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

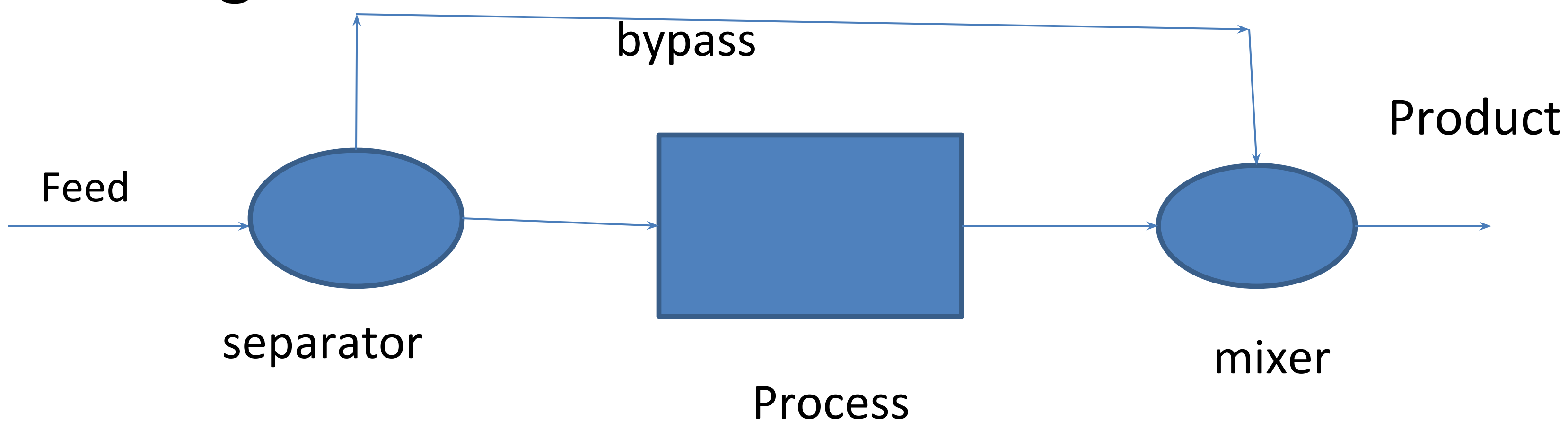
Course: Material and Energy Balances UCH301

