UNIVERSITY OF DAIYLA
COLLEGE OF ENGINEERING
CHEMICAL ENGINEERING DEPARTMENT

PRODUCTION OF ACETONE

A PROJECT SUBMITTED TO THE COLLEGE OF ENGINEERING OF THE UNIVERSITY OF DIYALA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHLOR OF SCIENCE IN CHEMICAL ENGINEERING

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1.1 Introduction :

Acetone (systematically named **propanone**) is the organic compound with the formula **$(CH_3)_2CO$** . It is the simplest and the most important of the ketones . It is a colorless mobile ,low boiling flammable volatile liquid with a mildly pungent and somewhat aromatic odor . It is miscible with water and with organic solvents such as ether , methanol , ethyl alcohol , and esters and serves as an important solvents in its own right , typically as the solvent of choice for cleaning purposes in the laboratory . Acetone is used as a solvent for cellulose acetate and nitrocellulose , as a carrier for acetylene and as raw materials for the chemical synthesis of the of a wide range of products such as ketene , methyl methacrylate , bisphenol A . It is also used in the manufacture of a wide variety of coatings and plastics .

Acetone is found naturally in the environments and is also produced by industries . As a member of the ketone bodies it is present in very small quantity in normal urine and in the blood .Acetone occurs naturally in plants , trees , volcanic gases , forest fires , and as a product of the breakdown of body fat .

The most familiar household use of acetone is as the active ingredient in nail-polish remover.

1.2 Literature review

1.2.1 History

Acetone is probably produced for the first time in the middle ages . In any event it was well known at the beginning of seventeenth century and was used for various medicinal purposes during world war 1 ; a method of producing acetone through bacterial fermentation was developed by Chaim Weizmann , to help the British war effort .

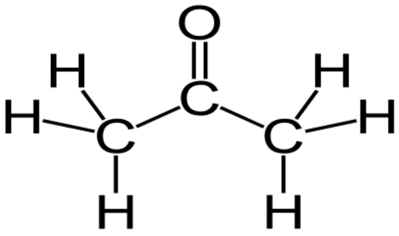
Synonyms :

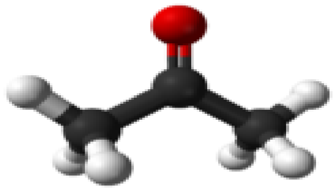
Acetone is also called 2-propanone , beta-ketopropane . propan-2-one and dimethyl ketone .

1.2.2 Chemical formula :

The chemical formula for acetone is **(CH_3COCH_3)** .

And its structure is :





1.2.3 Physical properties :

Table (1.1) shows the physical properties of acetone :

Property	Value
Molecular weight (g/m)	58.08
Boiling point at 760 mm Hg	56.3^o C
Flash point	-18^o C
Frizzing point	-94.7^o C
Vapor pressure at 20^o C	182 mmHg
Specific gravity (20/20^o C)	0.792
Liquid density at 20^o C	0.79 g/cm^2
Vapor density at 1 atm	2
Viscosity at 25^o C	0.33 Cp
Surface tension at 25^o C	23.1dynes/cm
Specific heat at 25^o C	2.44 j/g/C^o
Auto ignition temperature	465 C^o
Evaporation rate (n-butyl acetone =1)	14.4 C^o
Solubility at 25^o C solvent in water	100%
Hansen solubility parameters:	
total	9.8
Non-polar	7.6
Polar	5.1
Hydrogen bonding	3.4
Partition coefficient ,n-octanol/water(log pow)	-0.24
Flammable limits (vol.%in air) lower	2.15

1.2.4 Uses of Acetone :

Acetone has a wide applications in chemical industry :

1- As a solvent :

Acetone is a popular solvent for many plastics and synthetic fibers including those used in laboratory bottles made of polystyrene, polycarbonate and some types of polypropylene. It is also used for thinning fiberglass resin; paint, vinyl, adhesives and varnishes. It can be used to dissolve epoxies and glue before and after it sets. it is also used to dissolve hazardous chemical spills, as a degreaser and as a cleaner. It is also used as a solvent carrier in many pharmaceuticals. It's also used as a volatile component in some paints and varnishes.

Although it's itself flammable, is used extensively as a solvent for the safe transporting and storing of acetylene which cannot be safely pressurized as a pure compound. Vessels containing a porous material are first filled with acetone followed by acetylene, which dissolves into the acetone. One liter of acetone can dissolve around 250 liters of acetylene.

2- Cosmetic uses:

Acetone has a long history in the cosmetic industry. It is commonly used in nail polish remover and in chemical peels. It is also used by make-up artists to remove skin glue on wigs and fake tnustachesc.

3- Medicinal uses:

Acetone is used in a variety of general medical applications and is also listed as a component in food additives and food packaging. Dermatologist's offices use acetone with alcohol for acne treatments to peel dry skin.

4- Laboratory:

It is used as a solvent in many chemical experiments and as an equipment cleaner. It is also used for safely storing acetylene, Which is unsafe in its pure form.

5- Domestic and other niche uses:

Acetone is alien the primary component in cleaning agents such as nail polish remover. Acetone is a component of super glue remover and easily removes residues from glass and porcelain.

This chemical is also used as an artistic agent, when rubbed on the back of a laser print or photocopy placed face-down on another surface and burnished firmly, the toner of the image transfers to the destination surface. Acetone can also be used in combination with automatic transmission fluid to create an effective penetrating oil. Brake fluid is sometimes used in place of ATP. These mixtures (usually l:l) can be useful in loosening rusted or stuck bolts.

5- As a Chemical intermediate:

The amount of acetone used annually in the production of other chemicals is increasing. For example, the production of derivative solvents now accounts for approximately one-third of total acetone usage. Large amounts are also used in the production of methacrylate's, This application begins with the

initial conversion of acetone to its cyanohydrins:

$CH_3)_2CO + HCN \longrightarrow (CH_3)_2C(OH\ CN)($

In a subsequent step, the nitrile is hydrolyzed to the unsaturated amine, which is esterified:

$(CH_3)_2C(OH)CN+CH_30H \longrightarrow CH_2=(CH_3)_2CCO_2CH_3+NH_3$

The second major use of acetone entails its condensation with phenol to give bisphenol-A:

$(CH_3)_2CO + 2\ C_6H_50H \rightarrow (CH_3)_2C(C_6H_40H)_2+H_20$

Bisphenol-A is a component of many polymers such as polycarbonates, polyurethanes and epoxy resins.

Acetone is also used in the production of acetone amines which serve as antioxidants for rubber, ketone, and various cosmetic products.

1.2.5 Hazards :

1- flammability:

The most hazardous property of acetone is its extreme flammability. At temperatures greater than acetone's flash point of -20 °C (—4 °F), air mixtures of between 2.5% and 12.8% acetone, by volume, may explode or cause a flash fire. Vapors can flow along surfaces to distant ignition sources and flash back. Static discharge may also ignite acetone vapors. Acetone . has, however very high ignition initiation energy point, so accidental ignition is rare. Even pouring or spraying acetone over red—glowing coal will not ignite it, due to the high concentration of vapor and the cooling effect of evaporation of the liquid. it auto-ignites at 465 °C (869 °F). Auto ignition temperature is also dependent upon the exposure time, thus at some tests it is quoted as 525°C. Also, industrial acetone is likely to contain small amount of water which also inhibits ignition.

2- Irritating to eyes.

3- Repeated exposure may cause skin dryness or cracking.

4- Vapors may cause drowsiness and dizziness.

1.2.6 Acetone environmental effects:

Acetone evaporates rapidly, even from water and soil. Once in the atmosphere, it has a 22-day half-life and is degraded by UV light via photolysis (primarily into methane and ethane). Acetone dissipates slowly in soil animals, or waterways since it is sometimes consumed by microorganisms, but it is a significant groundwater contaminant due to its high solubility in water. The LDSO of acetone for fish is 8.3 g/L of water (or about 0.3%) over 96 hours, and its environmental half-life is about 1 to 10 days. Acetone may pose a significant risk of oxygen depletion in aquatic systems due to the microbial consumption.

1.2.7 production :

1.2.7.1

Previously, acetone was produced by the distillation of acetate, for example

calcium acetate:

$(CH_3COO)_2Ca$ ------> CH_3COCH_3

1.2.7.2

During World War 1 acetone was produced via bacterial fermentation. This acetone butanol ethanol process was abandoned due to the small yields.

1.2.7.3

Acetone now is produced directly or indirectly from propene:

$CH_3CH=CH_2$ +$PdCl_2$ +H_2O ---> CH_3COCH_3)a (

b) $CH_3CH = CH_2 + H_2SO_4$ ----> CH_3COCH_3(

1.2.7.4

Most commonly, in the cumene process, benzene is alkylated .with propene and the resulting cumene (isopropyl benzene) IS oxidized to give phenol and acetone

$C_6H_5CH(CH_3)_2 + O_2$ -----> $C_6H_5OH + 2(CH_3)_2CO$

This conversion entails the intermediacy of cumene. hydro -peroxide,

$C_6H_5C(CH_3)_2$-O-O-H).

This method is preferred technology because of its lower costs and nearly 90% of acetone is produced this way.

1.2.7.5

Acetone is also produced by direct oxidation of propene with

Pd(II)/Cu(II) catalysts.

- Process Description

The process purpose is to produce acetone from isopropyl alcohol (IPA) at the given conditions. This chapter is formed, some properties, manufacturing process of acetone. In manufacturing process, feed drum, vaporizer, heater, reactor ,furnace, cooler, condenser, flash unit, scrubber, acetone and IPA columns are used

- General Process Descriptions :

At the beginning of the process, feed including i-propyl alcohol and water, arid. recycle stream are mixed in feed drum. From here, this mixture is send to vaporizer to change stream’s phase as vapor. After vaporizer, mixture is heated to reaction temperature in the heater. Reactor used is a tubular flow reactor. Acetone, hydrogen gas (H_2) are produced and water and i-propel-alcohol are discharged. The mixture with acetone, hydrogen, water, i- propyl-alcohol are sent to cooler and then to condenser. After condenser the mixture is sent to flash unit. Hydrogen, acetone, i-propyl-alcohol and water are obtained as top product. This top product is sent to scrubber to remove hydrogen. The bottom product of flash unit which is formed by acetone, water, i-propyl-alcohol are mixed with the bottom product of scrubber before acetone column. In acetone column, acetone is obtained from top product with 99 wt.% .i-propyl alcohol and water and else 01% of acetone is sent to i-propyl-alcohol column from bottom product. The top product of this column is sent to feed drum and bottom product is thrown away as waste water.

1-Feed drum :

Feed drum is a kind of tank used for the mixing of the recycle stream and feed stream . Recycle stream concentration was assumed to be same with feed stream . the temperature of the feed stream is assumed to be 25^oC , at 2 bar pressure , which is assumed to be constant .

2- Pre-heater :

Since the temperature leaving the vaporizer is not enough for the reaction a pre-heater was used . the unit is working at 2 bars , and assumed to be constant . the entrance and leaving temperatures are 109.5^oC and 325^oC .

3- Reactor :

The reactor was the starting point for the calculations. The temperature values for the entering and leaving streams where found from literature , which are 325^oC and 350^oC respectively . the reaction taken place inside endothermic ,for this reason the reactor was tube heated . for heating , molten salt was used . the pressure is 1.8 bar and assumed to be constant .

4- Cooler :

The entrance temperature of the cooler is 350° C and leaving is 94.7^0 C. For cooling, water was used. Instead of water a refrigerant may be used. Better results may get. But since it costs too much, it wasn't chosen as the material. From the temperature values it's easily seen that the cooling load is on the cooler not on the condenser, for this process. But in reality the unit cannot cool that much, and the load is mostly on the condenser. In this process, the mixture cooled down to its dew point. The pressure is 1.5 bar, and assumed to be Constant .

5- Condenser :

In the condenser water was used as cooling material. The leaving and entering temperatures are 94.7^o C and 81^o C , respectively. the pressure is 1.5 bar, and assumed to be constant.

6- Flash :

flash unit was assumed to be isothermal, for this reason temperature was not changed. It is 81^o C in the entrance and exit. The pressure is 1.5 bar, and assumed to be constant.

