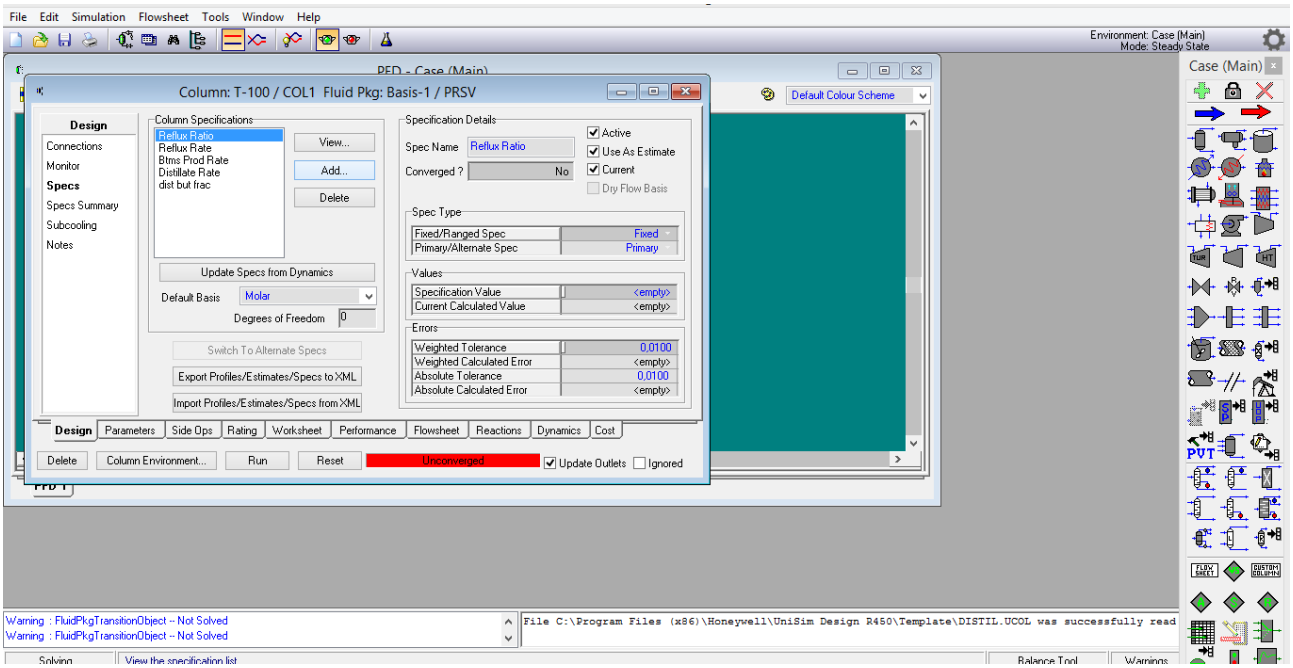
Now we have to change the feed condition (molar flow, temperature, pressure and composition), to do so, go on the feed stream and double click on it, the feed window will open.



Now to solve the distillation column we have to insert the specifications (three if the there is a partial condenser) that can be the molar component fraction of the distillate or in the bottom stream, or the reflux rate, or reflux ratio.

In our case the best solution is to use the molar component fraction in the distillate and in the bottom. (then when we will run the simulation in dynamics mode we can change the reflux rate and all the specifications required to achieve the steady state conditions)

To add a condition, enter in the column window, go on **design, specs** and click on **add**