Course Instructor: Dr. Raj Kumar Gupta

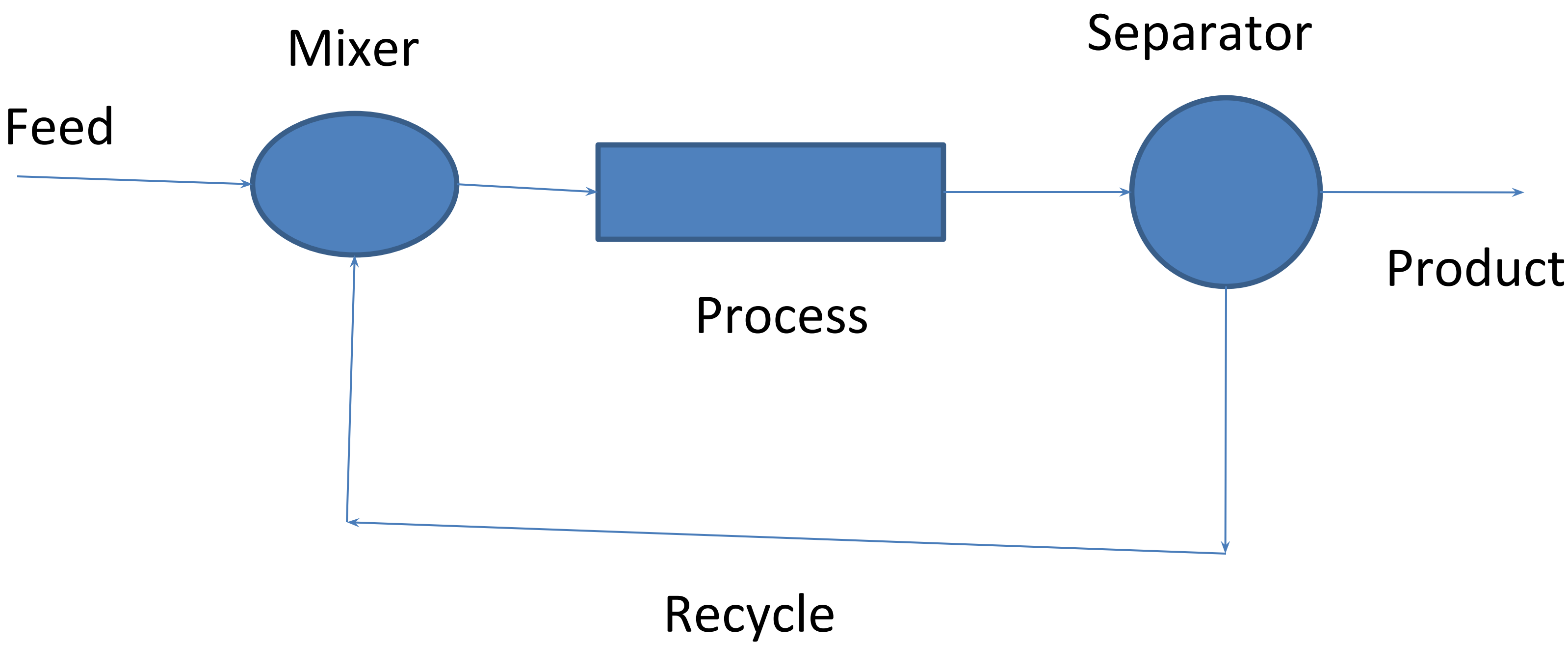
MATERIAL BALANCE CALCULATIONS INVOVING BYPASS AND RECYCLE STREAMS

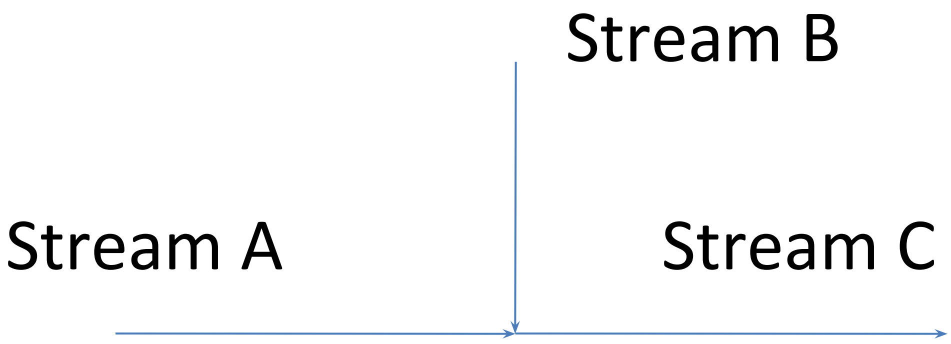
BYPASS, AND RECYCLE STREAMS

- A bypass stream is one that skips one or more stages of the process and goes directly to the next stage.

