Appendix A – MATLAB Code for Utilities Coordination

```
% Figure(1) refers to Case 1
% Figure(2) refers to Case 2
% Figure(3) refers to Case 3

% Click "Run and Advance" to generate the Matlab 3D co-ordinates for all 3
% cases.
% Click "Run" wouldl only generate Figure(1).

% The utility source is taken to be in the middle of the plant.

% The values [0.5 0.5 0.5] and [0.9290 0.6940 0.1250] are RGB colours for
% grey (heat exchangers) and yellow-orange (other equipment) as Matlab does
% not have a pre-built value for them.

% The vectors are sometimes given a +0.2 or -0.2 to indicate the
% approximate suggested coordinates for the new heaters/heat exchangers to
% be installed (+0.2 or -0.2 from a nearby existing equipment in line with
% the stream).

%HE33E061
x1 = 2.9400;
y1 = 2.9620;
z1 = 0.1560;

%HE31E01
x2 = 4.2300;
y2 = 0.1500;
z2 = 1.1900;

%HE31E02
x3 = 5.3000;
y3 = 0.1600;
z3 = 0.4600;

%HE31E03 (G - heater)
x4 = 4.7800;
y4 = 1.4332;
z4 = 2.6200;

%HE31E04
x5 = 5.5300;
y5 = 0.3800;
z5 = 1.4450;

% HE31E05 (C - cooler)
x6 = 5.5690;
y6 = 0.4300;
z6 = 0.6500;

% HE32E01 (H - heater)
x7 = 4.4800;
y7 = 1.5250;
z7 = 1.0700;
```

```
% HE32E02 (I - 32E02)
x8 = 2.0143;
y8 = 1.6650;
z8 = 1.0620;

% HE32E03 (EN - heat exchanger)
x9 = 1.3868;
y9 = 1.6000;
z9 = 1.7600;

% HE32E04 (DN - heat exchanger)
x10 = 3.7444;
y10 = 1.2000;
z10 = 1.0400;

% HE32E05
x11 = 2.7800;
y11 = 2.0375;
z11 = 1.0900;

% HE32E06 (Q - heater)
x12 = 2.0275;
y12 = 1.1350;
z12 = 1.0620;

% HE32E07 (D,M - heat exchanger)
x13 = 1.3868;
y13 = 1.2000;
z13 = 1.5300;

% HE32E08
x14 = 6.6900;
y14 = 3.0200;
z14 = 0.0900;

% HE33E01
x15 = 6.2800;
y15 = 0.6000;
z15 = 1.3500;

% HE33E02 (FO - heat exchanger)
x16 = 6.2800;
y16 = 0.6000;
z16 = 4.6000;

% HE33E03
x17 = 5.7800;
y17 = 0.4500;
z17 = 4.6000;

% HE33E04 (J - heater)
x18 = 3.2800;
y18 = 0.2117;
z18 = 1.4700;
```

```
% HE33E05 (AP - heat exchanger)
x19 = 2.9800;
y19 = 0.2160;
z19 = 1.5900;

% HE33E06 (A - heater)
x20 = 2.6800;
y20 = 0.2336;
z20 = 1.4900;

% HE33E07 (BG - heat exchanger)
x21 = 2.9800;
y21 = 0.2250;
z21 = 0.0900;

% HE33E08 (B - cooler)
x22 = 3.2800;
y22 = 0.1860;
z22 = 0.1200;

% HE33E09 (K - heater)
x23 = 5.3755;
y23 = 0.2000;
z23 = 3.0100;

% HE33E10 (CL - heat exchanger)
x24 = 5.3700;
y24 = 1.6500;
z24 = 1.0450;

% HE33E11
x25 = 4.7550;
y25 = 1.2000;
z25 = 1.0450;

% HE33E12
x26 = 5.2800;
y26 = 1.6120;
z26 = 2.6500;

% HE33E13
x27 = 5.6400;
y27 = 1.6212;
z27 = 2.5950;

%HE33E14
x28 = 5.6400;
y28 = 1.6212;
z28 = 2.6950;

%HE33E15
x29 = 5.4300;
y29 = 1.6120;
z29 = 2.6000;
```

```
%Utility source
x30 = 4.2500;
y30 = 2.2500;
z30 = 2.7500;

sz = 230;

figure(1)
scatter3(x1, y1, z1, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k'); hold on;
scatter3(x2, y2, z2, sz, 'b', 'filled', 'MarkerEdgeColor','k')
scatter3(x3, y3, z3, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x4, y4, z4, sz, 'b', 'filled', 'MarkerEdgeColor','k');
scatter3(x5, y5, z5, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x6, y6, z6, sz, 'r', 'filled', 'MarkerEdgeColor','k');
scatter3(x7, y7, z7, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x8, y8, z8, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x9, y9, z9, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k');
scatter3(x10, y10, z10, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x11, y11, z11, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x12, y12, z12, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x13, y13, z13, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x14, y14, z14, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x15, y15, z15, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x16, y16, z16, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x17, y17, z17, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x18, y18, z18, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x19, y19, z19, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x20, y20, z20, sz, 'b', 'filled', 'MarkerEdgeColor','k')
scatter3(x21, y21, z21, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x22, y22, z22, sz, 'b', 'filled', 'MarkerEdgeColor','k')
scatter3(x23, y23, z23, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x24, y24, z24, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x25, y25, z25, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x26, y26, z26, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x27, y27, z27, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x28, y28, z28, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x29, y29, z29, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
hold off
grid on
xlabel('x-coordinates')
ylabel ('y-coordinates')
zlabel ('Floor Level')

figure(2)
scatter3(x1, y1, z1, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k'); hold on;
scatter3(x2, y2, z2, sz, 'b', 'filled', 'MarkerEdgeColor','k')
scatter3(x3, y3, z3, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x4, y4, z4, sz, 'b', 'filled', 'MarkerEdgeColor','k');
scatter3(x5, y5, z5, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x6, y6, z6, sz, 'r', 'filled', 'MarkerEdgeColor','k');
scatter3(x7, y7, z7, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x8, y8, z8, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x9, y9, z9, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k');
