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

Specify:

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

==>

<u>Solution</u>

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

	Basis Tools Win				Environment: Basis
🗋 👌 🔒	I 📚 🔺 🗄	P¥T 🖞 🖽 🕂			Environment: Basis Mode: Steady State
		Simulation Basi	Manager		
4		Component	List View: Compo	nent List - 1	
⊕-L ⊕-F	dd Component	Selected Components i-Butane	<add <substitute="" pure=""> Remove> Sort List</add>	Components Available in the Library Match npentane View Filters Sim Name FullyosofoPentane CSH18 nHex CC5 nHexplopelPentane CSH28 nC25 n-Pentadecane C3H28 nC15 n-Pentadecane C3H28 nPentodecane nPentane CSH29 nPentodecane nPentane NPEntodecane CSH29 nPentodecane nPentane NPEntodecane NPEntodecan	
	elected Componer	nt by Type Component Databa		Show Synonyms Cluster	
	Delete		Name Compor	R CBA* 1	
	1				
	ļ				▲

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

File Edit Basis Tools Window Help	
🗅 👌 🗄 😓 📕 🦉 🖞 🧰 🕼	Environment: Basis Mode: Steady State
Simulation Basis Manager Simulation Basis Manager Fluid Package: Basis-1 Foreity Package Election Property Package Filter Annie Filte Property Package Filter Start K10 Byrds Carting Models Dens Seader Models Dens Berter Models Dens Seader Models Dens Berter Models De	Mode: Steedy State
Chao Seader O Electropide Models Dear Fuels Rkg UniSim C Miscellaneous Types Advanced Thermodynamics Component List Selection Component List Selection UniSim Thermo Regression Entropenent List -1 View Delete Name Basis-1 Property Pkg Noxee	
Required Info : Basis-1 A property package must be selected.	
	Errors

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.

File Edit Simulation Flowsheet PFD Tools Window Help		
🗅 👌 🖯 😓 📢 🏛 🛤 🎼 💳 🌫 🌮 👁 🛛	· 🛆	Environment: Case (Main) 📫
¢	PFD - Case (Main)	Case (Main) ×
H M 🗈 H 🕅 🔎 A 🛤 🦻 🏶 🛔	Default Colour Scheme	
		196
	A Distillation Column Input Expert	
	Condenser Energy Stream Condenser	┿┻ <u>⋕</u> ⋳⋬ ኇ Ď
	Column Name T-100 Ovhd Liquid Outlet	22 20 20 20 20
	1 2 Water Draw	
	Inlet Streams	-₩₩₩-
	Feed 5_Mair Stream Type Draw Stage < Stream > <th></th>	
		B S C +
	n-1 Reboiler Energy Stream Qreb Bottoms Liquid Outlet	
	Stage Numbering n+1	8+8 8+8 1 +8
	Top Down Bottom Up	S [™] ∎ Q₁
PFD 1	< Prev Next > Connections (page 1 of 4) Cancel	-0: -0
		£ 0 0*
Warning : FluidPkgTransitionObject Not Solved Warning : FluidPkgTransitionObject Not Solved	<pre>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>></pre>	
waming , malankgi tansilonoojeet ~ Not Solveo	v	Balance Tool Warnings
<u> </u>		

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.

