Material balances for Example 3.19: Ethylene Oxide Flowsheet

The example demonstrates the formulation and solution of material balances for a simple process flowsheet with recycle. The solution is computed using CVX, a convex optimization package distributed by cvxr.com. The following example solves Example 3.19 of the Murphy textbook.

JCK 9/28/2012

Contents

Functions Used

- `CVX`
- `displaytable.m`

Process Flowsheet

The process flowsheet consists of three units, five streams, and three components: ethylene (E), oxygen (O), and ethylene oxide (EO). The feedstream consists of 196 kgmol/hr E and 84.5 kgmol/hr. The reaction stoichiometry is given by

```
                Reaction:  2 E + O --> 2 EO
            ____________________________________
           |                  5                 |
       ____V____         _________         _____|_____
  1   |         |   2   |         |   3   |           |     4
----->|  Mixer  |------>| Reactor |------>| Separator |--------->
      |_________|       |_________|       |___________|
```

Component Numbering

To minimize the potential for coding errors, we use component indices chosen as mnemonics of the species contained in the process flowsheet.

```
O  = 1;   % oxygen
E  = 2;   % ethylene
EO = 3;   % ethylene oxide
```

Stoichiometric Coefficients

Stoichiometric coefficients are stored in a vector. The index corresponds to the species involved in the reactions.

```
v(O)  = -1;
v(E)  = -2;
v(EO) =  2;
```

Reactor Conversion

The reactor performance is stated in terms of the fraction of the feed E converted to EO. This fraction is fce3.

```
fce3 = 0.06;
```

Separator Efficiencies

The separator efficiency is specified in terms of the fraction of each incoming component that goes to the preferred outlet stream.

```
fo5  = 0.995;
fe5  = 0.98;
feo4 = 0.97;
```

Solution of the Steady State Equations

The stream variables are represented by a matrix n(3,5) of variables, and the extent of reaction is a single variable x. Once these are declared, we simply write out all of the material balance equations and process specifications.

```
cvx_begin quiet

    % Declare the problem variables
    variables n(3,5);     % A table of molar flowrates
    variables x;          % Extent of reaction

    % Mixer Balance
    0 == n(O,1) + n(O,5) - n(O,2);
    0 == n(E,1) + n(E,5) - n(E,2);
    0 == n(EO,1) + n(EO,5) - n(EO,2);

    % Reactor Balance
    0 == n(O,2) - n(O,3) + v(O)*x;
    0 == n(E,2) - n(E,3) + v(E)*x;
    0 == n(EO,2) - n(EO,3) + v(EO)*x;

    % Seperator Balance
    0 == n(O,3) - n(O,4) - n(O,5);
    0 == n(E,3) - n(E,4) - n(E,5);
    0 == n(EO,3) - n(EO,4) - n(EO,5);

    % Feed Stream Specifications
    n(O,1) == 84.5;
    n(E,1) == 196;
    n(EO,1) == 0;

    % Reactor Conversion
```

```
    2*x == fce3*n(E,2);

    % Seperator Effciencies
    n(O,5) == fo5*n(O,3);
    n(E,5) == fe5*n(E,3);
    n(EO,4) == feo4*n(EO,3);

cvx_end
```

Display Results

```
disp('Stream Table [kgmol/hr]');
displaytable([n;sum(n)],{'O','E','EO','TOTAL'},'Stream','%5.1f');
fprintf('\nEO purity     = %5.3f  mol%%\n',100*n(3,4)/sum(n(:,4)));
```

```
Stream Table [kgmol/hr]
       Stream(1)  Stream(2)  Stream(3)  Stream(4)  Stream(5)
O           84.5     2050.8     1976.1        9.9     1966.3
E          196.0     2487.3     2338.1       46.8     2291.3
EO           0.0        4.6      153.9      149.2        4.6
TOTAL      280.5     4542.7     4468.1      205.9     4262.2


EO purity     = 72.488  mol%
```

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