scatter3(x10, y10, z10, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
```

```
scatter3(x11, y11, z11, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x12, y12, z12, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x13, y13, z13, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x14, y14, z14, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x15, y15, z15, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x16, y16, z16, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x17, y17, z17, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x18, y18, z18, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x19, y19, z19, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x20, y20, z20, sz, 'b', 'filled', 'MarkerEdgeColor','k')
scatter3(x21, y21, z21, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x22, y22, z22, sz, 'b', 'filled', 'MarkerEdgeColor','k')
scatter3(x23, y23, z23, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x24, y24, z24, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x25, y25, z25, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x26, y26, z26, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x27, y27, z27, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x28, y28, z28, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x29, y29, z29, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x30, y30, z30,[300],'r', 'd', 'filled', 'MarkerEdgeColor','k')
%1. HE for K and A (HE33E05 & HE33E09)
v1_1 = [x23, y23-0.2, z23];
v1_2 = [x23, y23-0.2, z19];
v1_3 = [x23, y19-0.2, z19];
v2_1 = [x23, y23-0.2, z19];
v2_2 = [x23, y19-0.2, z19];
v2_3 = [x19, y19-0.2, z19];
v1=[v1_1;v1_2;v1_3];
v2=[v2_1;v2_2;v2_3];
plot3(v1(:,1),v1(:,2),v1(:,3),'g', 'Linewidth', 2)
plot3(v2(:,1),v2(:,2),v2(:,3),'g', 'Linewidth', 2)
%2. HE for H01 and K (HE33E09)
v3_1 = [x30, y30, z30];
v3_2 = [x30, y30, z23];
v3_3 = [x30, y23+0.2, z23];
v4_1 = [x30, y30, z23];
v4_2 = [x30, y23+0.2, z23];
v4_3 = [x23, y23+0.2, z23];
v3=[v3_1;v3_2;v3_3];
v4=[v4_1;v4_2;v4_3];
plot3(v3(:,1),v3(:,2),v3(:,3),'r', 'Linewidth', 2)
plot3(v4(:,1),v4(:,2),v4(:,3),'r', 'Linewidth', 2)
%3. HE for H02 and L (HE33E10)
v5_1 = [x30, y30, z30];
v5_2 = [x30, y30, z24];
v5_3 = [x30, y24+0.2, z24];
v6_1 = [x30, y30, z24];
v6_2 = [x30, y24+0.2, z24];
v6_3 = [x24, y24+0.2, z24];
v5=[v5_1;v5_2;v5_3];
v6=[v6_1;v6_2;v6_3];
plot3(v5(:,1),v5(:,2),v5(:,3),'r', 'Linewidth', 2)
plot3(v6(:,1),v6(:,2),v6(:,3),'r', 'Linewidth', 2)
%4. HE for H03 and L (HE33E05)
v7_1 = [x30, y30, z30];
```

```
v7_2 = [x30, y30, z24];
v7_3 = [x30, y24-0.2, z24];
v8_1 = [x30, y30, z24];
v8_2 = [x30, y24-0.2, z24];
v8_3 = [x24, y24-0.2, z24];
v7=[v7_1;v7_2;v7_3];
v8=[v8_1;v8_2;v8_3];
plot3(v7(:,1),v7(:,2),v7(:,3),'r', 'Linewidth', 2)
plot3(v8(:,1),v8(:,2),v8(:,3),'r', 'Linewidth', 2)
hold off
grid on
xlabel('x-coordinates')
ylabel ('y-coordinates')
zlabel ('Floor Level')

figure(3)
scatter3(x1, y1, z1, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k'); hold on;
scatter3(x2, y2, z2, sz, 'b', 'filled', 'MarkerEdgeColor','k')
scatter3(x3, y3, z3, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x4, y4, z4, sz, 'b', 'filled', 'MarkerEdgeColor','k');
scatter3(x5, y5, z5, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x6, y6, z6, sz, 'r', 'filled', 'MarkerEdgeColor','k');
scatter3(x7, y7, z7, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x8, y8, z8, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x9, y9, z9, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k');
scatter3(x10, y10, z10, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x11, y11, z11, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x12, y12, z12, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x13, y13, z13, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x14, y14, z14, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x15, y15, z15, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x16, y16, z16, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x17, y17, z17, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x18, y18, z18, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x19, y19, z19, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x20, y20, z20, sz, 'b', 'filled', 'MarkerEdgeColor','k')
scatter3(x21, y21, z21, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x22, y22, z22, sz, 'b', 'filled', 'MarkerEdgeColor','k')
scatter3(x23, y23, z23, sz, 'r', 'filled', 'MarkerEdgeColor','k')
scatter3(x24, y24, z24, sz, [0.5,0.5,0.5], 'filled', 'MarkerEdgeColor','k')
scatter3(x25, y25, z25, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x26, y26, z26, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x27, y27, z27, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x28, y28, z28, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
scatter3(x29, y29, z29, sz, [0.9290 0.6940 0.1250], 'filled', 'MarkerEdgeColor','k')
v1_1 = [x23, y23-0.2, z23];
v1_2 = [x23, y23-0.2, z19];
v1_3 = [x23, y19-0.2, z19];
v2_1 = [x23, y23-0.2, z19];
v2_2 = [x23, y19-0.2, z19];
v2_3 = [x19, y19-0.2, z19];
v1=[v1_1;v1_2;v1_3];
v2=[v2_1;v2_2;v2_3];
plot3(v1(:,1),v1(:,2),v1(:,3),'g', 'Linewidth', 2)
plot3(v2(:,1),v2(:,2),v2(:,3),'g', 'Linewidth', 2)
```

```
hold off
grid on
xlabel('x-coordinates')
ylabel ('y-coordinates')
zlabel ('Floor Level')
```

