- **T.Y.B.Sc. CBCS COURSE IN CHEMISTRY CH: 504 Industrial Chemistry**
- **Core Course- (Semester VI)**
- **Chapter : Sugar Industry (L: 9, M: 12)**

- **A POWERPOINT PRESENTATION FOR T. Y. B. Sc. CBCS COURSE IN INDUSTRIAL CHEMISTRY ON THE TOPIC**

ENTITLED

"Sugar Industry"

BY

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Dondaicha. Dist- Dhule. **(M. S.)**

----- September 2020 -----

“Sugar Industry”

Syllabus: **(M-12, L-09)**

Introduction, Sugar Industry in Maharashtra and India, Manufacture of cane sugar-[Refining (with flow sheet)], general idea of Sulphitation and Carbonation, Concentration/Evaporation, Crystallization Separation of crystals. Grades, Baggase, Celotex.

Introduction: - Cane sugar (Sucrose) ($C_{12}H_{22}O_{11}$), Disaccharide sugar .

Occurs naturally in every fruit and vegetable. It is the main product of photosynthesis. Sucrose is an important source of energy, which provides 13% of energy to man required for existence.

$$6CO_2 + 6H_2O + h\upsilon + \text{Chlorophyll} \longrightarrow C_6H_{12}O_6 + 6O_2$$

Sources

Sugarcane (56%)

Sugar beets (44%)

Member of grass family

Bamboo like stalk, height of 8 to 15 feet.

It contains 8.5 to 15% sugar

In growing sugarcane plant, glucose is present and when plant attains maturity, sugar (sucrose) is formed.

There should be no delay in transporting the freshly cut canes to the factory.

Loss in wt. & inversion (fast in cut canes), which does not form crystals and passes into molasses.

In growing sugarcane plant, glucose is present and when plant attains maturity, sugar (sucrose) is formed. The analysis of a ripe cane sugar plant shows that it contains 71% water, 18% sucrose and 9.5% fibre.

Many by-products are obtained from sugar industry : - Bagasse, Molasses, Alcohol, acids, etc.

Manufacture of cane sugar:-

Raw materials:-

i) Sugar canes ii) Processing materials such as lime (CaO), Calcium triphosphate or Phosphoric acid (H_3PO_4) and iii) Process water.

Steps involved in the manufacture:- There are number of physical and chemical processing steps:

i) Cleaning of canes

ii) Extraction of juice

iii) Purification of juice

iv) Concentration of juice to syrup by evaporation

v) Crystallization

vi) Centrifugation

vii) Refining of Crysals

viii) Packaging

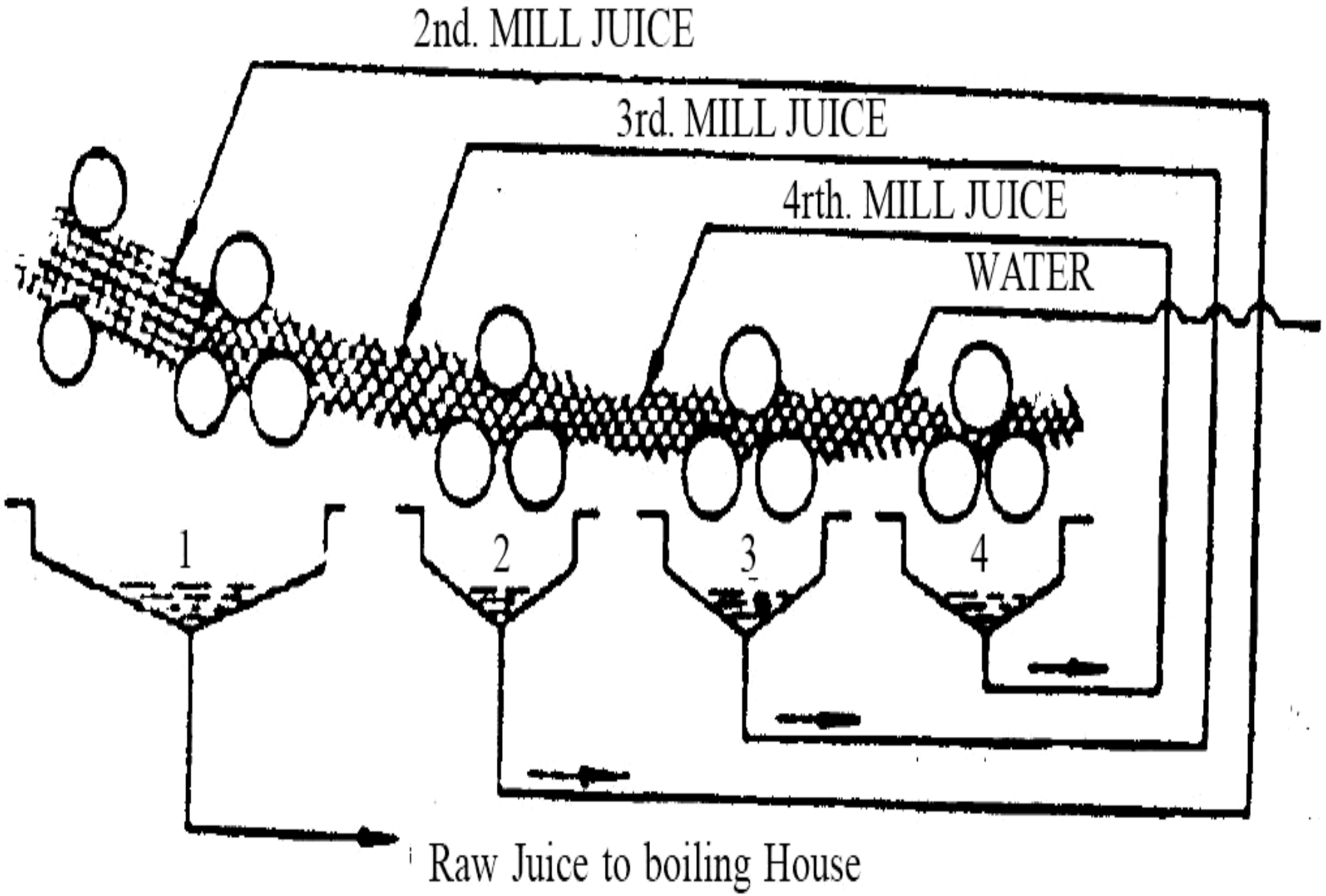
Procedure:-

i) Cleaning of canes: - The purpose of the step is to prepare the canes ready for juice extraction by removing external solid impurities adhered to canes.

It is very essential to remove soil, rocks and field trash associated with the sugar canes. For this purpose, the canes must be washed before milling. Washing can be carried out by simple wash with warm water on the carriers.

ii) Extraction of juice (Compound imbibition process): -

Juice extraction by milling is the process of squeezing the maximum juice from the canes under a set mills using high pressure between heavy iron rollers.


2nd. MILL JUICE
3rd. MILL JUICE
4rth. MILL JUICE
WATER
1
2
3
4
Raw Juice to boiling House

iii) Purification of Juice: -

The purpose of this step is to remove suspended solids from the juice, typically mud, waxes, fibres and other colloidal impurities. All these impurities hamper crystallization of sucrose. The cane juice is acidic having pH from 5.1 to 5.7.

The juice after extraction should be immediately made alkaline, because on standing pectic substances present in it undergo fermentation into pectic acids, which catalyze the change of cane sugar into non crystallizable sugars (glucose and fructose).

Screening: – After weighing the juice is filtered first through a perforated metallic sheet and further by a stationary or vibrating metallic sieve cloth to remove suspended impurities.

