# **PROCESS SIMULATOR**

# (UniSim ® Design Suite by Honeywell Process Solutions)

Process simulation is the use of a computer program to quantitatively model the characteristic equations of a process flow sheet by employing:

- Mass and energy balance.
- Equilibrium relationships.
- Rate correlations (reactions and mass/ heat transfer)

#### To determine

- Stream flow rate, compositions and properties
- Operating conditions
- Equipment configurations
- Steady state process simulation
- Rigorous petroleum simulation
- Petroleum / crude oil handling
- Data regression, data fit and optimization

Some transient models are used to:

- Improve current processes
- Answering "What If" scenarios
- Determine optimal process conditions within given constraints
- Assisting in locating constraining parts of a process (de-bottlenecking)

UniSim <sup>®</sup> Design Suite (by Honeywell Process Solutions) provides the user with an intuitive and interactive approach toward process modelling, simulation and optimization. The software enables you to create detailed high fidelity plant simulations for analyzing and optimizing your plant's operation. Through the completely interactive UniSim Design interface, you have access to a series of equipment geometry, performance details and the ability to customize your simulation using its OLE extensive capability.

At any time, you can access the help information by pressing F1 on your keyboard. You can also look at the entire help structure by clicking the UniSim Help Topics command on the Help menu. In the following case study, UniSim ® Heat Exchangers, part of UniSim ® Design Suite version R440 are loaded onto the computer; UniSim ® Shell and Tube Exchanger Modeler is used to check whether a given exchanger will achieve the required duty for the specified inlet and outlet conditions, giving the ratio of the actual to required surface area; it determines whether a specified exchanger has adequate surface area to meet a duty you specify. The Modeler also calculates the stream pressure drops of the Hot and Cold streams.

# A Case Study – Heat Exchanger Rating (Checking)

A kerosene stream with a flow rate of 45,000 lb/h is to be cooled from 390°F to 250°F by heat exchange with 150,000 lb/h of crude oil at 100°F. A maximum pressure drop of 15 psi has been specified for each stream. Prior experience with this particular crude oil indicates that it exhibits significant fouling tendencies, and a fouling factor of 0.003 h.ft<sup>2</sup>°F/Btu is recommended. Physical properties of the two streams are provided in the table below. Design a shell and tube heat exchanger for this service.

Fluid property	Kerosene	Crude Oil
C <sub>p</sub> , Btu/lb <sub>m</sub> . <sup>o</sup> F	0.59	0.49
k, Btu/h.ft.°F	0.079	0.077
μ, lb <sub>m</sub> /ft.h	0.97	8.7
Specific gravity	0.785	0.85
Pr	7.24	55.36

Table 1. Criteria for fluid Placement, in order of Priority

Tube side fluid	Shell side fluid
Corrosive fluid	Condensing vapour (unless corrosion)
Cooling water	Fluid with large $\Delta T$ (> 100°F)
Fouling fluid	
Less viscous fluid	
Higher pressure stream	
Hotter fluid	

## Solution

#### 1. Fluid placement

Kerosene is not corrosive, but crude oil may be as it depends on salt and sulfur contents and temperature. At the low temperature of the crude oil stream in this application, corrosion should not be a problem provided the crude oil has been desalted (if necessary). However, the crude oil should be placed in the tubes due to its relatively high fouling tendency as indicated in Table 1. Also, the kerosene should be placed in the shell due to its large  $\Delta T$  of  $140^{\circ}F$ .

#### 2. Shell and head types

The recommended fouling factor for kerosene is 0.001 - 0.003 h. ft<sup>2</sup>. °F /Btu indicating a significant fouling potential. Therefore, a floating head exchanger is selected to permit mechanical cleaning of the exterior tube surfaces. Also, the floating tubesheet will allow for differential thermal expansion due to the large temperature difference between the two streams. Therefore a type AES exchanger is specified.

#### 3. Tubing

Following the design guidelines for a fouling crude oil service, 1 in. 14 BWG tubes are selected with a length of 14ft.