Appendix B – Simple Demonstration of AEA

The following HEN is a simple tutorial for AEA and the step-by-step calculation demonstrated in this section acts as a guide to understand how more complex system were input into the software. The 3 rules first proposed by Linnhoff and Hindmarsh [19] are shown below and are used together with the assumption that no phase change occurs during the heat exchange process, leaving only sensible heat change to take place.

1. Don't transfer heat across the pinch.
2. Don't use cold utilities above the pinch.
3. Don't use hot utilities below the pinch.

Step 1: Process Stream Data Input

The process stream data are as follows:

Table B.1 Process Streams' Data for Simple HEN Case

Stream Number	Temperature In (°C)	Temperature Out (°C)	Heat Flowrate (kW/°C)
1 hot	200	100	2.0
2 hot	150	60	3.0
3 cold	80	120	6.0
4 cold	50	140	2.5

The assumption here is that there is no phase change occurring (only sensible heat change) and a minimum approach temperature of 20 °C.

AEA v10.0 is launched as a new case study. Process streams data are input under "Process Streams" in the software as shown below in Figure B.1. The streams are named accordingly and include their effective heat flow rates (MCp). The heat transfer coefficient is a numerical constant set by the software, which is changeable. However, the value is left untouched as it is not an integral part for this case study.

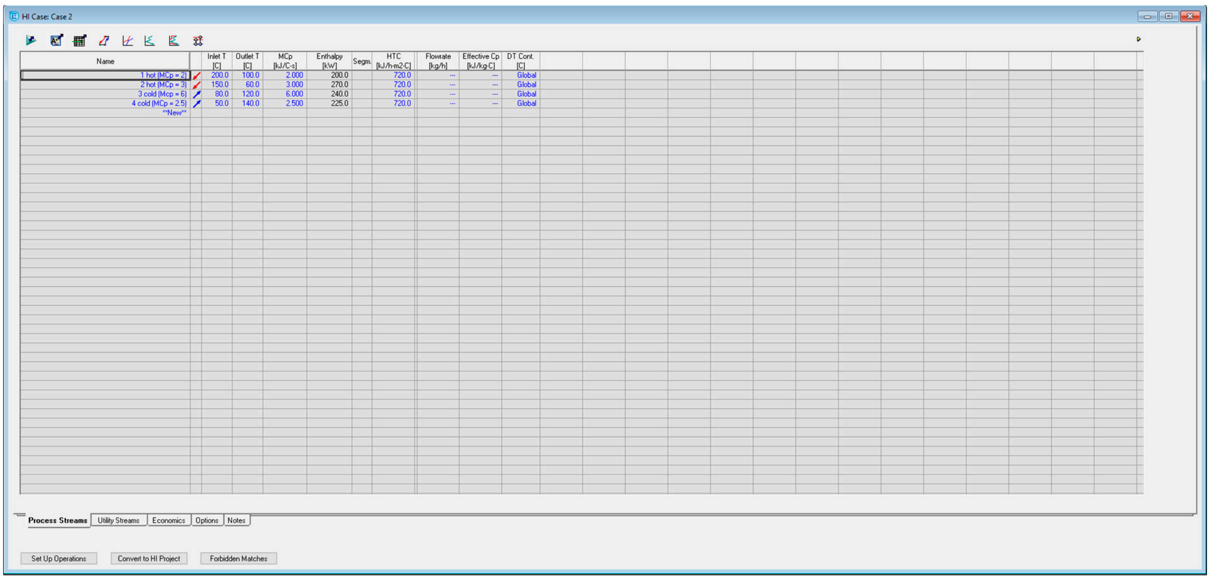

Figure B.1 Process Streams' Data in Aspen Energy Analzyer for Simple HEN Case

Step 2: Utility Data Input

The available utilities and their properties are as follow in Table B.2.

Table B.2 Utilities Streams' Data for Simple HEN Case

Utility	Temperature In (°C)	Temperature Out (°C)	Heat Capacity (kJ/kg°C)
Cooling Water	20	25	4.183
LP Steam	125	124	2,196
MP Steam	175	174	1,981

Utilities data streams are input under “Utility Streams”. The streams are named accordingly, and the pre-fixed heat capacities are changed to fit the given heat capacities in Table B.2. Other variables such as the cost index and heat transfer constants are pre-fixed by the software, but are changeable. Again, the value is left untouched as it is not an integral part for this case study. Following this, the software also confirms that the presence of these 3 utilities fulfils the external hot and cold utilities requirements.

