Methanol Production Flowsheet

Contents

Problem Statement

Methanol (CH3OH) can be produced from synthesis gas (36 mol% CO, 60 mol% H2, and 4 mol% inert N2) as shown in the accompanying figure. The reaction is

```
CO + 2 H2 -> CH3OH
```

In steady-state operation the reactor has a fractional conversion of 20% of the limiting reactant. 5% of the recycled gas is purged.

1. What fraction of the incoming CO is converted to CH3OH?
2. What fraction of the incoming H2 is converted to methanol?
3. What fraction of the reactor inlet consists of inerts?

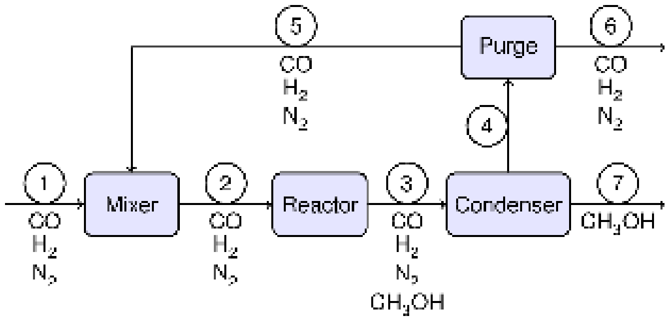
Required Matlab

- `CVX`
- `displaytable.m`

Flowsheet

The flowsheet has been transcribed from the problem statement. The streams are numbered and labeled with component flows.

```
[I,m] = imread('methanol_production_flowsheet.png','png');
I = imresize(I,0.25,'Method','nearest','Antialiasing',false);
imshow(I,m);
axis off;
```



CVX Model

We'll use the following abbreviations

```
C   Carbon Monoxide (CO)
H   Hydrogen (H2)
N   Nitrogen (N2)
M   Methanol (CH3OH)
```

```
cvx_begin

    % Stream Variables (20)
    variables C1 H1 N1
    variables C2 H2 N2
    variables C3 H3 N3 M3
    variables C4 H4 N4
    variables C5 H5 N5
    variables C6 H6 N6
    variables M7

    % Extents of Reaction (1)
    variables X

    % MATERIAL BALANCES (14)

    % Mixer (3)
    0 == C1 + C5 - C2;
    0 == H1 + H5 - H2;
    0 == N1 + N5 - N2;

    % Reactor (4)
    0 == C2 - C3 - X;
    0 == H2 - H3 - 2*X;
    0 == N2 - N3;
    0 == -M3 + X;

    % Condenser (4)
    0 == C3 - C4;
    0 == H3 - H4;
    0 == N3 - N4;
    0 == M3 - M7;
```

```
    % Purge (3)
    0 == C4 - C5 - C6;
    0 == H4 - H5 - H6;
    0 == N4 - N5 - N6;

    % SPECIFICATIONS (7)

    % Feed rates
    C1 == 36;
    H1 == 60;
    N1 == 4;

    % 20% Fractional Conversion
    H3 == 0.80*H2;

    % Purge Fraction
    C6 == 0.05*C4;
    H6 == 0.05*H4;
    N6 == 0.05*N4;

cvx_end
```

```
Homogeneous problem detected; solution determined analytically.
Status: Solved
Optimal value (cvx_optval): +0
```

Stream Table

The stream variables are organized into a stream table. To keep the width small enough to fit on a sheet of paper, the stream table is presented with columns representing components, and rows denoting streams.

```
flows = [ ...
    C1   C2   C3   C4   C5   C6    0;
    H1   H2   H3   H4   H5   H6    0;
    N1   N2   N3   N4   N5   N6    0;
     0    0   M3    0    0    0   M7];

comps = {'C','H','N','M'};
displaytable(flows,comps,'S');
```

```
   S(1)  S(2)  S(3)  S(4)  S(5)  S(6)  S(7)
C    36   245   220   220   209    11     0
H    60   250   200   200   190    10     0
N     4    80    80    80    76     4     0
M     0     0    25     0     0     0    25
```

What fraction of the incoming CO is converted to CH3OH?

```
Yield_CO = (C1-C6)/C1;
```

```
displaytable(Yield_CO,'Fraction of CO converted to CH3OH = ');
```

```
Fraction of CO converted to CH3OH =   0.69444
```

What fraction of the incoming H2 is converted to CH3OH?

```
Yield_H2 = (H1-H6)/H1;
displaytable(Yield_H2,'Fraction of H2 converted to CH3OH = ');
```

```
Fraction of H2 converted to CH3OH =   0.83333
```

What fraction of the reactor inlet consists of inerts?

```
y_inerts = N2/(C2 + H2 + N2);
displaytable(y_inerts,'Mole fraction of inerts in reactor feed = ');
```

```
Mole fraction of inerts in reactor feed =   0.13913
```

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