		Tools Window Help	и						F	nvironment: Case	Main)	
🗋 🚵 🖶 😓	0 💭 🗛 📴		<u>A</u>							nvironment: Case Mode: Stead		(Main) ×
	H 🕅 🔎 A		PFD - Case (Main)		9	Default Colour Scheme						limani) A X
пиы	11 14 P A	##\$ / \$#/ II			9			s-1 / PRSV				\rightarrow
						i i i	Ì				-1 0	7 A
	→	Feed					n		'rim/Alt imary	Lower Up	<u>ā</u>	N 🛉
	Worksheet	Stream Name Vapour / Phase Fraction	Feed <empty></empty>					Fixed P	imary imary	<empty> <e <empty> <e< td=""><td>b</td><td></td></e<></empty></e </empty>	b	
	- Conditions Properties	Temperature [C]	54,15	— <u></u> → .				Fixed P	imary	<empty> <e< td=""><td></td><td></td></e<></empty>		
	- Composition	Pressure [kPa] Molar Flow [kgmole/h]	441,0 113,4	Qcond					imary imary	<pre><empty> <e <empty=""> <e <="" pre=""></e></e></empty></pre>	1,4 2	2 🗖
	K Value User Variables	Mass Flow [kg/h] Std Ideal Lig Vol Flow [m3/h]	<pre> <empty> <empty></empty></empty></pre>	5								
	- Notes Cost Parameters	Molar Enthalpy [kJ/kgmole] Molar Entropy [kJ/kgmole-C]	<empty> <empty></empty></empty>								- ₩- +	∲ (i+ #
	Cost i didilicitais	Heat Flow [kJ/h]	<empty></empty>	Qreb								
		Liq Vol Flow @Std Cond [m3/h] Fluid Package	<empty> Basis-1</empty>									<u>ا</u> → →ا− ۲۵۵ م
		Phase Option	Multiphase	5								<u>₩</u> -{§+®
		1									8 7	// 📩
											10 P	***
1	Worksheet Atta	achments Dynamics						Flowsheet Reaction	ns Dynar	nics Cost		(¢
- 🖻 +		Unknown Flow Rate				>						
PFD 1	Delete	Define from Other Stream	+ +				=	Unconverged	v u	pdate Outlets		1-1
											1	66
												(- (+
												¥ 4
				1							♦	\diamond
	TransitionObject Not S TransitionObject Not S		0	File C:\Program Files	(x86)\Honeywell\U	niSim Design R450\Te	mplate	≥\DISTIL.UCOL w	as succe	ssfully read		
-				U				Balan	ce Tool	Warnings	*	Ĩ -

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)

File Edit Simulation	Flowsheet Tools Wind	dow Help					
🗋 👌 🖶 😓 🛛 🚺	🖻 A 🎼 💳 🗢	🔅 🌮 🐨 🖉				Environment: Case (Mode: Stead)	(Main) 📫
	Column: T-100	pr / COL1 Fluid Pkg: 1	ED - Case (Main) Basis-1 / PRSV		🕞 🗉 😒 🗐 Default Colour Scheme 🗸		Case (Main) 🗵
Design	Column Specifications Reflux Ratio	View	Specification Details Spec Name Reflux Ratio	✓ Active			→ → -1 @ =
Monitor Specs	Reflux Rate Btms Prod Rate Distillate Rate dist but frac	Add	Converged ? N	Use As Estimate Current Dry Flow Basis			
Specs Summary Subcooling Notes		Delete	Spec Type Fixed/Ranged Spec Primarv/Alternate Spec	Fixed			₽₽₽₽
	Default Basis Mola		Values Specification Value Current Calculated Value	<empty> <empty></empty></empty>			
	Switch To All Export Profiles/Estin	es of Freedom 0 ternate Specs nates/Specs to XML	Errors Weighted Tolerance Weighted Calculated Error Absolute Tolerance Absolute Calculated Error	0.0100 <empty> 0.0100 <empty></empty></empty>			
Design Parame			_^	mics Cost	¥		
1							
Warning : FluidPkgTransition				:\Program Files (x86)\F	Noneywell\UniSim Design R450\Template\DIS	TIL.UCOL was successfully read	
Warning : FluidPkgTransition	nObject Not Solved		*			Balance Tool Warnings	

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.

D 👌 H & M (B) = M (B) = K (Ma) Environment: Care (Main) Mode: Stepsel State	- Ö
Case (Main)	
Colume: I-100_COLI Fluid Pkg: Basis-1 / PRSV	X
→ Comp Frac Specification Details	
Name datibutino Draw D @CDL Vew Spec Name Relixa Rabio ☑ Juse A Estimate	÷ 🗐 .
Basis Mole Fraction Add Converged ? No 🗹 Current	* 🏦 🛔
	» 🎫 🛛
Components Billutane Poper Jupe Fixed Components Fixed	
Primary/Alternate Spec Primary	1
Target Type OStream OStage mics Value (emoty)	
Parameters Summay Spec Type To Current Calculated Value (empty)	: =
Delete	• → □ → ? ∠*→8
weighted Laiculated Error <empty></empty>	}- § +∎
Export Profiles/Estimates/Specs to XML Absolute Tolerance 0,0100 Absolute Calculated Error https://www.absolute.calculatedError	
Import Profiles/Estimates/Specs from XMU	8 🚺 📲
Design Parameters Side Ops Rating Worksheet Performance Flowsheet Reactions Dynamics Cost	¢,
Leete Column Environment Run Reset Unconverged VUpdate Outlets Ignored	
	_(`+ I
le la constante de la constante 🗰 🔶	
	> 🔷
Warning : FluidFkgTianathonObject - Not Solved Varing : FluidFkgTianathonObject - Not Solved Varing : FluidFkgTianathonObject - Not Solved V	13+
Solving Balance Tool Warnings	