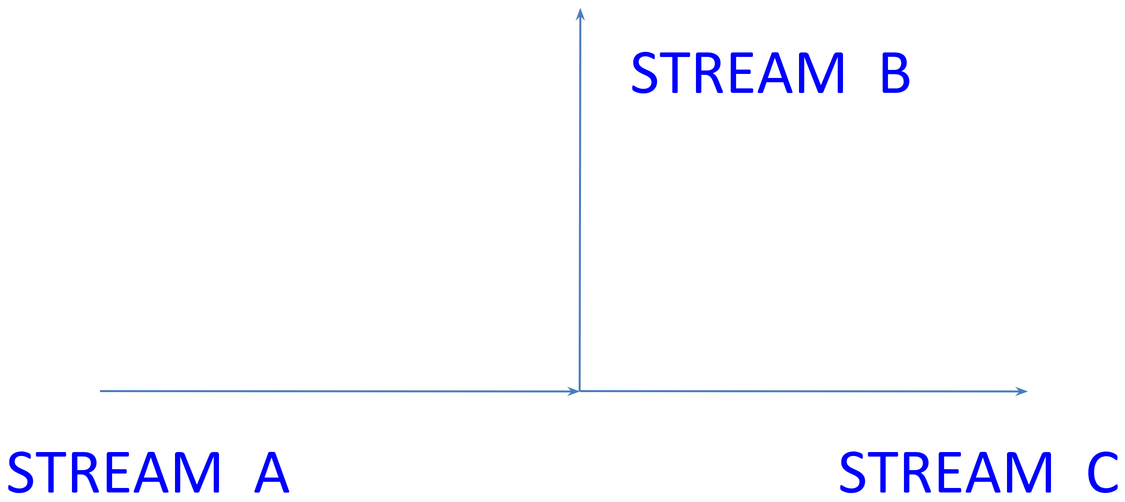


- A recycle stream is used to send the unconverted/unprocessed material back to the process





Mixing point



SPLITTING POINT

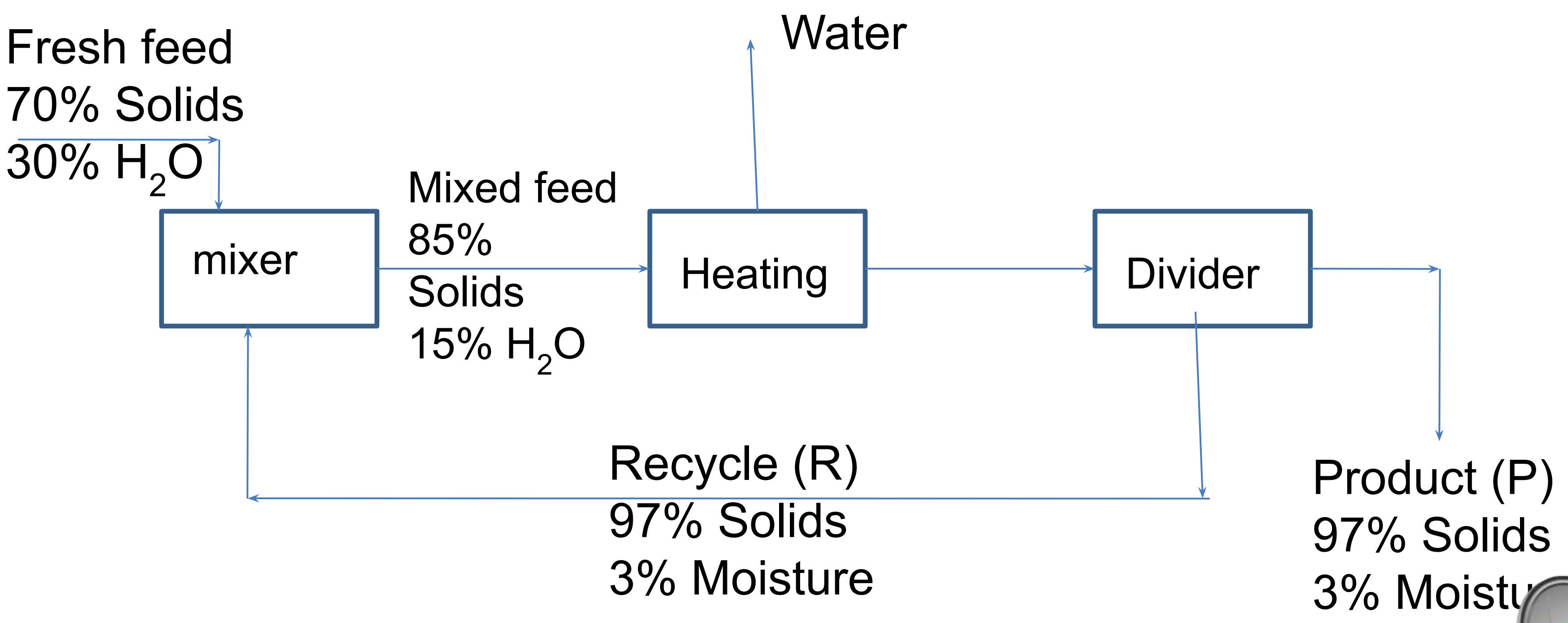
- ✔ Remember: Compositions of A, B, and C will be same

