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 ® 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^{o}F to 250^{o}F by heat exchange with 150,000 lb/h of crude oil at 100^{o}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^{2o}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_p, Btu/lb$_m$.^{o}F	0.59	0.49
k, Btu/h.ft.^{o}F	0.079	0.077
μ, lb$_m$/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 ΔT (> 100^{o}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 ΔT of 140°F.

2. Shell and head types

The recommended fouling factor for kerosene is 0.001 – 0.003 h. ft^2. °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 ® Shell- Tube Exchanger Modeler (UniSim ® 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 ® Shell and Tube Exchanger Modeler	UniSim ® STE	Shell and Tube heat exchangers
5. UniSim ® Cross Flow Exchanger Modeler	UniSim ® CFE	Air coolers and other crossflow exchangers
6. UniSim ® Plate – Fin Exchanger Modeler	UniSim ® PFE	Plate – fin heat exchangers
7. UniSim ® Fired Process Heater Modeler	UniSim ® FPH	Furnaces and fired heaters
8. UniSim ® Plate Heat Exchanger Modeler	UniSim ® PHE	Plate heat exchangers
9. UniSim ® Feedwater Heat Exchanger Modeler	UniSim ® FWH	Feedwater heat exchanger
10. UniSim ® Process Pipeline Heat Exchanger Modeler	UniSim ® PPL	Process Pipeline heat exchanger

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.

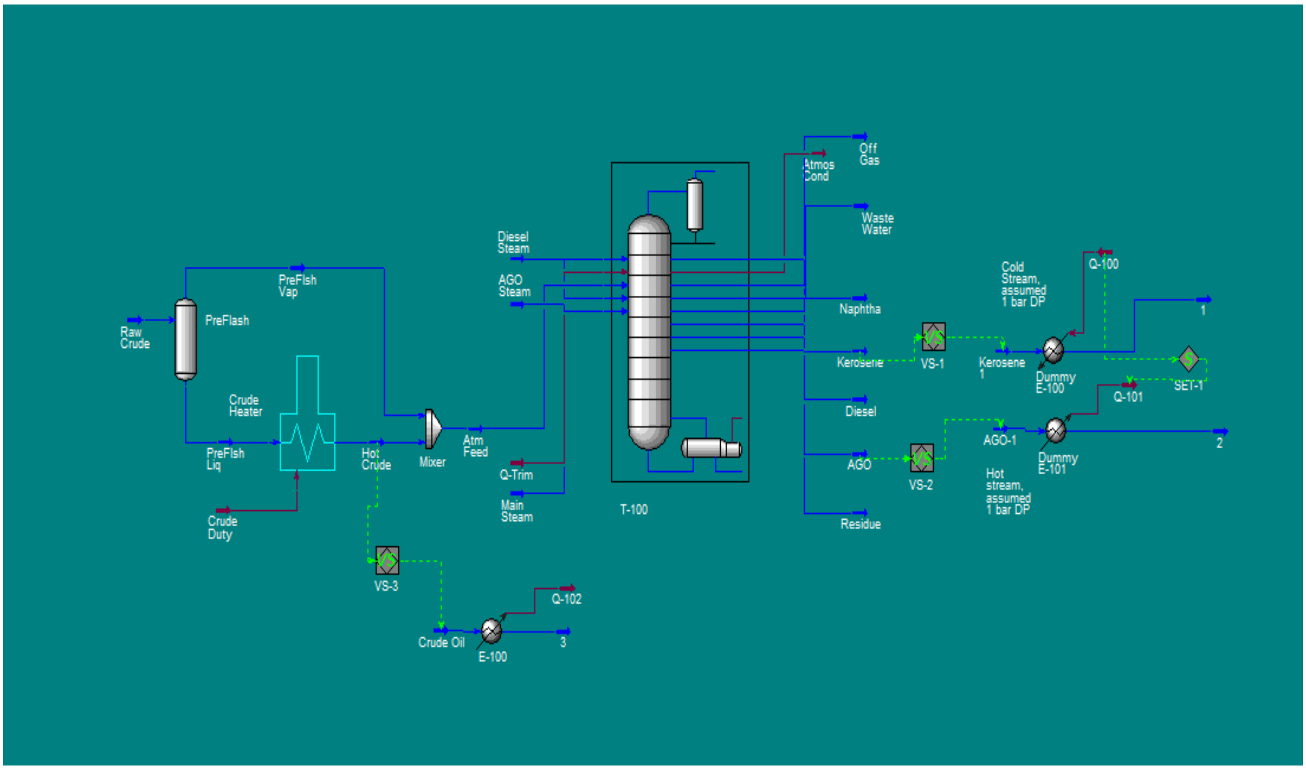


Figure 1. Screen shot of the crude distillation unit with heat exchanger E-100 as the basis for rating/checking design calculations from the PFD in the Simulation Environment (Source: UniSim Design R443, Courtesy of Honeywell Process Solutions, All rights reserved).

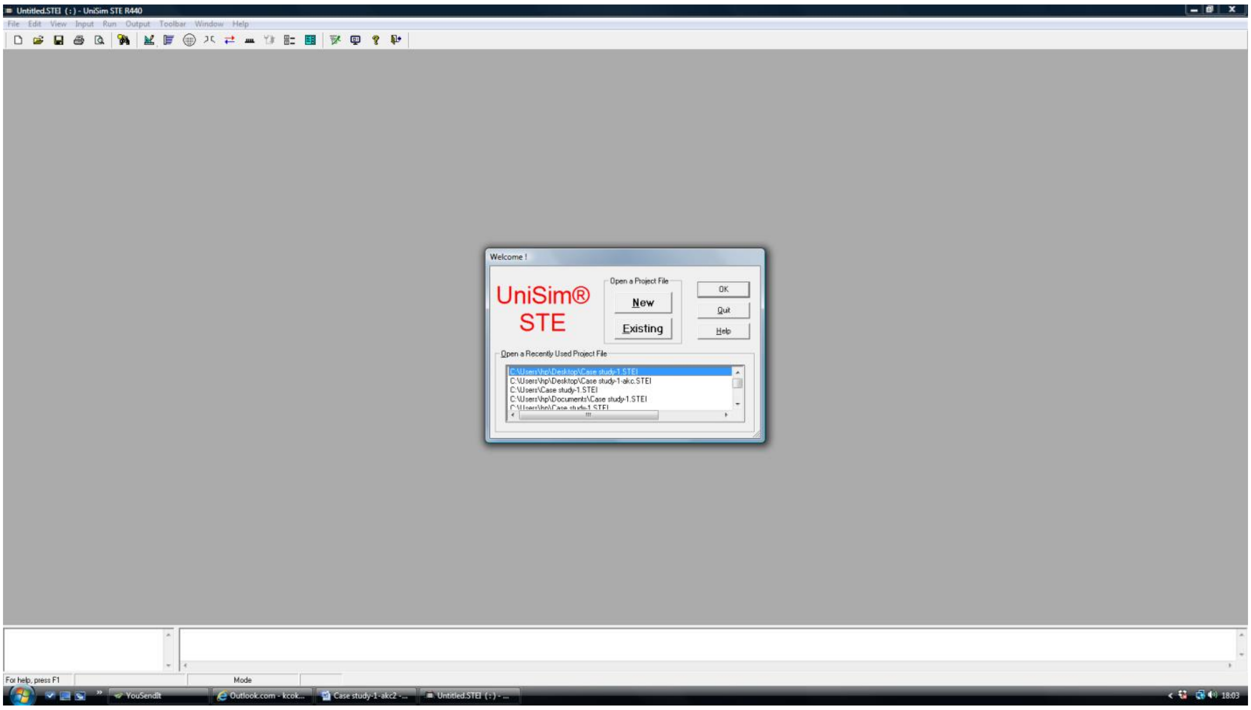


Figure 2. UniSim ® STE windows (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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.

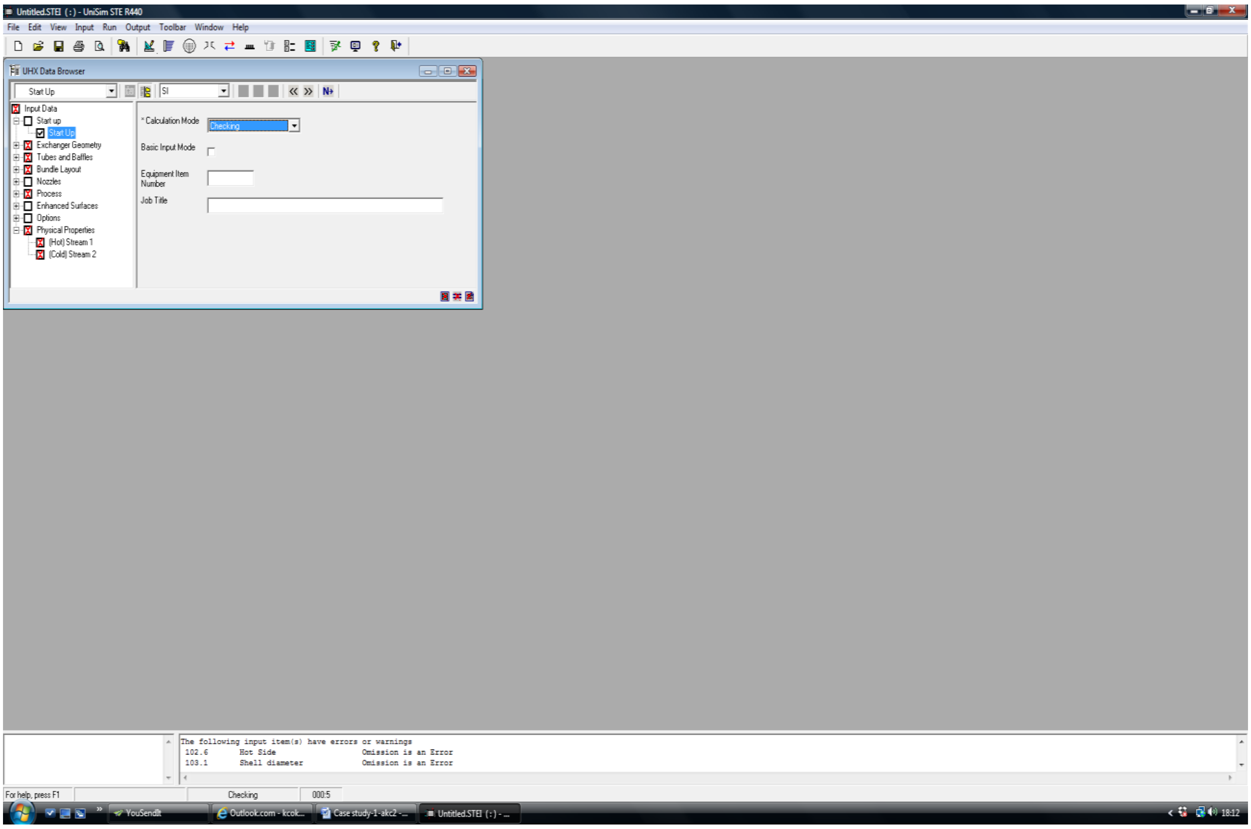


Figure 3. Screen shot of UniSim Shell – Tube Exchanger Modeler (UniSim STE) (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