A limitation of this software for its utility usage is that there needs to be a temperature change of at least 0.0001 °C in the inlet and outlet temperature and it disregards the phase change.

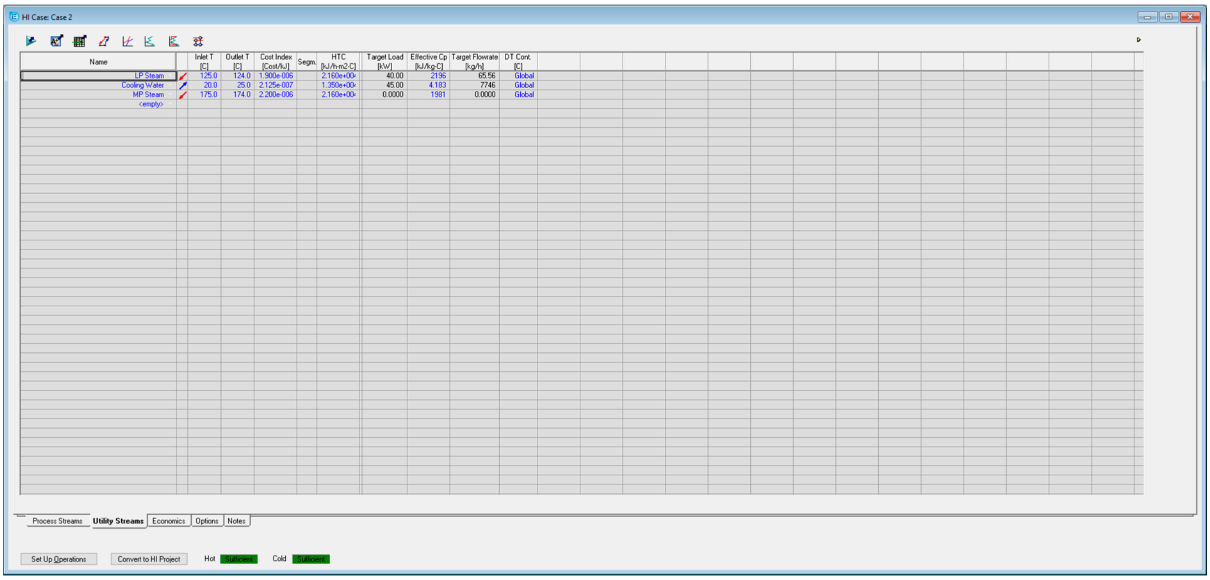

Figure B.2 Utilities Streams' Data in Aspen Energy Analyzer for Simple HEN Case

Step 3: Input Minimum Approach Temperature, Finding Grand Composite Curve

The software is capable of producing a Grand Composite Curve automatically and can be accessed through the “Target Views” tab as shown in Figure B.3 below.

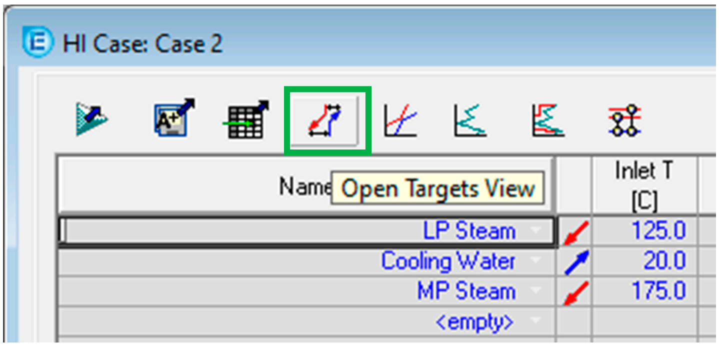

Figure B.3 Opening Targets View Tab

This will open up a new window as shown below.