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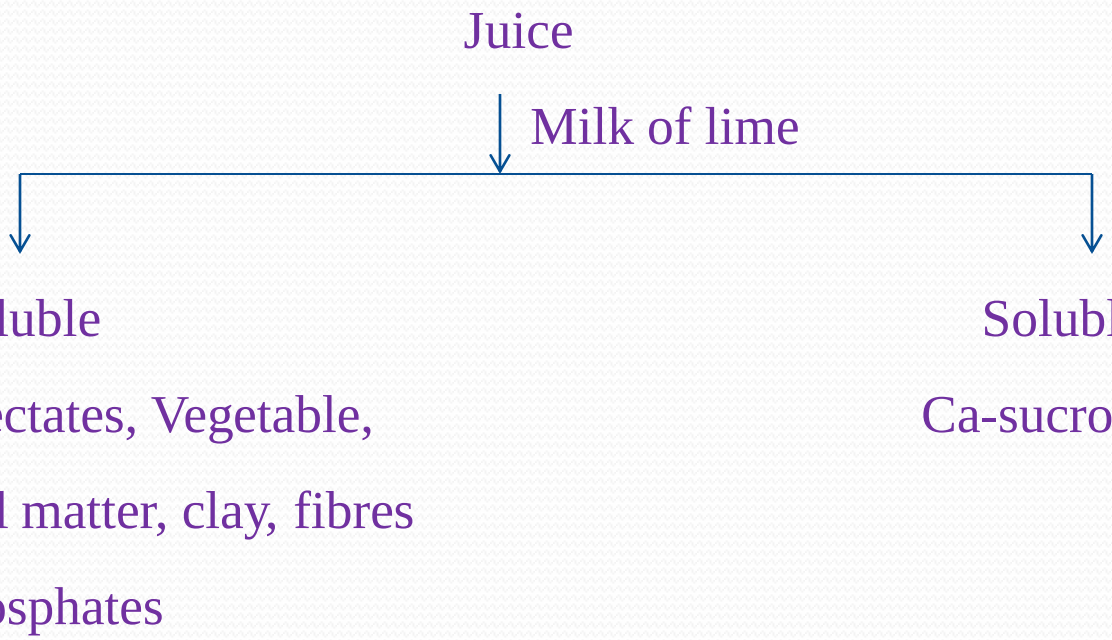
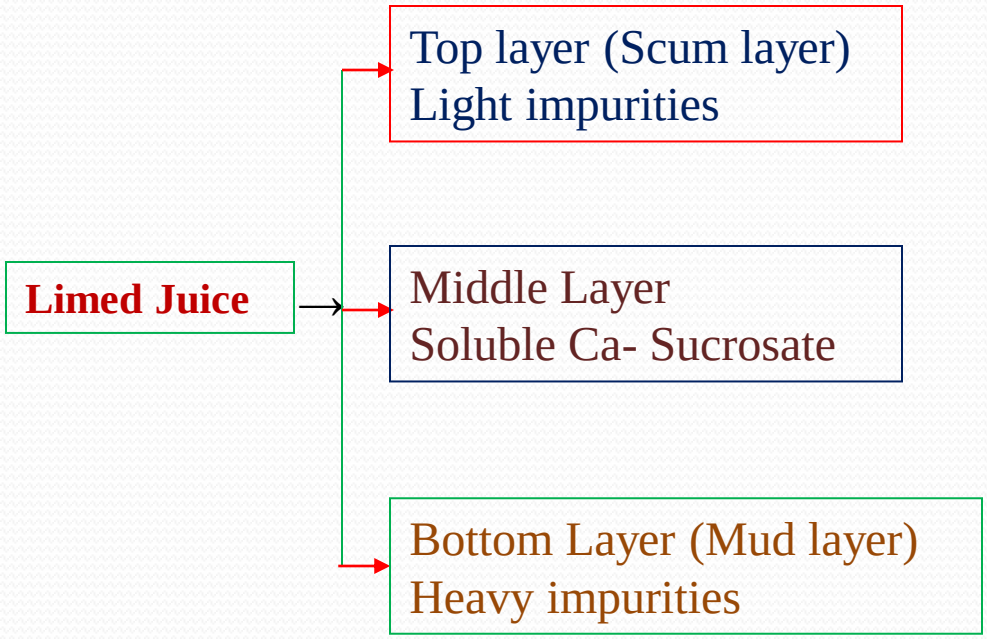
Purification of juice can be carried out by following three methods: -

a) **Clarification by lime defecation process: –** Defecation is a process of preparation of raw liquor for filtration and clarification by removing solid impurities.

If the phosphate content of the juice is less than 300 ppm, then it is treated with phosphoric acid to clarify the juice well. Polyelectrolytes are also used, some times to enhance the rate of coagulation and settling of the precipitate.




Limed Juice
Top layer (Scum layer)
Light impurities
Middle Layer
Soluble Ca- Sucrosate
Bottom Layer (Mud layer)
Heavy impurities

The juice is then neutralized by adding adequate amount of milk of lime till the pH reaches 7-7.3. This treatment precipitates pectic substances as insoluble calcium pectates, coagulates the vegetable proteins, gums etc, and converts sucrose into soluble calcium sucrosate. Along with colloidal matter, finely divided pitch, fibre, clay etc. are also precipitated. Lime converts phosphoric acid or soluble phosphates into insoluble tricalcium phosphate, which is precipitated. The limed juice is then passed through heaters, where it is heated to boiling, by high pressure steam.

The hot limed juice is then pumped into settling tanks, where it separates into three layers. The middle layer of clear juice is allowed to drain off through a pipe and is sent to the boiling house for evaporation to syrup. The top layer containing thick scum of impurities and the bottom layer (mud layer) containing heavy precipitates are removed by passing through a filter press. The filtered dried cake contains phosphates and used as a fertilizer.

b) Clarification by Sulphitation: -

In this process, the syrup is clarified by passing sulphur dioxide through limed juice.

$$SO_2 + H_2O \rightarrow H_2SO_3$$

$$Ca(OH)_2 + H_2SO_3 \rightarrow CaSO_3 + 2H_2O$$

The calcium sulphite ($CaSO_3$) formed in the sulphitation process keeps reducing atmosphere and prevents oxidation and darkening of juice. It also precipitates gums and albuminous matter and helps to filtration of scum. The production of white sugar is further increases by passing SO_2 gas through the concentrated syrup and the pH is maintained at about 5.5. This process is called double sulphitation.

SO_2 used in clarification serves three purposes.

i) It neutralizes excess quantity of lime added.

ii) It bleaches juice by acting on the colouring matter.

iii) It decreases the viscosity of juice.

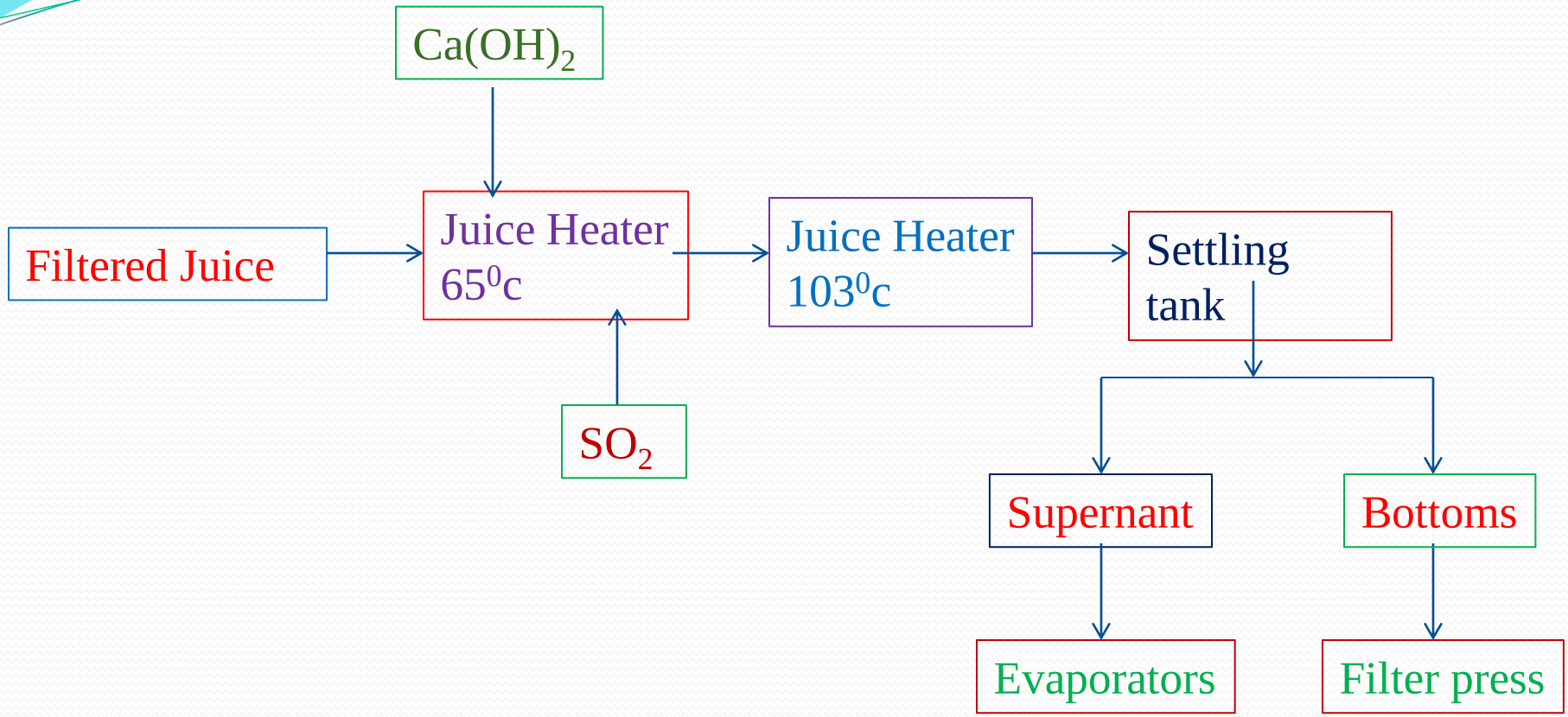


Fig. Sulphitation of limed juice

c) Clarification by carbonation: -

Clarification is also carried out by passing CO_2 through the limed or defecated juice to precipitate the excess of lime as $CaCO_3$.

$$C_{12}H_{22}O_{11}.\ 3CaO + 3CO_2 \rightarrow C_{12}H_{22}O_{11} + 3CaCO_3\downarrow$$

Calcium sucrosate Sucrose

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3\downarrow + H_2O$$

Carbonation process is more superior than sulphitation process because

i) It removes maximum amount of non sugars than by sulphitation process.

ii) Due to carbonation process higher recovery of sugar is obtained.

iii) Quality of sugar produced is also superior when carbonation process is used instead of sulphitation process.

iv) Due to mobility of syrup which insures uniform heating and better crystallization in evaporation, the carbonation process is more beneficial than sulphitation.