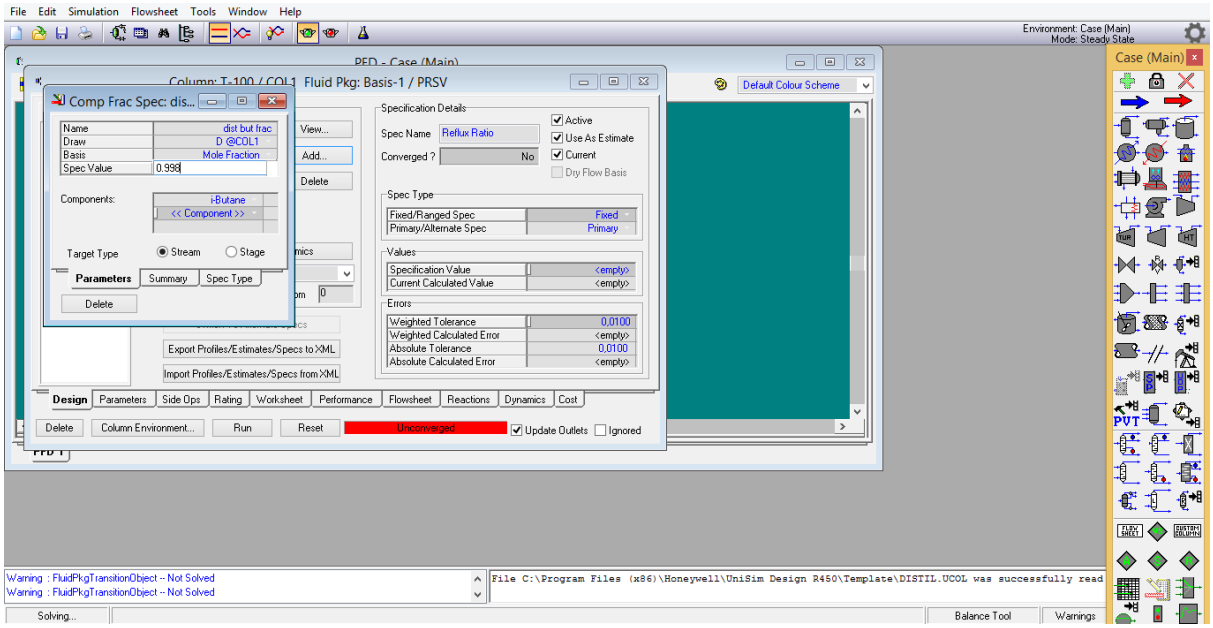
choose **comp frac spec**, it will appear the comp frac spec window, here select and insert:

the target type: **stream**

the component: **i-butane**

the draw: **distillate stream**

the spec value: the composition of the i-butane in the distillate stream.

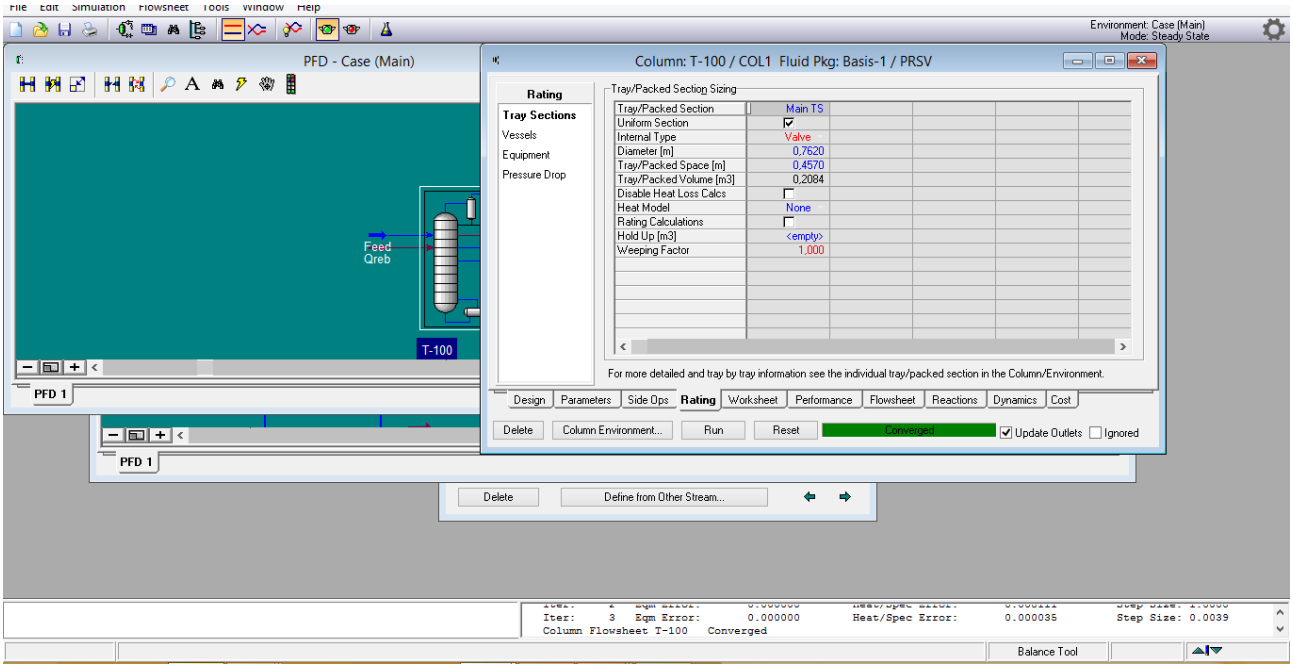


Once you have added it repeat the same things for the other specification.