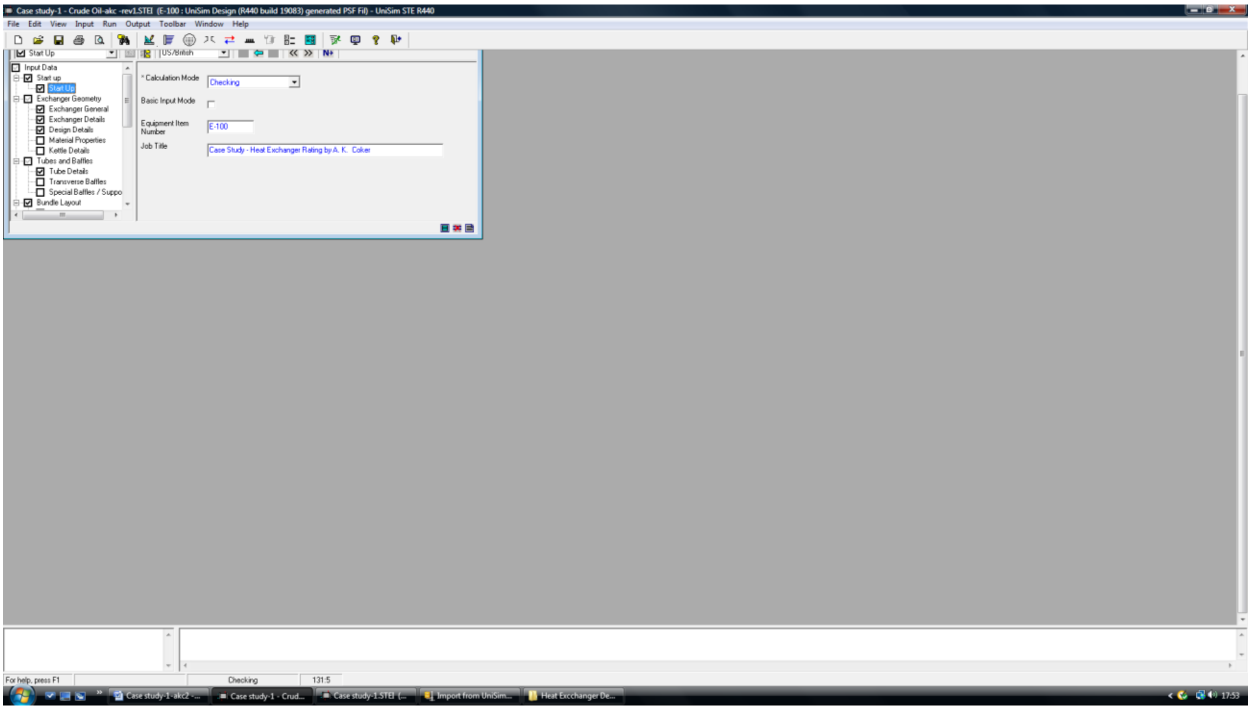


Figure 4. Screen shot of Input Data (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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 <F1> and get context sensitive help. If you select the rear head type and press <F1> you can see a listing of all the available rear head types.

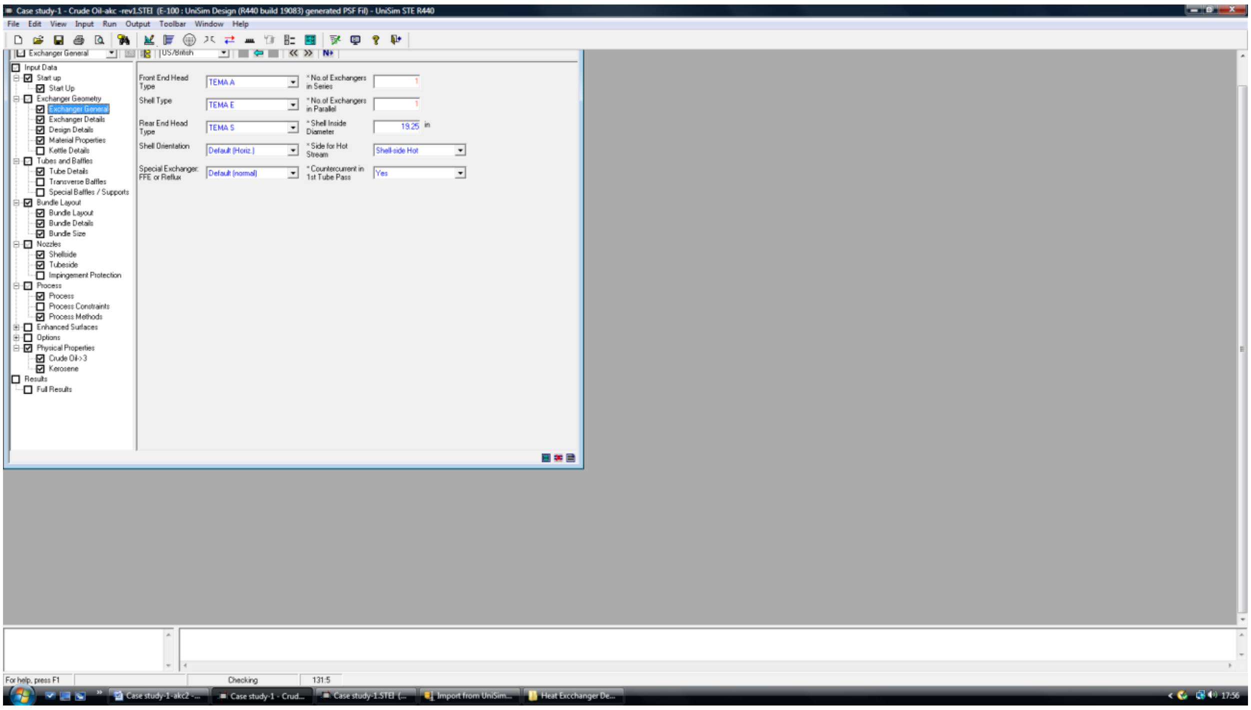


Figure 5. Screen shot of Exchanger Geometry – Exchanger General (Source: UniSim Shell – Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

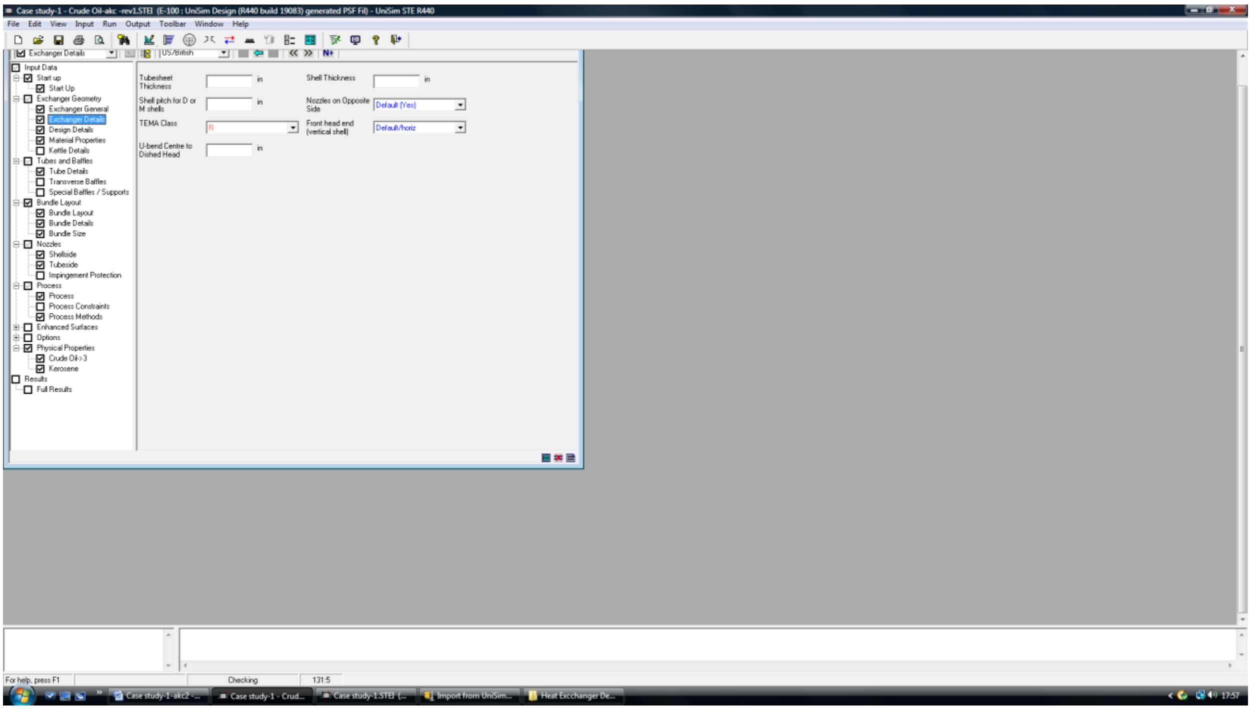


Figure 6. Screen shot of Exchanger Geometry – Exchanger Details (Source: UniSim Shell – Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