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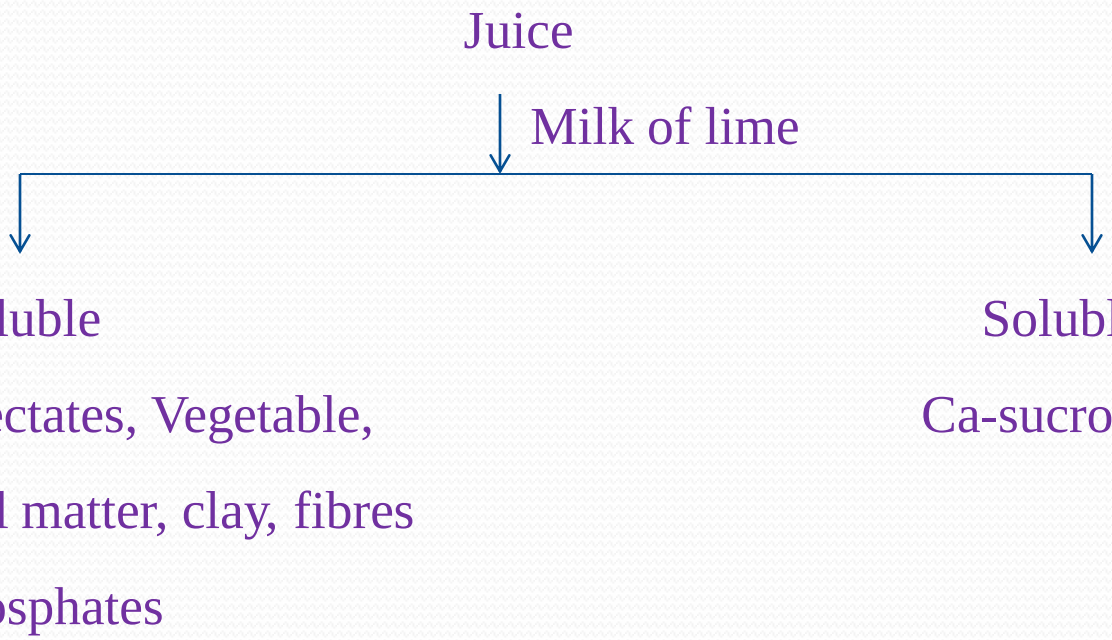

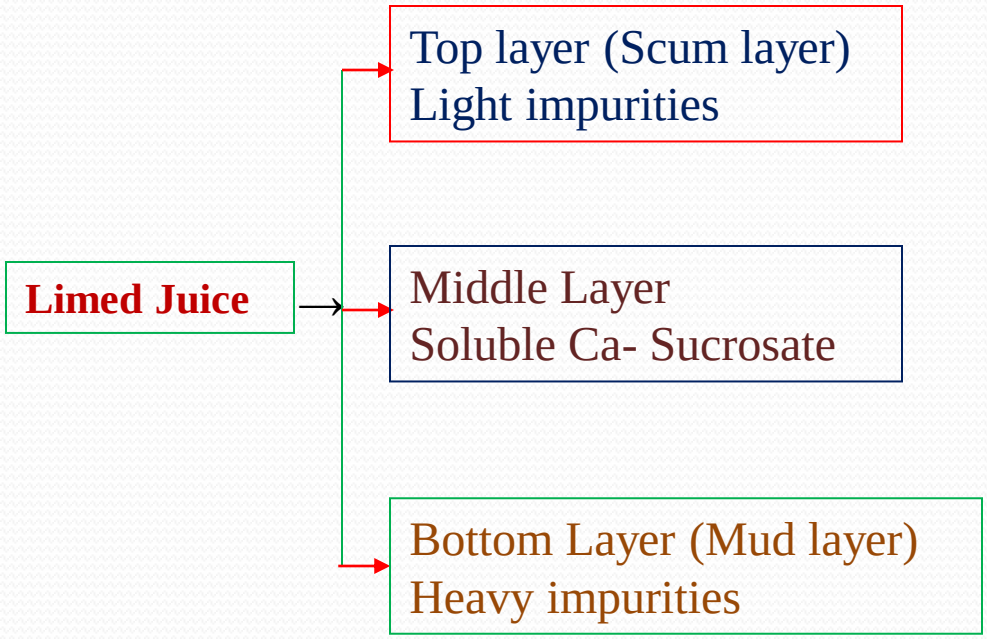
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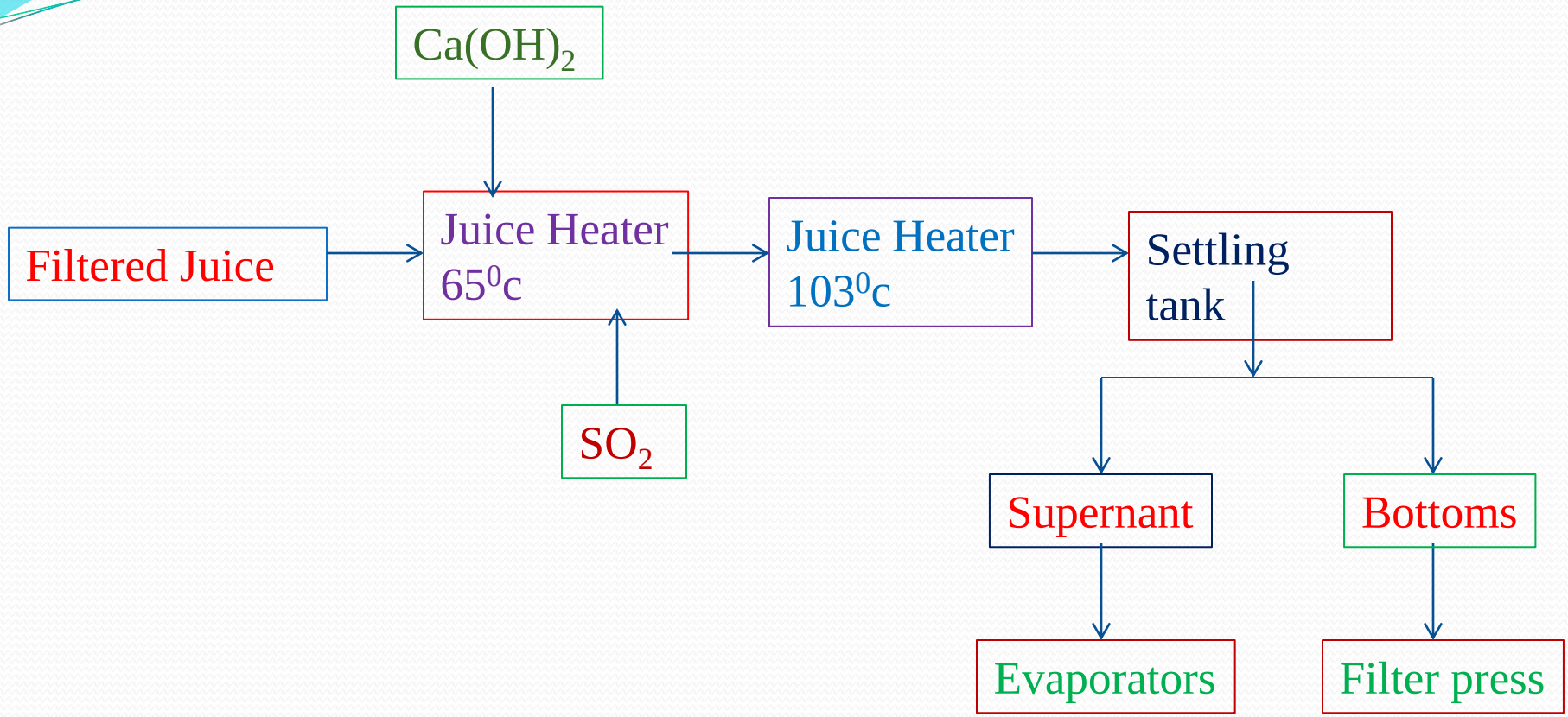
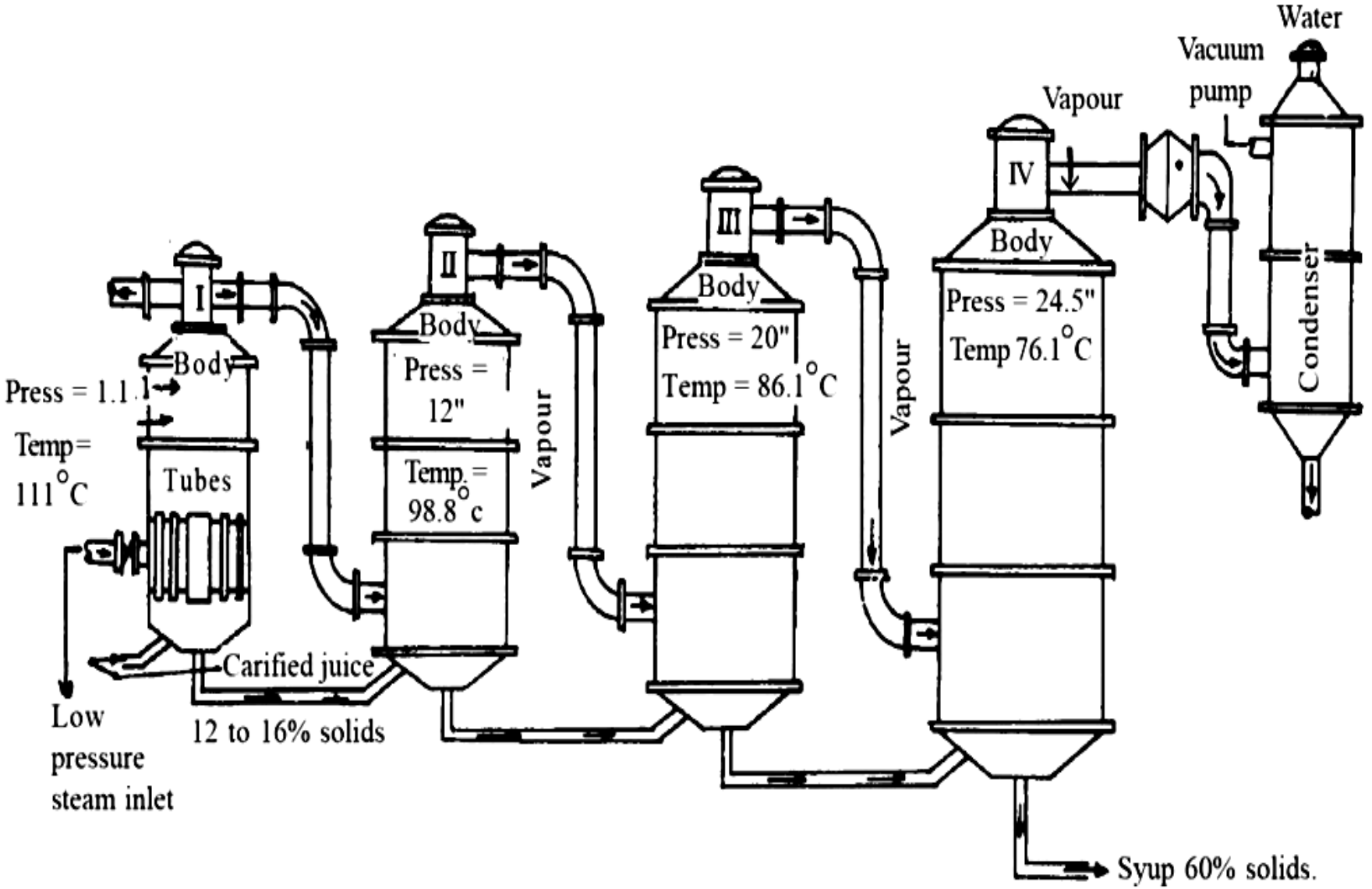