Exercise (involving Recycle Stream)

A drying operation is shown in figure. Calculate

(a) the fraction of dried product that must be recycled,

(b) rate of water removed

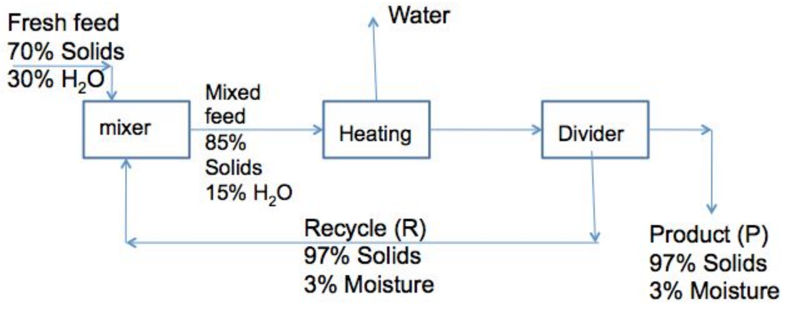


SOLUTION

Basis: 100 kg/h of Fresh Feed (FF)

There are two components:

Solids & water



Overall balance for the solids:

Solids in FF = Solids in P

$100*0.7 = P*0.97$

$P = 72.2$ kg/h

Hence, water being evaporated

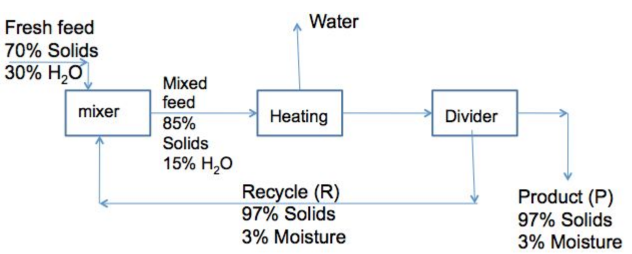
$= 100-72.2 = 27.8$ kg/h

Now, for the calculation of R, material balance over the mixer may be applied

M.B. over Mixer:

Total Balance: FF + R = MF

$$100 + R = MF$$



Water balance:

water in FF + water in R = water in MF

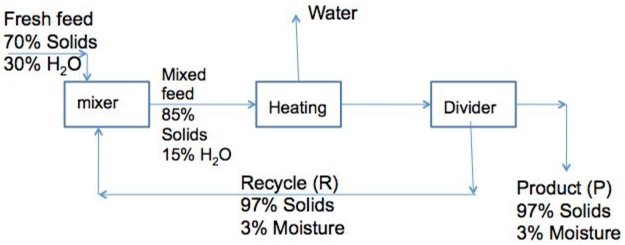
$$100*0.3 + R*0.03 = MF*0.15$$

Solving the two equations:

R = 125 kg/h; MF = 225 kg/h

Now, Dried product = MF - Water evaporated

= 225-27.8 = 197.2 kg/h



Therefore, fraction of Dried product recycled

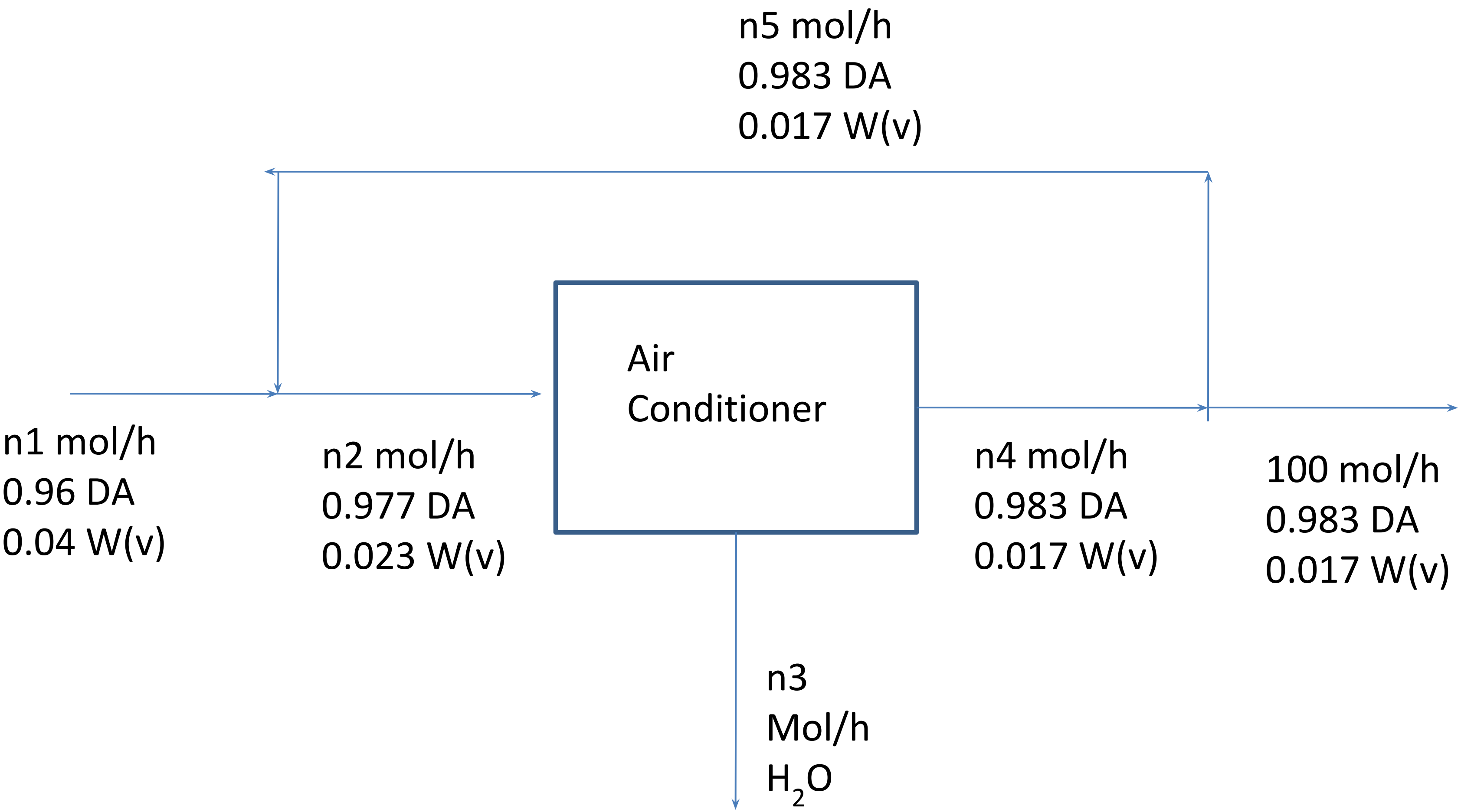
= Amount of Recycle/Amount of dried product

= 125/197.2 = 0.634

Problem (Involving Recycle Stream)

- *Fresh air containing 4 mol% water vapor is to be cooled and dehumidified to a water content of 1.7 mol%.* A stream of fresh air is combined with a recycle stream of previously dehumidified air and passed through the cooler (dehumidifier). The blended stream entering the cooler contains 2.3 mol% H_2O. In the air cooler (dehumidifier) some of the water in feed stream is condensed and removed as liquid. A fraction of the dehumidified air leaving the cooler is recycled and the remainder is delivered to a room. Taking 100 mol of dehumidified air delivered to the room as a basis, calculate the moles of fresh feed, moles of water condensed, and moles of dehumidified air recycled.

