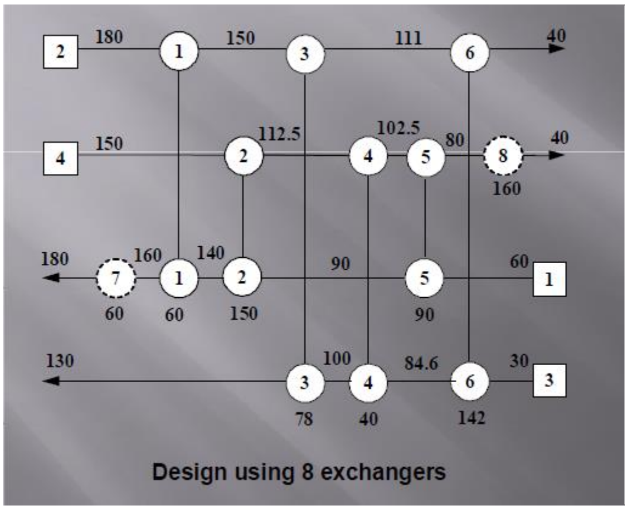
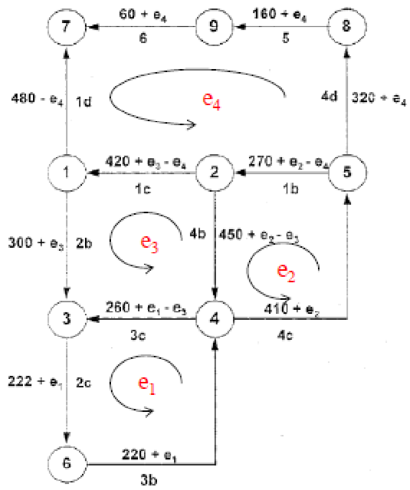
HEN ASSIGNMENT

-Meghana PV

-CH12B083



Design using 8 exchangers



To remove an exchanger from the given design, we optimize using the concept of loops and paths, simplified by making use of a reduced process graph, with an environment node in which the paths and loops are indicated by undirected loops. In the reduced process graph, there are 4 loops for which heat loads are to be circulated which are found by considering a spanning tree and finding its fundamental loops using its chords.

Spanning Tree: 6, 1d, 1c, 1b, 4d, 4b, 3c, 3b

Chords: 5, 2b, 4c, 2c

Loops: 6, 1d, 1c, 1b, 4d, 5;

3c, 4b, 1c, 2b;

1b, 1c, 4c;

3c, 3b, 2c

Here, our loops are indicated in the reduced process graph, with the corresponding loop loads circulated indicated by e1, e2, e3 and e4.

The choice of **spanning tree is not important** as any loop of another spanning tree can be obtained by a ring-sum of the fundamental loops of the spanning tree considered. Therefore, the solution remains the same for a particular HEX to be deleted irrespective of the choice of the loops/spanning tree, only the formulation changes in terms of the corresponding loop loads as the stream enthalpies will be changed according to the number and direction of the loops it belongs to.

Optimization Formulation:

Minimize e4 (This is the energy penalty, as it is equal to the extra load circulated by either of the utilities to the environment, indicated by edge 5 or 6)

Subject to the constraints:

1. Min. approach Temperature Constraints, here 10 degrees Celsius
2. Positivity of the exchanger and utilities' heat loads
3. Heat Load of exchanger to be deleted set to 0.

Results:

Heat Exchangers to be deleted	Energy Penalty (kW)	Loop Loads (e1,e2,e3,e4 in kW)
4	40	-0.2431, 0.2302, 40.0000, 40.0000
4,2	40	-0.0194, 190.0000, 40.0000, 40.0000
4,3	40	118.0000, 0.1417, 40.0000, 40.0000
4,5	40	-0.1428, -50.0000, 40.0000, 40.0000
4,6	40	-142.0000, 0.1416, 40.0000, 40.0000
4,2,3	40	118.0000, 190.0000, 40.0000,40.0000
4,2,5	280	-0.1114, 190.0000, 40.0000, 280.0000
4,2,6	40	-142.0000, 190.0000, 40.0000,40.0000
4,3,5	40	118.0000, -50.0000, 40.0000, 40.0000
4,3,6	No feasible solution	
4,5,6	40	-142.0000, -50.0000, 40.0000, 40.0000
4,2,3,5	280	118.0000, 190.0000, 40.0000,280.0000
4,2,3,6	No feasible solution	
4,2,5,6	280	-142.0000, 190.0000,40.0000,280.0000
4,3,5,6	No feasible solution	