7- Scrubber :

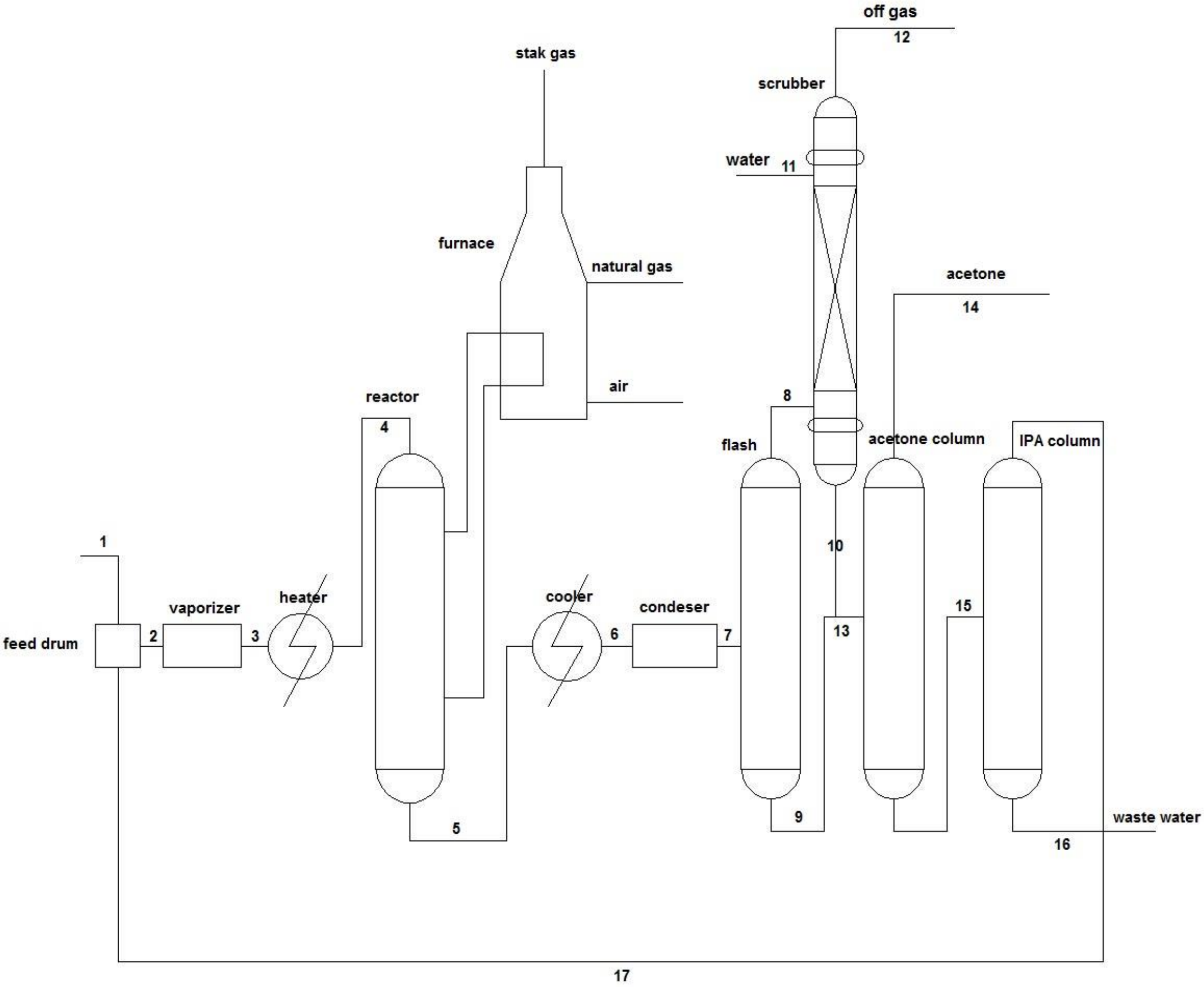
Scrubber was assumed to be adiabatic. The temperature of water entering the unit was assumed to be 25^o C. The temperature of the off gas, including hydrogen and a very little amount of acetone, was assumed to 70^o C. But this assumption is too high, a lower temperature should have been assumed , since a lot of water is used in the unit. It should have been around 40^o C - 50° C. The temperature at the leaving stream was found to be 25.94^o C .The pressure of the unit is 1.5 bar, and assumed to be constant .

8- Acetone column :

The acetone column is used to separate the acetone from the mixture. The entrance temperature is 45° C. The leaving temperatures for the top and bottom product are 1023^o C and 105^o C, respectively, which are the bubble and dew points. Top product of the unit includes acetone i-propyl-alcohol and 99wt% of the product is acetone .From the bottom i-propyl-alcohol, water and a very little amount of, 0.1%, acetone is discharged. The pressure is 1,1bar, and assumed to be constant.

9- IPA Distillation column :

In IPA the distillation column, i-propyl-alcohol and water are separated. The entrance temperature is 105^o C. The leaving temperatures of the top and bottom products are both 111.5^o C. The top product is recycled to the feed drum. For this reason it’s assumed to have the same concentration with the feed stream. But in reality a very little amount of acetone exists in the stream. It's calculated but neglected on the recycle stream calculations. The bottom product is assumed to be pure water and it’s thrown away. Since its temperature is very high it cannot be recycled to the scrubber. But if a cooler is used. a recycle can be used. The pressure is 1.1 bar and assumed to be constant .


off gas
12
stak gas
scrubber
water
11
furnace
natural gas
acetone
14
air
reactor
8
4
flash
acetone column
IPA column
1
10
heater
cooler
15
vaporizer
condeser
13
feed drum
2
3
6
7
9
5
waste water
16
17

2 Material and Energy balance

2.1 Material Balance :

2.1.1 Introduction :

Material balance are important first step when designing a new process or analyzing an existing one . They are almost always prerequisite to all other calculations in the solution of process engineering problems.

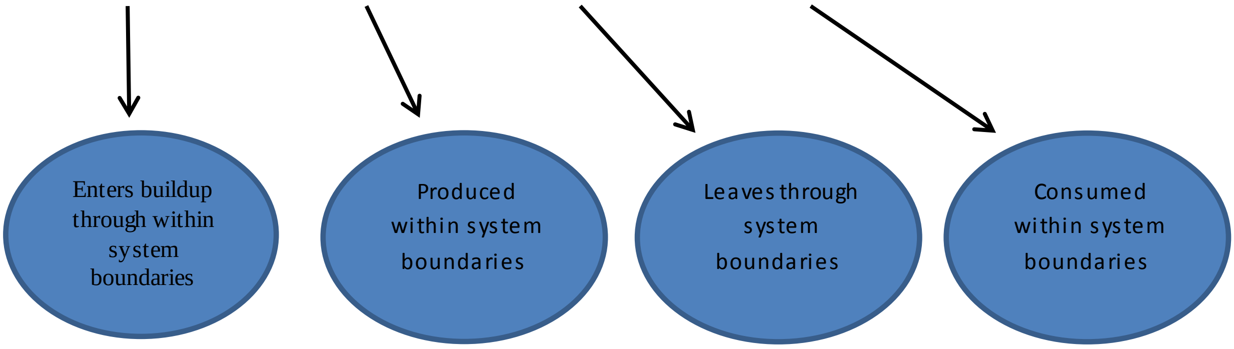
Material balances are nothing more than the application of the law of conservation of mass. which states that mass can neither be created nor destroyed. Thus. You cannot. for example, specify an input to a reactor of one ton of naphtha and an output of two tons of gasoline or gases or anything else. One ton of total material input will only give one ton of total output, i.e. total mass of input = total mass of output.

A material balance is an accounting for material. Thus, material balances are often compared to the balancing of current accounts. They are used in industry to calculate mass flow rates of deferent streams entering or leaving chemical or physical processes.

2.1.2 The general Balance Equation

A balance (or inventory) on a material in a system (a single process unit, a collection of units, or an entire process) may be written in the following general way:

Input + generation - output - consumption = accumulation



This general balance equation may be written for any material that enters or leaves any process system; it can be applied to the total mass of this material or to any molecular or atomic species involved in the process. The general balance equation may be simplified according to the process at hand. For example , by definition , the accumulation term for steady-state continuous process is zero.

Thus the above equation becomes :

In put + generation = output + consumption

For physical process, since there is no chemical reaction, the generation and consumption terms will become zero, and the balance equation for steady-state physical process will be simply reduced to:

Input = output

2.1.3 Material Balance around process units :

Assumption :

Product = 10,000 ton/year Acetone .

With shutdown 60 day.

Purity = 99%

10,000 * 1000 kg * 0.99/7200 hr *58 = 23.7068 kmol/hr.

2.1.3.1 Reactor

$CH_3CH_3CHOH \longrightarrow CH_3COCH_3 + H_2$

Conversion = 80 %

IPA	Acetone
100	80
X	23.7068

X = 29.6335 kmol/hr of IPA in feed

In feed :

IPA = 88 %

H_2O = 12 %

Total feed = IPA + water

F = 29.6335 + 0.12 F

F = 33.6744 kmol/hr

Water = 4.0409 kmol/hr

$N_{acetone(5)}$ = 23.7068 kmol/hr

$N_{H2(5)}$ = 23.7068 kmol/hr

$N_{IPA(5)}$ = 29.6335 – 23.7068 = 5.9267 kmol/hr

$N_{H2O(5)}$ = 4.0409 kmol/hr

$N_{total(5)}$ = 57.3812 kmol/ hr

$Y_{acetone(5)}$ = 23.7068/57.3812 = 0.4131

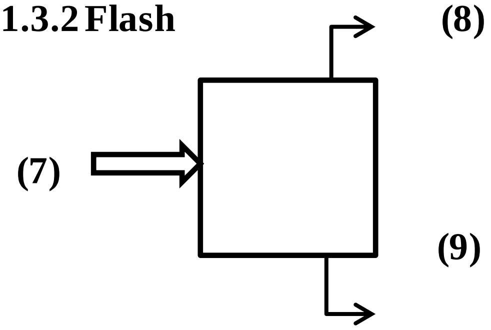
$Y_{H2O(5)}$ = 4.0409/57.3812 = 0.0704

$Y_{H2(5)}$ = 23.7068/57.3812 = 0.4131

$Y_{IPA(5)}$ = 5.9267/57.3812 = 0.1032

Component	In (kg)	Out (kg)
Acetone	-	1374.9944
H_2	-	47.4136
H_2O	72.7362	72.7362
IPA	1778.01	355.602
Total	1850.7462	1850.7462

2.1.3.2 Flash



Assume that there's no change in temperature and pressure .

Pressure = 1.5 bar = 1125.092 mmHg

$K_i = p_i^o/p_{T} = y_i/x_i$

$T = 81\ C^o$

For acetone :-

$\text{Log}p^o = A - B / T + C$

$\log P^o = 7.02447-1161/(224+81)$

$p^o_{acetone} = 1651.6$ mmHg

$k_{acetone} = 1651.6/1125.092 = 1.467$

For IPA :-

$\log P^o = 8.37895-1788.02/(277.438+81)$

$p^o = 381.89$ mmHg

$k_{IPA} = 381.89/1125.092 = 0.339$

for H_2O :-

$\log P^o = 7.96681- 1668.21/(228+81)$

P^o = 369.89 mmHg

K_{H2O} = 369.89/1125.092 = 0.328

Using trial and error method

F = 33.6744

Component	Ki	Zi
Acetone	1.467	0.704
IPA	0.399	0.176
water	0.328	0.1199

		Try V/L= 0.01	
Component	Ki	Ai=L/VKi	Vi=FZi/(1+Ai)
Acetone	1.467	68.166	0.342
IPA	0.399	250.626	0.023
H_2O	0.328	304.878	0.013
		$V_{calc.}$= 0.378	

F = V + L

L = F – V

L = 33.6744 – 0.378 = 33.2964 kmol/hr

Let us first consider bubble point calculations, In this case the liquid-phase composition xi is given (it corresponds to the case where V is very small ($V \geq 0$) and xi = zi

$p_{acetone}^{sat}$ = 2.2019 bar

p_{IPA}^{sat} = 0.5091 bar

p_{water}^{sat} = 0.4931 bar

$p_1 = X_1\, p_{acetone}^{sat}$ = 1.554 bar

$p_2 = X_2\, p_{IPA}^{sat}$ = 0.089 bar

$p_3 = X_3\, p_{water}^{sat}$ = 0.059 bar

$p = p_1 + p_2 + p_3 = 1.702$

$y_{acetone} = p_1/p = 0.913$

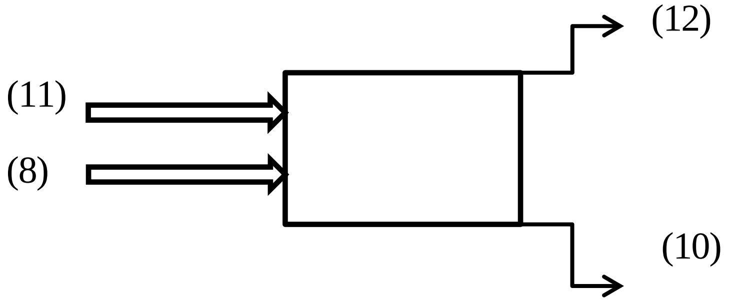
$y_{IPA} = p_2/p = 0.057$

$y_{water} = p_3/p = 0.034$

Component	Stream (8) Y*V(kmol/hr)	Stream (9) X*L(kmol/hr)
Acetone	0.3451	23.440
H_2O	0.0128	3.9922
IPA	0.0215	5.860 .
H_2	23.7068	-

Component	In (7)(kg)	Out (8)(kg)	Out (9)(kg)
Acetone	1374.9944	20.01	1359.52
H_2O	72.7362	0.216	71.8596
IPA	355.602	1.29	351.6
H_2	47.4136	47.4136	-
Total	1850.7462	1850.7462	

2.1.3.3Scrubber



Assume that 99% recovery of acetone with off gas .

$N_{acetone(12)}$ = 0.3451*0.01= 0.003451 kmol/hr

$N_{acetone(10)}$ = 0.3451 – 0.003451 = 0.341649 kmol/hr

$N_{total(8)}$ = 24.0862 kmol/hr

$N_{total(12)} = 23.7071451$ kmol/hr

From volume 2 the value of ratio of liquid to gas is about L/G = 1.3.

L/G = 1.3

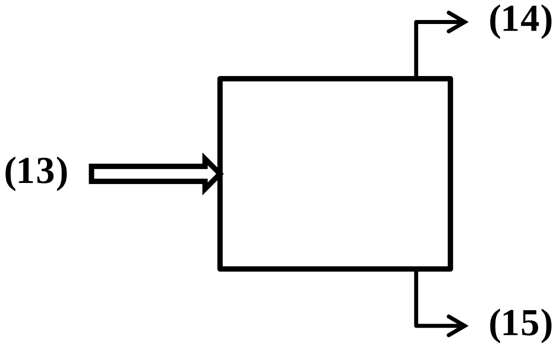
$L_{(11)} = 1.3 * G = 1.3 * 24.0862 = 31.31206$ kmol/hr

$N_{H2O(10)} = 31.31206 + 0.0128 = 31.32486$ kmol/hr

Component	In		Out	
	Stream(8)	Stream(11)	Stream(10)	Stream(12)
H_2O	0.0128	31.31206	31.32486	-
IPA	0.0215	-	0.0215	-
Acetone	0.3451	-	0.341649	0.003451
H_2	23.7068	-	-	23.7068
Total	55.39826		55.39826	

Component	In (kg)		Out (kg)	
	Stream(8)	Stream(11)	Stream(10)	Stream(12)
H_2O	0.2304	563.61708	563.84748	
IPA	1.29		1.29	
Acetone	20.0158		19.815642	0.200158
H_2	47.4136			47.4136
Total	632.56688		632.56688	

2.1.3.4Acetone column



$N_{acetone(13)} = N_{acetone(10)} + N_{acetone(9)}$

$N_{acetone(13)} = 0.341649 + 23.440 = 23.781649$ kmol/hr

$N_{IPA(13)} = N_{IPA(10)} + N_{IPA(9)}$

$N_{IPA(13)} = 0.0215 + 5.860 = 5.8815$ kmol/hr

$N_{H2O(13)} = N_{H2O(10)} + N_{H2O(9)}$

$N_{H2O(13)} = 31.32486 + 3.9922 = 35.31706$ kmol/hr

$N_{total(13)} = 64.980209$ kmol/hr

Assume that 1% recovery of acetone in the bottom product.