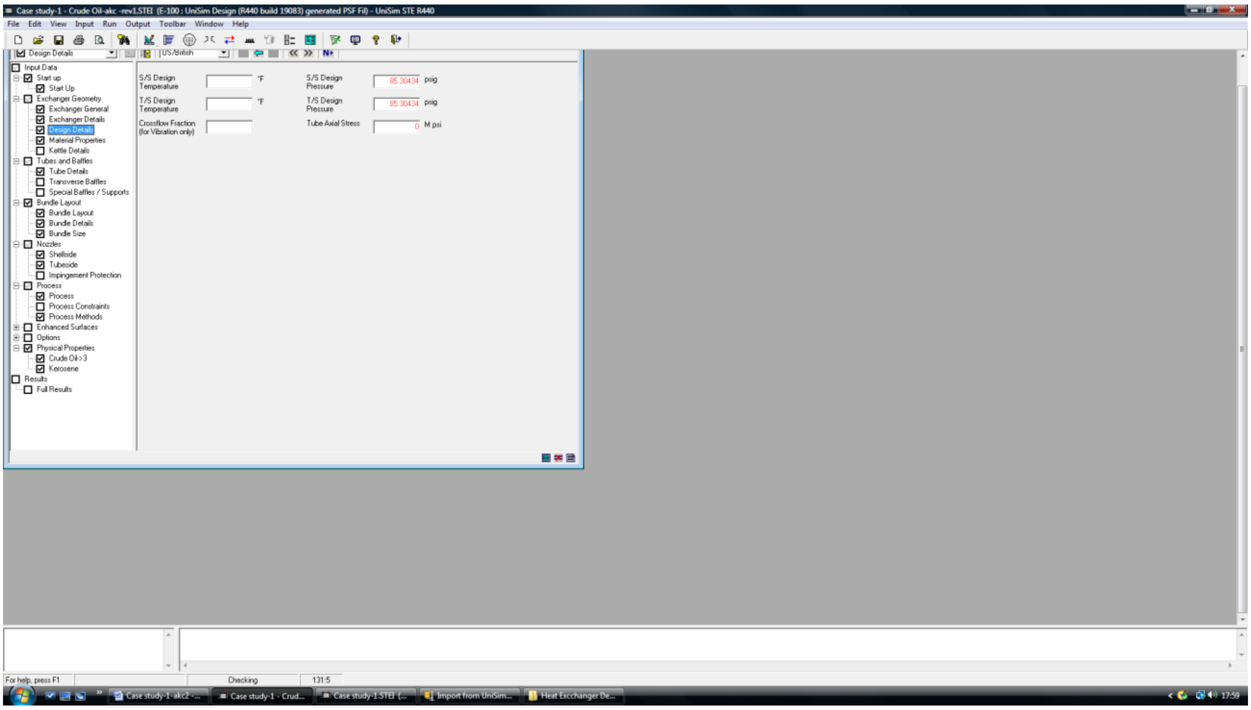


Figure 7. Screen shot of Exchanger Geometry – Design Details (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

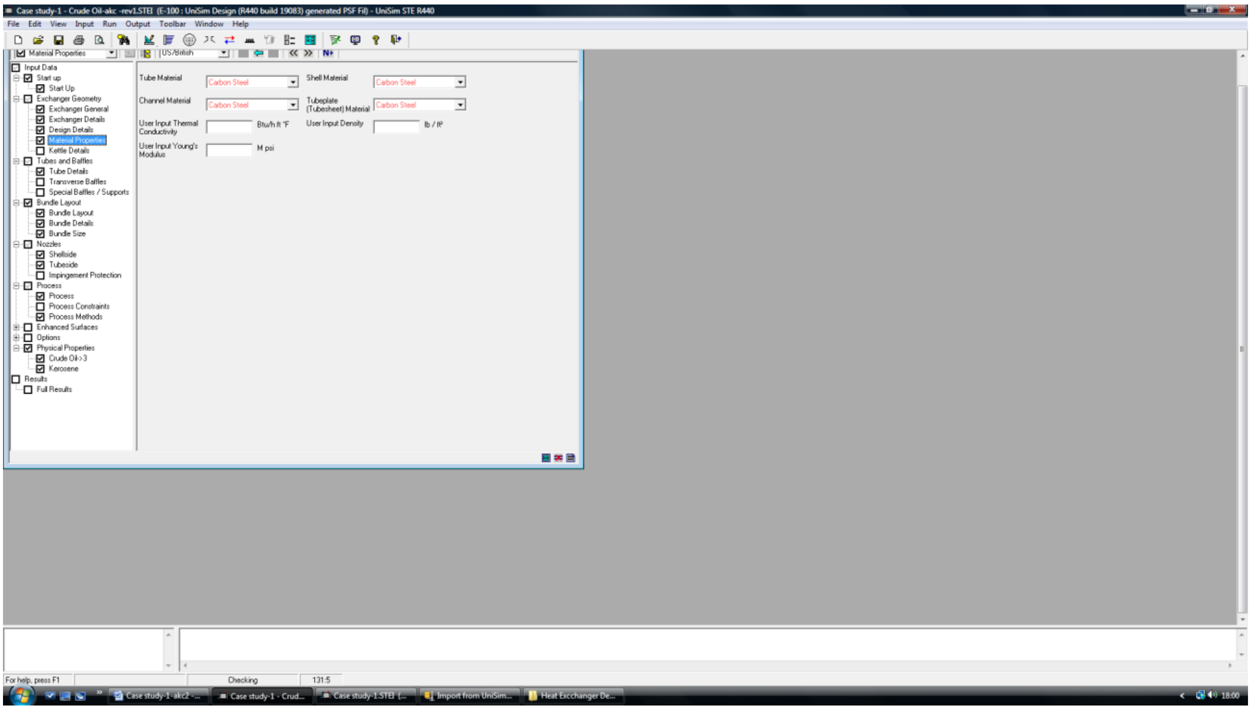


Figure 8. Screen shot of Exchanger Geometry – Material Properties (Source: UniSim Shell – Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

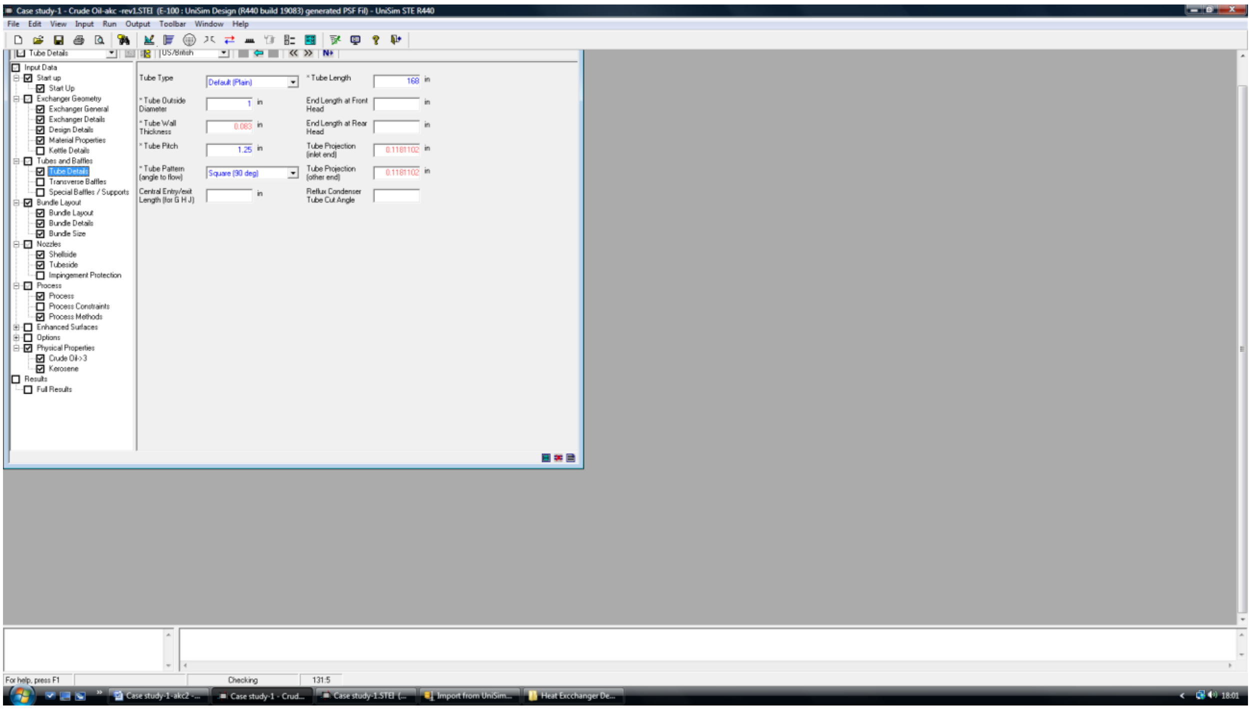


Figure 9. Screen shot of Tubes and Baffles – Tube Details (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

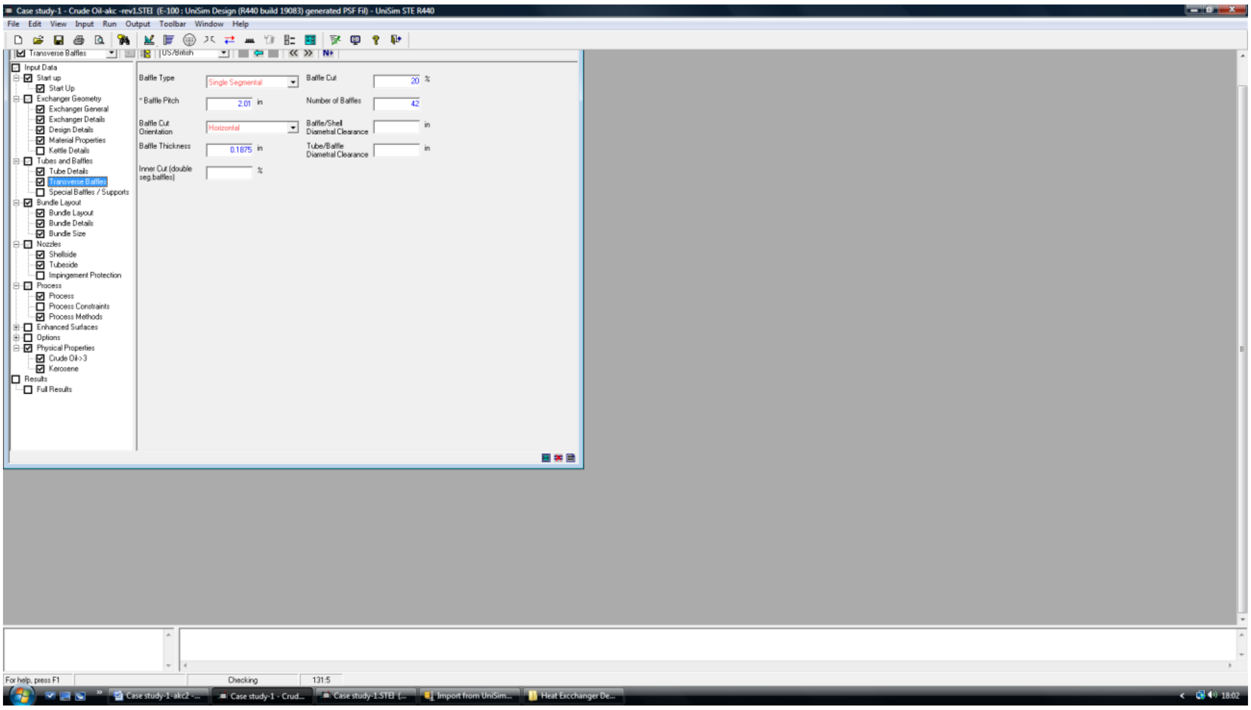


Figure 10. Screen shot of Tubes and Baffles – Transverse Baffles (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