After that you can run the column (in steady state).

Save your results!

To size the column, go in the column window, **rating** and add the size specifications



If they are not mentioned you can use the Unisim tool: press **ctrl + U**, **tray sizing**

(Remember that once you have found the size with the tool then you will report it in the column environment)

Now before switching to dynamics mode, we have to introduce 3 valves and 1 pump for the reflux.

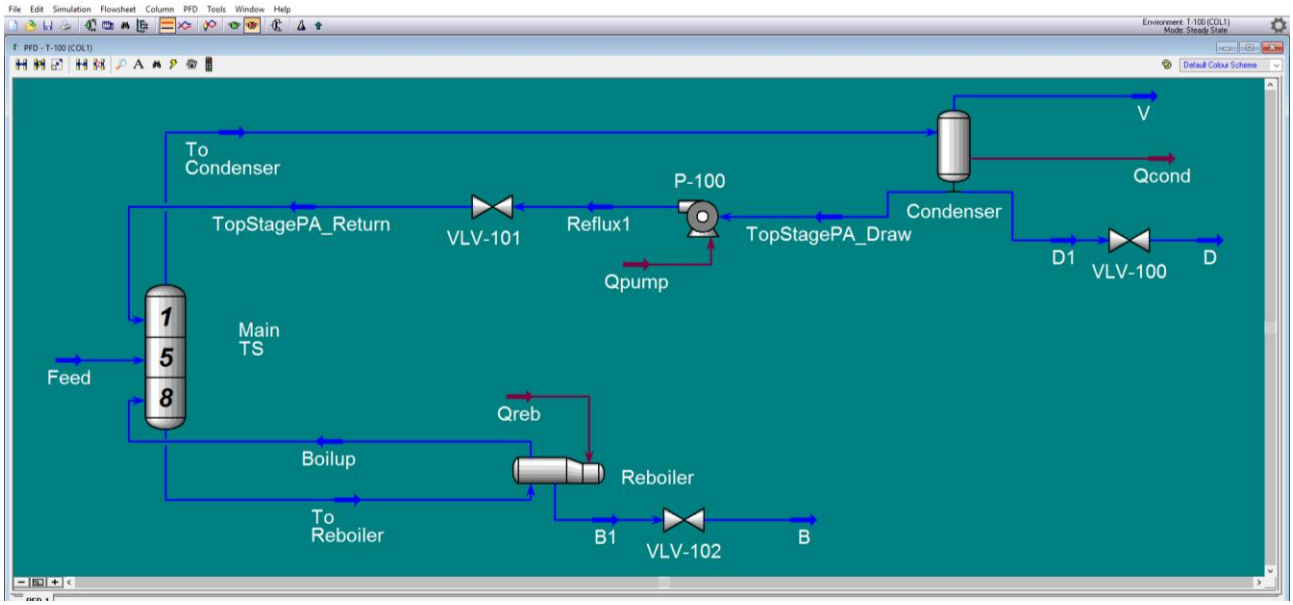
Go on the PFD of the column (press **ctrl + P**) and select the **main**