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

					Env	ironment: Case (M Mode: Steady	fain) State
C PFD - Case (Main) H M E H M P A A P W F Feed Greb Fred Fred Fred		Tray/Packed Section Sizing Tray/Packed Section Internal Type Diameter (m) Tray/Packed Space (m) Tray/Packed Sp	sheet Performance Flow	tray/packed section in	the Column/Environment.	mud: Steaty	3(8)2 🤫
	Delete Colum	n Environment Run	Reset	Converged	Update Outlets 🗌 I	gnored	
FD 1	Delete	Define from Other Stream	(
	Iter: Column 1		.000000 Heat/S	Spec Error:	0.000035	Step Size:	
					Balance Tool		▲ ▼

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







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.

File Edit Simulation Flowsheet Col	lumn PFD Tools Window Help		Environment: T-100 (COL1) Mode Steady State
f: PFD - T-100 (COL1)			Mode Steady State
HHE HH PA .	n P 🕸 📕		🕲 Default Colour Scheme 🔍
	To Condenser	P-100	Qcond
	TopStagePA_Return	VLV-101 Reflux1 Conde Opump	D1 VLV-100 D
Feed	1 Main 5 TS 8	Qreb	
	Boilup	Reboiler	
	To Reboiler	B1 VLV-102 B	

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)**

File Edit Simulation Flowsheet Tools Window Help		
	Environment: Case Mode: Stead	Main) State
t: Column: T-100 / CQL1 Fluid Pkg: Basis-1 / PRSV		
H-H H H-H H H-H		
Solver Trace Level Low 2/3 Phase Involate from Ideal K's Evel Fixed O Adaptive Azeotopic 1/3 Phase Two Ligads Check 2 Ligads Check Evel Fixed O adaptive Image: Azeotopic Delta P Use Estimates for Single Staged Tower Image: Azeotopic Image: Azeotopic Image: Azeotopic		
Solving Method Solving Method		
Advanced Solving Options		
PFD 1 Design Parameters Side Ops Rating Worksheet Performance Flowsheet Reactions Dynamics Cost		
Delete Column Environment Run Reset Unconverged I by Update Outlets Ignored		
Warning : Fuid Pkg Transition Not Solved Varning : Fuid Pkg Transition Object Not Solved V Completed.		\$
Holding Initialize fluids in Pumps, Valves or other unit operations using external streams or pump arounds composition for Modified I/O solver Balance Tool	Warnings	▲.▼

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)

File Edit Simulation Flowsheet Tools Window Help		
🗋 👌 🕼 🖏 🕼 🛤 🎼 💳 🏷 🛷 👁 👗		Environment: Case (Main) 🔅 🏠
C: PFD - Case (Main) H H IM P A P W III	Default Colour Scheme	
Feed Greb T PFD 1 PFD 1	Dynamics Dynamic Specifications Pressures Ship Chart Finst Order Filter Time Constant Opynamic Initialize Stream Worksheet Attachments Dynamics	itaul Colour Scheme
	Delete Define from Other Stream	
		0.000035 Step Size: 0.0039
		Balance Tool

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

File Edit Simulation	Flowsheet Tools Window Help				
🗋 👌 🖯 😓 🕘	i∎ # [5 <mark>=</mark> ≫ ở ∞ 4			Environment: Case (M Active: T-100 (0	ain) 🔅
¢:	PFD - Case (Main)		■ 🖾 µid Pkg: Basis-1 / PRSV		
ниви	🕅 🔎 А м ۶ 🕸 🛔	🇐 🛛 Default Colour Sche	eme 🗸		
	<u>ک</u> ا	X	P-100 @COL1		
	₩ 2 ₩ ₩ 2 A # 2 % Feed 5 8 Bollup	PFD Dynamics Dep Specs Holdup Holdup Specification (Specification) (Specification) (Strip Chart Department of the specification) (Strip Chart Department of the	37,72 cempby 75,00 [RPa] 200,0 //li> 2733 //li> cempby resplay resplay cempby resplay resplay cempby resplay resplay cempby resplay resplay <t< th=""><th>On/Off Method Onewar Ramp Speed Ramp Re-Stat Conditions Power 0.0000 D0 NoT use 0n/Off checkbox if manipulating speed or power directly On □ Ignored</th><th></th></t<>	On/Off Method Onewar Ramp Speed Ramp Re-Stat Conditions Power 0.0000 D0 NoT use 0n/Off checkbox if manipulating speed or power directly On □ Ignored	
				>	
P	FD 1				
	Dele	e Define from Other Stream	(
		Iter: 3 Eqm Error: Column Flowsheet T-100 Conv	0.000000 Heat/Spec Error: /erged	0.000035 Step Size:	
	Select three specifications. Minus one if the pump does not determine the flow rate. M	nus one if pressures at both ends are calculated el	sewhere.	Balance Tool	▲.▼