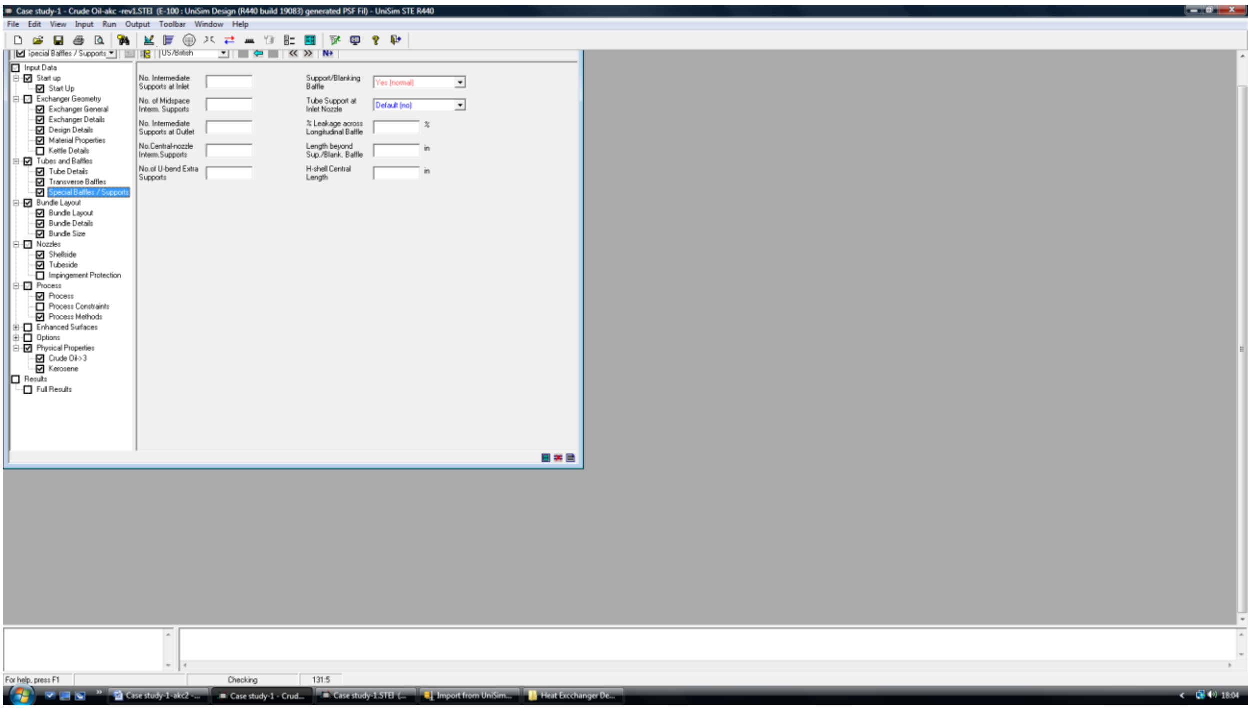


Figure 11. Screen shot of Tubes and Baffles – Special Baffles / Supports (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

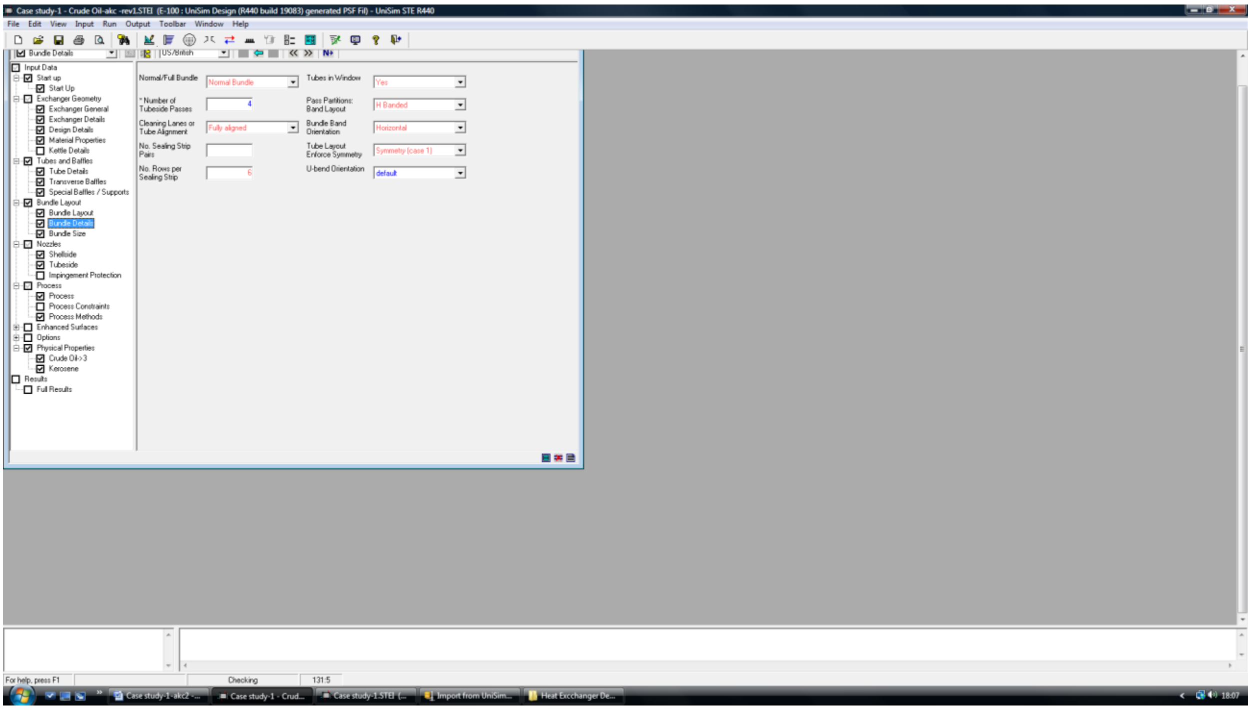


Figure 12. Screen shot of Input Bundle layout – Bundle Details (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

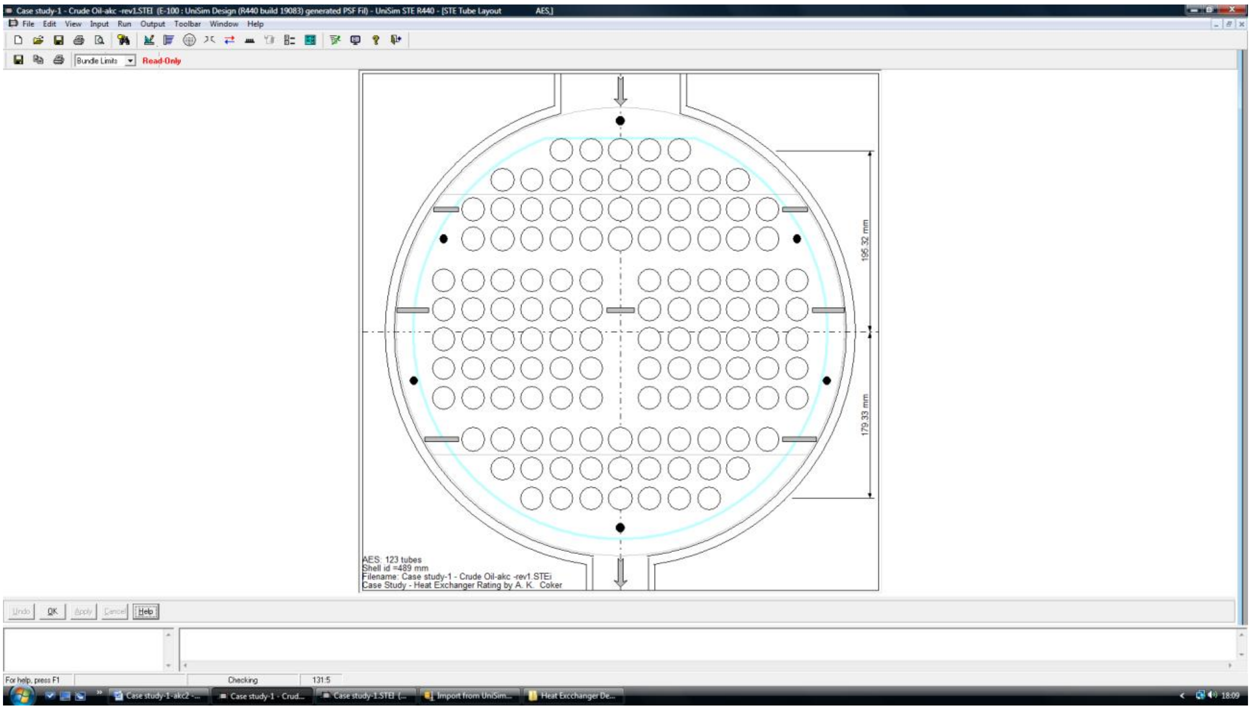


Figure 13. Screen shot of Output Bundle layout – Bundle Details (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

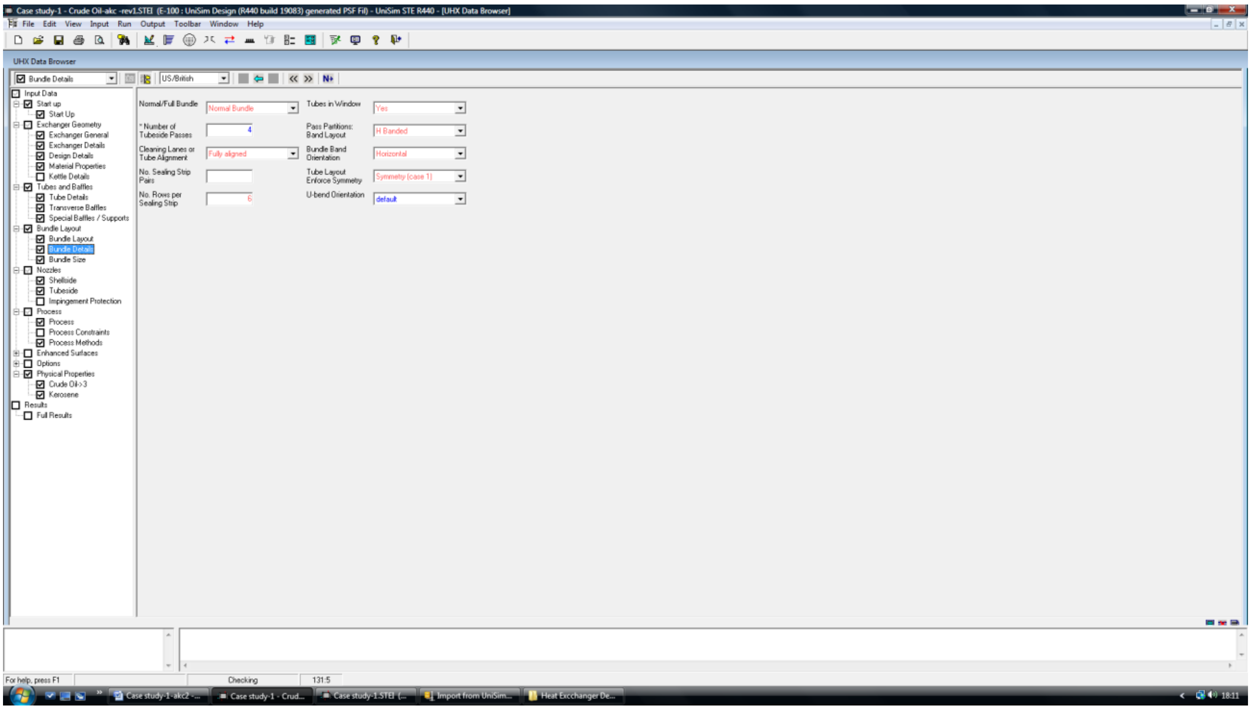


Figure 14. Screen shot of Bundle layout – Bundle Details (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