From the palette (**f4**) insert valves  and the pump 

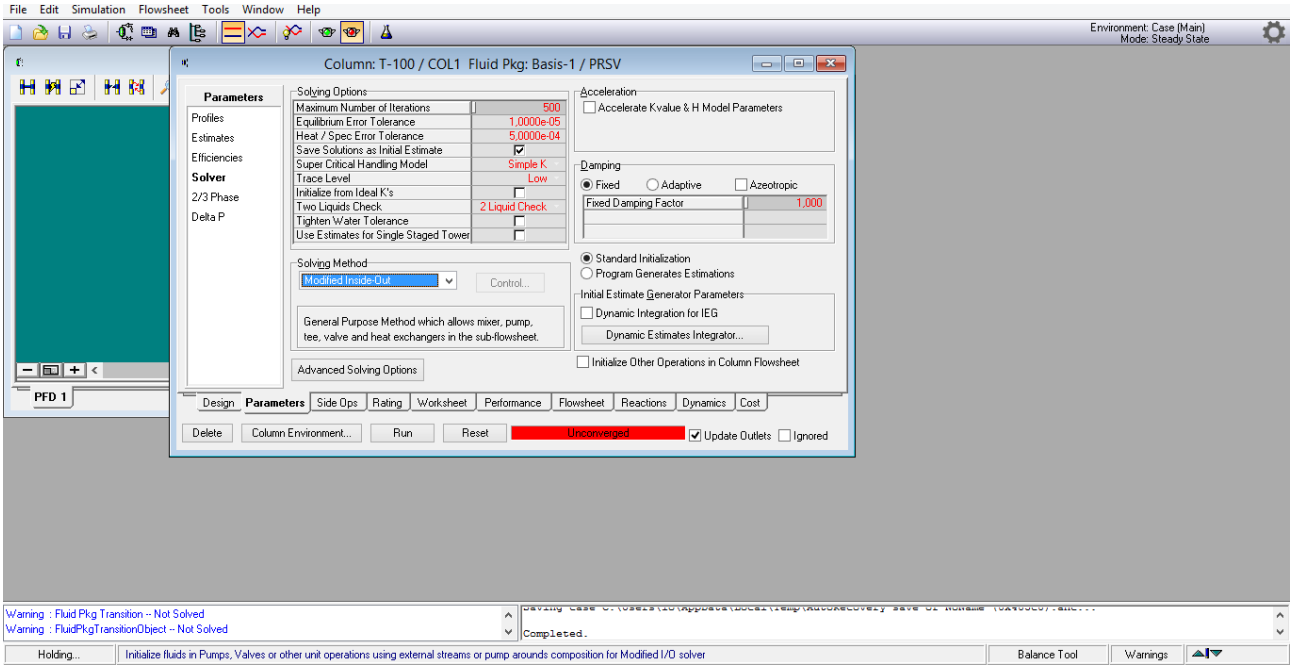
You have to break the connections which come out from the condenser, reboiler and the reflux with 
Connect the streams to the valves and add in the valve window, **parameters**, the pressure drop (usually it's about 2-4 bar). In our case to achieve the atmospheric pressure of the column after the shutdown procedure we put 336 kPa for the distillate valve and 343 kPa for the bottom valve, by doing so the distillate stream and the bottom one come out at 1 atm.

For the pump we have to insert the power (create the red arrow) and introduce a value of 0.559972 kW. For the following valve introduce a pressure drop of 205.8 kPa.

Here it is reported the final column PFD.



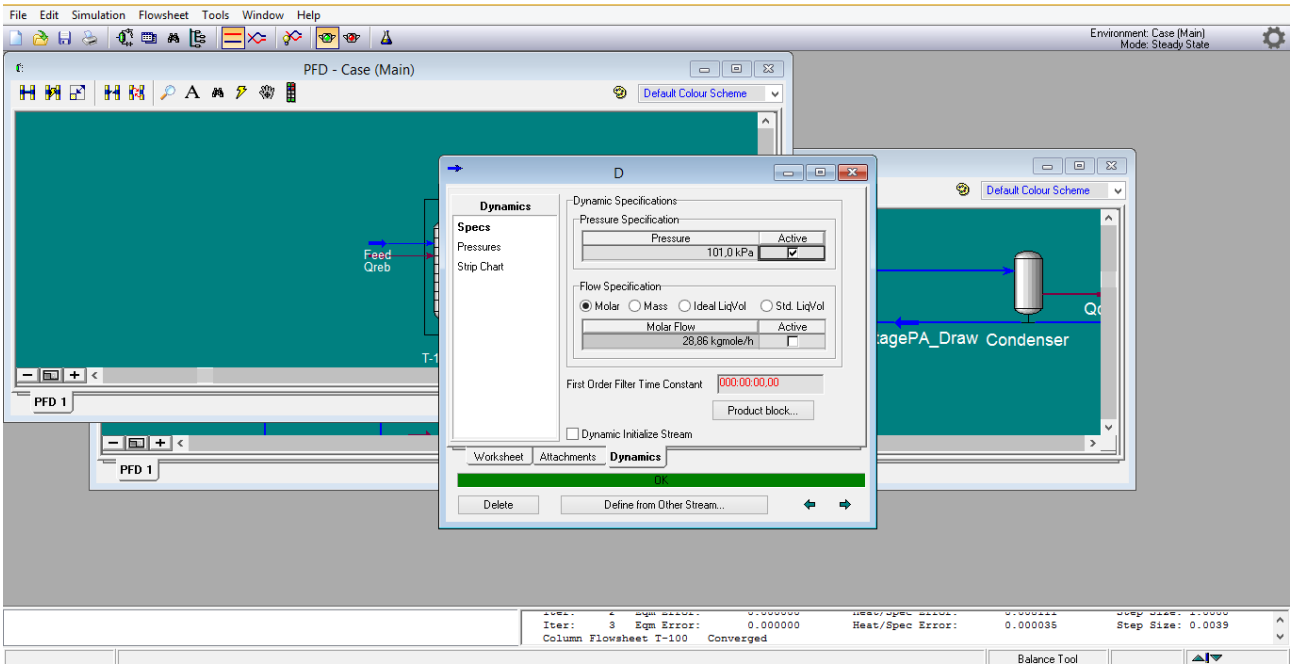
Due to the presence of the pump in the column environment, we might modify the solver of the column in **modified inside out** (**column window, parameters, solver, solving method**)



