Department of Chemical Engineering
Thapar Institute of Engineering & Technology, Patiala

Course: Material and Energy Balances UCH301

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Material Balances

Material Balance

- A material balance is an account for the materials.

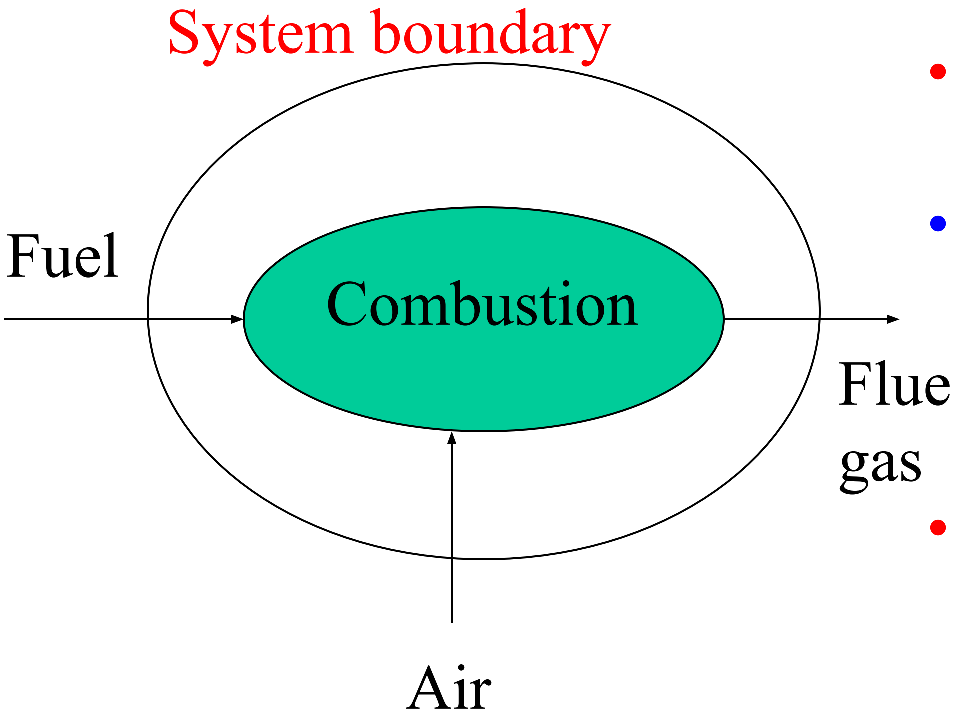
- For applying material balance on a process:

✔ Identify the system boundary for which the material balance is being done

✔ Identify all streams entering/exiting the system boundary

✔ A simple sketch representing the system is drwan

Solving Material Balance Problem



- A simple process is shown in the sketch
- System boundry is marked for the combustion process
- Some information of the process is a prerequisite to make a sketch to decide the material flow streams
- As here, combustion requires fuel and air, and the exit gas is called flue gas.

Solving Material Balance Problems

- The *system* is any process or portion of a process chosen for analysis. A system is said to be "open" if material flows across the system boundary during the interval of time being studied; "closed" if there are no flows in or out.
- You would almost always need to make a sketch/block diagram for the physical process using the problem statement
- Information about the entering or exiting streams is also to be extracted from the problem statement using your own understanding of the physical process

GENERAL MATERIAL BALANCE EQUATION

- Material Balance:

$$\left(\textit{Flow of material } \text{in } \textit{ through system boundaries} \right)$$
$$-\left(\textit{Flow of material out through system boundaries} \right)$$
$$+\left(\textit{Genration of material within the system} \right)$$
$$-\left(\textit{Consumption of material within the system} \right)$$
$$=\left(\textit{Accumulation of material within the system} \right)$$

Solving Material Balance Problems

- *Accumulation* is usually the rate of change of holdup within the system. It may be positive (material is increasing), negative (material decreasing).
- If the system does not change with time, it is said to be at *steady state*, and the net accumulation will be zero.

Material balances can be written for:

- You may write total mass balance
- You may write total mole balance
- You may write component mass balance
- You may write component mole balance

Solving Material Balance Problems

- Mass is conserved (In = Out)
- Moles are conserved only when there is no reaction.
- Volume is NOT conserved.

Forms of Balance Equations

Differential Form:

✔ All the terms are rates, so the balance describes an instant in time. Usually written for a continuous process.