Fig. Sulphitation of limed juice

iv) Evaporation of juice or Concentration: -

The role of this step is to concentrate the juice by evaporation to thick syrup for crystallization.

The clarified, bright yellow to olive green color juice is concentrated into thick syrup by evaporation in multiple effect evaporators joined in series, in order to achieve maximum steam economy. i.e. In only one evaporator live steam is used, the heat required for the remaining stages being supplied by the vapor formed of the liquid itself from previous stage.


Water
Vacuum pump
Vapour
IV
Body
Press = 24.5"
Temp 76.1°C
Condenser
III
Body
Press = 20"
Temp = 86.1°C
Vapour
II
Body
Press = 12"
Temp = 98.8°c
Vapour
I
Body
Press = 1.1.1
Temp = 111°C
Tubes
Carified juice
12 to 16% solids
Low pressure steam inlet
Syup 60% solids.

Caramellization: – Sugars when in solution are very sensitive to heat and even quite low temperature turns the sugars brown by forming traces of other compounds, called caramels.

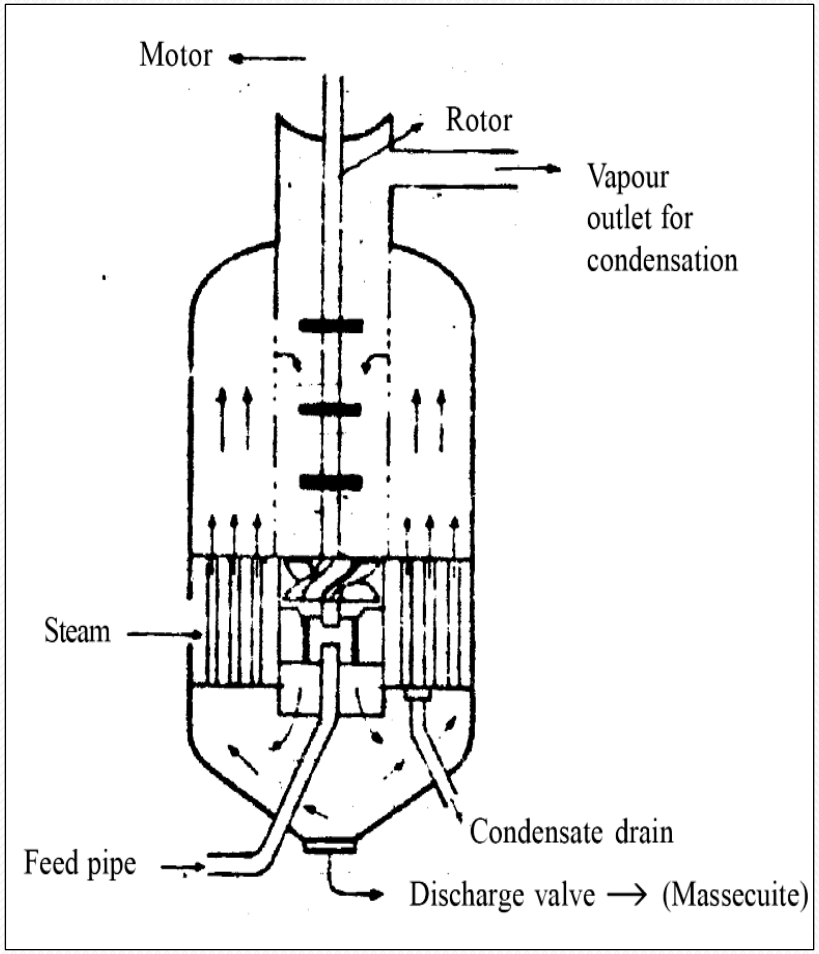
This process of formation of caramels is called caramellization. Reaction occurring in caramellization is probably as follows.

$$11C_{12}H_{22}O_{11} \rightarrow C_{125}H_{188}O_{80} + 7CO_2 + 27H_2O.$$

Heat also helps inversion and invert sugars turn brown more rapidly than sucrose. Therefore, it is of greatest importance to boil sugar syrups at the lowest possible temperature and hence vacuum pans are used in order to bring down the boiling point of water.

v) Crystallization: -

The role of this step is to further concentrate the syrupy liquid to supersaturation for rapid crystallization. This is carried out by removing most of the water by heating in a single evaporator, called vacuum pan.



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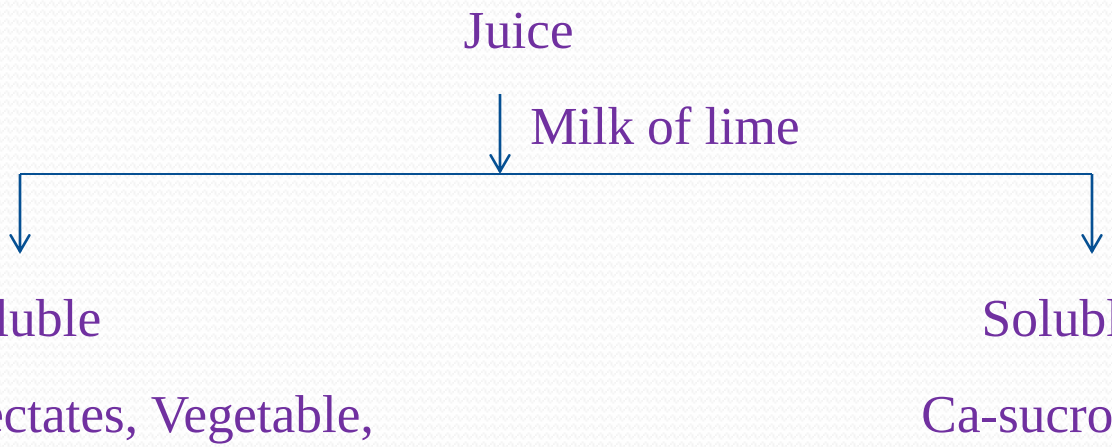