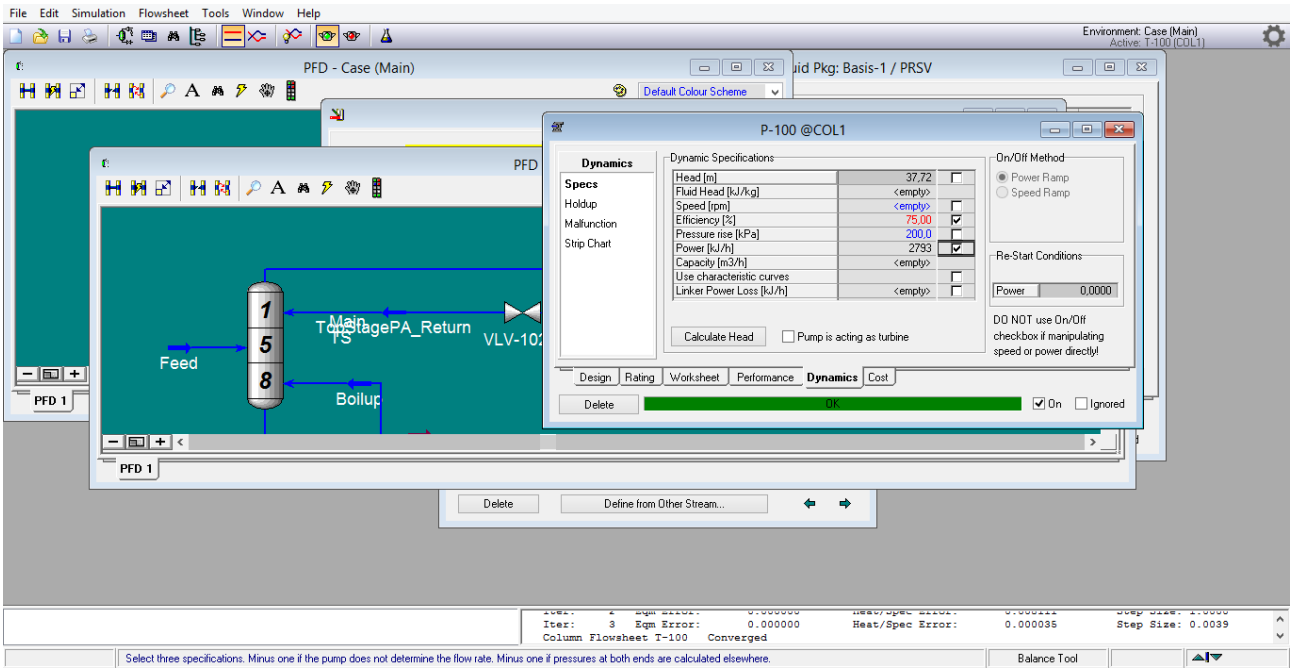
Now you can use the dynamics assistant  to insert the specification on the output and inlet streams, the P-F relation on the valve, and the dynamics specification of the pump; or do it yourself.

So for the dynamics specification of the streams go in their window, **dynamics, specs** and check the pressure for the distillate and the bottom, instead of pressure use the molar flow specification for the feed stream.

The choice of specifications depend on the equipment (you can check them on the documentation of Unisim that reported all the unit operation, usually where there is a valve, the specification is the pressure)