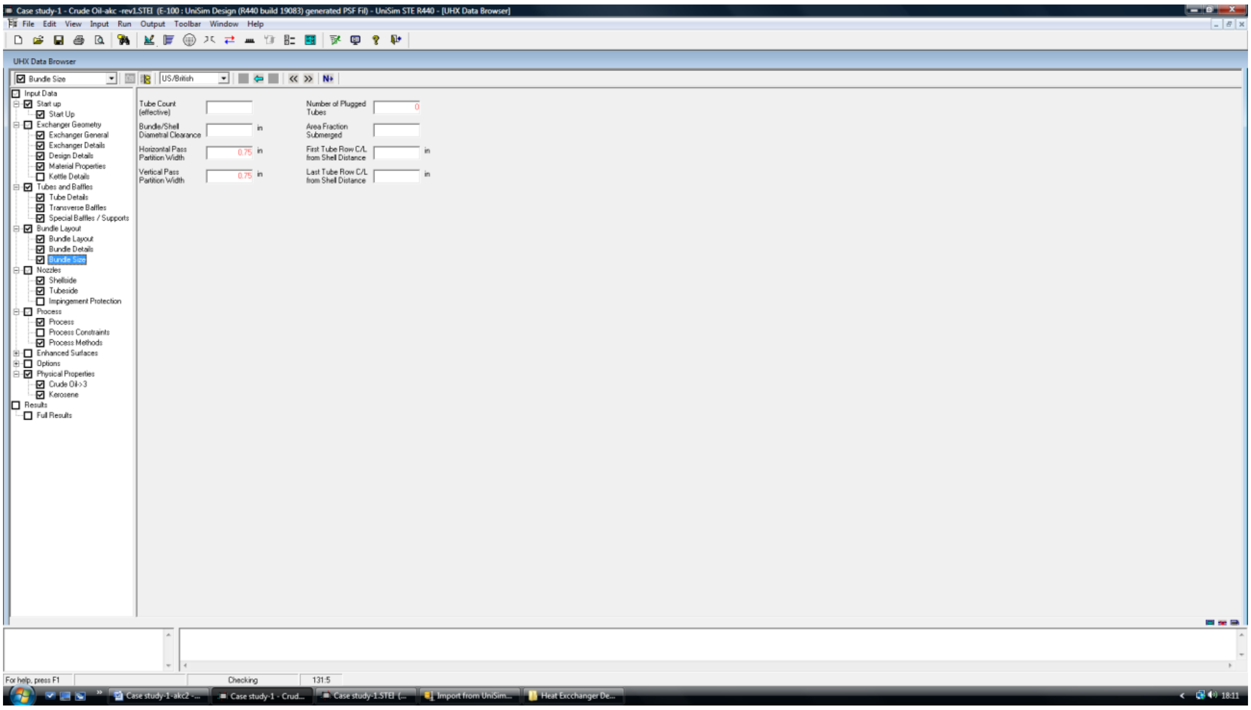


Figure 15. Screen shot of Bundle layout – Bundle Size (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

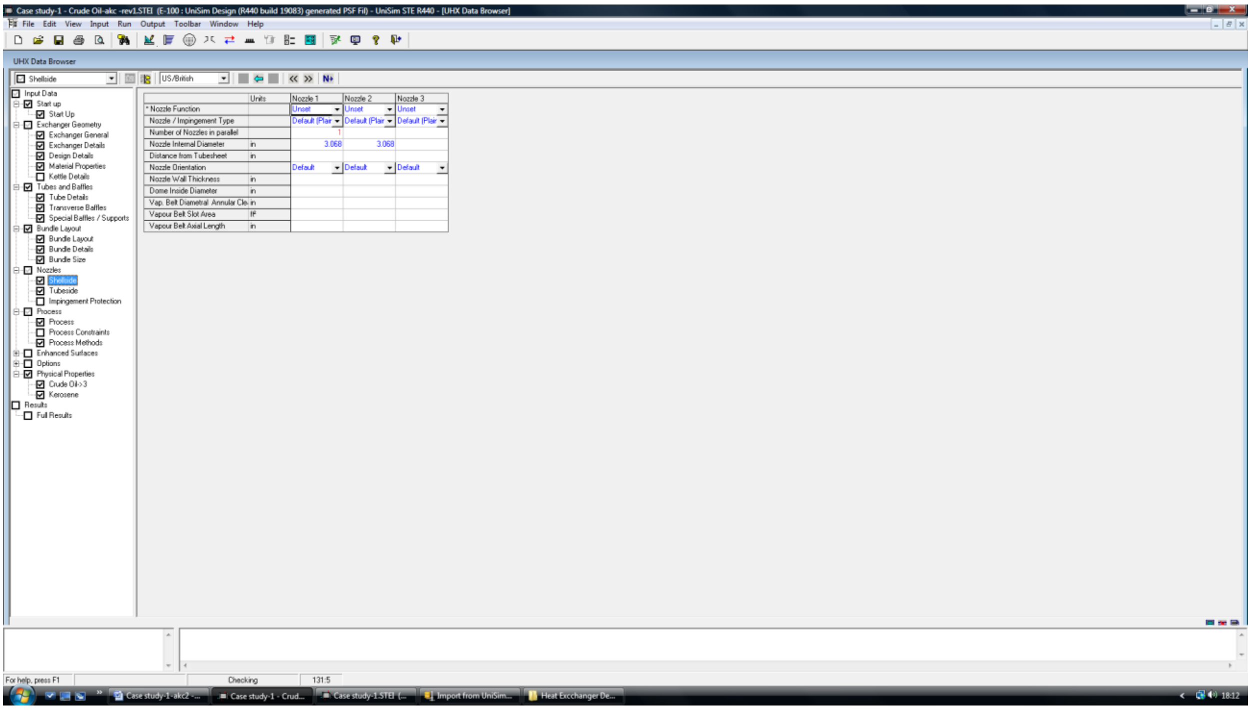


Figure 16. Screen shot of Nozzles – Shell side (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

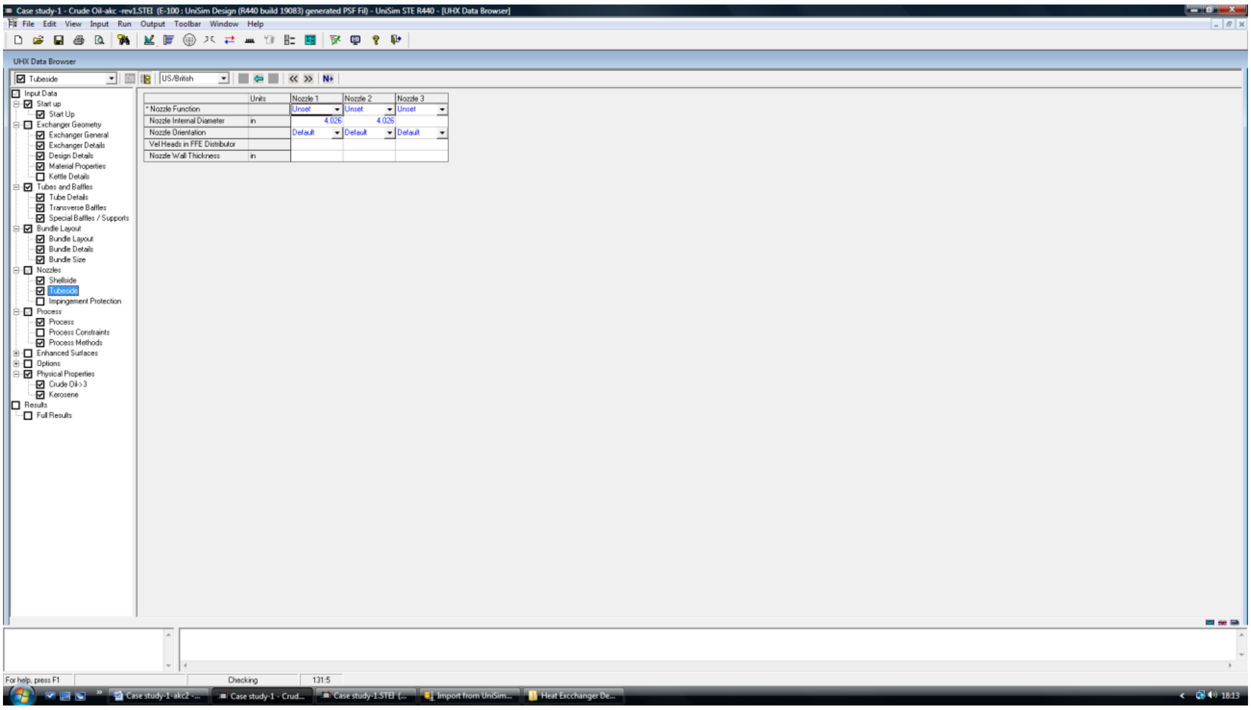


Figure 17. Screen shot of Nozzles – Tube side (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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.