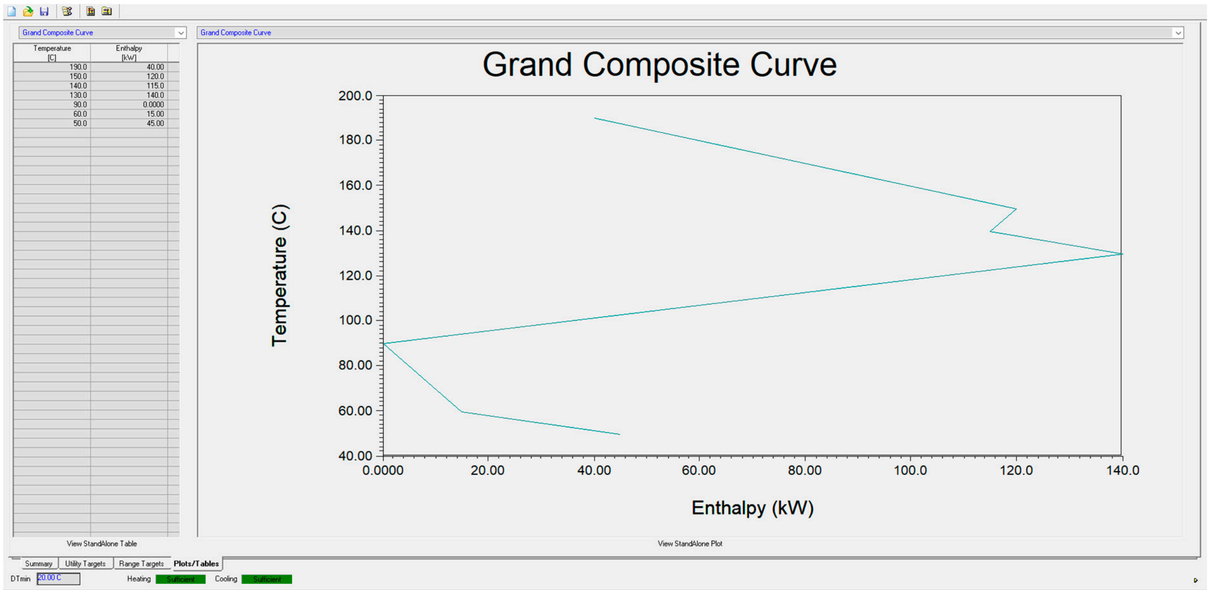

Figure B.4 Grand Composite Curve for Simple HEN Case

The first thing that needs to be done is to ensure that the minimum approach temperature, written as “DTmin” in the bottom left corner of the window corresponds to the one set by the question which is, in this case, 20 °C. The cascade table on the left and the Grand Composite Curve on the right allows users to identify the pinch temperature both numerically and graphically, (90 °C). This software also found that the minimum heating and cooling utility is 40 kW and 45 kW from the cascade table.

<u>Step 4: Entering HEN Environment and Proceed Stream-Matching</u>

The stream matching are done with respect to Linnhoff and Hindmarsh [19]. The rules include:

Above the pinch, $CP_{hot} \leq CP_{cold}$
Below the pinch, $CP_{hot} \geq CP_{cold}$

The HEN designed from this data is produced as follows with a pinch line at 90 °C, where cooling water is used below the pinch, while LP and MP steam are used above the pinch.

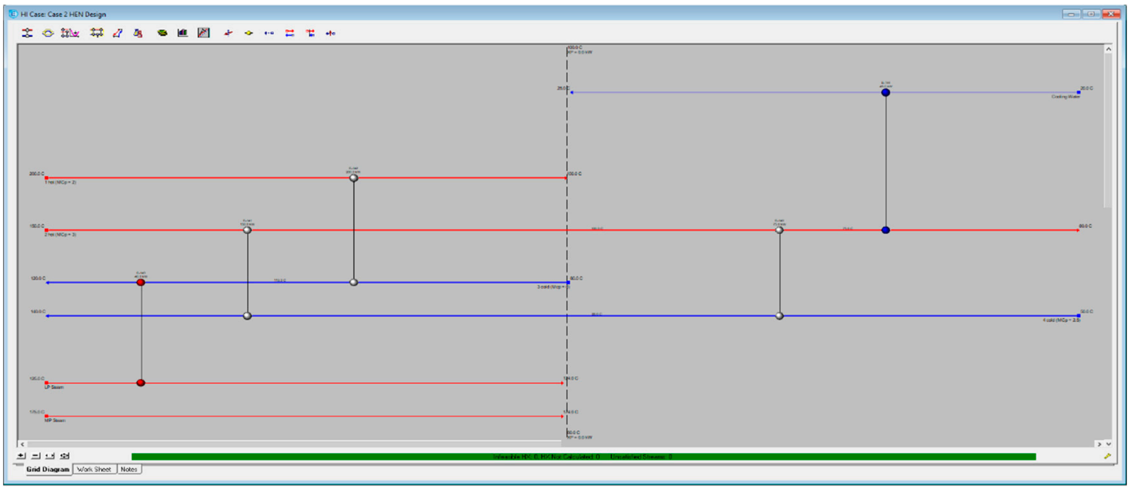

Figure B.5 MER HEN in Aspen Energy Analyzer for Simple HEN Case

As seen above, the HEN fulfils the MER design network fulfils the minimum heating and utilities requirements. Heat transfer across pinch does not take place and results in a heat exchange line which is perpendicular to the process streams lines. Not only that, the HEN designed does not require the consumption of MP steam.