Integral Form:

✔ Written using total amounts as terms, usually written for batch processes

Organization of Material Balance Problems

- Material balances without Chemical Reactions
- Material balances with chemical reactions

Specific Case(s):

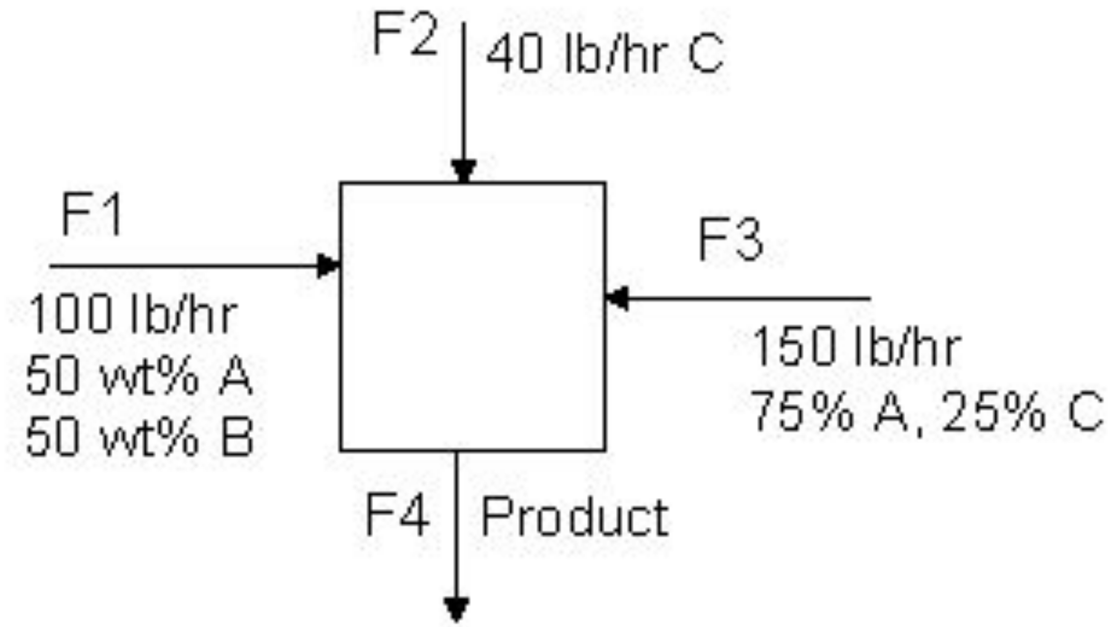
For a process at steady state in which no generation or accumulation takes place the overall material balance equation reduces to:

Mass/mole entering through system boundaries	=	Mass/mole exiting through system boundaries

Material Balances without Chemical Reactions

Problem

The figure describes a mixing tank problem. Find all flows and compositions. All streams are liquid phase streams.



Solution

- Our system here is mixing tank. The figure shows three input streams and one output stream. This is a simple mixing operation. The operation is steady state.

<u>Overall M.B. on the process:</u>

Total mass in/time (lb/hr) = Total Mass out/time (lb/hr)

F1+F2 + F3 = F4 F4 = 100 + 40 +150 =290 lb/hr

As you can see F4 will have all the three components (A, B & C), to find the compositions of A, B & C in F4 we need to write component balances.

✔ REMEMBER THAT IN ANY STREAM SUM OF ALL COMPOSITIONS SHOULD BE 100%

Component balance for A:

A entering into the process = A leaving from the process

100*0.5 + 40*0.0 + 150*0.75 = A leaving from the process

A leaving from the process = 50 + 0+112.5 = 162.5 lb/hr

Component balance for B:

100*0.5 + 40*0 + 150*0 = B leaving from the process

B leaving from the process = 50 lb/hr

Component balance for C:

100*0.0 + 40*1.0 + 150*0.25 = C leaving from the process

C leaving from the process = 0 + 40+37.5 = 77.5 lb/hr

Composition of F4:

% A in F4 = (Mass of A in F4/Total Mass of F4)*100

= (162.5/290)*100 = 56.04 %

% B in F4 = (50/290)*100 = 17.24%

% C in F4 = (77.5/290)*100 = 26.72%

✔ Checking your answer: summation of %A, %B &%C should be 100

- I have seen that few student remain confused about particular values of composition of some component in various stream.
- It is perfectly all right if a component is 50% in feed stream & 75% in product stream or vice-versa,
- Because the composition is related to a particular stream only, and compositions of different stream do not have any particular relationship.
- It is the total mass of a component which should be equal in the inlet and outlet (not the compositions)