$N_{acetone(15)} = 23.781649 * 0.01 = 0.2378164$ kmol/hr

$N_{acetone(14)} = 23.781649 – 0.2378164 = 23.543832$ kmol/hr

Purity = 99 %

$N_{IPA(14)} = 5.8815 * 0.01 = 0.058815$ kmol/hr

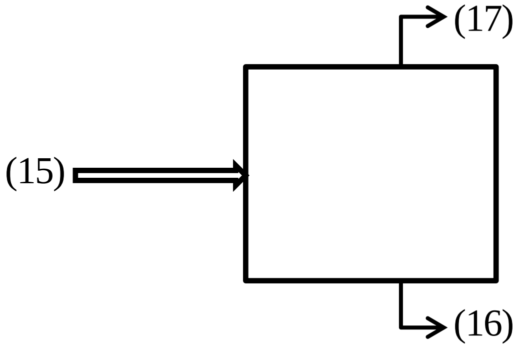
$N_{IPA(15)} = 5.8815 – 0.058815 = 5.822685$ kmol/hr

$N_{H2O(15)} = 35.31706$ kmol/hr

Component	In	Out	
	Stream (13)	Stream (14)	Stream (15)
H_2O	35.31706	-	35.31706
IPA	5.8815	0.058815	5.822685
Acetone	23.781649	23.543832	0. 2378164
Total	64.980209	64.980209	

Component	In(kg)	Out(kg)	
	Stream (13)	Stream (14)	Stream (15)
H_2O	635.70708	-	635.70708
IPA	352.908	3.5289	349.3611
Acetone	1379.335642	1365.542256	13.7933512
Total	2367.950722	2367.950722	

2.1.3.5 IPA Column



$N_{IPA(17)} = N_{IPA(15)} = 5.822685$ kmol/hr

$N_{acetone(17)} = 0.\ 2378164$ kmol/hr

Assume that the composition of recycle stream is feed stream .

$Y_{H2O} = 0.12$

$Y_{IPA} = 0.88$

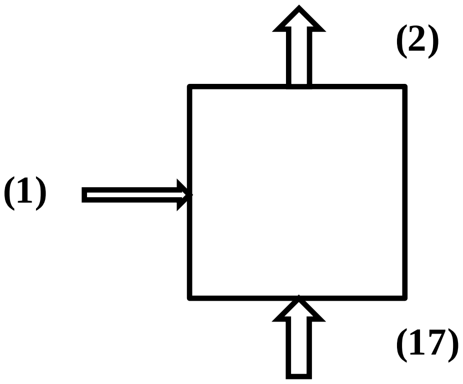
$N_{H2O(17)} = 05.822685 * 0.12 = 0.6987222$ kmol/hr

$N_{H2O(16)} = 35.31706 - 0.6987222 = 34.6183378$ kmol/hr

Component	In	Out	
	Stream (15)	Stream (16)	Stream (17)
Acetone	0. 2378164	-	0. 2378164
IPA	5.822685	-	5.822685
H_2O	35.31706	34.6183378	0.6987222
Total	41.3775614	41.3775614	

Component	In (kg)	Out (kg)	
	Stream (15)	Stream (16)	Stream (17)
Acetone	13.7933512	-	13.7933512
IPA	349.3611	-	349.3611
H_2O	635.70708	623.1300804	12.5769996
Total	998.8615312	998.8615312	

2.1.3.6 Feed drum :



IPA = 5.822685 kmol/hr

H_2O = 0.6987222 kmol/hr

Input = output

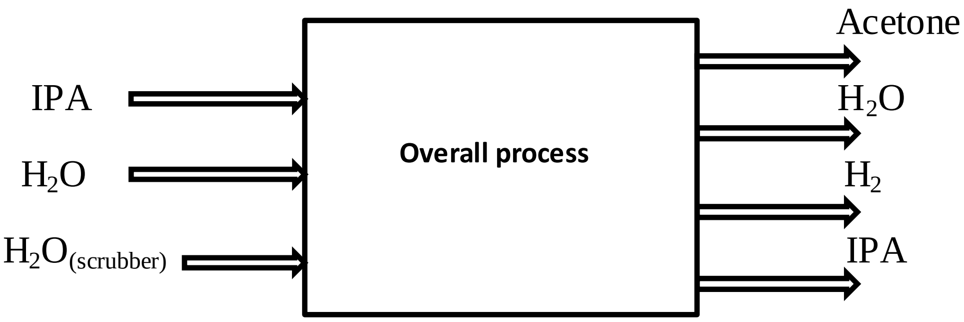
$IPA_{(1)}$ = 29.6335 - 5.822685 = 23.810815 kmol/hr

$H_2O_{(1)}$ = 4.0409 - 0.6987222 = 3.3421778 kmol/hr

Component	In		Out
	Stream (1)	Stream (17)	Stream (2)
IPA	23.810815	5.822685	29.6335
H_2O	3.3421778	0.6987222	4.0409
Total	33.6744		33.6744

Component	In (kg)		Out (kg)
	Stream (1)	Stream (17)	Stream (2)
IPA	1428.6489	349.3611	1778.01
H_2O	60.1592004	12.5769996	72.7362
Total	1850.7462		1850.7462

2.1.3.7 Over all material balance :



Component	In (kg)	Out (kg)
IPA	1428.6489	3.5289
H_2O	60.1592004	623.1300804
H_2O (scrubber)	563.61708	0
Acetone	0	1365.542256
H_2	0	47.4136
Acetone$_{(scrubber)}$		0.0132024817
Acetone$_{(IPA\ column)}$		13.7933512
Total	2051.8081	2051.8081

2.2 Energy balance :

2.2.1 Introduction

Energy is transferred either as heat or work. A system does not contain " heat", but the transfer of heat or work to a system changes its internal energy .

Heat taken in by a system from its surroundings is conventionally taken as positive and that given out as negative. The equation that we used to calculate the power Q (heat duty) or W (work) for any equipment is:

$Q - W = \Delta HR + (-\Delta Hin) + (\Delta Hout) + (\Delta KE) + (\Delta PE)$ .....(l)

Where ΔKE = the change in the kinetic energy.

ΔPE = the change in the potential energy.

Enthalpy can be calculated from specific and latent heat data. If the kinetic and potential energy terms are neglected equation (I) simplifies to:

$H2 – H1 = Q - W$......(2)

This simplified equation is usually sufficient for estimating the heating and cooling requirements of the various unit operations involved in chemical processes.

For many processes the work term will be zero, or negligibly small, and equation (2) reduces to the simple heat balance equation:

$H2 — HI = Q$ (3)

Where heat is generated in the system; for example, in a chemical reactor:

$Q = QP + cs$ (4)

QS = heat generated in the system. If heat is evolved (exothermic processes) Qs is taken as positive, and if heat is absorbed (endothermic processes) it is taken as negative.

QP = process heat added to the system to maintain required system temperature, so

$QP=H2-H1-Qs$ (5)

H1 = enthalpy of the inlet stream, H2 = enthalpy .

2.2.2 Calculation Of Specific Enthalpy (H)

Tabulated values of enthalpy are available only for the more common materials- In the absence of published data the following expressions can be used to estimate the specific enthalpy (enthalpy per unit mass).

For pure materials, with no phase change :

$$H_T = {}_{dT}\int^{T} Cp\, dT \,\ldots\ldots\ldots(6)$$

Where H_T = specific enthalpy at temperature T

Cp = specific heat capacity of the material , constant pressure ,
T = the datum temperature .

If the phase takes place between the specific and datum temperature , the latent heat of the phase transition is added to the sensible-heat change the sensible- heat calculation in the split into two parts.

$$H_T = {}_{dT}\int^{TP} Cp\, dT + {}_{Tp}\int^{T} Cp\, dT \;\ldots.(7)$$

Where Tp = phase transition temperature ,

Cp1= specific heat capacity first phase , below Tp,

Cp2 = specific heat capacity second phase , above Tp,

The specific heat at constant pressure will vary with temperature and use the equation (7) , values of Cp must be available as a function of temperature . for solids and gases Cp is usually expressed as an empirical power series equation :

$Cp = A + BT + CT^2 + DT^3 + ET^4$ ……(8)

Absolute (K) or relative (C^o) temperature scales may be specified when the relationship is in the form given in equation (8)

2.2.3 Enthalpy of Mixture :

For gases, the heats of mixing are usually negligible and the heat capacities and enthalpies can be taken as additive Without Introducing any significant error into design calculations as following:

$Cp\,(\text{mixture}) = XA\ Cp,A + XB\ Cp,B + Xc\ Cp,C + \ldots\ldots$ (9)

Where XA. XB, XC, etc. are the mole fractions of the components a, b, c.

$N{*}CP = NA\times CP, A + NB\ N\times CP, B + NC\times CP, C + \ldots\ldots$(10)

Where N= the stream total molar flow rate,

CP = the stream heat capacity,

NA, NB, NC, = Components molar flow rates,

CP, A, CP,B, CP,C, = Components heat capacities.

For mixtures of liquids and for solutions, the heat of mixing (heat of solution) may be significant , and so must be included when calculating the enthalpy of the mixture.

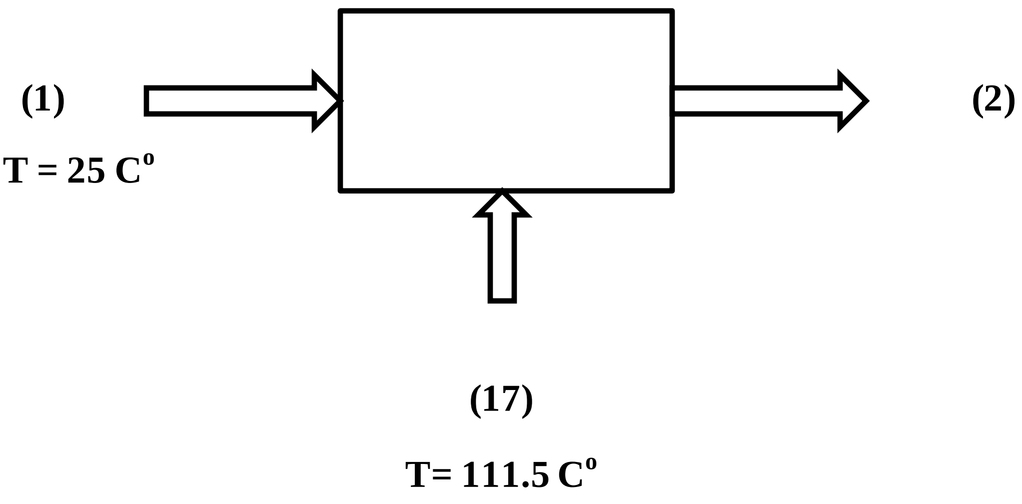
For binary mixtures the specific enthalpy of the mixture at temperature T is given by :

$H_{\text{mixture}},T = XAHA,T + XB\ HB,T + \Delta H\ m, T$ (4)

Where HA ,T and HB ,T are the specific Enthalpies of a components A and B and ΔH m , T is the heat of mixing when 1 mole of solution is formed , at temperature T . Heats of mixing and heats of solution are determined experimentally and are available in the handbooks for the more commonly used solutions. If no values are available, judgments must be used to decide if the heat of mixing for the system is likely to be significant .

2.2.4 Energy Balance Around Process Units :

2.2.4.1 Feed drum :



M_{IPA} = 349.3611 kg

M_{H2O} = 12.5769996 kg

$T_{ref.}$ = 25 C^o

Cp_{IPA} = 2.497 kj

Cp_{H2O} = 4.178 kj

Cp_{mix} = 2.497 * 0.88 + 4.178 * 0.12 = 2.69872 kj

$M_{total(1)}$ = 1428.6489 + 60.1592004 = 1488.8081 kg

$M_{total(2)}$ = 1850.7462 kg

$M_{total(17)}$ = 361.9380996 kg

$Q_{in} = Q_{out}$

$Q_1 + Q_{17} = Q_2$

$Q = m\ cp\ \Delta T$

1488.8081× 2.69872 ×25) + 361.9380996 × 2.69872 ×(111.5 – 25) = (1850.7462× 2.69872 ×(T – 25)

T = 62.026 C^o

2.2.4.2Vaporizer

(2)

T= 62.026 C^o

M_{IPA} = 1778.01 kg

M_{H2O} = 72.7362 kg

(3)

T= 109.5

M_{IPA} = 1778.01 kg

M_{H2O} = 72.7362 kg

At T= 60.026 C^o

Cp_{IPA} = 2.3122 kj/kg

Cp_{H2O} = 2.1003 kj/kg

For IPA :

Tc = 508.3 k Tb= 394.399 k

ΔH_f = 39838 kj/kmol

$\Delta H_v = \Delta H_f \times (Tc - T / Tc - Tb)^{0.38}$

$= 39838 \times (508.3 - 382.5 /508.3 - 394.399)^{0.38}$ = 2298.387222 kj/kg

For H_2O :

Tc = 647.3 k Tb = 375 k

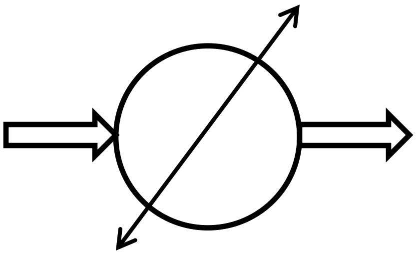
ΔH_f = 40683 kj/kmol

$\Delta H_v = 40683 \times (647.3 - 382.5 / 647.3 - 375)^{0.38}$ =676.89175 kj/kg

$Q = (M_{IPA}\ Cp_{IPA}\ \Delta T) + (M_{H2O}\ Cp_{H2O}\ \Delta T) + (M_{H2O}\ \Delta H_{v\ H2O}) + (M_{IPA}\ \Delta H_{v\ IPA})$ = 4346741.324 kj/hr

