4. MATERIAL BALANCE

The alcohol balance over each unit will be based on hourly production rate. For a production rate of 500 TPD of MEK, the hourly production rate will be

$=500 \times 10^3 /24$ kg/hr

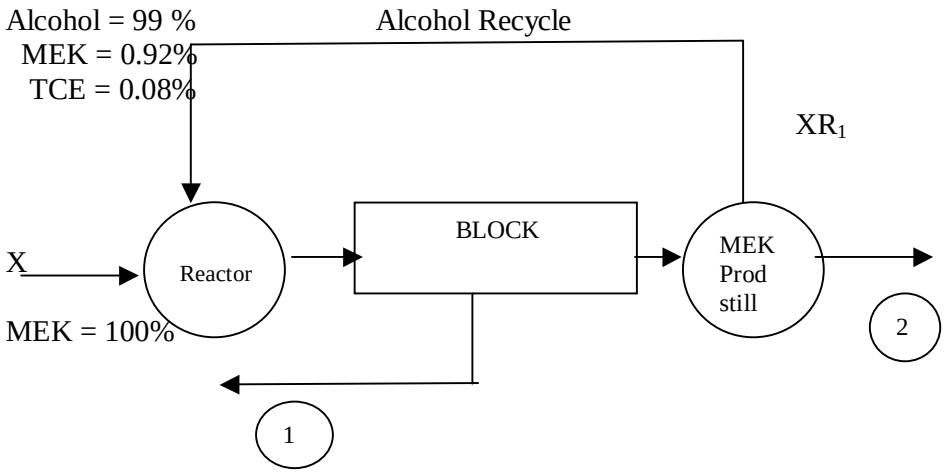
=20833.33 kg/hr

However allowing for 8 % spillage and other losses, the hourly production rate will be

= 1.08 x 20833.33 kg/ hr

=22500.00 kg/hr

Material balance is done over the whole process. In this diagram most of the inner processes are shown in the BLOCK.



X = Pure alcohol feed, kg/Hr

R_1 = Recycle ratio

MATERIAL BALANCE ACROSS THE REACTOR:-

Total feed of alcohol to reactor = $X + 0.99XR_1 = X (1+099R_1)$

For 89.1% conversion MEK produced,

$$= \left(\frac{X(1 + 0.99R_1)x\ 0.891}{74} \right) \text{ x 72 Kg MEK}$$

Total MEK from reactor $= \left[\frac{X\,(1 + 0.99\,R_1) \times 0.891 \times 72}{74} + 0.0092\,XR_1 \right]$ kg

The overall conversion = 98.5886%

MEK at final stream(2) = $\left(\frac{X}{74} \times 0.985886 \times 72 \right)$ kg

Hydrogen produced due to dehydrogenation reaction

$$= \left(\frac{X\,(1 + 0.99\,R_1) \times 0.891}{74} \times 2 \right) \text{ kg.}$$

H_2 produced are all coming out in the stream (1) is 68.49 wt % .

Total quantity of hydrogen at stream (1) = $\frac{X\,(1 + 0.99\,R_1) \times 0.891 \times 2}{74 \times 0.6849}$ kg/hr

MEK in stream (1)

$$= \left(\frac{X(1 + 0.99R_1) \times 0.891 \times 2}{74 \times 0.6849} \right) \times 0.0822 \text{ kg}$$

MEK Balance: -

(MEK from reactor) = (MEK at recycle)

+ (MEK at stream (1))

+(MEK at stream (2))

$$\frac{X(1 + 0.99R_1)}{74} \times 0.891 \times 72 + 0.0092\,XR_1 = 0.0092\,XR_1 + \frac{X}{74} \times 0.985886 \times 72 + \frac{(1 + 0.99R_1) \times 0.891 \times 2}{74 \times 0.6849} \times 0.0822$$

- $(1 + 0.99\,R_1)\,(0.8669 - 2.8902 \times 10^{-3}) = 0.9592$
- $(1 + 0.99\,R_1) = 1.1102$
- $R_1 = \frac{0.1102}{0.99} = 0.1113$