Appendix B.0 – Case 0

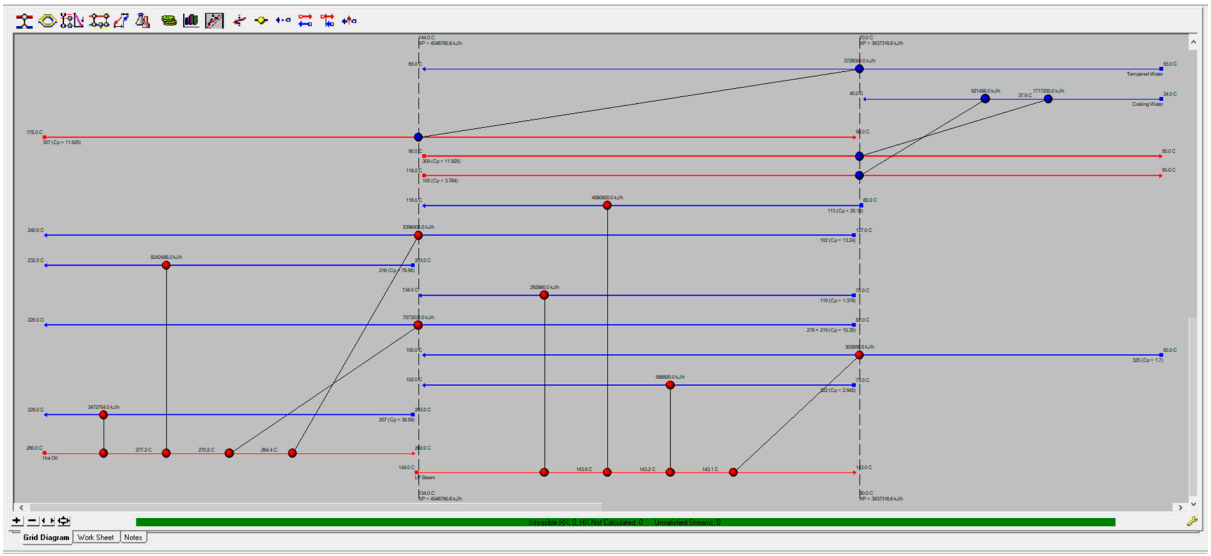

Figure B.6 Aspen Energy Analzyer of Case 0

Table B.3 Full Evaluation of Case 0

Stream	Process	Utility Required (GJ/year)	Initial Temperature (°C)	Final Temperature (°C)	Utility	Cost (RM/year)
A	Cooling	29,808	175	90	Tempered Water	50,794
B	Cooling	13,738	90	50	Cooling Water	2,572
C	Cooling	7,372	118	50	Cooling Water	1,380
D*	Cooling	440,842	220	82	Tempered Water	751,216
E*	Cooling	423,072	216	83	Tempered Water	720,935
F*	Cooling	67,622	130	130	Tempered Water	115,232
G	Heating	32,486	60	116	LP Steam	1,558,982
H	Heating	43,171	127	240	Hot Oil	1,390,816
I	Heating	65,940	203	232	Hot Oil	2,124,340
J	Heating	2,343	75	134	LP Steam	112,432
K	Heating	60,584	82	220	Hot Oil	1,951,801
L	Heating	2,447	50	100	LP Steam	117,421

M*	Heating	366,192	83	216	Hot Oil	11,797,353
N*	Heating	497,722	49	203	Hot Oil	16,034,750
O*	Heating	67,622	65	103	LP Steam	3,245,115
P*	Heating	4,694	73	102	LP Steam	225,278
Q	Heating	27,782	203	228	Hot Oil	895,021
Sum		2,153,437				41,095,440

Appendix B.1 – Case 1

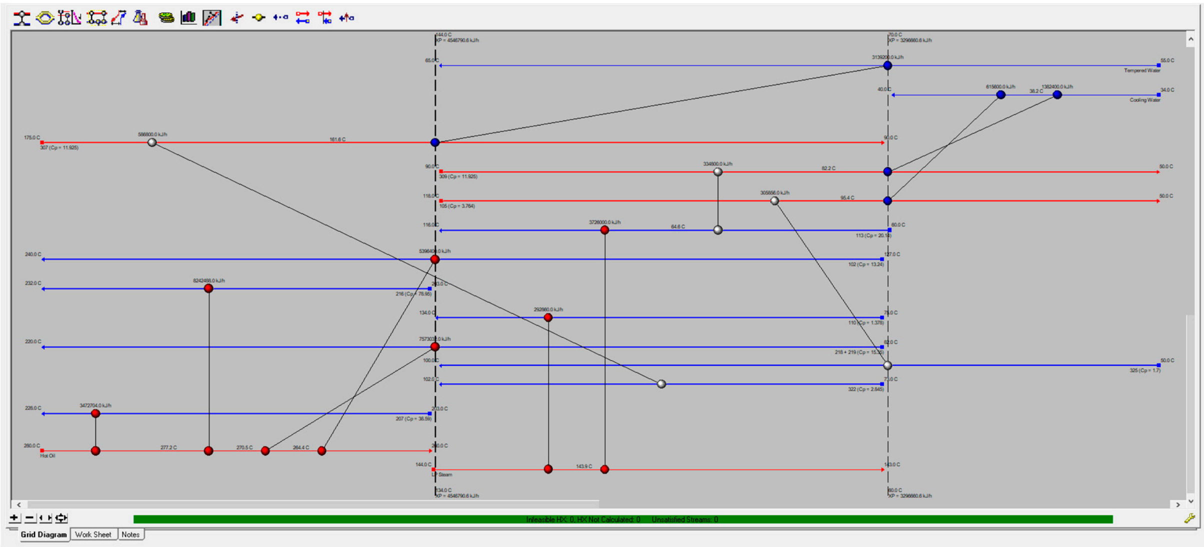

Figure B.7 Aspen Energy Analzyer of Case 1

Table B.4 Full Evaluation of Case 1

Stream	**Process**	**Utility Required (GJ/year)**	**Initial Temperature (°C)**	**Final Temperature (°C)**	**Utility**	**Operating Cost (RM/year)**
A	Cooling	25,114	175	90	Tempered Water	42,794
B	Cooling	11,059	90	50	Cooling Water	2,070
C	Cooling	4,925	118	50	Cooling Water	921
D*	Cooling	-	220	82	-	-
E*	Cooling	-	216	83	-	-
F*	Cooling	-	130	130	-	-
G	Heating	29,808	60	116	MP Steam	1,363,037
H	Heating	43,171	127	240	Hot Oil	1,390,816
I	Heating	65,940	203	232	Hot Oil	2,124,339
J	Heating	2,343	75	134	LP Steam	112,431
K	Heating	60,584	82	220	Hot Oil	1,951,800
L	Heating	-	50	100	-	-
M*	Heating	-	83	216	-	-
N*	Heating	-	49	203	-	-
O*	Heating	-	65	103	-	-
P*	Heating	-	73	102	-	-
Q	Heating	27,782	203	228	Hot Oil	1,333,720
Sum		270,726				8,321,934