2.2.4.3 Preheated :

T=109.5 T=325 C°



M_{H2O} = 72.7362 kg M_{H2O} = 72.7362
kg

M_{IPA} = 1778.01 kg M_{IPA} = 1778.01 kg

T_{ref} =109.5 C° Cp_{IPA} = 2.468 kj/kg Cp_{H2O} = 2.019
kj/kg

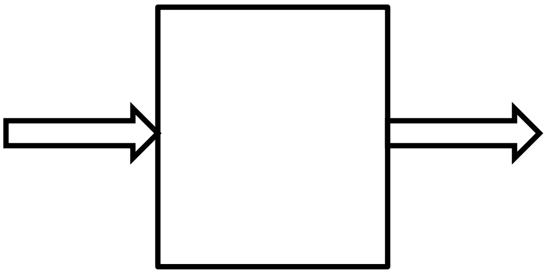
$Q_{in} = (M_{H2O} * Cp_{H2O} * \Delta T) + (M_{IPA} * Cp_{IPA} * \Delta T)$

Q = 977288.8511 kj/hr

2.2.4.4 Reactor :

$CH_3CH_3CHOH \longrightarrow CH_3COCH_3 + H_2$

T = 325 C° T = 350 C°



$\Delta H_{in,IPA} = - 272.29 \int_{25}^{325}(32.42 + 1.886 \times 10^{-1} \times T + 6.405 \times 10^{-5} \times T^2 - 9.261 \times 10^{-8} \times T^3\, dt\,)$

$\Delta H_{in,IPA} = - 252\ .186$ kj/kmol

$\Delta H_{out,IPA} = - 272.29 \int_{25}^{350}(32.42 + 1.886 \times 10^{-1} \times T + 6.405 \times 10^{-5} \times T^2 - 9.261 \times 10^{-8} \times T^3\, dt\,)$

$\Delta H_{out,IPA} = - 249.691$ kj/kmol

$\Delta H_{out\ acetone} = -216.685 + \int_{25}^{350}(71.96 + 20.1 \times 10^{-2} \times T + 2512.78 \times 10^{-5} \times T^2 + 34.76 \times 10^{-8} \times T^3)\, dt$

$\Delta H_{out\ acetone} = -182.745$ kj/kmol

$\Delta H_{out,H2} = \int_{25}^{350}(28.84 \times 10^{-3} + 0.00765 \times 10^{-5} \times T + 0.3288 \times 10^{-8} \times T^2 - 0.8698 \times 10^{-12}\,)\, dt$

$\Delta H_{out,H2} = 9.466$ kj/kmol

$\Delta H^o_r = \Delta H_{in} - \Delta H_{out}$

$\Delta H^o_r = (-216.685 - (- 272.29)) = 55.509$ kj/kmol

$\Delta H_r = 23.7068 \text{ kmol} \times 55.509 = 1315.9407$ kj

$Q = (\sum Ni \times Hi)_{out} - (\sum Ni \times Hi)_{in} + \Delta H_r$

$Q = 4681.204$ kj/hr

2.2.4.5 Cooler :

T = 350 C^o

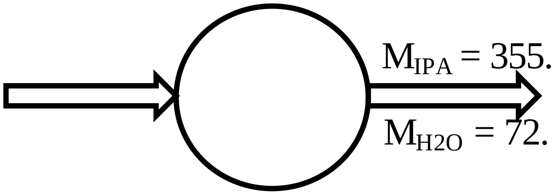
(5)

M_{IPA} = 355.602 kg/hr

M_{H2O} = 72.7362 kg/hr

$M_{acetone}$ = 1374.9944 kg/hr

M_{H2} = 47.4136 kg/hr



T = 94.7 C^o

(6)

M_{IPA} = 355.602 kg/hr

M_{H2O} = 72.7362 kg/hr

$M_{acetone}$ = 1374.9944 kg/hr

M_{H2} = 47.4136 kg/hr

T_{ref} = 94.7 C^o

Cp_{H2} = 12.608 kj/kg

Cp_{IPA} = 2.536 kj/kg

Cp_{H2O} = 2.035 kj/kg

$Cp_{acetone}$ = 1.896 kj/kg

$Q =[(M_{H2} \times Cp_{H2}) + (M_{IPA} \times Cp_{IPA}) + (M_{H2O} \times Cp_{H2O}) + (M_{acetone} \times Cp_{acetone})] \times \Delta T$

Q = 1086200.628 kj/hr

2.2.4.6 Condenser :

T = 94.7 C^o

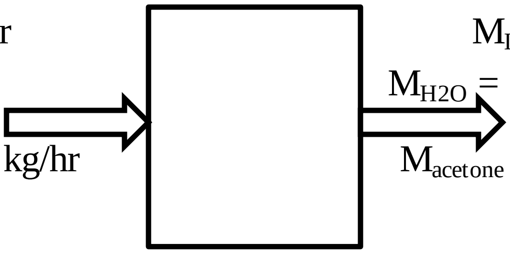
(6)

M_{IPA} = 355.602 kg/hr

M_{H2O}=72.7362 kg/hr

$M_{acetone}$ = 1374.9944 kg/hr

M_{H2} = 47.4136



T= 81 C^o

(7)

M_{IPA} = 355.602 kg/hr

M_{H2O} = 72.7362 kg/hr

$M_{acetone}$ = 1374.9944 kg/hr

M_{H2} = 47.4136

For acetone :

At T = 94.7 C^o and p= 1.5 bar

Cp = 1.297 kj/kg .k

$Q = M\ Cp\ \Delta T = 1374.9944 \times 1.297 \times (81 - 94.7) = -24432.13799$ kj

$\Delta H_{vap} = \Delta H_f\ [(Tc - T)/(Tc - Tb)]^{0.38} = 29140 \times \{508.1\text{-}354/(508.1 - 341.5)\}^{0.38} =$

28289.029 kj/kmol

ΔH_{vap} = 487.742 kj/kg

For IPA :

At T =94.7 C^o and p= 1.5bar

Cp = 1.761kj/kg.k

$Q = M\ Cp\ \Delta T = -8579.1471$ kj

Tc = 508.3 k Tb = 366.6k ΔH_f = 39858 kj/kmol

$\Delta H_{vap} = \Delta H_f\ [(Tc - T)/(Tc - Tb)]^{0.38}$ = 686.156 kj/kg

For water :

At T =94.7 C^{o} and p= 1.5 bar

Cp= 1.898 kj/kg.k

$Q = M\ Cp\ \Delta T = -\ 1891.3303$ kj

$\Delta H_f = 40683$ kj/kmol Tc = 647.3 k Tb= 385.180 k

$\Delta H_{vap} = \Delta H_f\ [(Tc - T)/(Tc - Tb)]^{0.38} = 2357.892$ kj/kg

For hydrogen :

Cp = 13.225 kj/kg .k

$Q = M\ Cp\ \Delta T = -\ 8590.5145$ kj

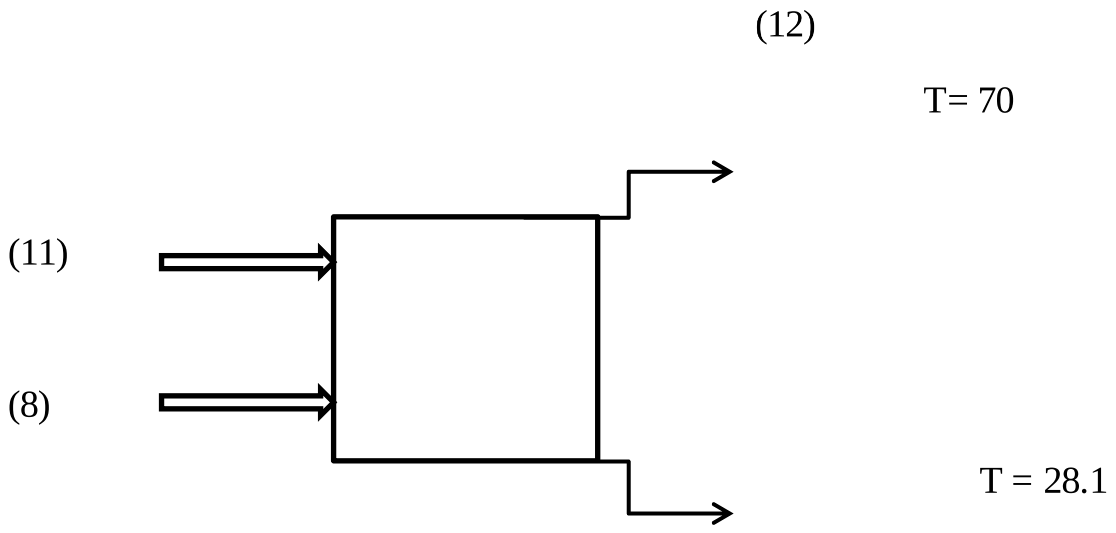
$Q_{\text{total}} = \sum Mi \times Cpi \times \Delta T + \sum Mi \times \Delta Hvap$

$\sum Mi \times Cpi \times \Delta T = -\ 43493.13079$ kj

$\sum Mi \times \Delta Hvap = 1086145.069$ kj

$Q_{\text{total}} = -43493.13079 + 1086145.069 = 1042651.938$ kj/hr

2.2.4.7 Scrubber :



T= 81 (10)

T_{ref} = 25 C^o

For acetone

Cp = 1.25 at T= 81

Cp = 1.229 at T = 70

CP = 1.249 at T= 25

For IPA

Cp = 1.716 at T =81

Cp = 1.71 at T = 25

For H_2O

Cp = 4.193 at T = 81

Cp = 4.183 at T = 25

For H_2

Cp = 14.419 at T = 81

Cp = 14.401 at T = 25

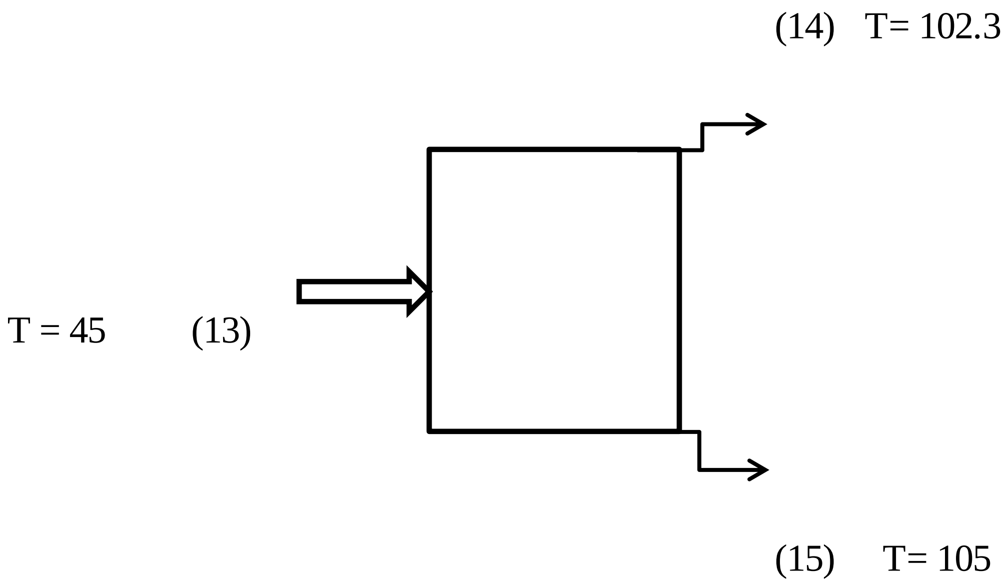
$Q_{in} = Q_{out}$

$(M_{H2\,(8)}\,Cp_{(8)}\,\Delta T)+(M_{acetone(8)}\,Cp_{(8)}\,\Delta T)+(M_{H2O(8)}\,Cp_{H2O}\,\Delta T)+(M_{IPA(8)}\,Cp_{IPA(8)}\,\Delta T) =(M_{H2(12)}\,Cp_{(12)}\,\Delta T)+(M_{acetone(12)}\,Cp_{(12)}\,\Delta T)+(M_{acetone(10)}\,Cp_{(10)}\,\Delta T)+(M_{H2O(10)}\,Cp_{(10)}\,\Delta T)+(M_{IPA(10)}\,Cp_{(10)}\,\Delta T)$

(94.8272×14.419(81-25))+(20.0158×1.25×(81-25))+(0.2304×4.193×(81-25)) +(1.29×1.716×(81-25)) =(94.8272×14.401×(70-25))+(0.200158×1.229×(70-25) +(19.8156×1.249×(T-25))+(563.8474×4.183×(T-25))+(1.29×1.71×(T-25))

T = 35 C

2.2.4.8 Acetone column :



Condenser :

For acetone :

Pc = 47 bar Tc = 508.1 k

P = 1.0133bar T = 329.2 K

$\text{Ln}P^{sat} = A - B / T$

Ln 1.0133 = A – B /329.2 Ln 47 = A – B /508.1

At 1.1 bar pressure boiling A= 10.91 B = 3587.3

Ln 1.1 = 10.91 – 3587.3/ Tb

Tb = 331.706 k

For IPA:

Pc= 47.6 bar Tc = 508.3 k

P =1.0133 bar T = 355.35 K

Ln1.0133 = A – B/355.35 Ln 47.6 = A – B/508.3

At 1.1 bar A= 12.807 B= 4546.375

Ln 1.1 = 12.807 – 4546.375/ Tb

$T_b = 357.653$ k

Substituting the results to the first equation :

$\Delta H_{acetone} = \Delta H_f\ (Tc - T/(Tc - Tb))$

$\Delta H_{acetone} = 29140 \times [508.1 - 375.3/\ (508.3 - 357.653)] = 451.038$ kj/kg

At T = 102.3 C^o

$\Delta H_{IPA} = 3985 \times [508.3 - 375.3\ /(\ 508.3 - 357.653)] = 633.567$ kj/kg

$\Delta H_{mixture} = 451.038 \times 0.99 + 633.567 \times 0.01 = 452.86$ kj/kg

The energy balance for the mixture :

$Q = M\ \Delta H_{mixture} = 1369.0711 \times 452.86 = 619997.5383$ kj/hr

For water :

Pc = 220.5 bar Tc = 647.3 k

P = 1.0133 bar T = 373.1 k

Ln 1.0133 = A – B /373.1

Ln 220.5 = A – B /647.3

At 1.1 bar A =12.72 B= 4743.39

Ln 1.1=12.72 – 4743.39 /Tb

Tb = 375.723 k

Reboiler T= 105 C^o = 378 k

$\Delta H_{vap,,acetone} = 29140\{508.1 - 378/\ (508.1 - 331.706)\}^{0.38} = 447.531$ kj/kg