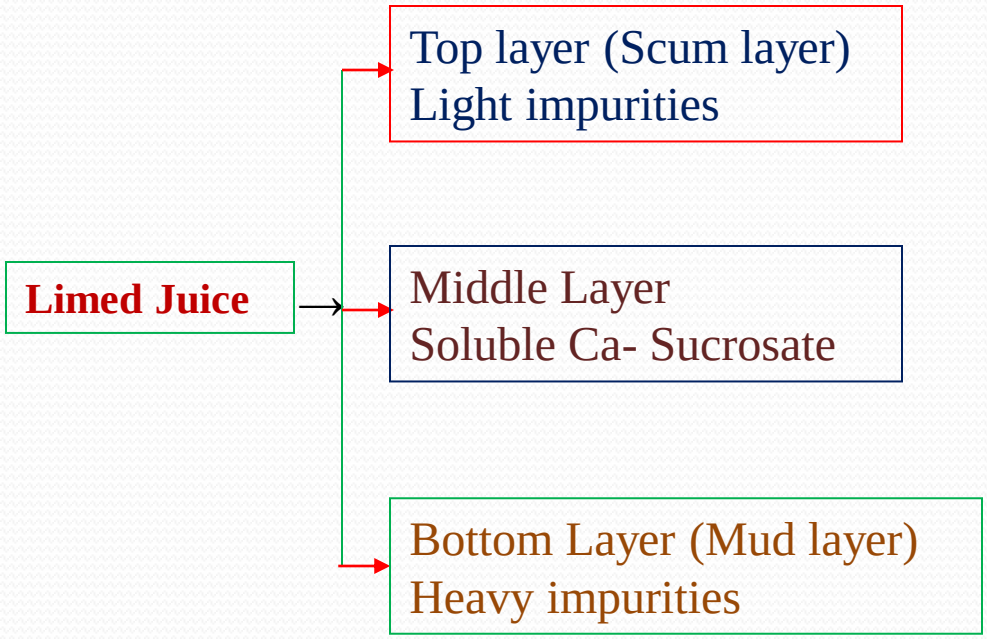
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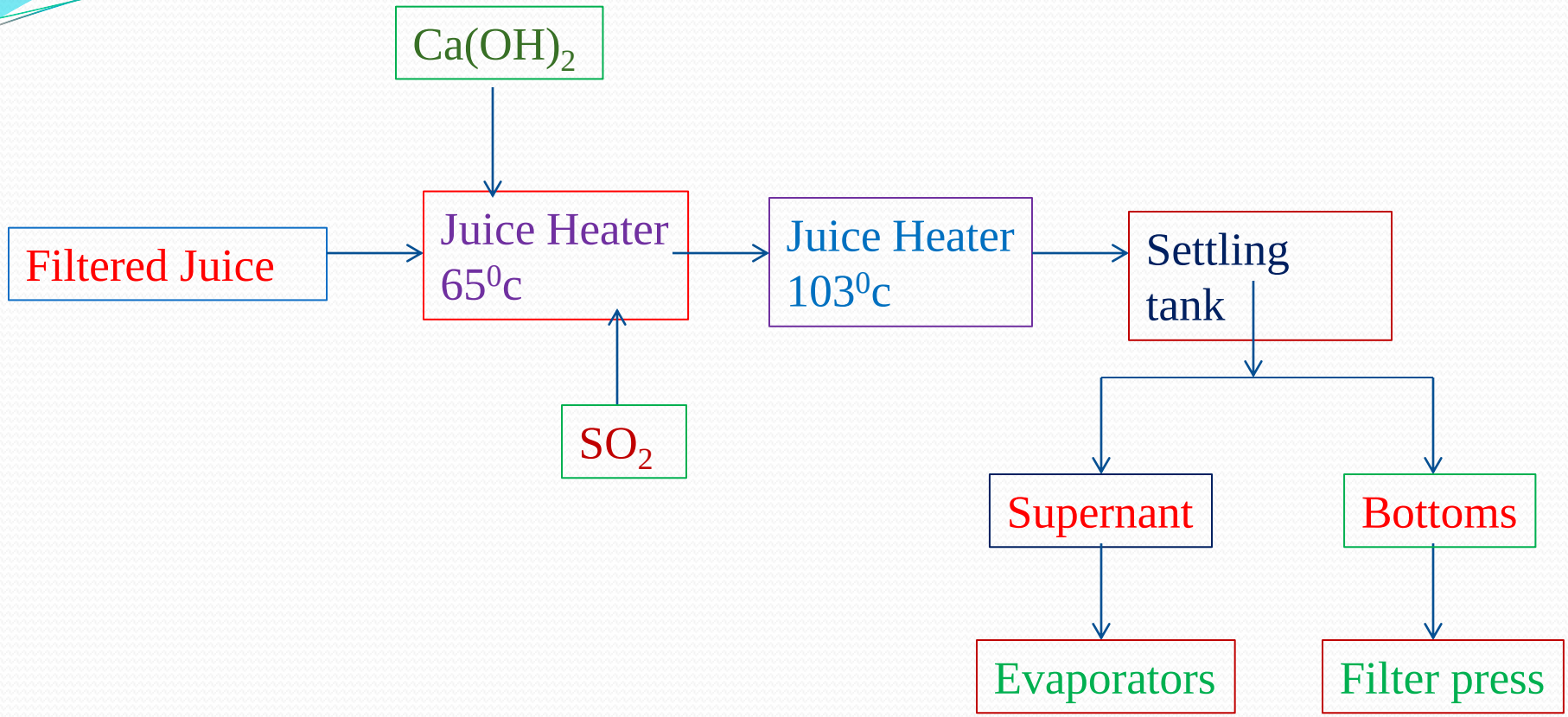