Appendix B.2 – Case 2

As seen above, the HEN fulfils the MER design network fulfils the minimum heating and utilities requirements. The lines are relaxed with the exception of two cooling lines. However, temperature cross between these lines does not occurs.

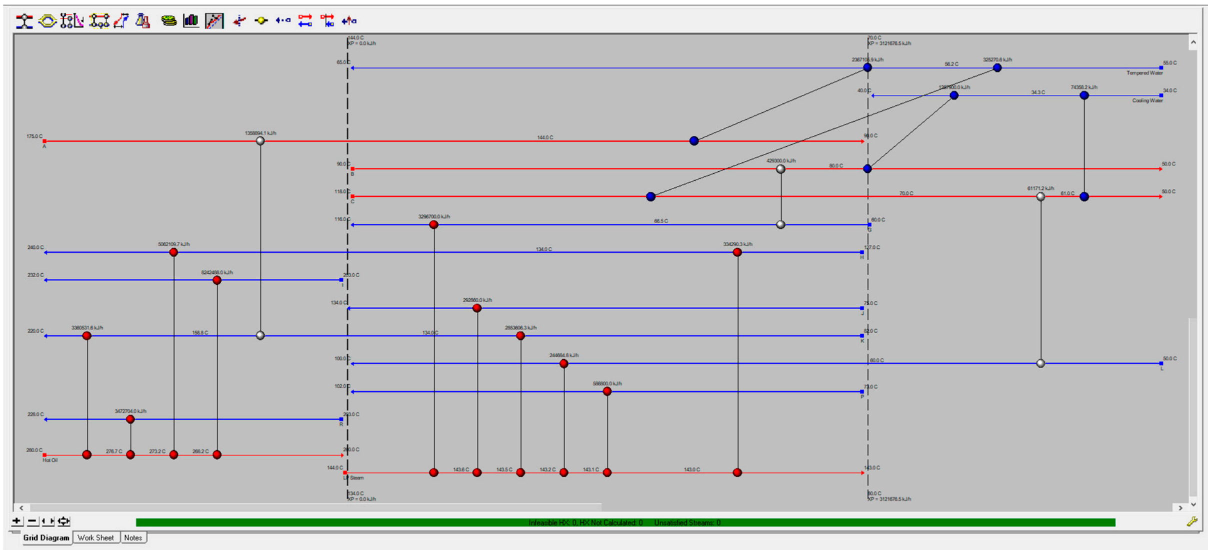

Figure B.8 Aspen Energy Analyzer of Case 2

Table B.5 Full Evaluation of Case 2

Stream	Process	Utility Required (GJ/year)	Initial Temperature (°C)	Final Temperature (°C)	Utility	Operating Cost (RM/year)
A	Cooling	18,922	175	90	Tempered Water	32,243
B	Cooling	6,883	90	50	Cooling Water	1,289
C	Cooling	6,883	118	50	Cooling Water	1,289
D*	Cooling	-	220	82	-	-
E*	Cooling	-	216	83	-	-
F*	Cooling	-	130	130	-	-
G	Heating	26,381	60	116	MP Steam	1,265,997
H	Heating	43,171	127	240	Hot Oil	1,390,822
I	Heating	65,952	203	232	Hot Oil	2,124,739
J	Heating	2,333	75	134	LP Steam	111,950
K	Heating	49,709	82	220	Hot Oil	1,601,441
L	Heating	1,958	50	100	LP Steam	93,982
M*	Heating	-	83	216	-	-
N*	Heating	-	49	203	-	-
O*	Heating	-	65	103	-	-
P*	Heating	4,694	73	102	LP Steam	151,237
Q	Heating	27,792	203	228	Hot Oil	1,333,720

Sum	254,678		8,108,708

Appendix B.3 – Case 3

The HEN in this environment follows the HEN of the existing plant with the addition of 1 new economiser between stream 307 and stream 218+219 as shown in the green box. While this occurs across the pinch line, it does not violate the temperature cross rules. Here, stream 307 is cooled down from 161.6 to 93.1 °C while stream 218+219 heats up from 136.6 to 82 °C.