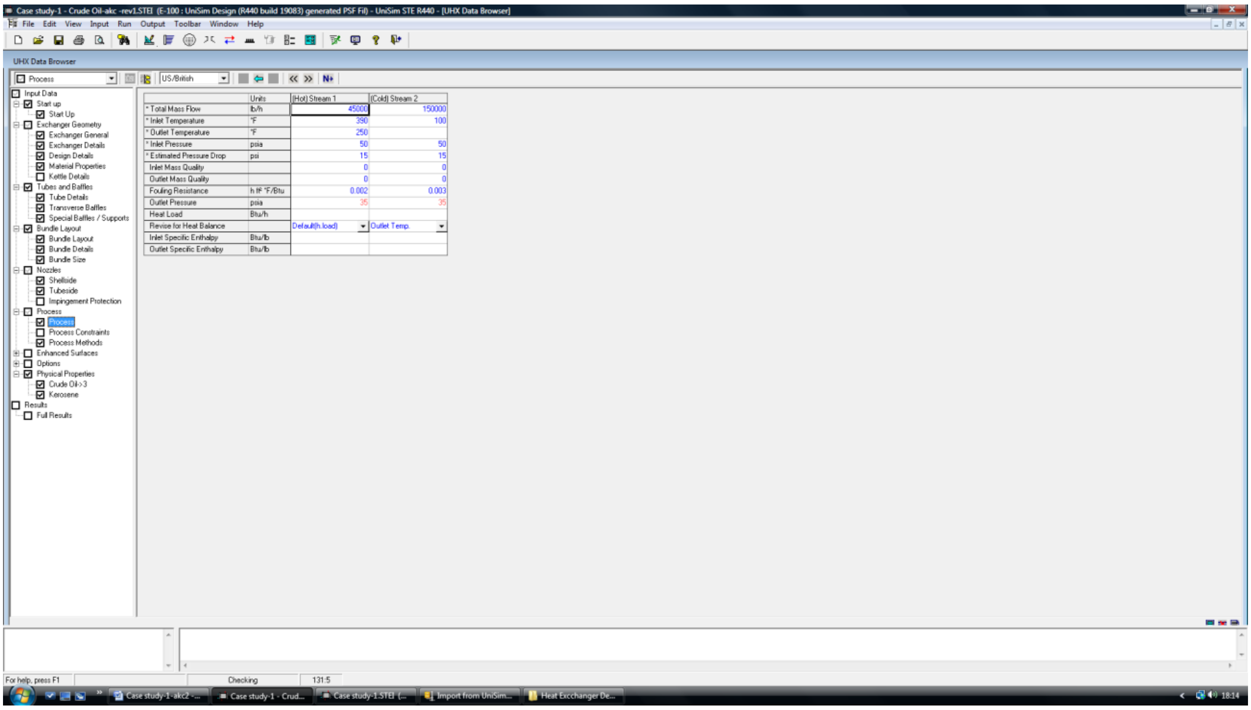


Figure 18. Screen shot of Process – Process (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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 pseudo-components 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.

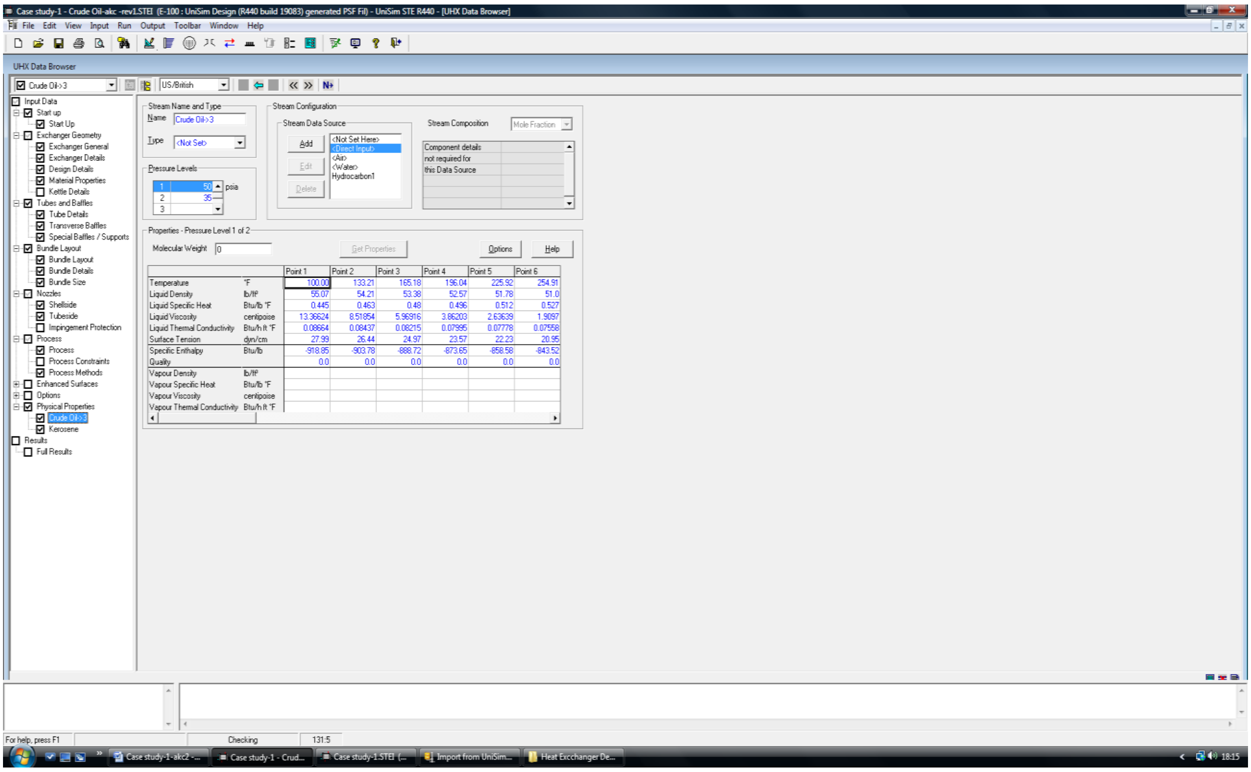


Figure 19. Screen shot of Physical Properties: Crude oil (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

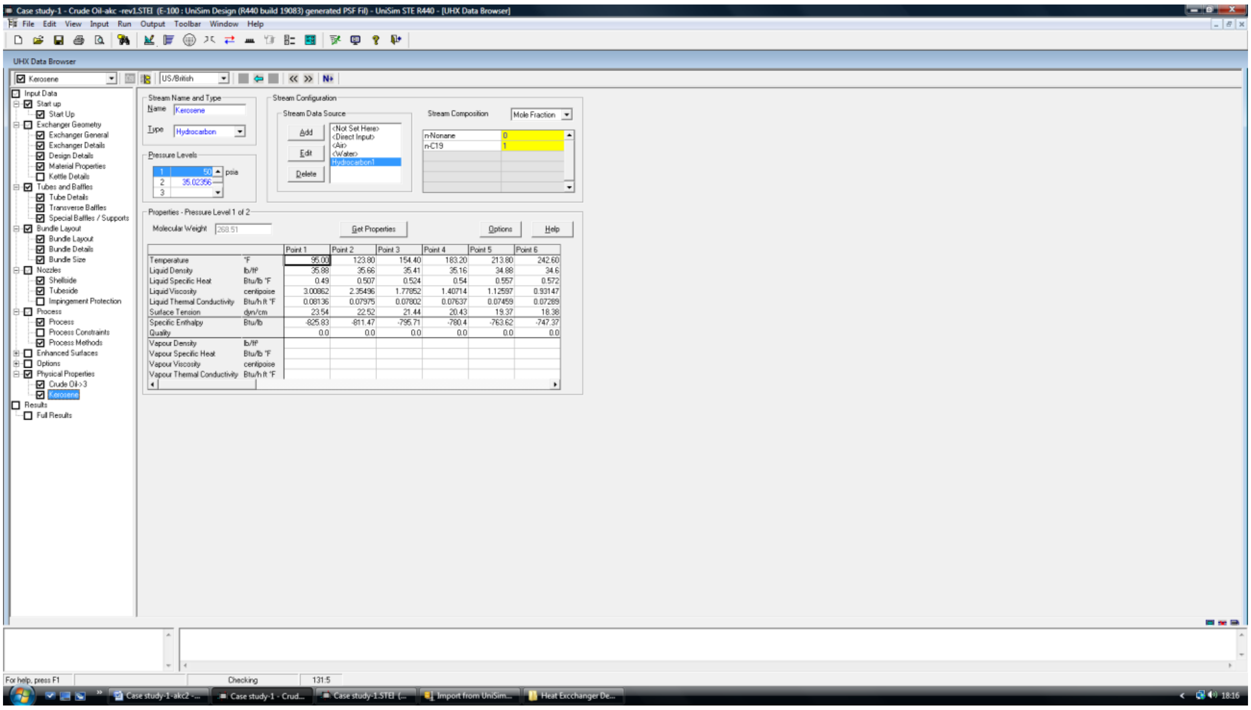


Figure 20. Screen shot of Physical Properties: Kerosene (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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.

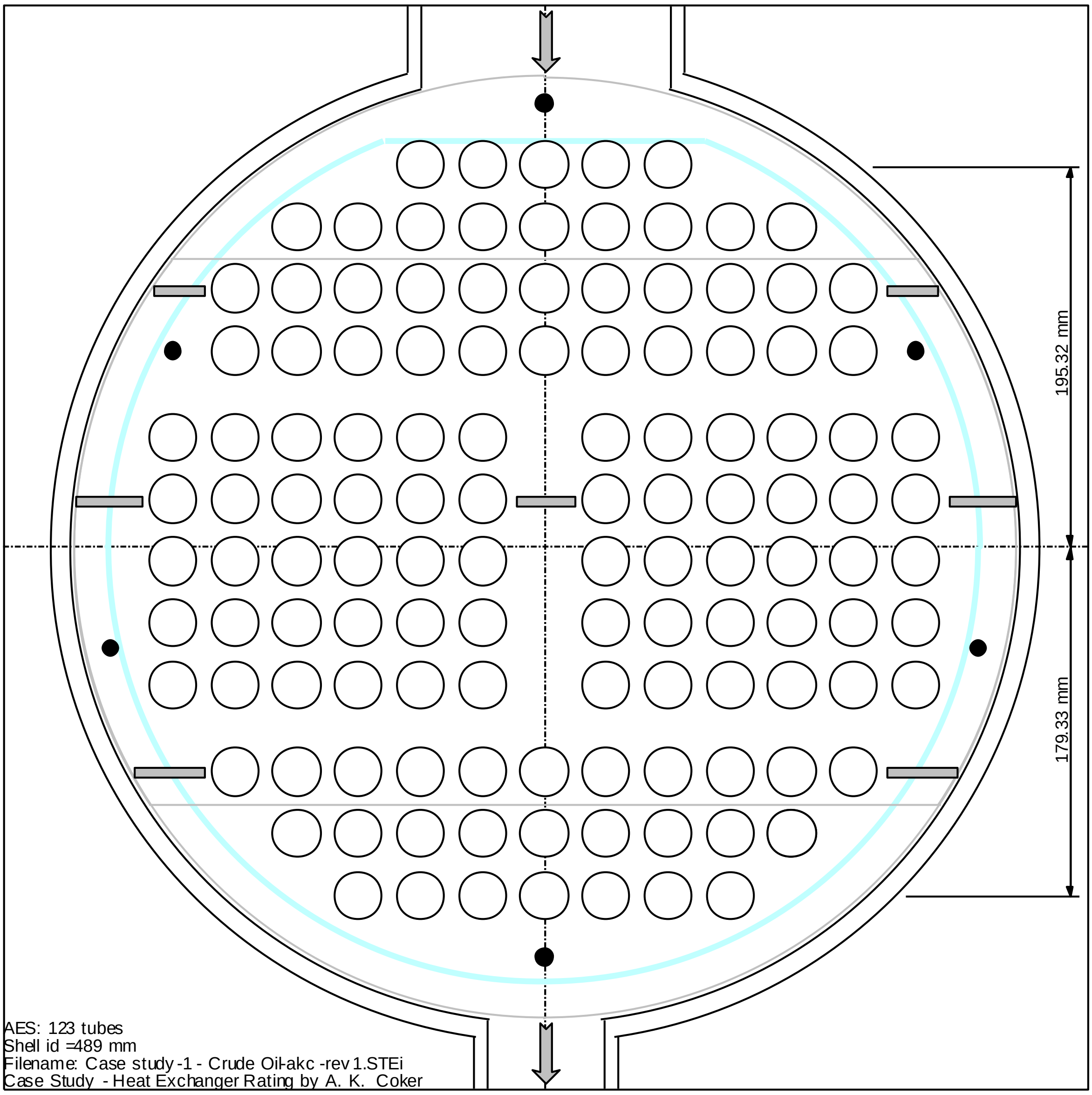


Figure 21. Bundle Tube Layout (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