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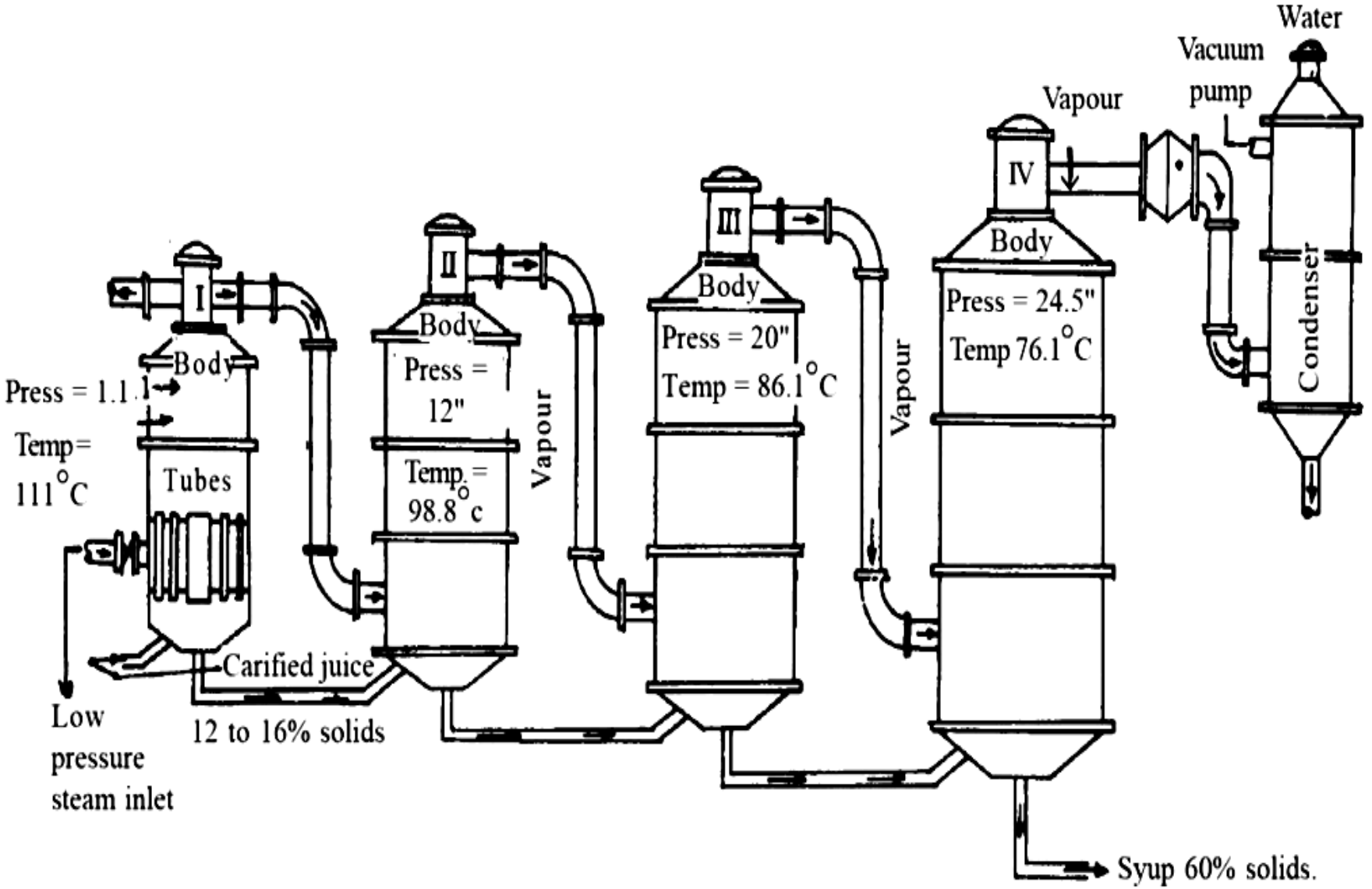
Water
Vacuum
pump
Vapour
I
II
III
IV
Body
Body
Body
Body
Press = 1.1.1
Temp=
111°C
Tubes
Press =
12"
Temp =
98.8°c
Press = 20"
Temp = 86.1°C
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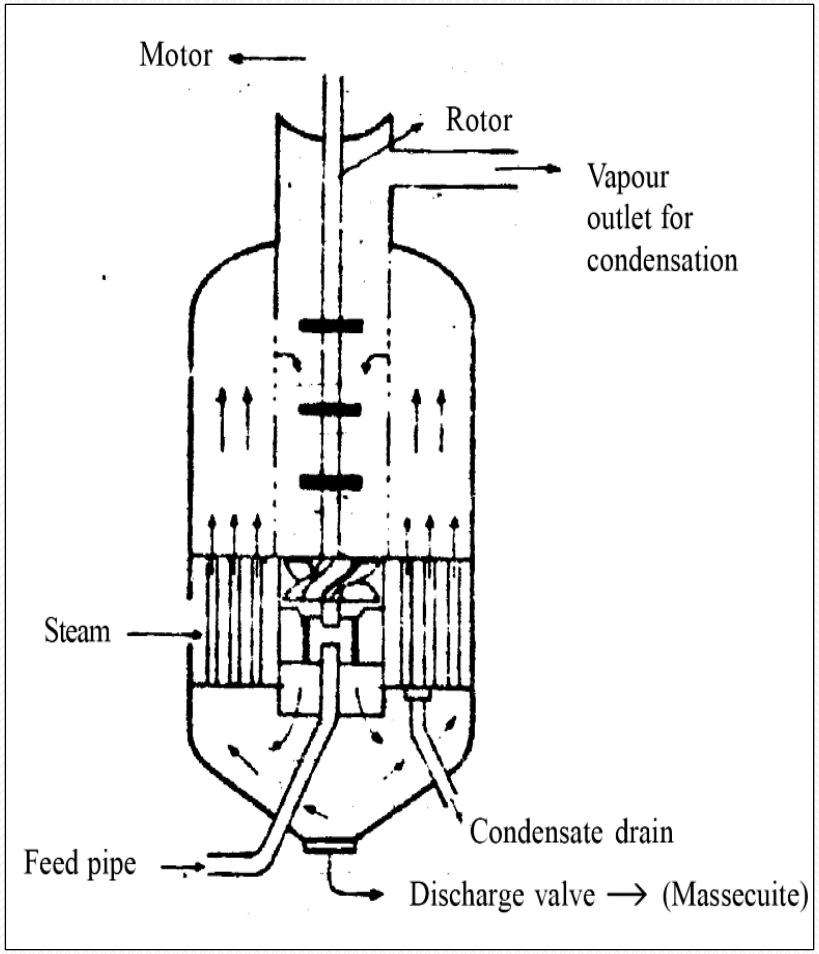
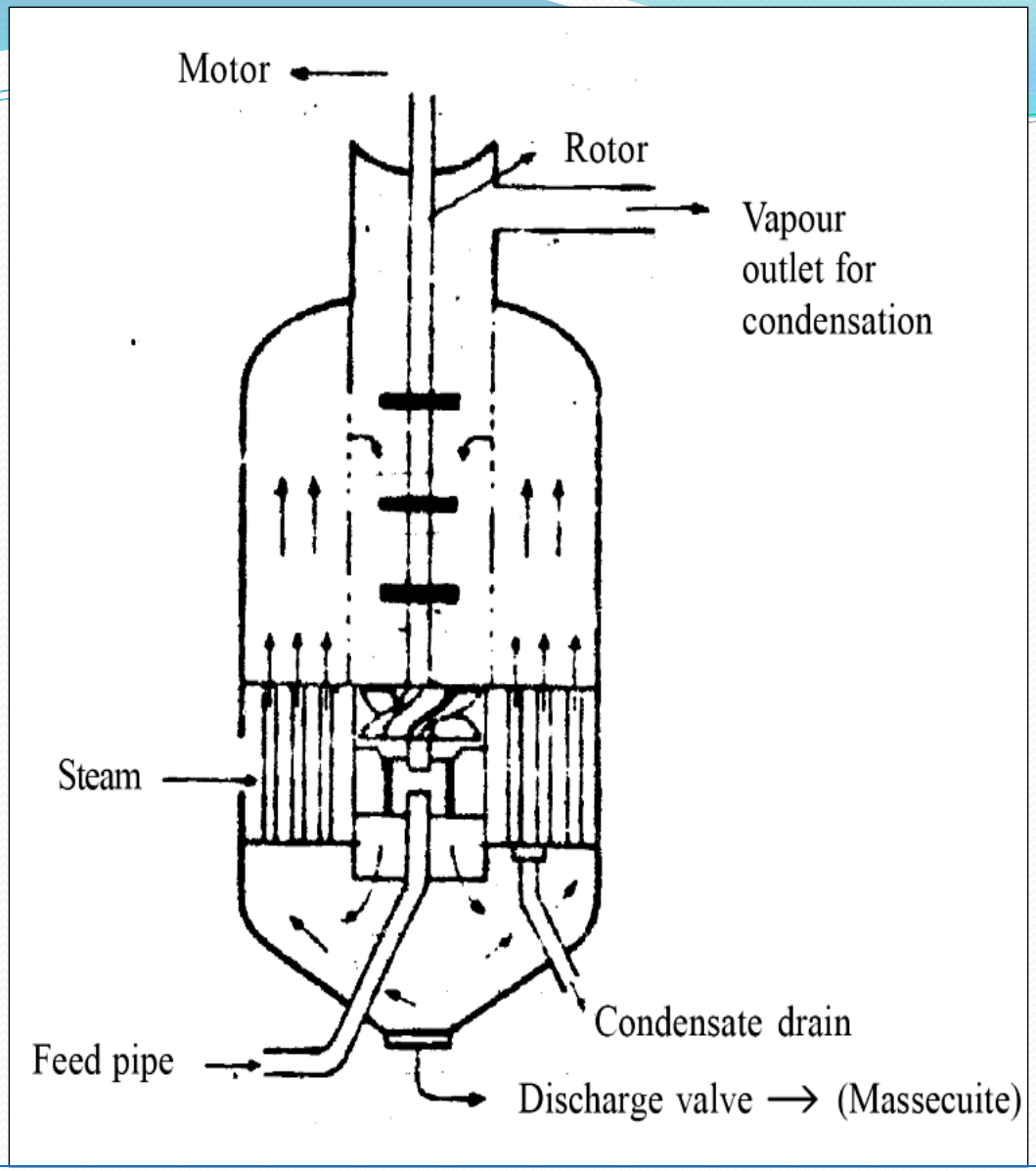
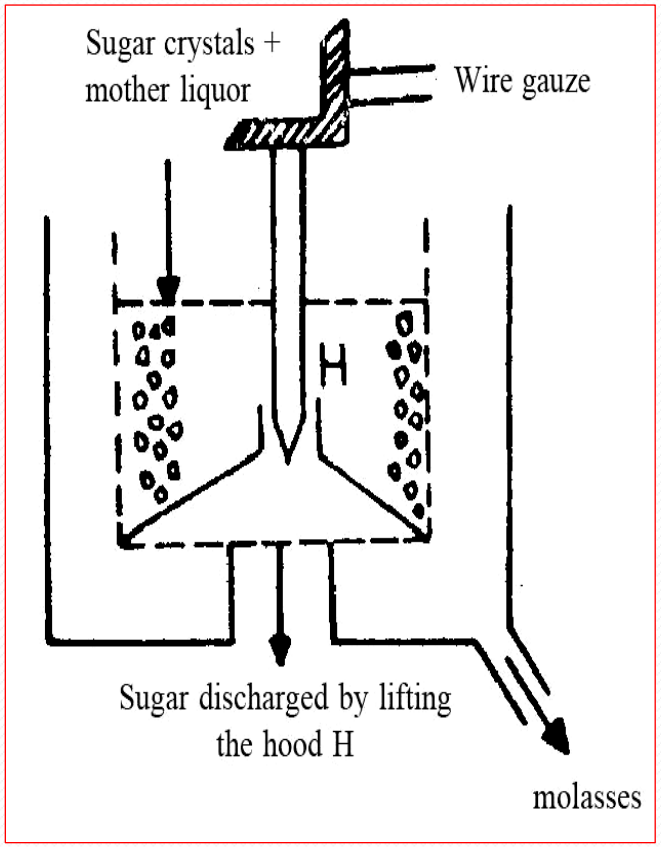




The crystallization of sucrose in vacuum pan is called as 'Sugar boiling" and each boiling is termed a 'strike'.

vi) Centrifugation: -

The role of centrifugation is the separation of the sugar crystals from the mother liquor. The massecuite from the crystallizer is centrifuged in order to separate the crystals of sugar from the mother liquor, by revolving in centrifugal machine as shown in fig.(4).



A centrifugal machine composed of cylindrical basket suspended on a "spindle" has perforated sides lined with wire cloth. The machine revolves at a speed from 1000 to 1800 rpm. The perforated lining retains the sugar crystals. While, the mother liquor (molasses) passes through lining because of the centrifugal force exerted. The sugar crystals are carefully washed by injecting a fine spray of water or by means of jet of steam and air, to remove last traces of molasses still sticking them.

Melassigenic effect of salt:-

When salt is added in saturated solution of sugar, the solution dissolves more sugar. This increase in the solubility of sugar in water due to presence of salts is called a 'melassigenic effect.' Thus the presence of salts gives rise to the formation of molasses containing higher percentage of sugar. Hence it is essential to remove salts present in cane juice or syrup before crystallization in order to have high sugar recovery. But, the Presence of invert sugars has the opposite effect as they reduce the solubility of sucrose in water.

2.3 Manufacture of Raw Cane Sugar: -

A) Raw materials – (1) Sugar canes and (2) Processing materials such as lime (CaO), calcium triphosphate or phosphoric acid and (3) Process water.