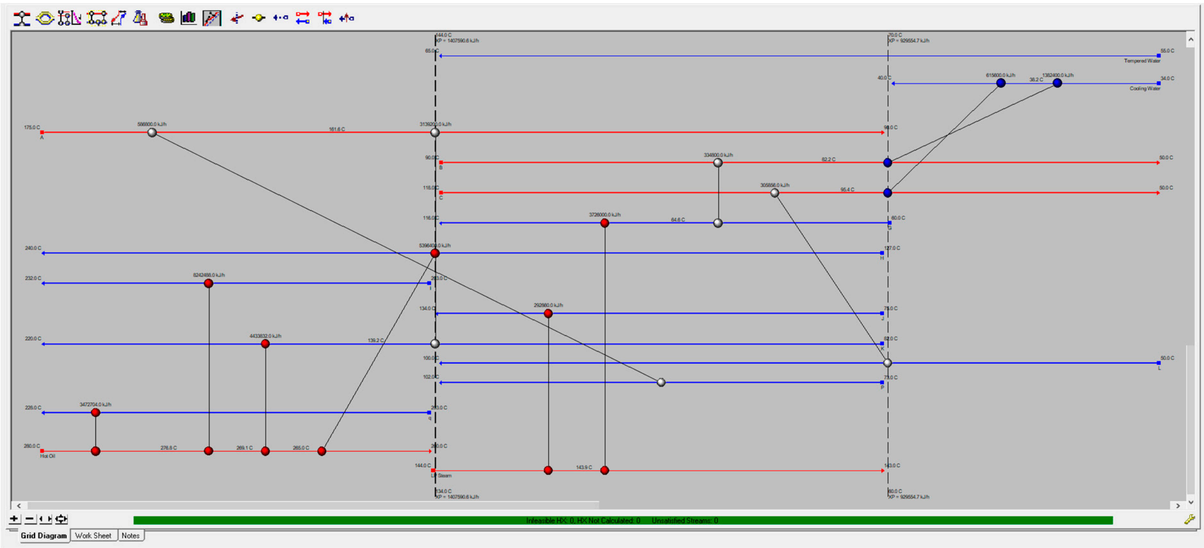

Figure B.9 Aspen Energy Analyzer of Case 3

Table B.6 Full Evaluation of Case 3

Stream	**Process**	**Utility Required (GJ/year)**	**Initial Temperature (°C)**	**Final Temperature (°C)**	**Utility**	**Operating Cost (RM/year)**
A	Cooling	-	175	90	Tempered Water	-
B	Cooling	11,059	90	50	Cooling Water	2,070
C	Cooling	4,925	118	50	Cooling Water	922
D*	Cooling	-	220	82	Tempered Water	-
E*	Cooling	--	216	83	Tempered Water	-
F*	Cooling	-	130	130	Tempered Water	-
G	Heating	29,808	60	116	MP Steam	1,363,038
H	Heating	43,171	127	240	Hot Oil	1,390,816
I	Heating	65,940	203	232	Hot Oil	2,124,340
J	Heating	2,343	75	134	LP Steam	112,432
K	Heating	35,470	82	220	Hot Oil	1,142,730
L	Heating	-	50	100	LP Steam	-
M*	Heating	-	83	216	Hot Oil	-
N*	Heating	-	49	203	Hot Oil	-
O*	Heating	-	65	103	LP Steam	-
P*	Heating	-	73	102	LP Steam	-
Q	Heating	27,792	203	228	Hot Oil	1,333,720
SUM		220,508				7,470,069

Appendix B.4 – Pinch Temperature Cross

Figure B.10 and Figure B.11 error given out when temperature cross occurs during stream matching process. It may not appear clear at first as to where did the temperature cross occurred but as mentioned in Case 1, the first temperature pinch set (134 °C and 144 °C), is crossed, hence this is not feasible. AEA has also gave out a warning alert in which the software indicates a temperature cross is occurring through the presence of a yellow heat exchanger.

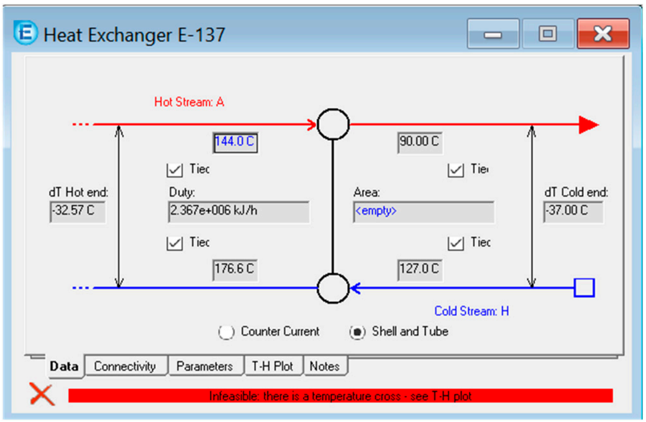

Figure B.10 Stream A and H for Case 2

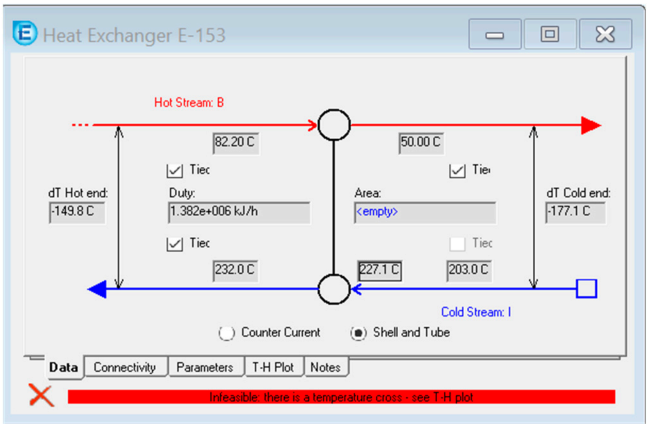

Figure B.11 Stream B and I for Case 3