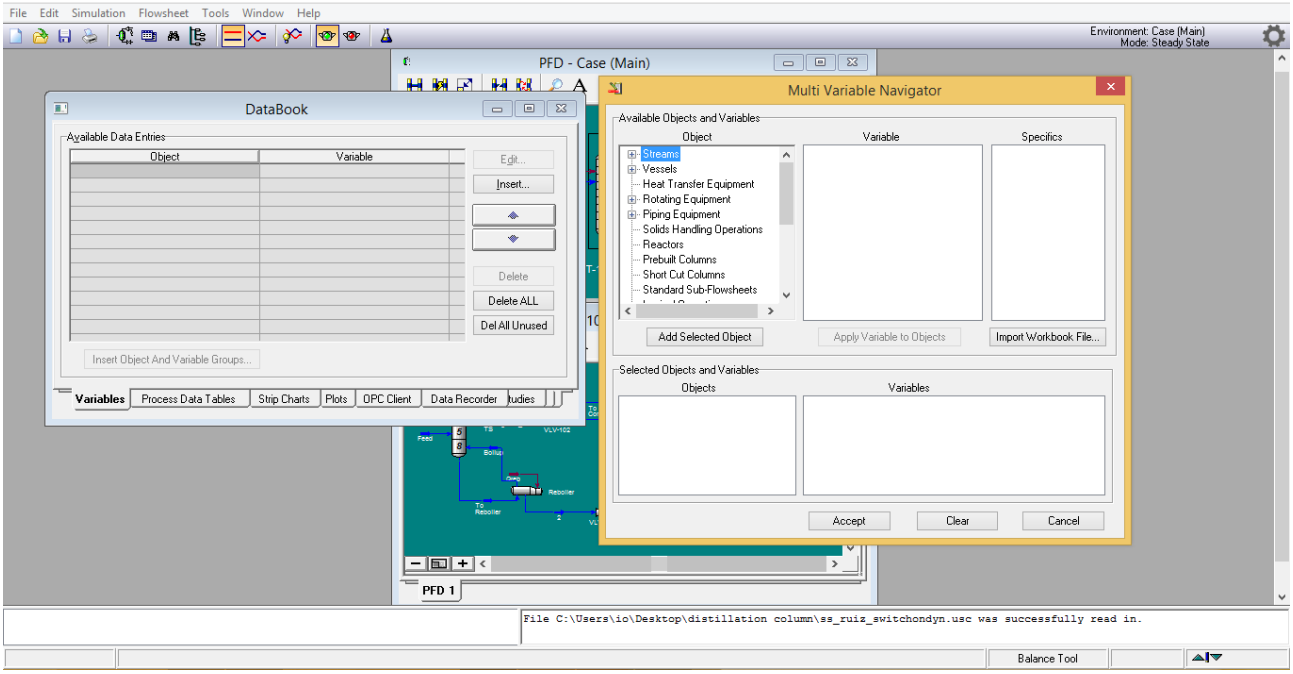
For the pump specification go on his window, **dynamics, specs** uncheck the pressure drop and check the power.



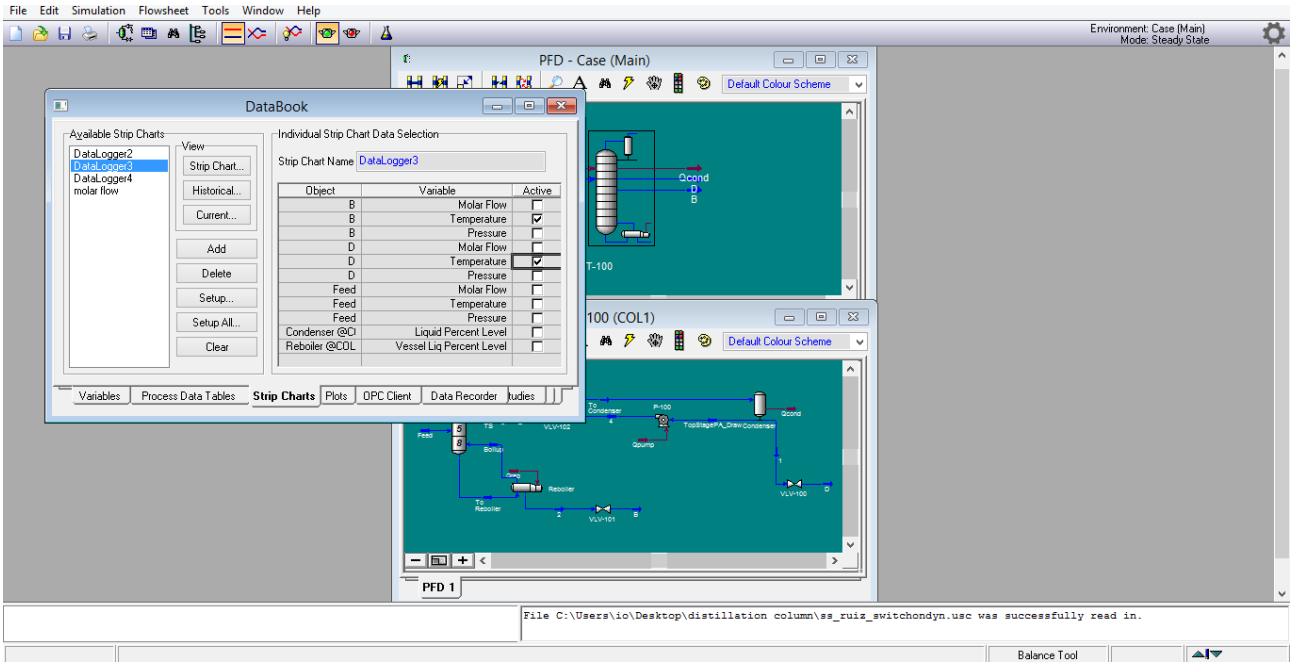
Before switching on dynamics mode it is recommended to open the dynamics assistant and if there any items press on makes change.