$\Delta H_{vap,water} = 40683\ \{647.3 - 378\ /(647.3 - 375.723)\}^{0.38} = 2252.947$ kj/kg

$\Delta H_{vap,IPA} = 39858\ \{508.3 - 378\ /(508.3 - 357.653)\}^{0.38} = 628.663$ kj/kg

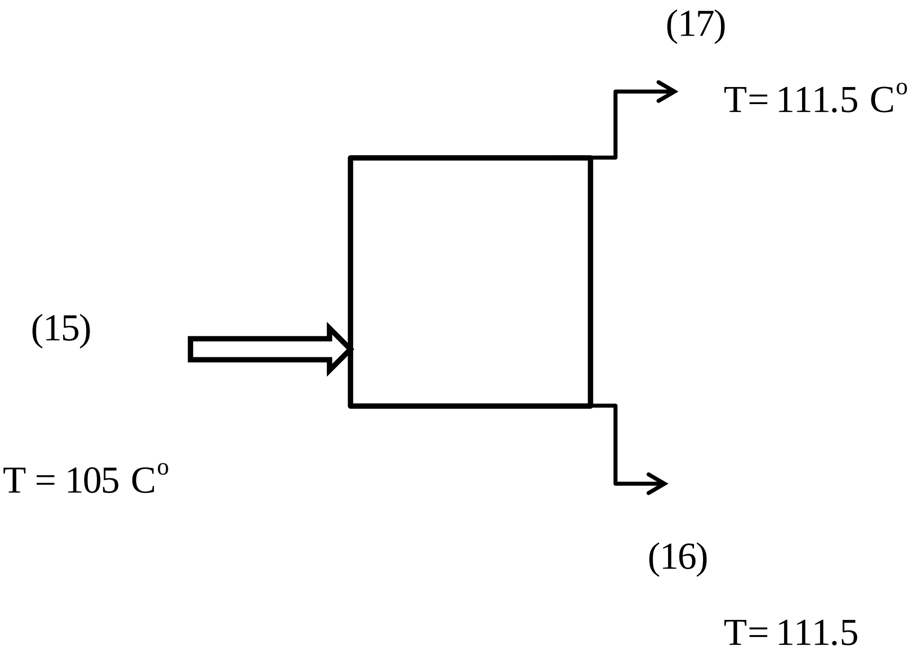
$Y_{H2O} = 0.8535$ $Y_{IPA} = 0.1407$ $Y_{acetone} = 0.0057474$

$\Delta H_{vap,mixture} = (447.531 \times 0.0057474)$
$+(2252.947 \times 0.8535)+(628.663 \times 0.1407)$

= 2013.91528 kj/kg

$Q = M\ \Delta H_{vap,mixture} = 998.86153 \times 2013.91528 = 211622.5$ kj/hr

2.2.4.9 IPA column :



Same procedure is followed as in acetone column .

$Tb_{IPA} = 84.653$ C^o $\qquad Tb_{water} = 102.723$ C^o

$\Delta H_{f,water} = 40683$ kj/kmol $\qquad \Delta H_{f,IPA} = 39858$ kj/kmol

$\Delta H_{f,acetone} = 29140$ kj/kmol

$\Delta H_{vap,IPA} = 633.576$ kj/kg

$\Delta H_{vap,acetone} = 451.038$ kj/kg

Since acetone is neglected $Y_{water} = 0.12$ and $Y_{IPA} = 0.88$

$\Delta H_{vap.mix} = (2238.566*0.12) + (633.567*0.880) = 826.167$ kj/kg

$Q_{mixture} = M*\Delta H = 233.5615874*375.73145 = 87756.43408$ kj

Reboiler :

$\Delta H_{vap,water} = 40683*(647.3 - 384.5/(647.3 - 375.723))^{0.38} = 2232.196$ kj/kg

$Q = M*\ \Delta H_{vap,water} = 2232.196*623.1300804 = 139090.1414$ kj

3.1 Introduction :

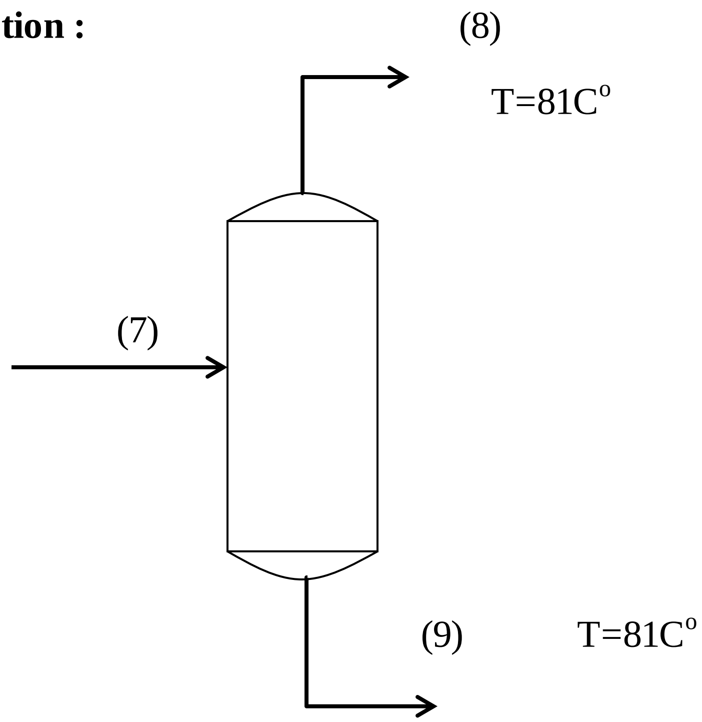
Every industrial chemical process is designed to produce economically a desired product from a variety of starting material through a succession of treatment steps . The raw materials undergo a number of physical treatment steps to put them in the form in which they can be reacted chemically . Then they pass through the reactor .The products in the reaction must then undergo further physical treatment (separation , purification , etc.) for final product to be obtained . All these units need to be designed (determine the internal and external structure and diminution of the units).

We will design in this chapter (flash distillation , scrubber , and distillation).

3.2Design of flash distillation :

P= 1.5 bar

T= 81 C°



$U_{perm} = k_{drum} \sqrt{\frac{\rho l - \rho v}{\rho v}}$

$K_{drum} = \exp[A + B \ln Flv + C (\ln Flv)^2 + D (\ln Flv)^3 + E (\ln Flv)^4]$

$Flv = \frac{Wl}{WV} \sqrt{\frac{\rho v}{\rho l}}$

$Flv = \frac{1282.82304}{45.70295} \sqrt{\frac{0.9875}{2.758}} = 1.02 * 10^{-5}$

K_{drum} = exp [-1.8774 – 0.8145 (1.98* 10^{-7}) – 0.1870 (1.98* 10^{-7} $)^2$ – 0.0145 (1.98* 10^{-7} $)^3$ – 0.001 (1.98* 10^{-7} $)^4$]

K_{drum} = 0.15298

$$U_{perm} = k_{drum} \sqrt{\frac{\rho l - \rho v}{\rho v}}$$

$$U_{perm} = 0.15298 \sqrt{\frac{2.758 - 0.9875}{0.9875}}$$

U_{perm} = 0.2742 m^2/s

$$A_c = \frac{V * (MW) v}{Uperm * \rho v * 3600}$$

$$A_c = \frac{23.7068 * 138}{0.2742 * 0.9875 * 3600}$$

A_c = 3.3561 m^2

$$D = \sqrt{\frac{4Ac}{\pi}}$$

$$D = \sqrt{\frac{4 * 3.3561}{3.14}}$$

D = 2.0676 m

h_v = 0.9144 + 0.5 *D

h_v = 1.9482 m

h_f = 0.4064 + 0.5 * D

h_f = 1.4402 m

$$h_L = \frac{Vsurge}{\frac{\pi * D^2}{4}}$$

$L_{flow\ rate}$ = 1282.8226 kg/hr ÷ 3600

= 0.3563 kg/ s ÷ ρl kg/m^3

= 0.3563 kg/ s ÷ 2.758

= 0,1292 m^3/s * 300 s

$V_{surge} = 38.7606\ m^3$

$$h_L = \frac{38.7606}{\frac{3.14*2.0676^2}{4}}$$

$h_L = 0.721$ m

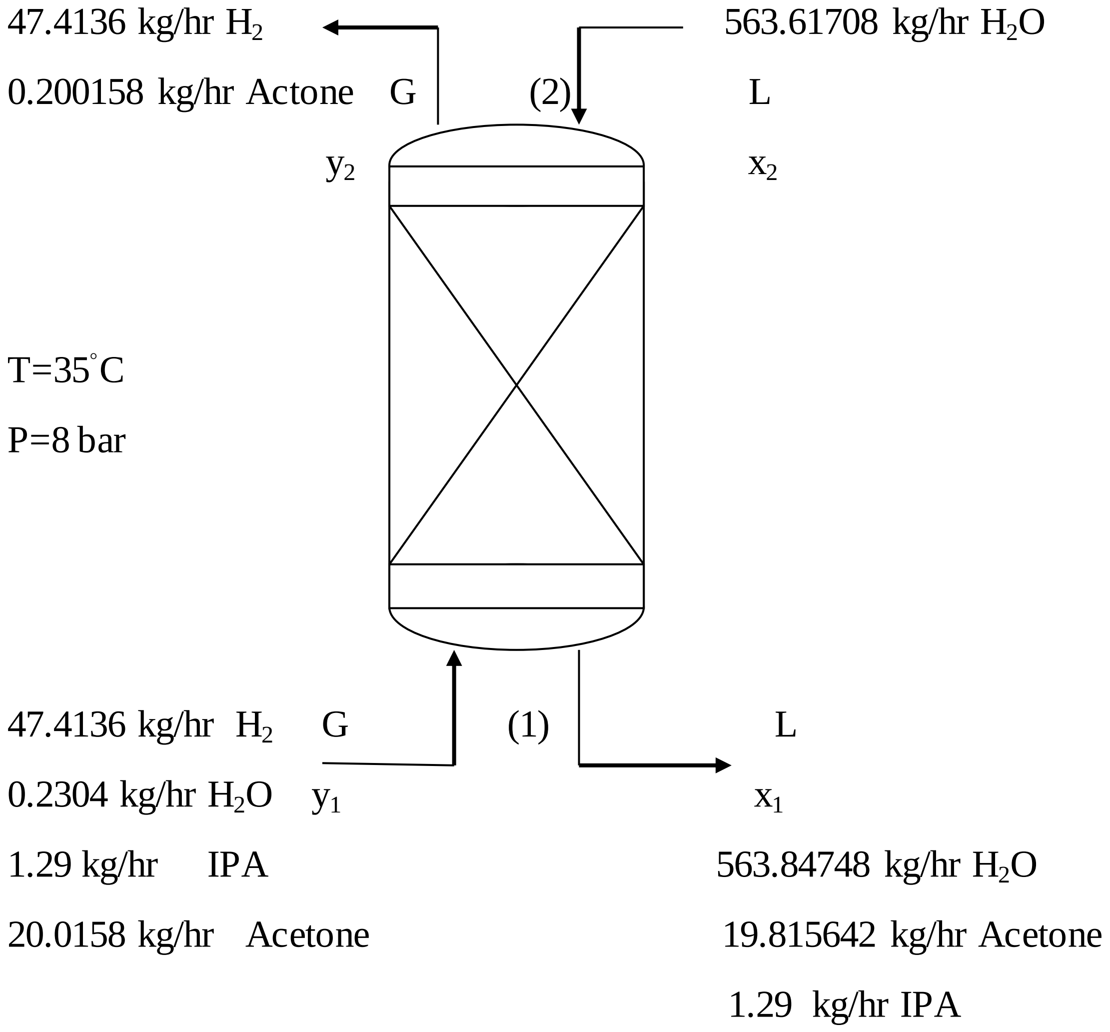
$H_{total} = h_v + h_f + h_L$

$H_{total} = 1.9482 + 1.4402 + 0.721$

H = 4.1099 m

D = 2.0676 m

3.3 Design of Scrubber :



Inlet gas

Component	Kg/hr	M . wt	K mol /hr	Mol% y
H_2	47.4136	2	23.7068	0.98442
H_2O	0.2304	18	0.0128	0.00053
IPA	1.29	60	0.0215	0.000892
Acetone	20.0158	58	0.3451	0.01432
Total	68.9498		24.0862	

Column diameter

$F_{L.V} = (\frac{L}{G})(\frac{\rho_V}{\rho_L})^{0.5}$ [3]

Where :

$F_{L.V}$ = liquid vapour flow factor .

L = liquid mass flow rate kg/s .

G = gas mass flow rate kg/s .

P_v = vapour density kg/m^3 .

ρ_L = liquid density kg/m^3 .

vapour density

$\rho_V = \frac{PM_{av}}{RT}$ [3]

$M_{av} = \Sigma M_i y_i$ [3]

Where :

M_{av} = average molecular weight kg/k mol.

M_i = molecular weight of component i kg/k mol .

y_i = mol fraction of component i .

M_{av} = 2.7996

P = 1.5 bar = 150 kpa [3]

T = 81 °C = 354 K [3]

$$\rho_V = \frac{150*2.7996}{8.314*354} = 0.14268 \text{ kg/m}^3$$

<u>Liquid density</u>

Density of H_2O at 35 °C [6]

ρ_L = 994kg/m^3

L = 563.61708 kg/hr

L = 0.15656 kg/s

G = 68.9498 kg/hr

G= 0.01915 kg/s

$$F_{L.V} = \left(\frac{0.15656}{0.01915}\right)\left(\frac{0.14268}{994}\right)^{0.5} = 0.09794$$

$$V_W^* = \left[\frac{K_4\, \rho_V(\rho_L - \rho_V)}{13.1 F_P \left(\frac{\mu_L}{\rho_L}\right)^{0.1}}\right]^{0.5} \quad [3]$$

Where:

V_W^* = gas mass flow rate per unit cross – sectional area kg/m^2.s

K_4 = constant

μ_L = liquid viscosity kg/m.s

F_p = packing factor .