No other HEXs get deleted in the optimization process for any of these cases, as there are multiple solutions for each case , where the optimizer (fmincon) converges to the closest local solution, which is different from a solution with other exchanger deleted as well.

A case where another exchanger gets deleted is when we delete exchanger 6, exchanger 4 gets deleted as well with an energy penalty of 40kW and loop loads of -142.0000, -0.5441, 40.0000 and 40.0000

We can see that when we delete exchanger 4, the optimal solution is for an energy penalty of 40 kW and with deletion of the set of exchangers 5,6 or 3,5 or 2,6 or 2,3.

The Anomaly:

Heat Exchangers to be deleted	Energy Penalty (kW)	Loop Loads (e1,e2,e3,e4 in kW)
5,3	66.6667	-55.3333, -23.3333, -133.3333, 66.6667
5,4,3	40	118.0000, -50.0000, 40.0000, 40.0000

The anomaly occurs because the optimizer (fmincon) converges to a local minimum and gets stuck there, thus not reaching the global solution. This can perhaps be avoided by making use of a multiple objective formulation such as a goal attainment method, making sure that as many exchangers as possible get deleted.

Code:

MAIN FILE:

```
clc
clear all
close all

FCp=[3,2,2.6,4];
delTmin=10;
```

Original

```
T=[60,90,140,160,180; 180,150,111,40,0;30,84.6,100,130,0; 150,112.5,102.5,80,40];

e=zeros(4,1); % Loop Loads

H=zeros(4,5); % Enthalpy flows
H(1,:)=[(T(1,1)*FCp(1)),(270+e(2)-e(4)),(420+e(3)-e(4)),(480-e(4)),(T(1,5)*FCp(1))];
H(2,:)=[(T(2,1)*FCp(2)),(300+e(3)),(222+e(1)),(T(2,4)*FCp(2)),0];
H(3,:)=[(T(3,1)*FCp(3)), (220+e(1)),(260+e(1)-e(3)),(T(3,4)*FCp(3)),0];
H(4,:)=[(T(4,1)*FCp(4)), (450+e(2)-e(3)), (410+e(2)), (320+e(4)),(T(4,5)*FCp(4))];

Q=zeros(8,1); % Heat loads
Q(1)=H(2,1)-H(2,2);
Q(2)=H(4,1)-H(4,2);
Q(3)=-(H(3,3)-H(3,4));
Q(4)=H(4,2)-H(4,3);
Q(5)=-(H(1,1)-H(1,2));
Q(6)=-(H(3,1)-H(3,2));
Q(7)=-(H(1,4)-H(1,5));
Q(8)=H(4,4)-H(4,5)
```

```
Q =

    60
   150
    78
    40
    90
   142
    60
   160
```