#### 4. Tube Layout

Since cleaning of the tube exterior surfaces will be required, square pitch is specified to provide cleaning lanes through the tube bundle. Following the design guidelines, for 1in. tubes a tube pitch of 1.25 in. is specified.

## 5. Baffles

Segmental baffles with a 20% cut are required by the Simplified Delaware method. A baffle spacing of 0.3 shell diameters is chosen i.e.  $B_s/D_s = 0.3$ 

## 6. Sealing strips

One pair of sealing strips per 10 tube rows is specified in accordance with the requirements of the Simplified Delaware method and the design guidelines.

#### 7. Construction materials

Since neither fluid is corrosive, plain carbon steel is specified for tubes, shell and other components.

# Solution:

UniSim <sup>®</sup> Shell- Tube Exchanger Modeler (UniSim <sup>®</sup> STE) can be employed to determine 1 - 4 calculation types, namely:

Calculation Types	
1. Design	For cost or area optimized thermal design to the specified process conditions and geometrical constraints; for designing a heat exchanger to meet a heat load duty and pressure drop limits, which is specified
2. Checking (Rating)	To check whether a given exchanger will achieve the required duty for the specified inlet and outlet conditions, giving the ratio of the actual to required surface area; it determines whether a specified exchanger has adequate surface area to meet a given duty. It, furthermore, calculates the streams' pressure drops.
3. Simulation	To calculate the outlet conditions and performance of a given exchanger from the specified inlet conditions; It determines the heat load, pressure changes and stream outlet conditions that will occur with a specified exchanger, with given stream inlet conditions.
4. Thermosyphon	To calculate the performance of a vertical or horizontal thermosyphon reboiler, the circulation rate, and the pipework pressure drops; It determines the flow rate and duty of a specified exchanger, operating as a thermosyphon. The liquid height in the column and the pipework connecting the exchanger to the column are specified.
5. Geometry	It allows specifying and refinement of the geometry of an exchanger, including a detailed tube layout, without any need to specify information on the streams in the exchanger.

In this case study, option 2 is used to determine the heat exchanger duty and the streams pressure drops. After installation of UniSim Design R443 software on the computer, a new case is begun by clicking the Windows icon at the left side on the computer. *All programs* appear and by scrolling, the *Honeywell* folder appears. A click on this folder shows a list of design suites folders, namely:

- 1. UniSim Design Suite R440
- 2. UniSim Design Suite R443
- 3. UniSim Heat Exchangers R440
- 4. UniSim Tools

Clicking item 3 from the above shows the following:

- 1. Documentation
- 2. Installation and Licensing Guide
- 3. Release Notes

Name			Model
4.	UniSim <sup>®</sup> Shell and Tube	UniSim ® STE	Shell and Tube heat exchangers
	Exchanger Modeler		
5.	UniSim ® Cross Flow	UniSim ® CFE	Air coolers and other crossflow
	Exchanger Modeler		exchangers
6.	UniSim <sup>®</sup> Plate – Fin	UniSim ® PFE	Plate – fin heat exchangers
	Exchanger Modeler		
7.	UniSim ® Fired Process	UniSim ® FPH	Furnaces and fired heaters
	Heater Modeler		
8.	UniSim ® Plate Heat	UniSim ® PHE	Plate heat exchangers
	Exchanger Modeler		
9.	UniSim ® Feedwater Heat	UniSim ® FWH	Feedwater heat exchanger
	Exchanger Modeler		
10	. UniSim ® Process Pipeline	UniSim ® PPL	Process Pipeline heat exchanger
	Heat Exchanger Modeler		

Click item 4 of UniSim ® STE R440 icon loads the main UniSim ® STE window and over this is the **Welcome** view as shown in Figure 2. From this view, one can select to create a **New** file or open an **Existing** file. To start a new case simulation, click the **New** button as shown in Figure 2, and Figure 3 appears for the start of inputting the data.

Alternatively, item 4 of UniSim ® STE R440 icon can be loaded on the desktop, and double clicking on it shows Figure 3 to start inputting the data.