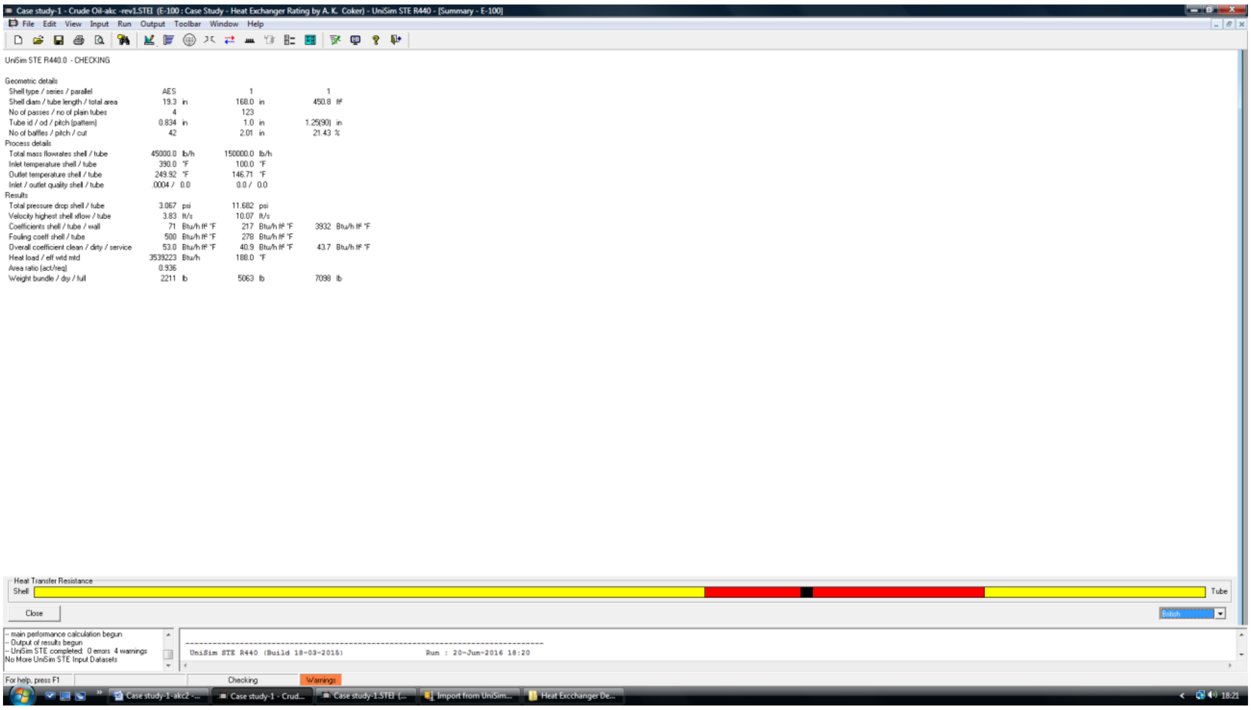


Figure 22. Screen shot of Results Summary (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

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.

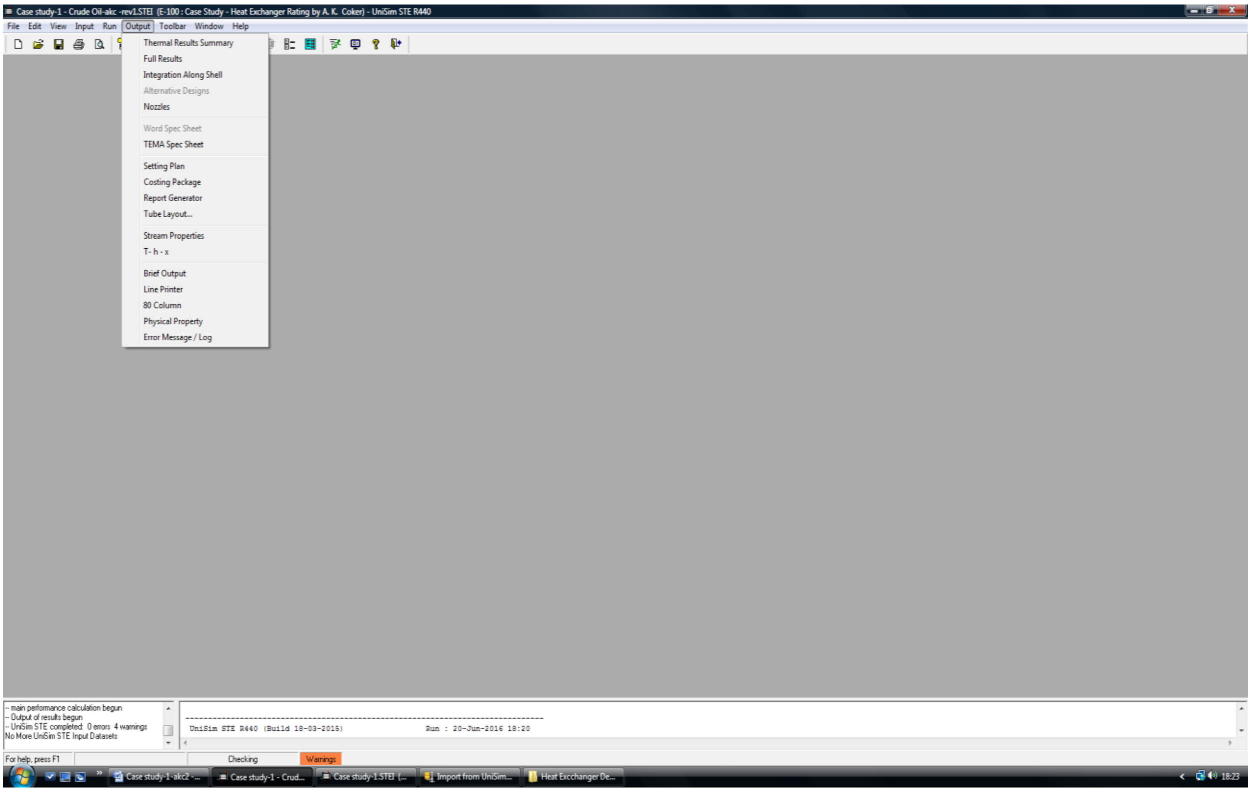


Figure 23. Screen shot of Output menu (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

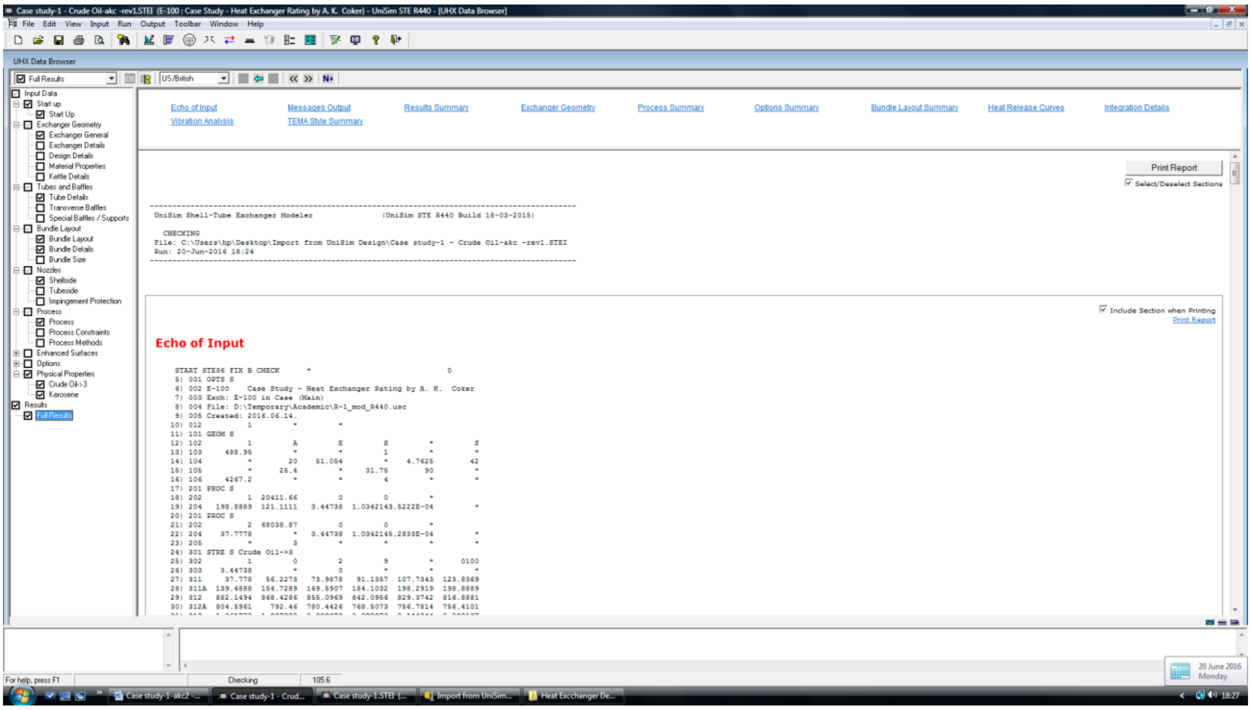


Figure 24. Screen shot of the Results (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).