With Deletion of HEX

```
sol0=zeros(4,1);

obj=@(e)e(4);
constr=@(e)con2(e,T,FCp,delTmin);
[LoopLoads,EnergyPenalty]=fmincon(obj,sol0,[],[],[],[],[],[],constr)
%[LoopLoads,Cost]=ga(obj,4,[],[],[],[],[],[],constr)

e=LoopLoads;
```

```
H=zeros(4,5); % Enthalpy flows
H(1,:)=[(T(1,1)*FCp(1)),(270+e(2)-e(4)),(420+e(3)-e(4)),(480-e(4)),(T(1,5)*FCp(1))];
H(2,:)=[(T(2,1)*FCp(2)),(300+e(3)),(222+e(1)),(T(2,4)*FCp(2)),0];
H(3,:)=[(T(3,1)*FCp(3)), (220+e(1)),(260+e(1)-e(3)),(T(3,4)*FCp(3)),0];
H(4,:)=[(T(4,1)*FCp(4)), (450+e(2)-e(3)), (410+e(2)), (320+e(4)),(T(4,5)*FCp(4))];

Q=zeros(8,1); % Heat loads
Q(1)=H(2,1)-H(2,2);
Q(2)=H(4,1)-H(4,2);
Q(3)=-(H(3,3)-H(3,4));
Q(4)=H(4,2)-H(4,3);
Q(5)=-(H(1,1)-H(1,2));
Q(6)=-(H(3,1)-H(3,2));
Q(7)=-(H(1,4)-H(1,5));
Q(8)=H(4,4)-H(4,5)

% Updated Temperatures
FCP=(repmat(FCp,5,1))';
T=H./FCP;
```

```
Local minimum found that satisfies the constraints.

Optimization completed because the objective function is non-decreasing in
feasible directions, to within the default value of the function tolerance,
and constraints are satisfied to within the default value of the constraint tolerance.




LoopLoads =

  118.0000
  190.0000
   40.0000
  280.0000


EnergyPenalty =

  280.0000


Q =

   20.0000
    0.0000
    0.0000
    0.0000
    0.0000
  260.0000
  340.0000
  440.0000
```

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CONSTRAINT FUNCTION:


```
function [c,ceq]=con2(e,T,FCp,delTmin)
```

Calculation of Updated Temp

```
H=zeros(4,5); % Enthalpy flows
H(1,:)=[(T(1,1)*FCp(1)),(270+e(2)-e(4)),(420+e(3)-e(4)),(480-e(4)),(T(1,5)*FCp(1))];
H(2,:)=[(T(2,1)*FCp(2)),(300+e(3)),(222+e(1)),(T(2,4)*FCp(2)),0];
H(3,:)=[(T(3,1)*FCp(3)), (220+e(1)),(260+e(1)-e(3)),(T(3,4)*FCp(3)),0];
H(4,:)=[(T(4,1)*FCp(4)), (450+e(2)-e(3)), (410+e(2)), (320+e(4)),(T(4,5)*FCp(4))];

Q=zeros(8,1); % Heat loads
Q(1)=H(2,1)-H(2,2);
Q(2)=H(4,1)-H(4,2);
Q(3)=-(H(3,3)-H(3,4));
Q(4)=-(H(3,2)-H(3,3));
Q(5)=-(H(1,1)-H(1,2));
Q(6)=-(H(3,1)-H(3,2));
Q(7)=-(H(1,4)-H(1,5));
Q(8)=H(4,4)-H(4,5);

% Updated Temperatures
FCP=(repmat(FCp,5,1))';
T=H./FCP;
```

Constraints

delta Tmin constraints - - Uncomment according to the choice of HEX to be deleted

```
c(1)=delTmin-(T(2,1)-T(1,4)); % HEX1
c(2)=delTmin-(T(2,2)-T(1,3));
% c(3)=delTmin-(T(4,1)-T(1,3)); % HEX 2
% c(4)=delTmin-(T(4,2)-T(1,2));
% c(3)=delTmin-(T(2,2)-T(3,4)); % HEX 3
% c(4)=delTmin-(T(2,3)-T(3,3));
% c(7)=delTmin-(T(4,2)-T(3,3)); % HEX 4
% c(8)=delTmin-(T(4,3)-T(3,2));
% c(5)=delTmin-(T(4,3)-T(1,2));  % HEX 5
% c(6)=delTmin-(T(4,4)-T(1,1));
c(3)=delTmin-(T(2,3)-T(3,2));  % HEX 6
c(4)=delTmin-(T(2,4)-T(3,1));

% Deleting HEX - Uncomment according to the choice of HEX to be deleted
 ceq(3)=Q(2);
ceq(4)=Q(3);
ceq(1)=Q(4);
ceq(2)=Q(5);
%ceq(2)=Q(6);

% Positive heat load constraints
c(5)=-Q(1);
```

```
%c(8)=-Q(2);
%c(6)=-Q(3);
% c(10)=-Q(4);
%c(9)=-Q(5);
c(6)=-Q(6);
c(7)=-Q(7);
c(8)=-Q(8);

end
```

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