In this example, heat exchanger E-100 is imported from the PFD of UniSim Design R443 Simulation Environment as shown in Figure 1.



Figure 1. Screen shot of the crude distillation unit with heat exchanger E-100 as the basis for rating/checking design calculations from the PFD in the Simulation Environment (Source: UniSim Design R443, Courtesy of Honeywell Process Solutions, All rights reserved).



Figure 2. UniSim ® STE windows (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

Click on **Input** menu shows Figures 3, which give access to all the input data. The menu itself is divided into the different types of data required to describe the heat exchanger and the conditions under which it will operate. These include the different aspects of geometry, process conditions and physical properties.

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Figure 3. Screen shot of UniSim Shell – Tube Exchanger Modeler (UniSim STE) (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).



Figure 4. Screen shot of Input Data (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

Select the **Exchanger Geometry** input form (Figure 5) and one sees the inputs, which give the basic exchanger shell and head types using the TEMA designations. This screen is typical of most screens in that the data are entered either in a text box or via a drop-down menu. The drop-down menu shows a list of possible inputs where one selects the appropriate item.

Note: If at any point, you are not sure what input you want or something is not clear, press  $\langle F1 \rangle$  and get context sensitive help. If you select the rear head type and press  $\langle F1 \rangle$  you can see a listing of all the available rear head types.

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Figure 5. Screen shot of Exchanger Geometry – Exchanger General (Source: UniSim Shell – Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).



Figure 6. Screen shot of Exchanger Geometry – Exchanger Details (Source: UniSim Shell – Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).



Figure 7. Screen shot of Exchanger Geometry – Design Details (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).



Figure 8. Screen shot of Exchanger Geometry – Material Properties (Source: UniSim Shell – Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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Figure 9. Screen shot of Tubes and Baffles – Tube Details (Source: UniSim Shell – Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).



Figure 10. Screen shot of Tubes and Baffles – Transverse Baffles (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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Figure 11. Screen shot of Tubes and Baffles – Special Baffles / Supports (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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Figure 12. Screen shot of Input Bundle layout – Bundle Details (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).



Figure 13. Screen shot of Output Bundle layout – Bundle Details (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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Figure 14. Screen shot of Bundle layout – Bundle Details (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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Figure 15. Screen shot of Bundle layout – Bundle Size (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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Figure 16. Screen shot of Nozzles – Shell side (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).



Figure 17. Screen shot of Nozzles – Tube side (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

Selecting **Process** from the Input menu or by clicking on the **Process Data** button shows Figure 18. This figure shows another form of input screen where the input items are arranged in a spreadsheet format. If the data do not fit on the screen, a scroll bar allows you to access the other input items. The spreadsheet view is used when data are required several times, in this case for the two streams in the exchanger. Note the left-hand column is for the hot stream, and the right-hand column is for the cold stream.



Figure 18. Screen shot of Process – Process (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

Finally, select **Input** from the **Physical Property Data** menu or by clicking on the **Physical Property Data** button.

The initial screen (Figures 19 and 20) shows the top-level information about each stream. Depending on the type of the physical property data you are working with, you can either enter the physical property data for the stream directly or enter data for components and allow UniSim ® STE to perform vapor – liquid equilibrium and mixture calculations. All the physical property data are managed through these screens. In this example, the components (light) and pseudocomponents of crude oil are created from the UniSim Design R443 and imported onto the shell and tube heat exchanger modeler (UniSim Design ® STE) as shown in Figure 19.



Figure 19. Screen shot of Physical Properties: Crude oil (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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Figure 20. Screen shot of Physical Properties: Kerosene (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

Run UniSim ® STE by carrying out one of the following:

- Click on the Run button in the Toolbar.
- Select the Run menu and then Calculate All
- Press <F4>

UniSim ® STE now displays a status window that reports progress of the run.