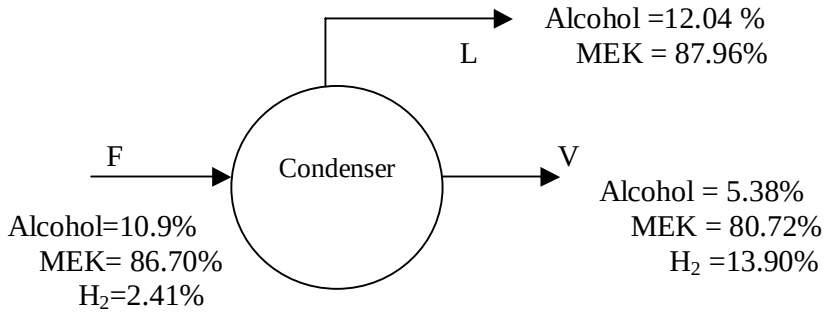
MATERIAL BALANCE ACROSS THE CONDENSER:-

Amount of feed to condenser = $X (1 + R_1)$ kg/hr

$$MEK = \left(\frac{X(1 + 0.99\ R_1)\ 0.891}{74} \times 72 + 0.0092XR_1 \right) \text{ kg}$$

Alcohol = $X(1 + 0.99\ R_1) \times 0.109$ kg

$$H_2 = \frac{X(1 + 0.99\ R_1) \times 0.891 \times 2}{74} \text{ kg}$$



F= Feed
L= Condensate from condenser
V= Vapor from the condenser

Overall material balance

$F = L + V$

Component balance

$(Alcohol)_{Feed} = L(0.1204) + V(0.0538)$

- ⇨ $(Alcohol)_{Feed} = F(0.1204) + V(0.0538 – 0.1204)$
- ⇨ $X(1 + 0.994R_1) \times 0.109 = X (1 + R_1) (0.1204) + V(0.0538 – 0.1204)$
- ⇨ $0.1210X = 0.1338X – 0.0666V.$

⇨ $V = 0.19204X$

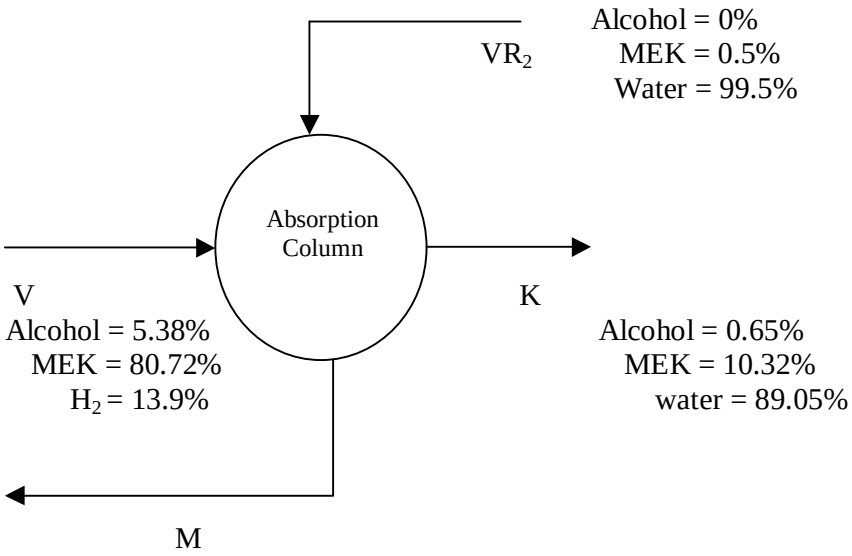
$L = X(1 + R_1) – V$

$L = 1.1113X – 0.19204$

$=> L = 0.9193X$

F = 1.1113X
L = 0.9193X
V = 0.19204X

MATERIAL BALANCE ACROSS THE ABSORPTION COLUMN:-



V = Vapor from condenser.
VR_2 = Absorber feed.
M = Vapor from absorber.
K = Absorber effluent.