Solution


n5 mol/h
0.983 DA
0.017 W(v)
Air
Conditioner
n1 mol/h
0.96 DA
0.04 W(v)
n2 mol/h
0.977 DA
0.023 W(v)
n4 mol/h
0.983 DA
0.017 W(v)
100 mol/h
0.983 DA
0.017 W(v)
n3
Mol/h
H_2O

Dry air balance for overall process (I):

$$0.96\, n1 = 100 * 0.983$$

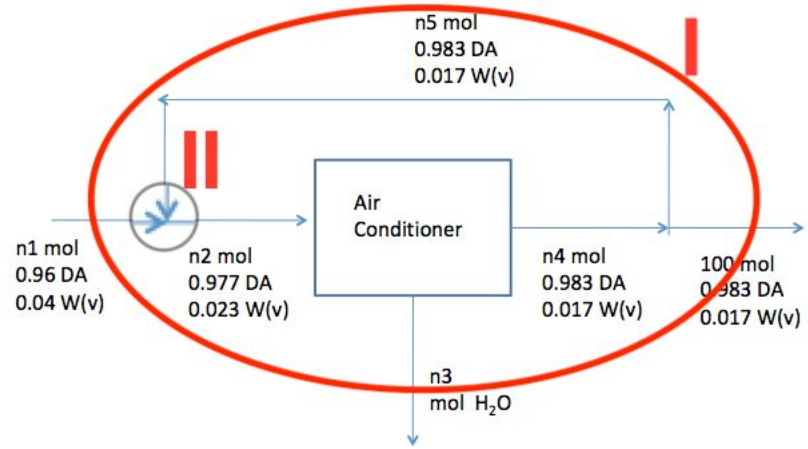
$$n1 = 102.4 \text{ mol/h}$$

Mol balance over the complete process:

$$n1 = n3 + 100$$

Therefore,

$n3 = n1 - 100 = 2.4$ mol H_2O condensed/h



Mol balance over mixing point (II):

$$n1 + n5 = n2$$

Water balance over mixing point

$$0.04\, n1 + 0.017 n5 = 0.023 n2$$

(n1 is known= 102.4)