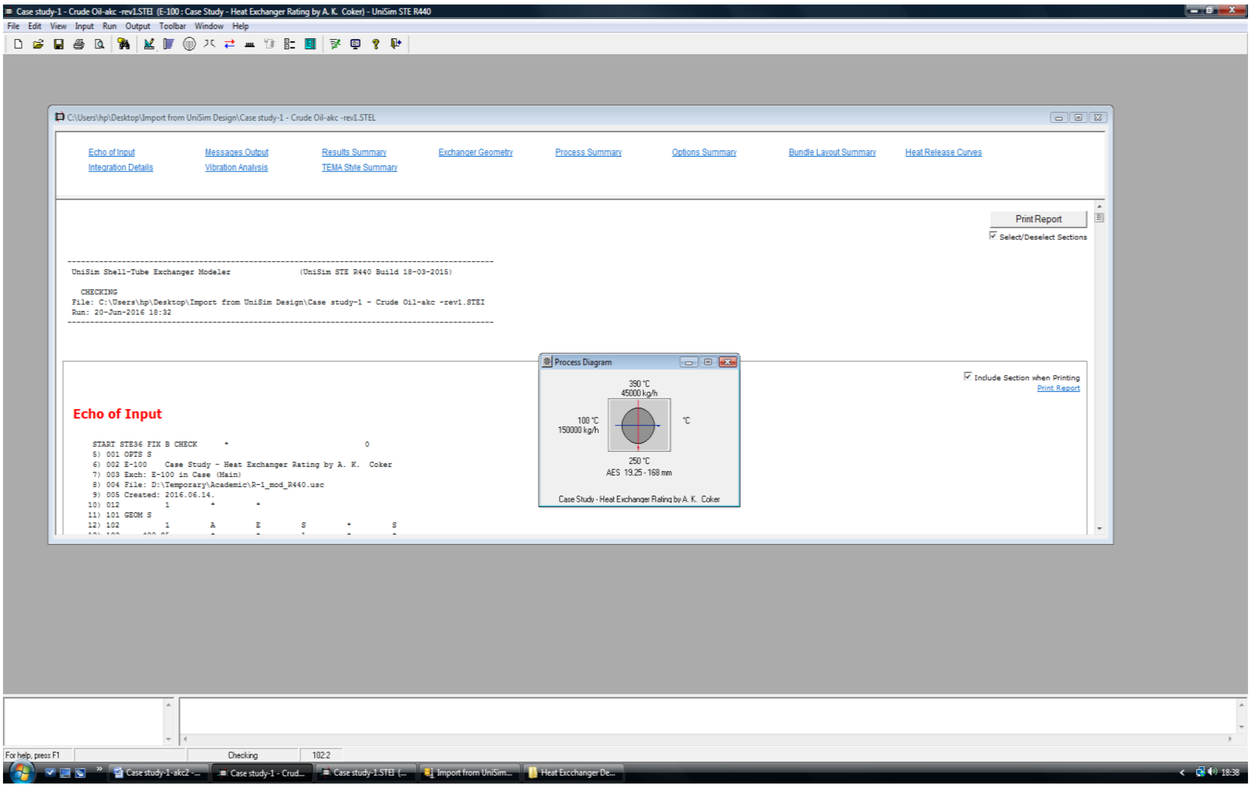
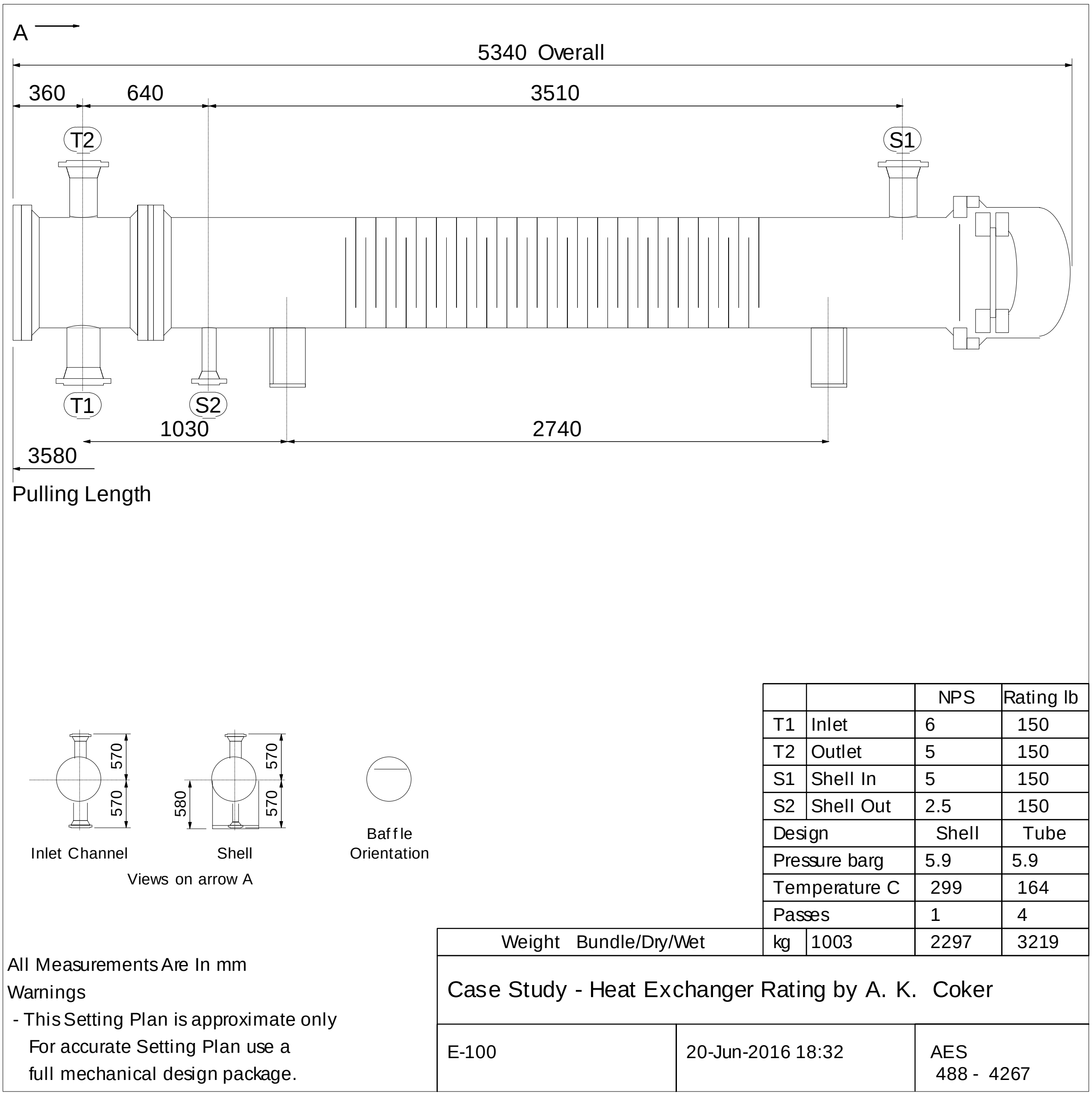


Figure 25. Screen shot of Process Diagram (Source: UniSim Shell –Tube Exchanger Modeler, Courtesy of Honeywell Process Solutions, All rights reserved).



		NPS	Rating lb
T1	Inlet	6	150
T2	Outlet	5	150
S1	Shell In	5	150
S2	Shell Out	2.5	150
Design		Shell	Tube
Pressure barg		5.9	5.9
Temperature C		299	164
Passes		1	4
Weight Bundle/Dry/Wet kg	1003	2297	3219

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

Heat Exchanger Specification Sheet

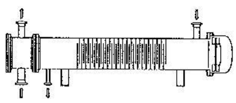
No.	Item	Unit								
1									Job No.	
2	Customer								Reference No.	
3	Address								Proposal No.	
4	Plant Location								Date	Rev.
5	Service of Unit	Case Study - Heat Exchanger Rating by A. K. Coker							Item No.	E-100
6	Size	19.3 / 168.0	Type	AES	Horizontal		Connected	1	parallel	1 series
7	Surf./Unit (Gross)	450.8	ft²	Shells/Unit	1		Surface/Shell (Gross)	450.8	ft²	
8	PERFORMANCE OF ONE UNIT									
9	Fluid Allocation		Shell Side				Tube Side			
10	Fluid Name									
11	Fluid Quantity, Total	lb/h	45000.0				150000.0			
12	Vapour		18.5							
13	Liquid		44981.5		45000.0		150000.0		150000.0	
14	Steam									
15	Water									
16	Noncondensable									
17	Temperature (In/Out)	°F	390.0		249.9		100.0		146.7	
18	Density	lb / ft³	47.221	0.4847	51.1286		35.846		35.4734	
19	Viscosity	centipoise	0.62011	0.01038	2.01888		2.88343		1.90847	
20	Molecular Weight, Vapor			88.4						
21	Molecular Weight, Noncondensable									
22	Specific Heat	Btu/lb °F	0.5969	0.5425	0.5248		0.4929		0.5194	
23	Thermal Conductivity	Btu/h ft °F	0.0618	0.0164	0.076		0.0811		0.0785	
24	Latent Heat	Btu/lb	112.9							
25	Inlet Pressure	psia	50.0				50.0			
26	Velocity	ft/s	3.83				10.07			
27	Pressure Drop , Allow. / Calc.	psi	14.9999		3.0667		14.9999		11.6818	
28	Fouling Resistance (Min.)	h ft² °F/Btu	0.002				0.017035 (0.0036 referred to OD)			
29	Heat Exchanged	3539223	Btu/h				MTD	188.0	°F	
30	Transfer Rate, Service	43.7	Dirty	40.9			Clean	53.0	Btu/h ft² °F	
31	CONSTRUCTION OF ONE SHELL						Sketch (Bun./Nozz. Orientation)			
32			Shell Side		Tube Side					
33	Des/Test Pres.	psig	85.3		85.3					
34	Design Temperature	°F	570.0		326.7					
35	No. Passes per Shell		1		4					
36	Corrosion Allowance									
37	Connections	In in	5.05		6.06					
38	Size /	Out in	2.32		5.05					
39	Ratings	Int. in								
40	Tube No. 123	OD 1.0 in	Thk 0.083 in		Length 168.0 in		Pitch 1.25 in		90 deg	
41	Tube Type		plain		Material		Carbon Steel			
42	Shell Carbon Steel	ID 19.3	OD in		Shell Cover		(Integ.)(Remov.)			
43	Channel or Bonnet		Carbon Steel		Channel Cover					
44	Tubesheet - Stationary		Carbon Steel		Tubesheet-Floating					
45	Floating Head Cover				Impingement Protection					
46	Baffles-Cross 42		Type Single Segmental		% Cut 21		Spacing c/c 2.01		Inlet in	
47	Baffles-Long				Seal Type					
48	Supports-Tube		U-Bend				Type			
49	Bypass Seal Arrangement				Tube-Tubesheet Joint					
50	Expansion Joint				Type					
51	rV2 - Inlet Nozzle		178.2		Bundle Entrance	2.9	Bundle Exit	8.0 lb/ft s²		
52	Gaskets	Shell Side					Tube Side			
53		Floating Head								
54	Code Requirements						Tema Class	R		
55	Weight/Shell	5063	Filled with water	7098			Bundle	2211	lb	
56	Remarks:									
57										
58										
59										
60										

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