Design pressure drop for absorber from from15 to50 mmH_2O /m packing

Select Δp = 42 mmH_2O /Packing [3]

For $F_{L.V}$ =0.4347 and ΔP = 42 mmH_2O /m packing

K_4 = 1.4 fig 11.44 [6]

K_4 at flooding = 3.3 [6]

$$\text{Percent flooding} = \left(\frac{K_4}{K_4\ at\ flooding}\right)^{0.5} * 100\%$$

$$= \left(\frac{1.4}{3.3}\right)^{0.5} *100\% = 65.13\%$$

Select 1 1/2 inch in talox saddle

F_P = 170 m^{-1} table 11.2 [3]

Viscosity of H_2O at 35°C

μ_L = 0.722 CP = 0.722*10^{-3} kg/m.s

$$V_W^* = \left[\frac{1.4*0.14268(994-0.14268)}{13.1*170\ \left(\frac{0.722*10^{-3}}{994}\right)^{0.1}}\right]^{0.5} \quad [3]$$

$$= 0.6053\ kg/m^2.s$$

$$A = \frac{G}{V_W^*}$$

Where :

A= cross-sectional area of column m^2 .

$$A = \left(\frac{0.01915}{0.6053}\right) = 0.0316\ M^2$$

$$A = \frac{\pi}{4} D^2$$

$0.0316 = \frac{\pi}{4} D^2$ D= 0.2007 M

PACKING HEIGHT (Z packing)

$Z = H_{OG} * N_{OG}$
N_{OG} = number of transfer units based on an overall gas-film coefficient.
H_{OG} = height of a transfer unit based on an overall gas-film coefficient,m

H_{OG} was obtained from table 15-4 in "Separation Process Engineering".
For ceramic packing with size 2 in, H_{OG} = 3 ft = 0.9 m

For N_{OG} calculation we need G_m and L_m and m
where
G_m = molar gas flow-rate per unit cross-sectional area
L_m = molar liquid flow-rate per unit cross-sectional area

m= is the slope of the equilibrium line

$G_m = \frac{N8}{A} = \frac{68.9498}{0.0316} = 2181.9556$

$L_m = \frac{N11}{A} = \frac{563.61708}{0.0316} = 17835.9835$

$(y_1-y_2)=m(x_1-x_2)$

(0.01432-0.0001455)=m(0.01078-0)

m =1.31

$\frac{mGm}{Lm} = \frac{1.31 * 2181.9556}{17835.9835} = 0.16038$

$\frac{y1}{y2} = \frac{0.01432}{0.0001455} = 98.41$

y_1 is mole fraction of formaldehyde in stream 10

y_2 is mole fraction of formaldehyde in stream 10

x_1 is mole fraction of formaldehyde in stream 13

x_2 is mole fraction of formaldehyde in stream 11

$$NOG = \frac{1}{1 - \frac{mGm}{Lm}} \ln[\left(1 - \frac{mGm}{Lm}\right)\frac{y1}{y2} + \frac{mGm}{Lm}]$$

$\mathbf{N}OG = \frac{1}{1-0.16038}\ \ln[(1 - 0.16038)98.41 + 0.16038\ ]$

$\mathbf{N}OG = 5.2$

$Z = H_{OG} * N_{OG}$
$Z = 0.9 * 5.2$
Z Packing =4.68 m

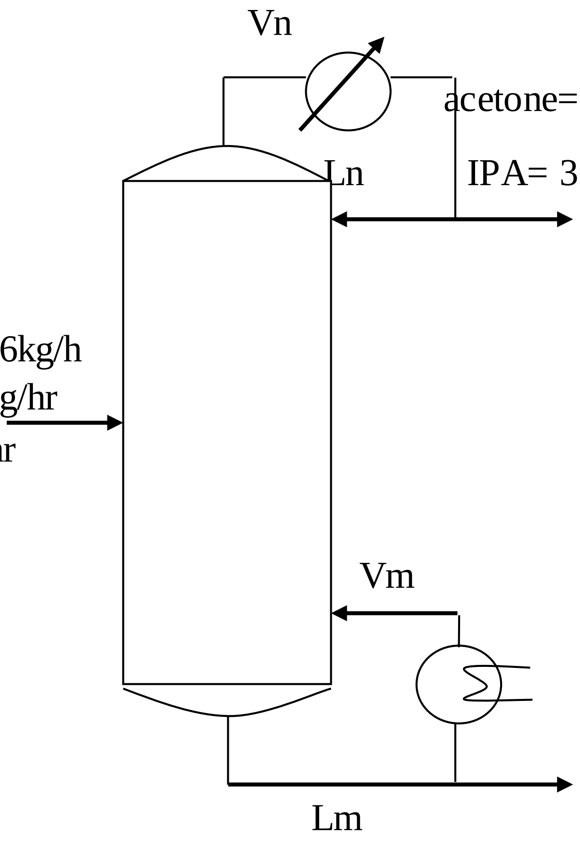
Z column= Z Packing * (D tower + 0.25)

Z column= 4.68 * (0.2007+ 0.25)

Z column = 2.1092

Absorber summary table	
Diameter (m)	0.2007
Height (m)	2.1092
Orientation	Vertical
Internals	Ceramic, saddles

3.4 Design of Distillation column :



acetone=1365.5422kg/hr

IPA= 3.5289 kg/hr

p = 1.1 bar

T = 102.3 C°

Acetone=1379.3356kg/h

H_2O=635.70708 kg/hr

IPA =352.908 kg/hr

P = 1.1 bar

T = 45 C°

IPA= 349.3611kg/hr

Acetone = 13.7933

kg/hr

H_2O =635.70708 kg/hr

P = 1.1 bar

T = 105 C°

Component	X_f Mol%	X_d Mol%	X_w Mol%
Acetone	58.2	99.7	1.3
H_2O	27.6	---	63.6
IPA	14.9	0.3	34.9
Total	100	100	100

Calculation number of plates

Calculation of equilibrium data:

$Inp^0 = A - \frac{B}{T+C}$ [10]

Where:

$p^0 = vapor\, prssure\ (mmHg)$

$A, B, C = constants$ [10]

$T = Temperature\ (K^o)$

Table (4-5) A,B and C constants[10]

Components	A	B	C
Acetone	14.3145	2756.22	228.060
IPA	16.1154	3483.67	205.807
H_2O	16.3872	3885.70	230.170

At top T=102.3 C^o = 375.3 K^o

$$Inp^0{}_{Acetone} = 14.3145 - \frac{2756.22}{375.3 + 228.060} \Rightarrow p^0{}_1 = 17090\,mmHg$$

$$Inp^0{}_{IPA} = 16.1154 - \frac{3483.67}{375.3 + 205.807} \Rightarrow p^0{}_2 = 25274\,mmHg$$

$$\alpha_{top} = \frac{p^0{}_{IPA}}{p^0{}_{Acetone}} = \frac{25274}{17090} = 1.478$$

At Bottom T=105 C^o = 378 K^o

$$Inp^0{}_{Acetone} = 14.3145 - \frac{2756.22}{378 + 228.060} \Rightarrow p^0{}_1 = 17443\,mmHg$$

$$Inp^0{}_{IPA} = 16.1154 - \frac{3483.67}{378 + 205.807} \Rightarrow p^0{}_2 = 25545\,mmHg$$

$$\alpha_{bot} = \frac{p^0{}_{IPA}}{p^0{}_{Acetone}} = \frac{25545}{17443} = 1.464$$

$$\alpha_{av} = (\,\alpha_{top} * \alpha_{bot})^{0.5}$$ [10]

$$\alpha_{av} = (1.478 * 1.464)^{0.5} = 1.470$$

$$Y = \frac{\alpha_{av} * X}{1 + (\alpha_{av} - 1) * X}$$ [10]

$$Y = \frac{1.47 * X}{1 + 0.47 * X} \qquad equilibrium\ curve$$

At X=0.10

$$Y = \frac{1.0384 * 0.1}{1 + 0.0384 * 0.1} = 0.103$$

X	Y
0.000	0.000
0.100	0.14
0.200	0.268
0.300	0.386
0.400	0.495
0.500	0.595
0.600	0.687
0.700	0.747
0.800	0.854
0.900	0.929
1.000	1.000

Calculation of q-line

$$q = \frac{\text{heat reguired to vaporized 1K mol of feed}}{\text{molar latent heat of feed}}$$

$$Q = \frac{C_{pmix} * \Delta T + \lambda mix}{\lambda mix}$$ [10]

where:

C_{pmix}= average molar heat capacity of feed KJ/Kmol. °C

$\lambda mix =$ Average molar latent heat of feed KJ/Kmol

$\Delta T = feed\ bubble\ point - feed\ temparature$°C

Table (5-1) specific heat and latent heat for components

Component	CP KJ/Kmol.C^o	λ KJ/Kmol	Xfmol%
Acetone	77.256	29638	58.2
IPA	102.6	39840	14.9
H_2O	75.366	38038	27.6

$C_{pmix}=C_{p1}*X_{f1}+C_{p2}*X_{f2}+C_{P3}*X_{f3}$ [10]

C_{pmix}= (77.256*0.582) + (102.6*0.149) +(75.366*0.276)

C_{pmix}=81.051 KJ/Kmol .C^o

$\lambda mix = \lambda 1 * Xf1 + \lambda 2 * Xf2 + \lambda 3 * Xf3$ [10]

= (29638*0.582) + (39840*0.149) + (38038*0.276)

=33683.964 KJ/Kmol

$$q = \frac{81.05(105-45)+33683.964}{33683.964} = 1.144$$

Slop of q-line $= \frac{q}{q-1} = \frac{1.144}{1.144=1} = 7.94$

V_1 = R + D

Assume R/D = 1.3

R= 1.3 D

V_1 =1.3 D + D

V_1 =54.286

R = 54.286 – 23.6026 = 21.6834

Calculation number of plates:

- Draw the equilibrium data X vs Y.

Draw the q-line with slope $= \frac{q}{q-1} = \frac{1.144}{1.144=1} = 7.94$

- Draw the top of operating line from Xd on the diagonal
- $Q = \frac{X_d}{R+1} = \frac{0.997}{21.6834+1} = 0.043$
- Draw the bottom operating line from Xw on the diagonal tp the point of intersection of the operating line and the q-line.
- Starting at Xd step off the number of stages.

  From plot No. of stage =16
  No. of plate = No. of stages – 1
  =16 – 1 = 15

Column efficiency

E_0=0.17 - 0.616 log ($\sum$ $\mu i * X_{fi}$) [18]

Where

E_0= plate efficiency

$X_{fi} = mol\ fraction\ of\ component\ i\ in\ the\ feed$

μi = viscosity of component I cp(mns/m^2)

At top T=102.3 C^o

At bottom T=105 C^o

$$\text{Tm} = \frac{102.3 + 105}{2} = 103.65\ \text{C}^o$$

Table (5-2) Viscosity of components at 100 C^{o}[16]

Component	μ mNs/m²	Xf mol%
Acetone	0.20	58.2
IPA	0.528	14.9
H_2O	0.20	27.6

$$\sum \mu_i X_{fi} = \mu_1 X_{f1} + \mu_2 X_{f2} + \mu_3 X_{f3}$$ [10]

$$\sum \mu\, i\, X_{fi} = (0.20 * 0.582) + (0.528 * 0.149) + (0.2 * 0.276)$$

=0.25 cp

E_0=0.17 - 0.616 log(0.25)

=0.54 =54 %

$$N_{act} = \frac{N_{the}}{E_0}$$ [13]

$$= \frac{15}{0.54}$$

$$= 27.7 \cong 28\ plate$$

Column diameter

Top

$$F_{L.v} = \frac{Ln}{Vn} * \left(\frac{\rho v}{\rho L}\right)^{0.5}$$ [13]

Where:

$F_{l.v}$= liquid vapour flow factor

Ln =liquid mass flow rate Kg/s

Vn= vapour mass flow rate Kg/s

ρv= vapour density Kg/m³

ρ_L=liquid density Kg/m³

D= 1365.542256 + 3.5289 = 1369.0711 Kg/h

Ln=R*D=21.6834 * 1369.0711 =29686 Kg/h

=8.24 Kg/s

Vn=Ln + D

=(R+1) * D

=D(R+1)

Vn=(21.6834 + 1)* 1369.0711

= 31055.187 Kg/h = 8.62 Kg/s

Vapour density

$$\rho_v = \frac{p*Mav}{R*T} \qquad [13]$$

Where:

$\rho_v = vapour\ density \frac{kg}{m^3}$

P = total pressure Kpa

T = absolute temperature K.