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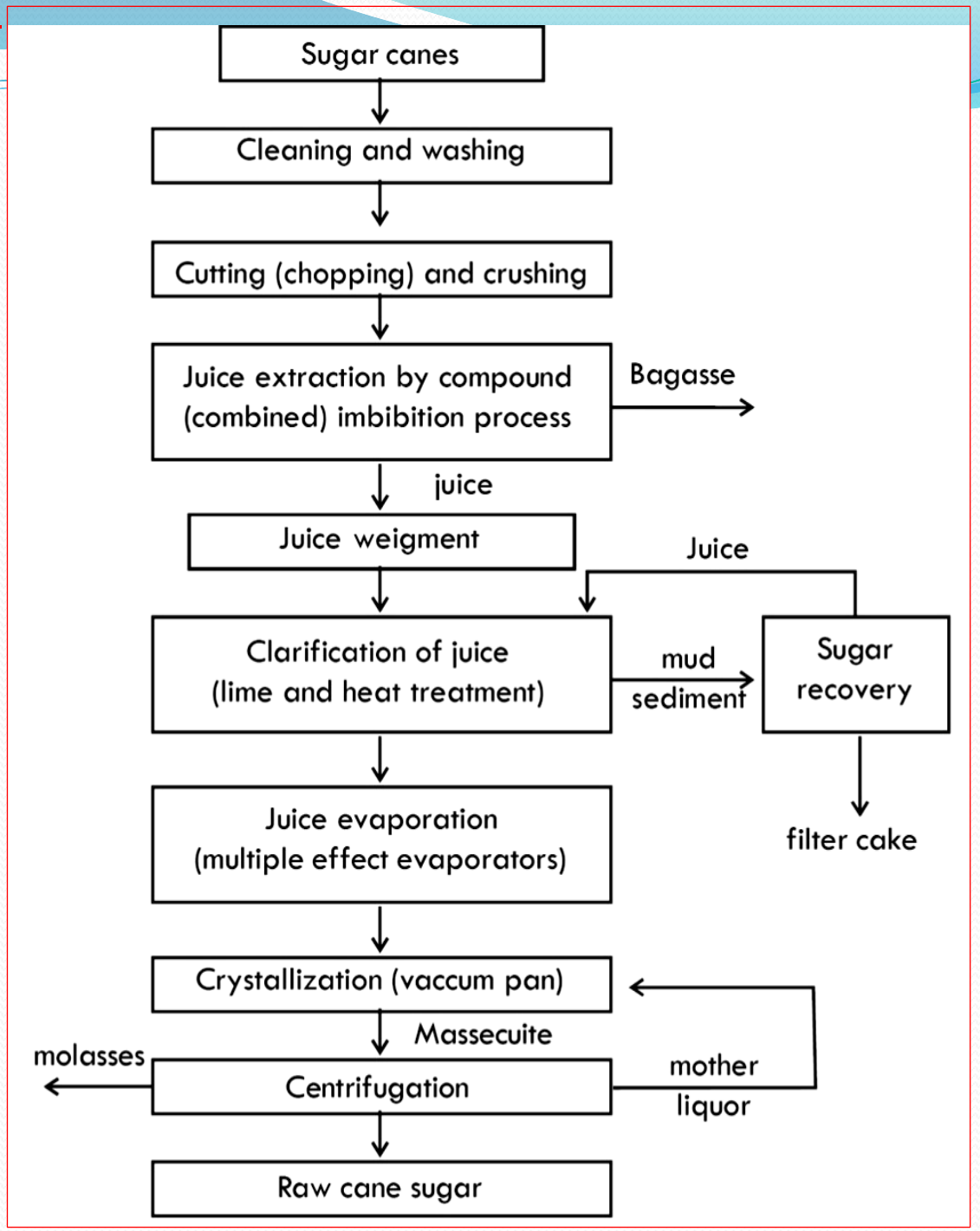
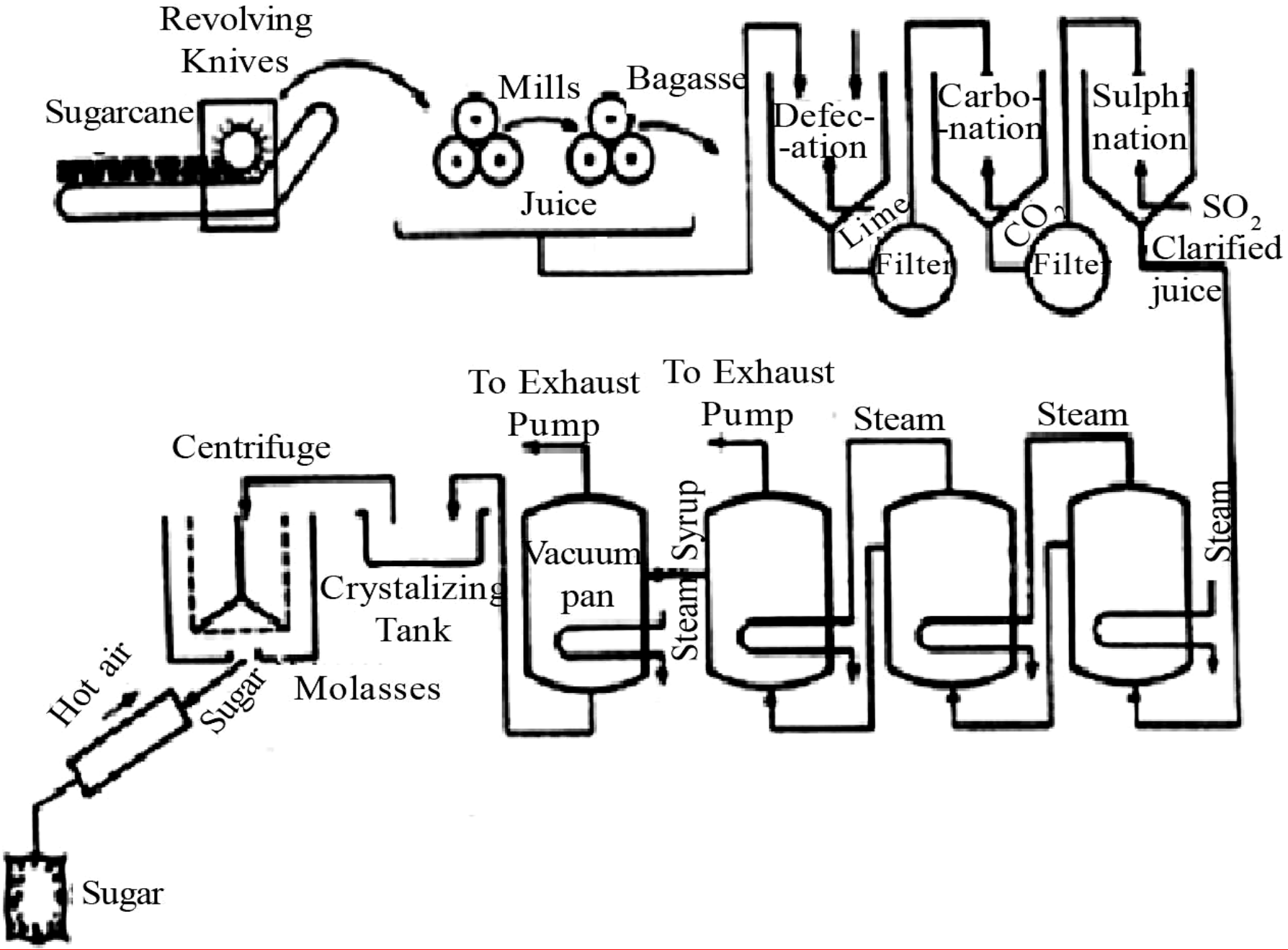
B) Flow-sheet: –

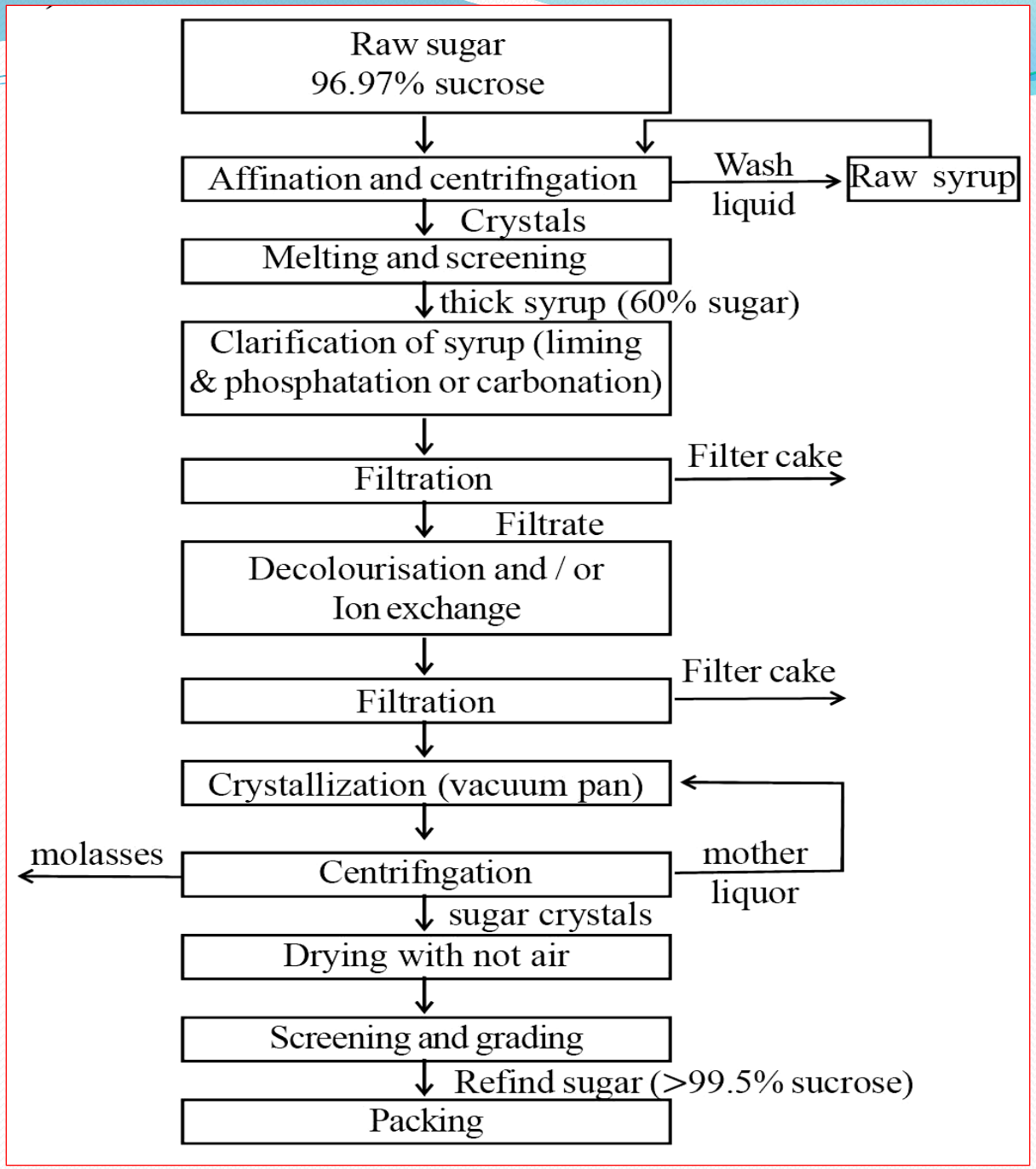

Sugar canes
Cleaning and washing
Cutting (chopping) and crushing
Juice extraction by compound (combined) imbibition process
Bagasse
juice
Juice weigment
Juice
Clarification of juice (lime and heat treatment)
mud sediment
Sugar recovery
filter cake
Juice evaporation (multiple effect evaporators)
Crystallization (vaccum pan)
Massecuite
molasses
Centrifugation
mother liquor
Raw cane sugar