Overall material balance

$V + VR_2 = K+M$

Alcohol balance

V x (0.0538) + 0 = K (0.0065) + M (0.0092) –(2)

H_2 balance

(V x 0.139) + 0 = 0 + M (0.6849)

$$M = \left(\frac{0.139}{0.6849} \right) V$$

M = 0.20294 V

M = (0.20294) (0.19204X)

M = 0.039X

Alcohol balance

K (0.0065) = (0.19204X) (0.0538) – (0.039X) (0.0092)

K= 1.5343X

From (1)

VR_2 = K + M - V
= 1.5343X+0.039X- 0.19204X

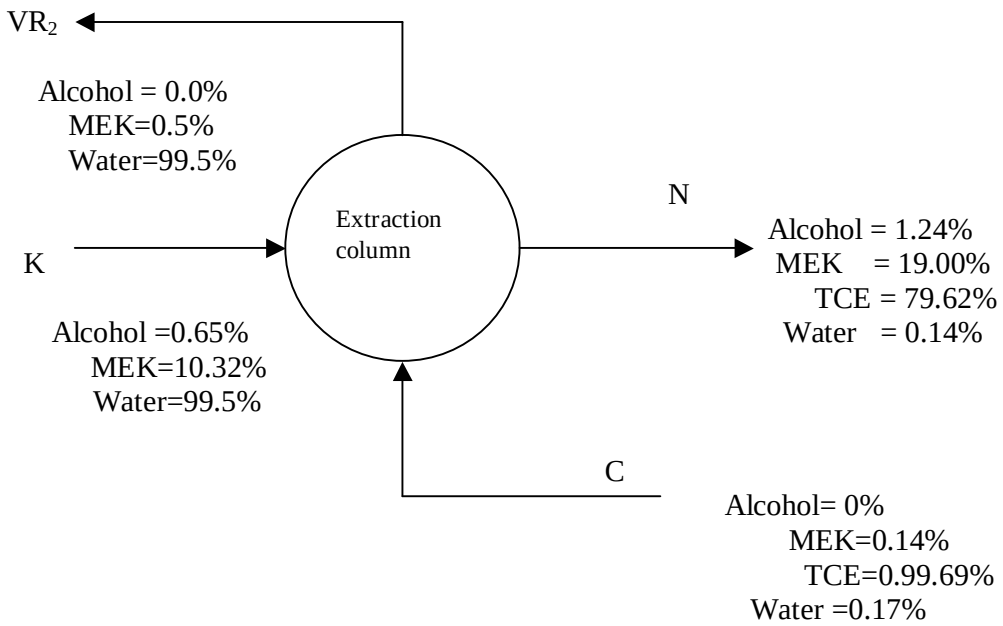
VR_2 = 1.38126X

$R_2 = \frac{1.38126X}{0.19204X}$

R_2 = 7.19256

V = 0.19204X kg/hr.
VR_2 = 0.19204 x 7.19256 = 1.38126X kg/hr
K = 1.5343X kg/hr
M = 0.039X kg/hr