$M_{av}= \sum M_i * X_{di}$

M_{av}= (58 *0.997) + (60 *0.003)

=58.006 kg/kmol

P=1.1 bar=110 KPa

T=102.3 ℃ =375.3 K

$\rho v = \frac{110*58.006}{8.314*374.3} = 2.05$ Kg/m^3

Liquid density

Table(5-3) Density of components at T=128°C[16]

Component	Top Kg/h	X_d wt%	ρ Kg/m³
$Acetone$	1365.542256	99.7	691.346
IPA	3.5289	0.3	701.708

$\rho_L = \rho_i * X_{di}$ [13]

$\rho L = (691.346 * 0.997) + (701.708 * 0.003)$

$= 691.37\ Kg/m^3$

$F_{L.v} = \frac{8.24}{8.62} \left(\frac{2.05}{691.37}\right)^{0.5} = 0.052$

$U_f = K_1\left(\frac{\rho L - \rho v}{\rho v}\right)^{0.5}$ [13]

Where:

U_f= vapour flooding velocity m/s

K_1= Constant

Select tray spacing = 0.45m [10]

For $F_{L.v}$=0.052 and tray spacing =0.45m

K1 =0.075 Fig. 12.27 [10]

$U_f = 0.075\left(\frac{691.37-2.05}{2.05}\right)^{0.5} = 1.37$ m/s

U=85% U_f [10]

U=0.85*1.37 =1.16 m/s

m= $\rho v * U * An$ [10]

Where:

m= vapour mass flow rate kg/s

$\rho v = vapour\ density \frac{kg}{m^3}$

$U = vapour\ velocity \frac{m}{s}$

$An = net\ area\ m^2$

An=$\frac{m}{\rho v * u}$

m=Vn=4.73 Kg/s

An=$\frac{8.62}{2.05*1.16} = 2.97\ m^2$

Down comer area =12%of total column cross sectional area [13]

An= (1-0.12) A_c

An=0.88 * A_c

A_c=cross sectional area of column m²

Ac=An/0.88

=2.97/0.88=3.37 m²

Ac=$\frac{\pi}{4} Dc^2$ [10]

Dc=2.07 m

Bottom

$F_{L.v}$=$\frac{Lm}{Vm} (\frac{\rho v}{\rho L})^{0.5}$ [10]

L_m=L_n + q*F [18]

F =$\frac{1379.335642}{58} + \frac{352.908}{60} + \frac{635.70708}{18}$

$= 64.980209\ Kmol/h$

Ln=$\frac{29686}{58.006} = 511.77\ Kmol\ /h$

q =1.144

L_m=511.77 + (1.144 * 64.980209)=586.107 Kmol/h

$$M_{av} = \sum Mi * X_{wi}$$

$$M_{av} = average\ molecular\ weight\ at\ bottom \frac{kg}{kmol}$$

= (58 * 0.013) + (18 *0.636)+(60*0.349)

=33.142 Kg/Kmol

L_m=586.107 * 33.142

=19424.758 kg/h=5.395 kg/s

L_m= V_m + w [10]

W=41.3775614 kmol/h

V_m = L_m - w

Vm = 586.107 – 41.3775614=544.729 Kmol/h

Vm=544.729 * 33.142 = 18053.423 Kg/h=5.014 kg/s

Vapour density

$$\rho v = \frac{P * Mav}{R * T}$$

P= 1.1 bar = 110 Kpa

T=105℃ = 378 K

$\rho v = \frac{110*33.142}{8.314*378}$ =1.16 Kg/m^3

Liquid density

Table (5-4) Liquid density of components at 105°C[16]

Components	Bottom Kg/h	Xw Wt%	ρ Kg/m³
$Acetone$	13.7933512	1.3	687.628
IPA	349.3611	34.9	698.517
H_2O	635.70708	63.6	943.579

$$\rho L = \sum \rho i * Xwi$$

= (687.628*0.013) + (698.517*0.349) +(943.579 * 0.636)

=852.856 Kg/m³

$F_{L.v}=\frac{5.395}{5.014}(\frac{1.16}{852.856})^{0.5}$

=0.10

For $F_{L.v}$=0.039 and tray spacing = 0.45m

K_1=0.075 Fig. 11.27 [10]

$U_f=0.075(\frac{852.856-1.16}{1.16})^{0.5}$ =2.032 m/s

U=85% U_f [10]

U=0.85*2.032 = 1.727 m/s

m = $\rho v * u * An$ [10]

m=Vm=5.014 kg/s

$An=\frac{m}{\rho v * u}=\frac{5.014}{1.16*1.727}$ = 2.5 m²

$Ac=\frac{An}{0.88}=\frac{2.5}{0.88}$ = 2.84 m²

$Ac=\frac{\pi}{4}D_c^2$

D_c=1.08 m

At top D_c=1.30m

At bottom D_c=1.902 m

Select high value of column diameter

Dc=2.07 m

Plate Design [10]

Column diameter	D_c=2.07m
Column area	A_c=3.37 m^2
Down comer area	A_d=12% Ac=0.12*3.37= 0.404 m^2
Net area	$A_n=A_c-A_d$=3.37-0.404= 2.966 m^2
Active area	$A_a=A_c - 2A_d$=3.37-2*0.404=2.562m^2
Hol area	A_h=10%A_a as first trial =0.1*2.562=0.2562 m^2

Weir length

For A_d/A_c=12%

$\frac{lw}{Dc}$= 0.77 Fig.11.31 [10]

$\frac{lw}{2.07}$=0.77

lw =1.5939 m weir length

Weir height [10]

h_w=40 to 90 mm

h_w=50mm

hole size [10]

d_h = 2.5 to 12.5mm

d_h = 5mm

plate thickness =5mm

Check weeping

$h_{ow}=750(\frac{Ln}{\rho l*lw})^{2/3}$ [10]

Where:

h_{ow} = height of the liquid over the weir mm.

L_n = liquid mass flow rate Kg/s

$\rho l = liquid\ density\ Kg/m^3$

$lw = weir\ length\ m.$

$h_{ow}=750(\frac{8.24}{691.37*1.5939})^{2/3}$= 28.65mm

$u_{min}=\frac{k2-0.9(25.4-dh)}{\rho v^{0.5}}$ [10]

Where:

u_{min}=minimum vapour velocity through the hole m/s

K_2= constant

d_h=hole size mm

for (h_w + h_{ow})=50+28.65=78.65 m

K_2=30.7 Fig.11.30 [13]

$U_{min}=\frac{30.7-0.9(25.4-5)}{(2.05)^{0.5}}$ =28.69 m/s

$Ú_{min}=\frac{V}{\rho v*Ah}$

Where:

$Ú_{min}$= actual minimum velocity through the hole m/s

$V = vapour\ mass\ flow\ rate \frac{kg}{s}$

$\rho v = vapour\ density \frac{kg}{m^3}$

$Ah = holes\ area\ m^2$

$Ú_{min}=\frac{8.62}{2.05*0.2562}$= 16.41 m/s

16.41 m/s>5.10 m/s

∴ Operating rate above weep point

Check entrainment

For 85% flooding and $F_{L.v}$=0.083

Fig.11.29 [13] $\varphi = 0.06$

Plate pressure drop

Dry plate drop

$h_d=51(\frac{uh}{\mathring{c}})^{2*}\frac{\rho v}{\rho l}$ [10]

where :

h_d=dry plate drop mm

u_h= actual vapour velocity through the hole m/s

$\mathring{c}$= constant =0.84

For plate thickness/hole diameter =5/5=1 and An/Aa=12%

$h_d=51(\frac{8.01}{0.84})^{2*}\frac{2.05}{691.37}$ =24.29 mm

Residual heat

$h_r =\frac{12.5*10^3}{\rho l}$ [13]

Where:

h_r = residual head mm

$h_r =\frac{12.5*10^3}{691.37}$ =18 mm

Total plate pressure drop

$h_t= h_d + (h_w + h_{ow}) + h_r$ [10]

h_t=total pressure drop mm

h_t=24.29+(50+28.65)+18=133 mm=0.120m/plate

$$\Delta p = \rho g h$$

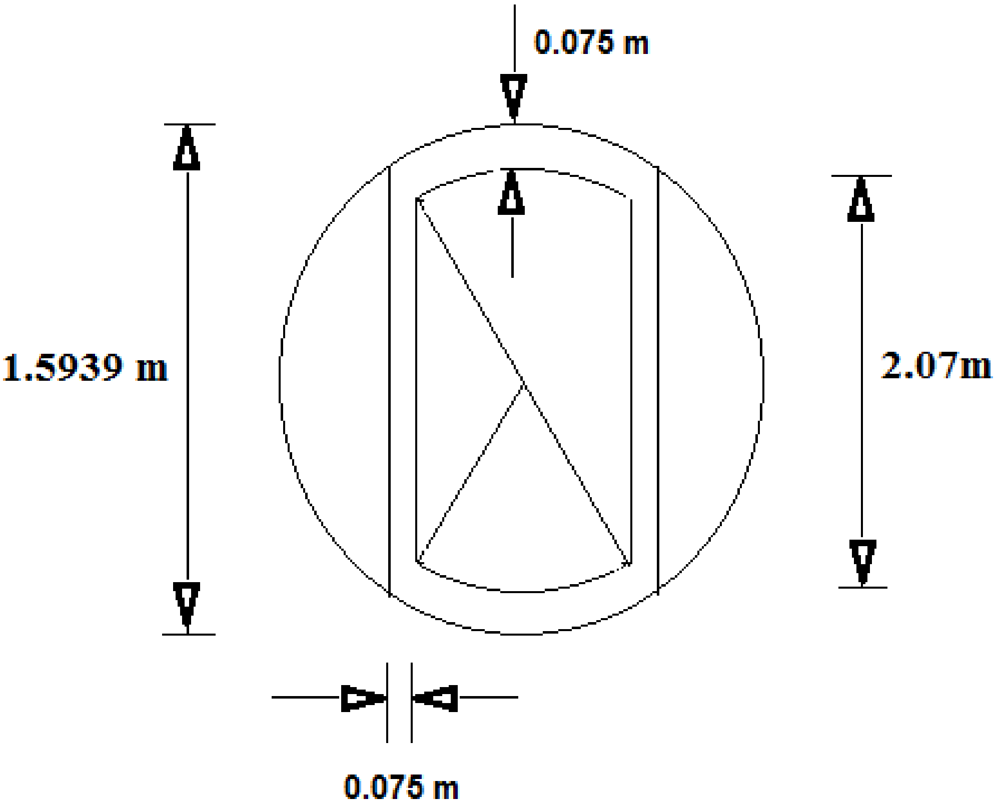
$\Delta p = 691.37$ * 9.81 * 0.120=813.88 Pa/plate = 0.81388 kpa

$total\,\Delta p$ =0.81388 * 22 =17.9 kPa

Plate layout

Allow 75mm unperforated strip round plate edge

75mm wide calming zone [10]



For l_w/D_c=77%

$\theta = 99^\circ$ Fig 11.32 [13]

$\alpha = 180 - 99 = 81^\circ$

Mean length of un perforated edge strips = (2.070 - 2*2.07)*$\pi * \frac{81}{360} * 2$

=2.924m

Area of un perforated edge strips =1.625 * 0.075 =0.123 m^2

Area of calming zone = (1.5939- 2*0.075)*0.075*2=0.128 m²

Total area available for perforation Ap

Ap=1.01 - 0.123 - 0.128 =0.759 m²

Ah/Ap=0.101/0.759 =0.13

For Ah/Ap =0.13

L_p/d_h = 2.7 Fig.11.33 [10]

L_p /5 =2.7

L_p =13.5mm hole pitch

Number of holes

Area of one hole $= \frac{\pi}{4} dh^2 = \frac{\pi}{4} * 0.005^2 = 1.96 * 10^{-5}$ m²

No. of hole=holes area/area of one hole= $0.2562/1.96 * 10^{-5}$ =13071

Height of column

H =(N-1)*z + 2z [10]

Where:

H=height of column m

N=no. of plates

Z=plate spacing m

H= (28-1)*0.45 + (2 * 0.45)

=13.05 m

Table of distillation design information :

Height	13.05 m
Diameter	2.07 m
Number of plates	28
plate spacing	0.45m
Column area	3.37 m^2
Down comer area	0.404 m^2
Net area	2.966 m^2
Active area	2.562m^2
Hol area	0.2562 m^2
weir length	1.5939 m
Weir height	50 mm
hole size	5 mm
plate thickness	5mm
height of the liquid over the weir	28.65mm
dry plate drop	24.29 mm
residual head	18mm
Total plate pressure drop	0.120m/plate
$total\ \Delta p$	17.9 kPa
Mean length of un perforated edge strips	2.924m
Area of un perforated edge strips	0.123 m^2
Area of calming zone	0.128 m^2
Total area available for perforation	0.759 m^2
hole pitch	13.5mm
Area of one hole	$1.96 * 10^{-5}$ m^2
Number of holes	13071

4.1 Introduction:

Designing control system for complete plant is the ultimate goal of a control designer. The problem is quite large and complex. It involves large number of theoretical and practical Considerations such as the quality of controlled response stability and safety of operation. The difficulties are aggravated by the fact that chemical are largely nonlinear and imprecisely known.

Consistent quality, increased productivity and reduced operating costs can all occur from effective control of major plant variables. A control system must be designed to fit the needs of the particular process to which it will be applied to. The more information and intelligence a designer can put into a control system the greater are its chances of success .

All processes are subject to disturbances that tend to change operating conditions .compositions. and physical properties of the streams. In order to minimize the effects that could result from such disturbances. chemical plants are implemented with substantial amounts of instrumentation and automatic control equipment. In critical cases and in especially large plants, Moreover, the instrumentation is computer monitored for convenience. safety. and optimization.

Since we cannot cover all aspects of plant control within one chapter we will focus our attention on the essential features and present a general methodology for the control system.

4.2 Requirements of control:

During the operation of chemical plant. the control system must satisfy several requirements and it must accomplish certain objectives. Among these requirements are the followings:

4.2.1 Safety:

The safe operation of a chemical process is a primary requirement for the well being of the people in the plant , thus. the operating pressure. temperature. And concentrations of chemicals should always be within allowable limits.

4.2.2 Product specification :

A plant should produce the desired amounts and quality of the final products.

4.2.3 Environmental regulations:

Various laws may specify that temperature , concentration of chemicals and rates of the effluents from a plant must be within certain limits.

4.2.4 Operational constraints :

The various types of equipment's used in a chemical plant have constraints inherent to their Operations

4.2.5 Economic:

The operation of a plant must conform With the market conditions, that is the availability of raw material and the demand of the final product , furthermore it should be as economical as possible in its utilization of raw material , energy ,capital and human labor. Thus it is required that the operating conditions are controlled at given optimum levels of minimum operating coast , maximum profit and so on .

All the requirements above dictate the need for continuous monitoring of the operation of a chemical plant and external control to guarantee the Satisfaction of operational objectives.

There are three general classes of needs that a control system is called on to satisfy.

1. suppressing the influence of external disturbance .
2. Insuring the stability of a chemical process.
3. Optimizing the performance of a chemical process.

4.3 Process variables:

A process variable is a condition of the process fluid (a liquid or gas) that can change the manufacturing process in some way. Common process variables include:

1. Pressure.
2. Flow.
3. Level.
4. Temperature.
5. Density.
6. pH (acidity or alkalinity).

7. Liquid interface (the relative amounts of different liquids that are combined in a vessel).

8. Mass.

9. Conductivity.

4.4 Hardware elements of a control system :

In every control system we can distinguish the following control elements

4.4.1 The chemical process :

If represent the material equipment together With the physical or chemical operation that occurs there .

4.4.2 The measuring instrument or sensor :

It is used to measure disturbances. the controlled output variables or secondary output variables it is the main source of information about what is going on in the process.

4.4.3 Transducers:

Many measurements cannot be used for control until they are converted to physical Quantities. Transducers are used for that purpose.