Part way through the run, a tube bundle layout diagram will appear (Figure 21). This gives you the opportunity to modify the tube layout if you wish. Also, Figure 22 is displayed, which shows the **Results Summary** illustrating that it is a **Checking** case. When the run completes, there are three possible outcomes and corresponding outputs will be displayed:

- Successful run with no fatal errors and no warnings a screen showing the **Results Summary** is displayed.
- Successful run with no fatal errors but with one or more warnings the **Results Summary** is displayed together with a list of the warnings associated with the run
- Failed run due to fatal errors the **Error Log** is shown with a description of the errors that have occurred.



Figure 21. Bundle Tube Layout (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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Figure 22. Screen shot of Results Summary (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

There are many different outputs that can be viewed from the **Output** menu as illustrated in Figure 23. The results can be printed or viewed from **Output** menu and among the various results are the following (Figures 24 - 27):

Thermal Results Summary Full Results TEMA Spec. sheet Setting Plan Tube Layout Line Printer, etc.



Figure 23. Screen shot of Output menu (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

tudy-1 - Crude Oil-akc -rev	LSTEL (E-100 : Case Study - Heat Exchanger Rating by A. K. Coker) - UniSim STE R440 - (UHX Data Bro	wser]					
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	18: 202 1 2041.46 0 0 0 19: 204 198.889 121.11 3, 44739 1.0342143.52228-04 20: 201 7800 8 21: 202 2 6038.87 0 0 22: 204 37.7778 0 0 23: 204 37.7778 0 0 24: 204 37.7778 0 0 24: 204 37.7778 0 0 25: 204 37.7778 0 0 26: 204 37.7778 0 0 27: 204 37.7778 0 0 28: 204 37.7778 0 0 29: 204 37.7778 0 0 20: 204 37.778						
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	v 4						20 June 20
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Figure 24. Screen shot of the Results (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).



Figure 25. Screen shot of Process Diagram (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).



Figure 26. STE Thermal Setting Plan (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