MATERIAL BALANCE ACROSS THE EXTRACTION COLUMN:-



N = Extract
C = Solvent

Overall material balance,

$K + C = N + VR_2$

Alcohol balance

$K \times 0.0065 + 0 = N \times 0.0124 + 0$

$=> N = (1.5343X)\left(\frac{0.0065}{0.0124}\right)$

$=> \quad N = 0.80427X$

From overall mass balance,

$C = N + VR_2 - K$

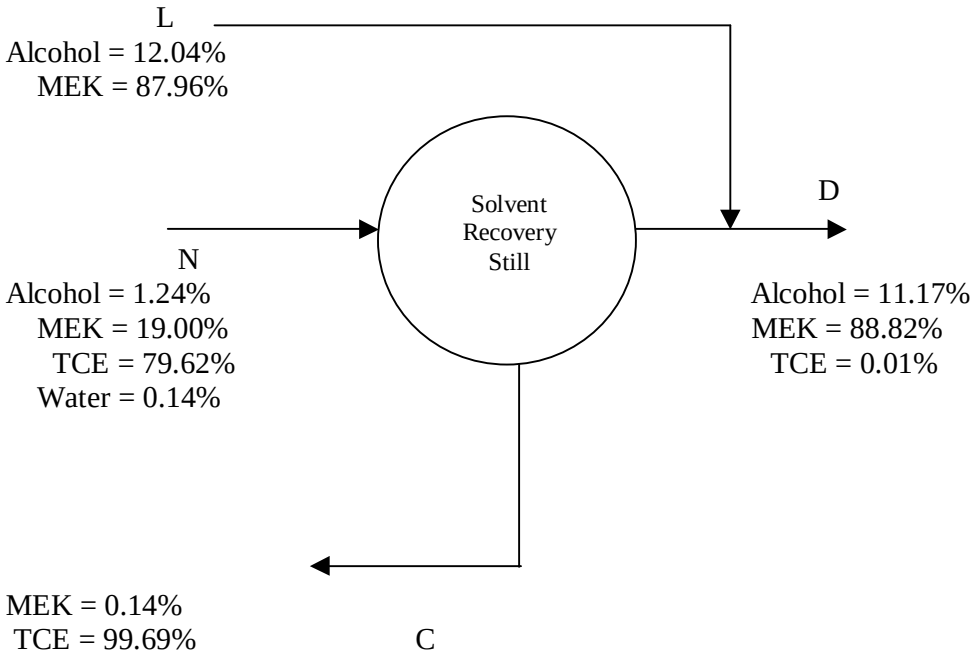
$=> C = 0.80427X + 1.38126X - 1.5343X$

$=> C = 0.65123X$

$N = 0.80427\ X$ kg.

$C = 0.65123\ X$ kg.

MATERIAL BALANCE ACROSS THE SOLVENT RECOVERY UNIT:-



Water = 0.17%

L = Condensate from condensate.
D = MEK still feed.