4.4.4Transmission line:

These are used to carry the measurement signal from the measuring device to the controller.

4.4.5The controller:

Receives the information from the measuring devices and decides what action should be taken.

4.4.6The final control element:

It is the hardware element that implements the decision taken by the controller. The control valve is the most frequently encountered control only one, control elements are:

- Relay switches

-Variable speed pumps

-Variable speed compressors

4.4.7Rccording clement:

Used to provide physical demonstration of how a chemical process behaves.

4.5 Classifications of control:

4.5.1 Feedback Control:

In feedback controller when an offset is. generated m the controlled variable, the controller acts to eliminate or reduce this offset, usually an oscillations produced in the value of the controlled variable whose amplitude , period ,damping and permanent offset depend on the nature of the system and the mode of action of the controller.

The usual controllers provide one, two. or three of these modes of corrective action :

1. proportional, in which corrective action is proportional to the error signal.

2. Integral, in which the corrective action at time t is proportional to the integral of the error up to that time .

3.derivative , in which the corrective action is proportional to the rate at which the error is being generated .

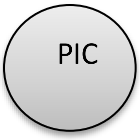
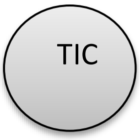
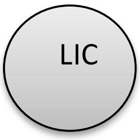
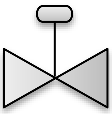
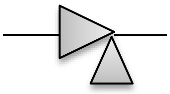
Table 4.1: The kinds of controller suitable for the common variables:

Variable	Controller
Flow and liquid pressure	PI
Gas pressure	P
Liquid level	P or PI
Temperature	PID
Composition	P , PI , PID

4.5.2 Feed forward control :

Feed forward control immediately takes corrective action when an input variable (load variable) changes and therefore it results in a fast control action. In practice, the load-change compensation principle and the feed forward technique are rarely used separately. They are however, increasingly being used in Conjunction with the alternative closed- loop feedback system of control. It is used as a compensation for the primary load disturbances affecting the system. Feedback control is a relatively simple technique for dealing With the problem external disturbances; especially when there are many sources of disturbances.

Table 4.2 :control loop element identification :

Symbol	**Meaning**
	Pressure indicator controller
	Temperature indicator controller
	Level indicator controller
	Valve
	Relief valve

4.6 Equipment control :

4.6.1Heat exchanger control :

Feed outlet temperature control :

Reason for control :

The heat exchanger is used to preheat the feed before it enters the reactor which must operate at 598 k to give the desire conversion.

The outlet temperature can be controlled by Changing the steam flow rate

Table 4.3 Element of control loop for the heat exchanger :

Process	Heating
Controller	Automatic (PID)
Controlled variable	Temperature
Measuring element	Thermocouple
Regulating element	Valve
Manipulated element	Steam flow rate
Set point	598 k

Action: The outlet stream temperature is measured using the thermocouple then the transmitter sends the measured value to the controller, the controller compares the measured value to the set point. If the temperature is increasing above 598K decreases the steam flow rate. And if it is decreased below 598K then increases the flow rate of the steam.

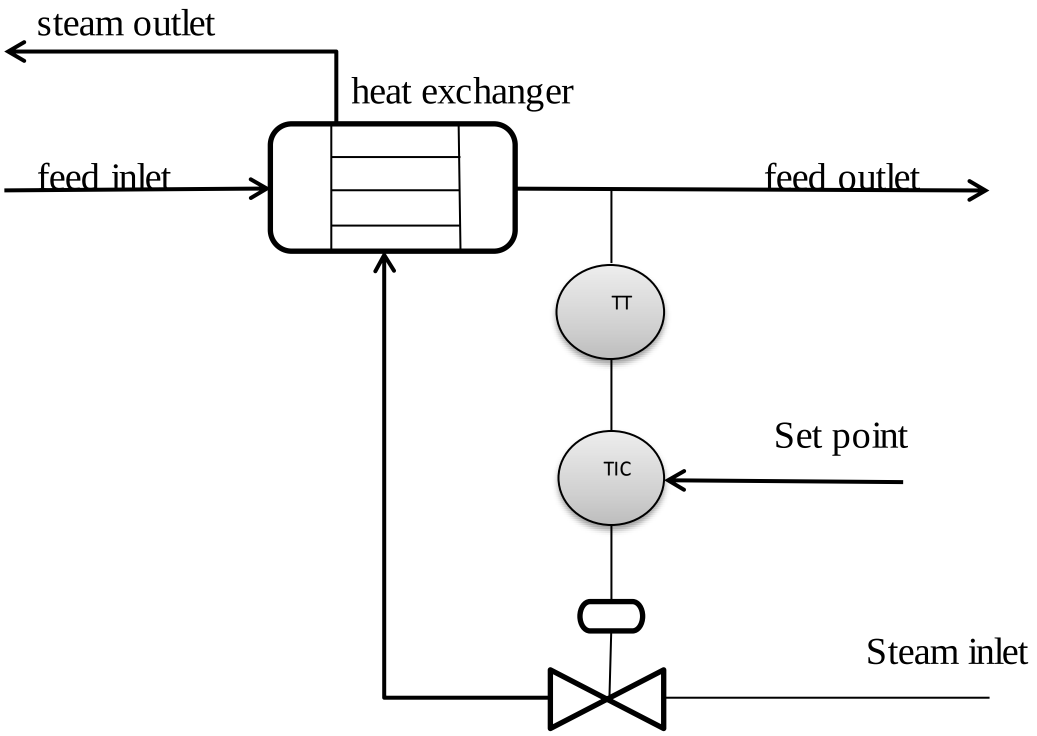


Figure 4.1 :control loop for preheaters

5.1 Introduction:

Safety considerations are. of paramount importance in all Phases of the design of the National Ignition Facility (NIF) such as Acetone plant. From the outset. maximizing public and employee safety and minimizing health risk and environmental impact have been integral parts of the design process. Earning the trust of the public and operating in a manner that protects the environment over time are a requirements.

5.2. Acetone:

5.2.1. Flammability:-

The most common hazard associated with acetone is its extreme flammability. It auto ignites at a temperature of 465 °C (869 “Fl. At temperatures greater than acetone's flash point of -20 'C (-4 °F), air mixtures of between 2.5% and 12.8% Acetone by volume, may explode or cause a flash fire. Vapors can flow along surfaces to distant ignition sources and flash back. Static discharge may also ignite acetone vapors.

5.2.2. Toxilogy:

Acetone is believed to exhibit only slight toxicity in normal use, and there is no strong evidence of chronic health effects if basic precautions are followed.

At very high vapor concentrations, acetone is irritating and, like many other solvents, may depress the central nervous system. It is also a severe irritant on contact with eyes, and a potential pulmonary aspiration risk. In one documented ease. ingestion of a substantial amount of acetone led to systemic toxicity, although the patient eventually Fully recovered. Some sources estimate LDSO for human ingestion at HSQ g/kg; LDSO inhalation by mice is given as 44 g per cubic meter, over 4 hours.

interestingly, acetone has been shown to have anticonvulsant effects in animal models of epilepsy. in the absence of toxicity, when administered in mill molar concentrations. it has been hypothesized that the high-fat low-carbohydrate ketogenic diet used clinically to control drug-resistant epilepsy in children works by elevating acetone in the brain.

5.2.3. Routes of Exposure:

- Eye contact:

Contact with the eye may cause moderate to severe irritation.

- Skin absorption:

Moderately irritating to the skin. Prolonged or repeated contact can result in defeating and Drying of the skin which may result in skin irritation and dermatitis (rash).

- Inhalation:

High concentrations may lead to central nervous system effects (drowsiness, dizziness, nausea, headache, paralysis and loss of consciousness and even death).High vapor concentrations are irritating to the eyes, nose, throat and lungs.

- Ingestion:-

Product may be harmful or fatal if swallowed. Pulmonary aspiration hazard. After ingestion, may enter lungs and produce damage. May produce central nervous system effects, which ‘ May include dizziness. loss of balance and coordination unconsciousness, coma and even death.

5.4.2Emergency and first aid:

- Inhalation:

Remove to fresh air. if not breathing. give If breathing is artificial respiration , if breathing is difficult, give oxygen and continue to monitor. Get immediate medical attention.

- Eye Contact:

flush eye(s) with water for 15 minutes. Get medical attention.

- Skin Contact:

Immediately flush skin with plenty of water. Remove clothing Get medical attention immediately.

Wash clothes separately before reuse.

- Ingestion:

If swallowed, DO NOT INDUCES VOMTNG. Give victim 21 glass of water or milk. Call a physician or poison control center immediately. Never give anything by mouth to an unconscious person. Get medical attention immediately.

5.2.5.Personal protective equipment:

-Eye / face protection :

Splash proof chemical goggles or full—face shield recommended to protect against splash of product.

Clothing/Gloves:

The glove(s) list below may provide protection against permeation. Gloves or other chemically resistant materials may not provide adequate protection. Protective gloves are recommended to protect. against contact ventilation product.

-Engineering Controls:

Use with adequate ventilation. Ventilation is normally required when handling or using this product to keep exposure to airborne contaminants below the exposure limit. Use explosion proof ventilation equipment.

5.2.6- Storage and handling:

- Storage Conditions:

Keep away from heat ,sparks and flame .store in a cool ,dry place ,keep container closed when not in use.

-Handling Procedure:

Use only in a well-ventilated area. Ground and bond containers when transferring material. Avoid breathing (dust, vapor, mist, gas). .Avoid contact with this material. Wash thoroughly after handling. Do not use air pressure to unload containers.

5.3 Location and site considerations:

The site chosen for the plant chemical directly affect the success or failure of the manufacturing process. The basic principle is to have the factory site so that the cost of production and distribution of the product at the minimum , and this can only be achieved if it is taking a number of important factors into consideration during the design and selection process plant site.

The most important considerations to be followed in the selection of the plant site are:

1. Sources of raw materials
2. Consuming markets
3. energy resources
4. the climate
5. transport services
6. Water Resources
7. Waste disposal
8. Labor
9. Financial considerations

10. Prevention From Fire And floods

11. Proximity From Positions Industrial

5.3.1. Sourcing of raw materials

That one raw material processing of the most important factors that go into determining the plant site especially when large quantities required. The factory near the site of the raw materials are not allowed to reduce transportation expenses only, but to reduce the capital invested in storage services as well.

5.3.2. Common Markets

The viability of the delivery of the final product to the consumer quickly and the lowest possible cost no less important than site - built near the source of raw materials. So From the necessary that Be there is

Comparison between Proximity From Items the source Crude And ease receipt Product to me The consumer. The choice Will depend On the quantity Required And the cost Transfer Articles Crude And the product. When Taking Marketing For the product Final The eyes consideration Must that Calculates an account Sale And distribution Outputs Occasional Often What Be Factor at Profit Work.

5.3.3. Energy Sources

In most chemical factories need large fuel and energy be when coal and oil shale amounts required large site near the source of the processing is necessary , therefore the process is economical. When large amounts of electrical power is available , it is one of the very important factors to be taken into consideration, it is noted that in the case of the need for a large ownership of the energy it is better to be near the site of the hydroelectric generators.

5.3.4. Climate

It is possible that a large climate impact of the economic process. When Aldharov be harsh climate, the cost of personal protective buildings and services must be part of the total cost. In hot weather it may be dismissed in cooling towers, air - conditioning and possibly freeze coefficient of important considerations.

5.3.5. Transportation services

The choice of modes of transportation for both raw materials and the final product depends no doubt on the quality and quantity of the materials used, if possible , provide the three modes of transportation of any roads and population as rail and maritime transport. It is important that the plant site near either the railway station or docks.

5.3.6. Water Resources

Most industrial processes require large amounts of water not only for industrial process but also used for cooling processes, washing and steam generation processes. To make the process economical, the plant site or plant near a river or lake is an important and necessary.

5.3.7. Waste disposal

The water supply is linked to a large extent with the waste disposal problem , whether solid, liquid or gaseous where there are strict limitations on the issue of waste disposal and it changes according to industrial unit site.

It is necessary to study the stamina to be allowed for water, earth, air metastatic sites and in several cases the level of a test as a result of the center. The additional cost due to treatment outcomes emitted must be balanced with other appropriate site selection factors.

5.3.8. Employment

Although the trend is the increased use of automated equipment in the lab , a chemical addition to the angel of the assistant engineers , but there are several processes still need a large workforce especially when using a rotation system , it is important to choose the industrial unit site , taking into account the payment of wages prevailing rate specific region and industry competition as well as skilled and intelligent workers. In remote spokesman it should be calculated to provide housing and causes of social amenities for the workers expense.

5.3.9. Financial considerations

When trying to create a sophisticated industry in a particular area should provide the necessary and which have a significant impact in the selection of the plant site and financial incentives. It is also necessary to take the applicable tax system into consideration . When choosing the location of his family in the area of future expansion should his account , especially in the busy industrial areas.

5.3.10. Prevention of fires, floods

As such We mentioned Previously,for the purpose of Large amounts of cooling water for the chemical factories processing location is often near rivers and lakes .walhakiqh that this site will be vulnerable to flooding so it is necessary to know the historic flood that has happened in that region. It is important to provide adequate services to prevent n fire in the region, as well as knowledge of its impact on neighboring sites. The Earth and its terrain with a price tag and buildings should take into consideration.

5.3.11. Proximity to industrial centers

The plant site near the important industrial centers be useful in terms of getting large numbers of manpower of different means of transport. Perhaps there are other industries adjacent to bid for materials and services at low prices , and there are several cases where materials processing manufacturers have directly.

•Due to this reason we find that the desired position is Baghdad .

5.4 Economic and feasibility considerations:

5.4.1. Cost estimation of Absorption column

Material of construction : Carbon steel

Absorber data	
Diameter (m)	0.2007
Height (m)	2.1092

Cost = 8000$
Pressure factor = 1.6
Material factor = 1
Cost = 8000*1.6*1 = 12800 $ in 2004
Cost in 2016 = (cost in 2004) *(cost index in 2015/cost index in 2004)
Cost index in 2004 = 480 $
Cost index in 2015 = 1081 $
Cost in 2016 = 12800 *(1081/480)
Cost in 2016 = 28826.66667 $
= 37186400 I.D

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