	0.000				07-09-04-2 N		Job No.		
Customer	Customer						Reference No.		
Address				2965 2710100			Proposal N	lo.	
Plant Location					4111		Date Rev.		
Service of Udd	se Study -	Heat Exchange	r Rating b	A.K. Col	ker		Item No.	E-100	23
Size 19.3	/ 168.0	) Тур	a Aes	Horizor	ital	Connected	1 para	llel 1	serie
Surf./Unit (Gro	<b>ss)</b> 45	50.8	ft²	Shells/U	nit 1	Surface/Sh	ell (Gross)	450.8	ft²
50 331 52	102110 1.22	1407 - ADD 1904 10	PER	FORMANC	E OF ONE	UNIT			
Fluid Allocatio	n			Shell	Side		Tube	Side	
Fluid Name	S.	10 11 <del>11 10 10</del>							
Fluid Quantity,	c.	Total Ib/h		4500	0.0		15000	0.0	
Vapour		20000000000000000000000000000000000000	18.	5			2000		
Liquid			44981.	5	45000.0	1500	0.00	150000.0	6
Steam								1 1000 A.	
Water							55500. 1 - 2010 - 2010 - 201		
Noncond	tensable								
Temperature (I	n/Out)	°F	390.	0	249.9	1(	0.00	146.7	
Density		lb / ft <sup>3</sup>	47.221	0.4847	51.1286	35.0	846	35.4734	1000
Viscosity		centipoise	0.62011	0.01038	2.01888	2.883	343	1.90847	
Molecular Weig	ght, Vapor	r		88.4					
Molecular Weig	ght, Nonc	ondensable	2 8 XXX X		-			† - †-	
Specific Heat		Btu/lb °F	0.5969	0.5425	0.5248	0.49	929	0.5194	
Thermal Condu	uctivity	Btu/h ft °F	0.0618	0.0164	0.076	0.0	811	0.0785	0.9
Latent Heat		Btu/lb	112.	9 I				11715	0.000
Inlet Pressure		psia		50	0.0		5	0.0	
Velocity		ft/s		3.	83		10	.07	
Pressure Drop	, Allow. /	Calc. psi	14.9999		3.0667	14.99	99	11.6818	
Fouling Resist	ance (Min	i.) h ft² °F/Btu			0.002	0.0170	35 (0.0036 n	eferred to O	D)
Heat Exchange	d	3539223	3	Btu/h		MTD	188.0		°F
Transfer Rate,	Service	43.7	D	irty 40	).9	Clean	53.0	Btu/ł	י ז ft² °F
· · · · · · · · · · · · · · · · · · ·		CONSTRUCT	ION OF O	NE SHELL		Ske	etch (Bun./N	ozz. Orienta	ation)
		She	I Side		Tube Side				
Des/Test Pres.	psig	85.3		85.3	3				
Design Temper	ature °F	570.0			326.7		1	1	
No. Passes per	Shell	1			4	R	T PT PT PT PT PT		
Corrosion Allo	wance						╶┑╢╻╌╵╟╣╢║		)
Connections	In in	5.05		6.06				U <i>"</i>	
Size /	Out in	2.32		5.05					
Ratings	Int. in			0.00					
Tube No. 123	6	OD 1.0	in <b>T</b> I	hk 0.083	in Len	th 168.0	in Pitch	1.25 in	90 de
Tube Type		p	lain		Mate	erial	Carbon St	eel	
Shell Carbo	n Steel	ID	19.3 <b>O</b>	D	in She	I Cover		(Integ.)(Re	emov.)
Channel or Bor	nnet	Carbon S	teel		Cha	nnel Cover		<u> </u>	
Tubesheet - Sta	ationary	Carbon S	teel		Tube	sheet-Floati	ng		
Floating Head	Cover				Impi	ngement Pro	tection		
Baffles-Cross	42	Т	ype Sing	le Segmen	tal % C	ut 21 Sr	pacing c/c 2	.01 Inlet	in
D. (()		2			Seal	Туре			
Barries-Long			3	U-Bend			Туре	0.000 (0.000) (0.000) (0.000) (0.000 (0.000 (0.000 (0.000 (0.000 (0.000 (0.000 (0.000 (0.000 (0.000 (0.000 (0.000 (0.000 (0.00) (0.000 (0.00) (0.000 (0.000 (0.00) (0.000 (0.00) (0.000 (0.00) (0.000 (0.00) (0.000 (0.000 (0.000 (0.000 (0.00) (0.000 (0.00) (0.000 (0.00) (0.000 (0.00) (0.000 (0.00) (0.00) (0.000 (0.00))	
Barries-Long Supports-Tube				610 800 10 T	Tube	-Tubesheet	Joint		
Baπles-Long Supports-Tube Bypass Seal Ar	rangemer	nt			Type				er (20)
Baπies-Long Supports-Tube Bypass Seal Ar Expansion Joir	rangemei 1t	nt			.,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,				lh/ft c2
Bames-Long Supports-Tube Bypass Seal Ar Expansion Joir rV2 - Inlet Nozz	rangemer nt le	nt17	78.2	Bundle E	intrance	2.9	Bundle Exil	L 0.U	
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Battles-Long Supports-Tube Bypass Seal Ar Expansion Joir rV2 - Inlet Nozz Gaskets Flc	rangemer It Shell Side Shell Side	nt 17 de	78.2	Bundle E	ntrance	2.9	Bundle Exil Tube Side	<u> </u>	
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Barries-Long Supports-Tube Bypass Seal Arr Expansion Joir rV2 - Inlet Nozz Gaskets Flc Code Requirem Weight/Shell Remarks:	rangemen ht le Shell Sid pating Hea hents 5063	nt 17 de ad	78.2 Fill	Bundle E	ntrance ater 7098	2.9	Tube Side Tema Class Bundle 22	s R 211	lb
Barries-Long Supports-Tube Bypass Seal Ar Expansion Joir rV2 - Inlet Nozz Gaskets Flc Code Requiren Weight/Shell Remarks:	rangemen It Shell Sid pating Hea nents 5063	nt 17 de ad	78.2 Fill	Bundle E	ntrance ater 7098	2.9	Tema Class Bundle 22	8.0 8 R 211	lb
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## Heat Exchanger Specification Sheet

Figure 27. Heat Exchanger Specification Sheet (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).