Overall material balance

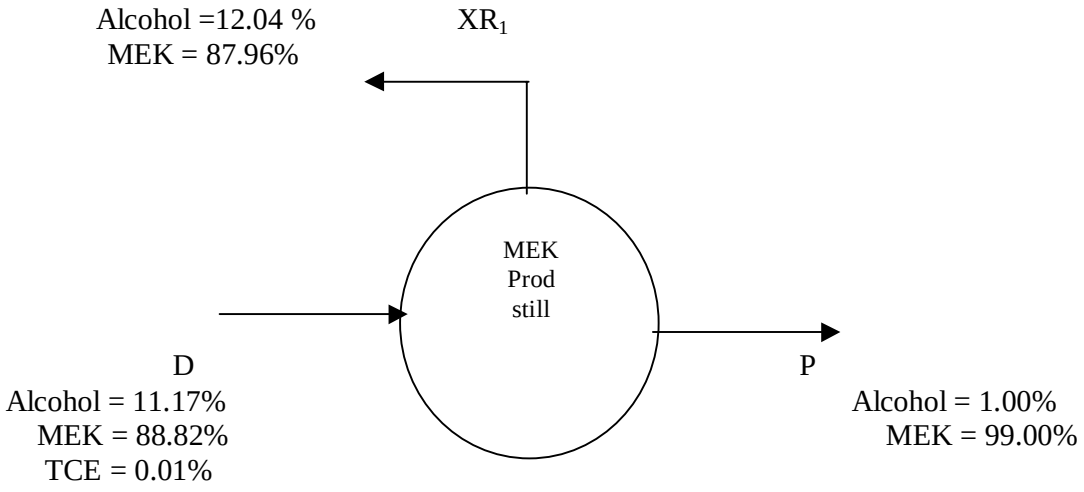
N + L = D + C

D = N + L – C

D = 0.80427X + 0.9193X – 0.65123X

D = 1.07234X

MATERIAL BALANCE ACROSS THE MEK PRODUCT STILL:-



P = MEK product
XR_1 = Alcohol recycle

Overall material balance

$D = P + XR_1$

=> 1.07234X = P + 0.1113X

=> P + 1.07234X – 0.1113X

=> P = 0.96104X

P = 22500 kg/Hr

$$(0.96104X) = P = \frac{22500.00}{}$$

$$X = \frac{22500}{0.96104}$$

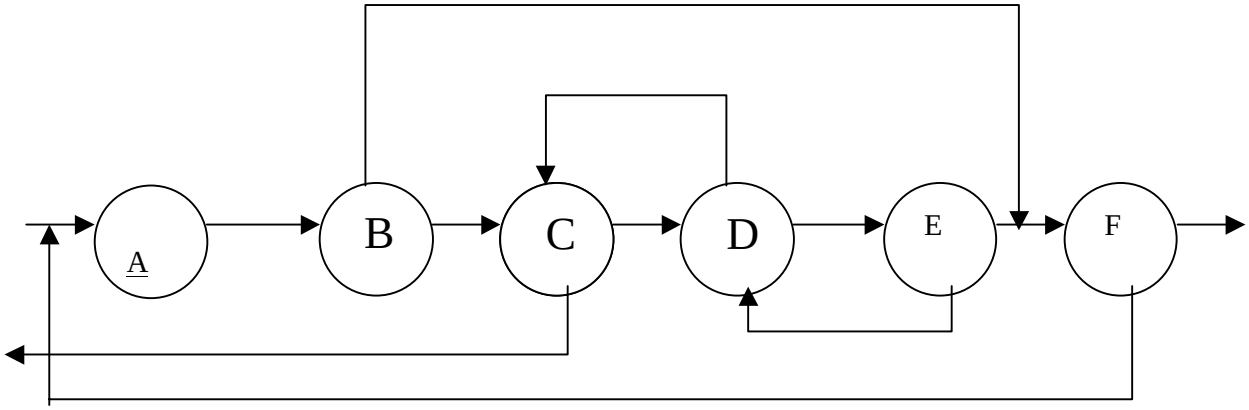
$$X = \frac{23412.13685}{} \text{ kg/Hr}$$

Fresh feed of alcohol required = 23412.13685 kg/hr.

Putting the values of X we get all the flow conditions of all the streams.
The material balance is shown in the flowsheet in the next page.

FLOWSHEET

	Feed		Liq. from condenser		Absorber feed		Absorber Effluent		MEK Still Feed		Alcohol Recycle	
	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%
Alcohol	23412.136	100.00	2591.342	12.04	--	--	233.488	0.65	2804.315	11.17		99.00
MEK	--	--	18931.435	87.96	161.691	0.5	3707.072	10.32	22298.946	88.82	23.9731	0.92
Hydrogen	--	--	--	--	--	--	--	--	--	--	--	--
TCE	--	--	--	--	--	--	--	--	2.5098	0.01	2.0846	0.08
Water	--	--	--	--	32176.557	99.5	31980.681	89.05	--	--	--	--
Total	23412.136	100.00	21522.777	100.00	32338.248	100.00	35921.241	100.00	25105.770	100.00	2605.77	100.00



	Vapour From Absorber		Reaction Products		Vapour From Condenser		Solvent		Extract		MEK Product	
	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%
Alcohol	8.391	0.92	2834.24	10.89	241.838	5.38	--	--	233.488	1.24	225.00	1.00
MEK	74.977	8.22	22556.739	86.70	3626.371	80.72	21.345	0.14	3577.639	19.00	22275.00	99.00
Hydrogen	624.722	68.49	626.921	2.41	626.921	13.90	--	--	--	--	--	--
TCE	--	--	--	--	--	--	15199.421	99.69	14992.191	79.62	--	--
Water	204.045	22.37	--	--	--	--	25.919	0.17	26.361	0.14	--	--
Total	912.136	100.00	26017.907	100.00	4495.130	100.00	15246.685	100.00	18829.679	100.00	22500.00	100.00

A = REACTOR
B = CONDENSER
C = ABSORPTION COLUMN
D = EXTRACTION COLUMN
E = SOLVENT RECOVERYCOLUMN
F = MEK PRODUCT STILL