Strip charts

To plot a variable in the time domain you can use the strip chart, go on the databook window (press **ctrl + D**), **variables, insert** and then select the variable. If you have to insert more than one variable and different object you can use also the multi variable navigator by pressing the command **insert object and variables group**.

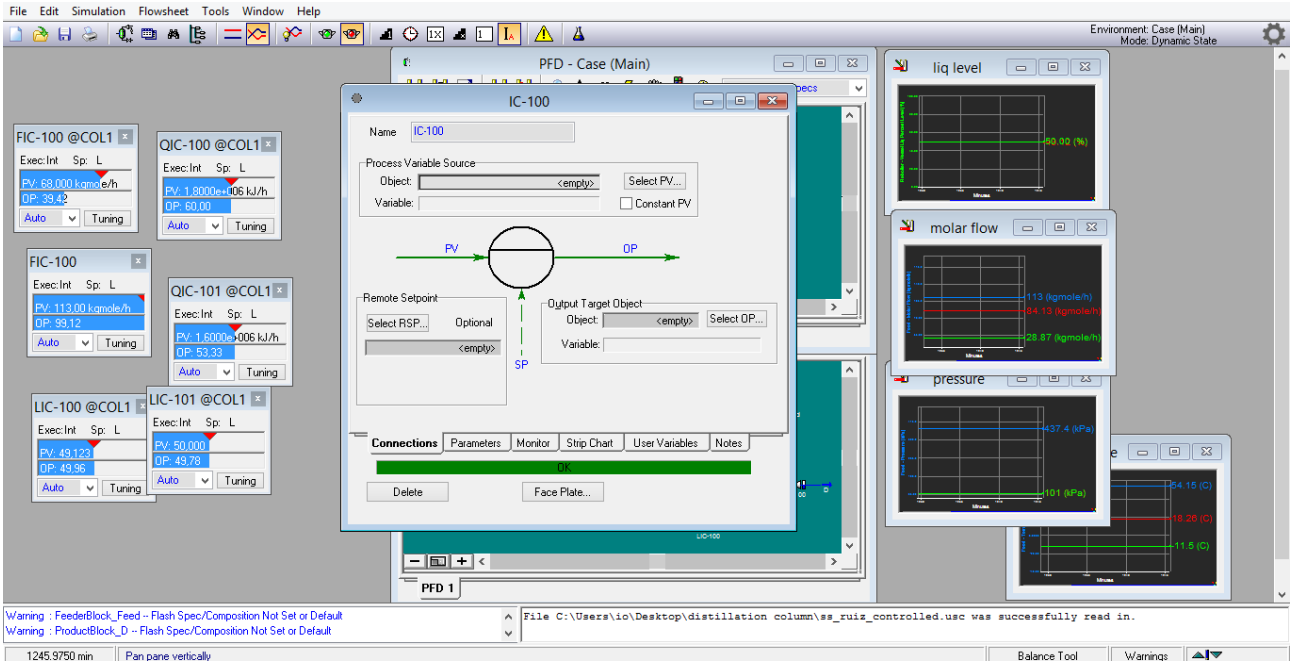


Once you have inserted all the variables go on **strip charts** in the databook window and **add** a datalogger in which you can **check** the variables that you want plot in it, after that you can view it by pressing **strip chart**



Controllers

To insert a controller chose PIC  in the palette (**f4**)



In our case, the 6 controllers are:

FIC-feed: flow rate controller on the column feed

FIC-reflux: flow rate controller on the reflux

QIC-reboiler temperature controller on Qreb

QIC-condenser pressure/temperature controller on Qcond

LIC-reboiler: level control on the reboiler

LIC-condenser: level control on the condenser

Now you have to add the controlled and the manipulated variables, in the controller window, **connections** insert PV and OP; insert the other parameter in the **parameters** page, **configurations**:

	PV		**OP**		**Operational parameters**	**Range**	
Controller	**object**	**variable**	**object**	**variable**	**action**	**PV min**	**PV max**
FIC-feed	Feed	Molar flow	Feed	Flow	reverse	0	150
FIC-reflux	TopStagePA_return	Molar flow	Qpump	Control valve	reverse	0	95
QIC-reboiler	Reboiler	Vessel Temperature	Qreb	Heat flow	reverse	55	75
QIC-condenser	Main Tower	Top Stage Pressure	Qcond	Heat flow	direct	101.3	450

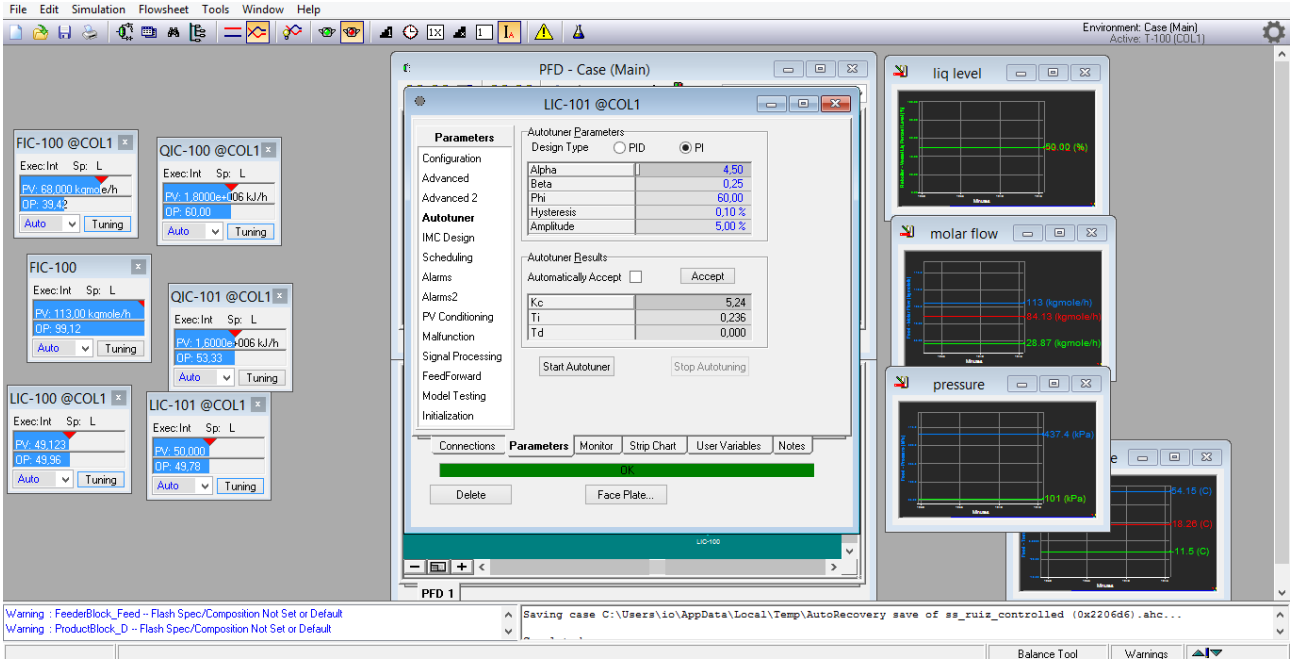
LIC-reboiler	reboiler	Vessel liq percent level	VLV-bottom	Actuator desired position	direct	0	100
LIC-condenser	Condenser	Liquid percent level	VLV-distillate	Actuator desired position	direct	0	100

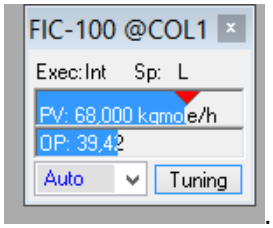
For the Kc Ti Td parameters, you can calculate them yourself or use the autotuner tool.

Autotuner tool

Here we have to switch on dynamics by pressing  (or **f9**). Be sure that the controller you tune is in **auto mode** and all of the rest in manual mode.

Go in the controller **window, parameters, autotuner**, select the design type (PI or PID) press **start autotuner**, and run the simulation (**f9**). The tool will calculate the parameters then you can **accept** them (if the tool doesn't calculate them, maybe there some problem in the PV range, and remember to open the valve at list at 50%).



To have a quick check of the controller you can use the face plate (press the command in the controller window) 

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Integrator

To check and modify the integrator press **ctrl + I,** here you can reset the simulation time, insert the end time simulation and use the real time integrator (simulation time = real time).