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**.

🖶 😓 📢 🎟 🛤 隆 💳 📯 🔗 🐵 👁	<u>A</u>			Environment: Case (Mode: Steady	(ain)
	PFD - Case (Main)		23	Mode: Steady	State
		Multi Vari	iable Navigator	×	
DataBook	Available -	Objects and Variables			
Agailable Data Entries		Object	Variable	Specifics	
Object Variable Insert Object And Variable Groups Variables Process Data Tables Strip Charts Plots DF		ele I Transfer Equipment g Equipment g Equipment Handling Operations ctors uit Columns dard Sub-Flowsheets	ply Variable to Objects Im Variables	port Workbook File	
		Ac	cept Clear	Cancel	
			cept Clear	Cancel	
	- D + <				

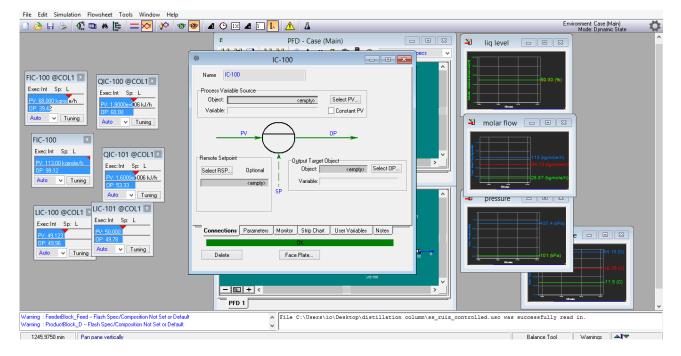
Once you have inserted all the variables go on **strip charts** in the databook window and **add** a datalogger in which you can **check** the variables that you want plot in it, after that you can view it by pressing **strip chart**

			ť						ase (Main) 🤹 🤹
				PFD - Case (Main)		- 0 X			
			нияны	L 🔎 A 🛤 🦻 🏶	🖁 🧐 Del	ault Colour Scheme			
	Da	itaBook			u	^	1		
Available Strip Charts	 View Stip Chat Historical Current Add Delete Setup Setup All Clear 	Individual Strip Chart D Strip Chart Name Det Dipect B B D D D Peed Feed Feed Condenser @CI Reboiler @COL trip Charts Plots OP	bata Selection aLogger/3 Variable A Molar Flow Temperature Pressure Molar Flow Temperature Molar Flow Temperature Ctient Data Recorder Nuclei Ctient Cate Conternation Ctient Cate Conternation Ctie		TopStageP/A_Draw	ault Colour Scheme			
			F	ile C:\Users\io\Deskto	pp/distilla	tion column\ss_rui	z_switcehondyn.use	was successfully read in.	

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	ОР		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.

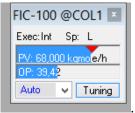
Autotuner tool

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%).

File Edit Simulation Flowsheet Lools Window Help		
🗋 👌 🔒 🖉 🕮 🛎 隆 💳 🔀 🔅 👁 👁 .	4 🕂 🖂 🖬 🚹 🔺	Environment: Case (Main) Active: T-100 (COL1)
FIC-100 @COL1 Image: Color of the section of the s	C PFD - Case (Main) Image: Configuration Image: Configuration Advanced 2 Autotuner Baselits Alarms2 Autotuner Baselits Matunction Start Autotuner Signal Phocessing Start Autotuner Face Flate Start Autotuner Delete Face Plate Delete Face Plate	
Warning : ProductBlock_D Flash Spec/Composition Not Set or Default	<u>v</u>],	¥
		Balance Tool Warnings

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



window)

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).