n2 = 392.5 mol/h ; and n5 = 290 mol/h

Remember

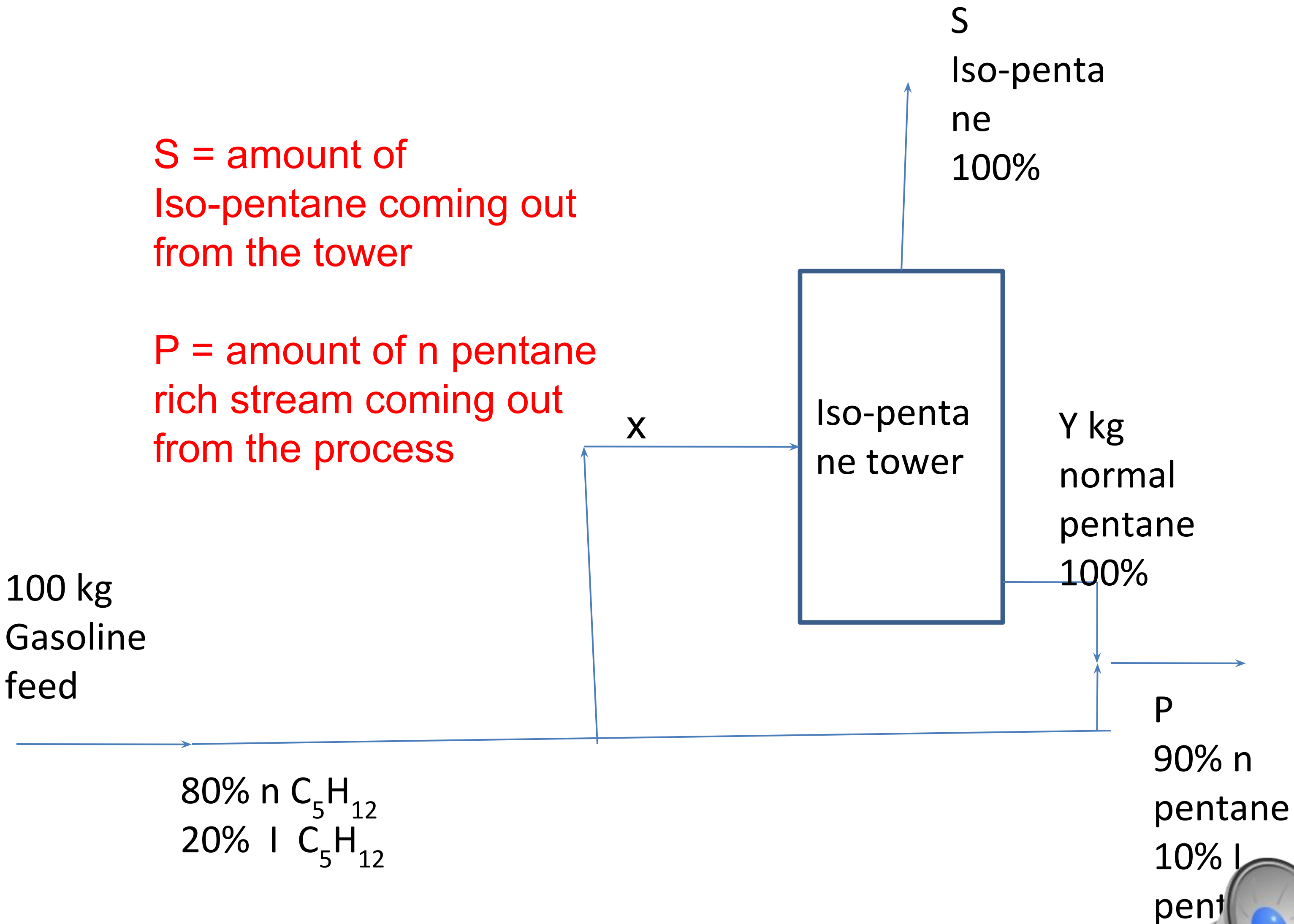
- ✔ Recycle amount can be more than the fresh feed (or feed to the process)
- ✔ For writing material balances for multiple unit process or processes involving recycle, identifying the subsystems in the process and corresponding streams for applying the balances is important.
- ✔ A common mistake made here is inclusion of the streams in the balances which do not cross the subsystem boundaries.

Exercise (Involving Bypass Stream)

- In the feed preparation section of a gasoline plant , isopentane is removed from the gasoline. Refer the figure shown (next slide) and calculate what fraction of this gasoline feed is passed through the isopentane tower.

S = amount of
Iso-pentane coming out
from the tower

P = amount of n pentane
rich stream coming out
from the process



Solution

We have to find the value of X/100

- Basis:100 kg/h feed

<u>Total M.B.</u> :

(Boundary for overall process; Streams crossing the boundary: Feed, P, & S)

Total mass in = Total mass out

$$100 = P + S$$

<u>N-C_5 balance (tie component)</u>

$$100*0.8 = S*0+P*0.9$$

 P = 88.9 kg/h

 S = 100-88.9 = 11.1 kg/h

Balance around Iso-pentane tower:

- Total balance: $X = 11.1 + Y$
- $N\text{-}C_5$ balance: $X*0.8 = Y$

  $X = 55.5$ kg/h

- Fraction of gasoline sent through isopentane tower is $= 55.5/100 = 0.555$