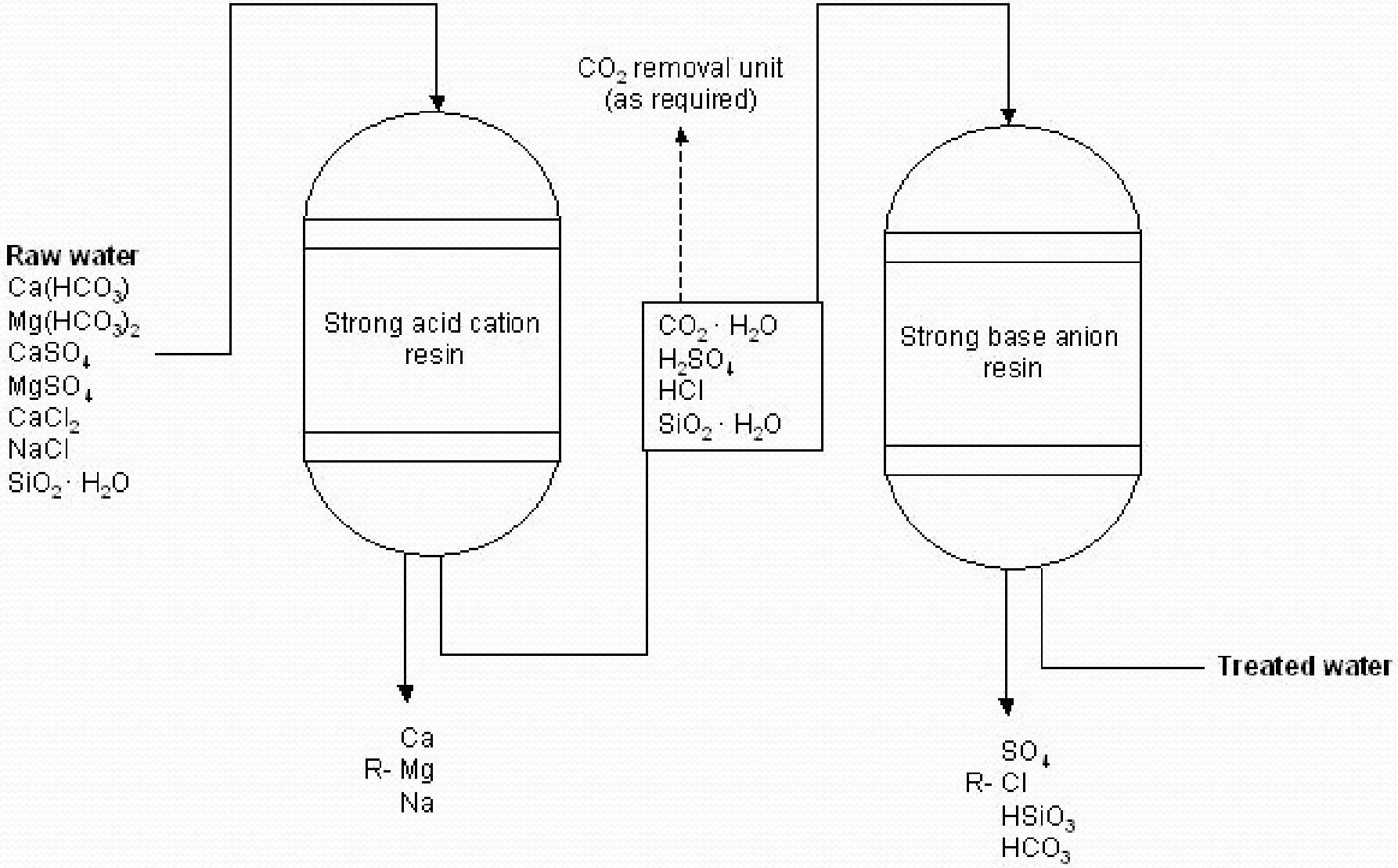

Revolving
Knives
Sugarcane
Mills
Bagasse
Juice
Defec-
-ation
Carbo-
-nation
Sulphi
nation
Lime
Filter
CO_2
Filter
SO_2
Clarified
juice
To Exhaust
Pump
To Exhaust
Pump
Steam
Steam
Steam
Centrifuge
Vacuum
pan
Syrup
Steam
Crystalizing
Tank
Hot air
Sugar
Molasses
Sugar

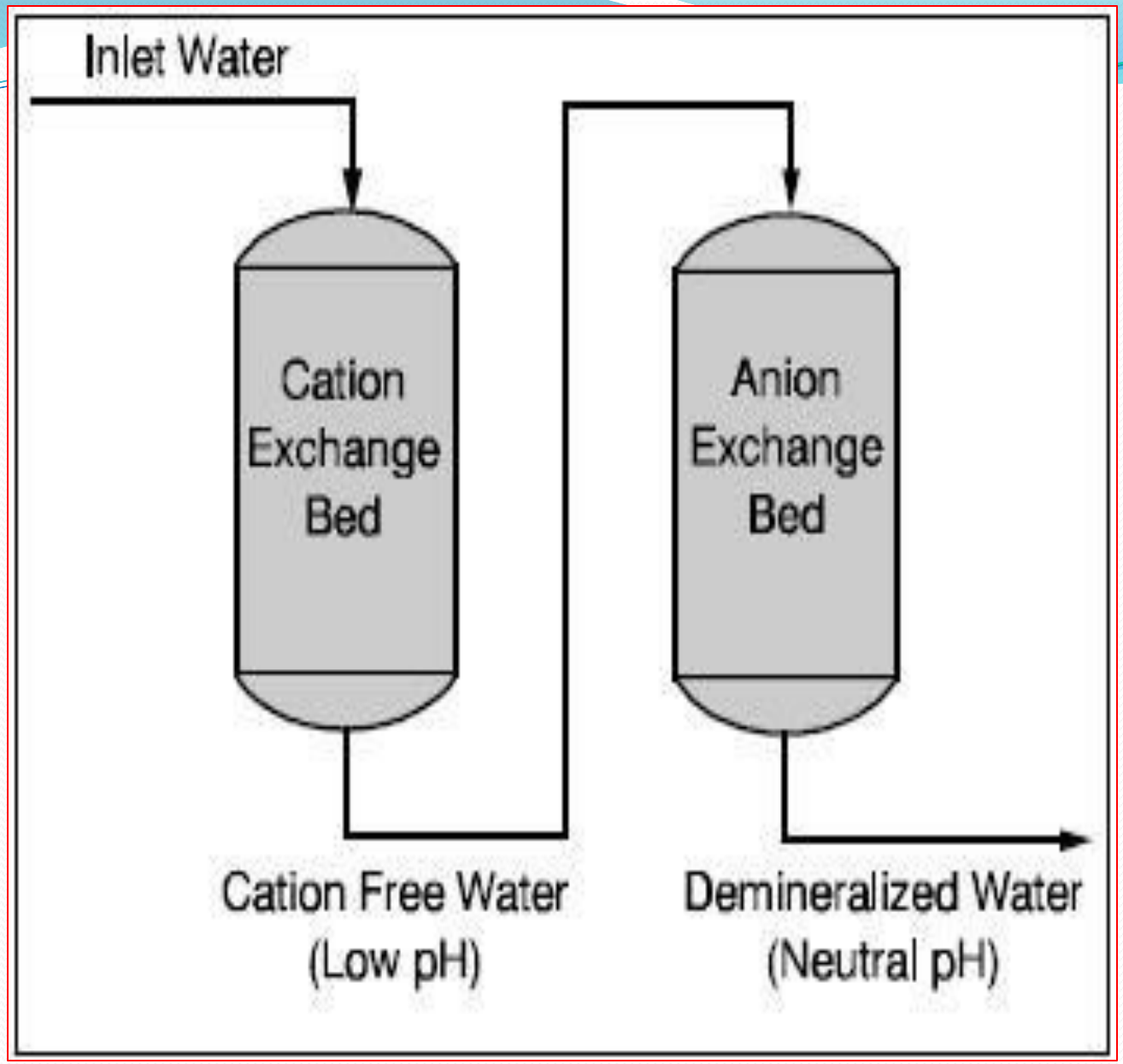
2.4 Refining of Raw Cane Sugar: -

It is the process of separation of sucrose from the impurities (e.g. invert sugars, inorganic ash and organic matter) present mostly in the film of molasses surrounding each crystal of the raw sugar.

1) **Raw Materials: -** i) Raw cane sugar and ii) processing material such as lime (CaO), phosphoric acid, carbon dioxide, activated carbon, ion exchange resin, process water etc.


Raw sugar
96.97% sucrose
Affination and centrifngation
Wash
liquid
Raw syrup
Crystals
Melting and screening
thick syrup (60% sugar)
Clarification of syrup (liming
& phosphatation or carbonation)
Filtration
Filter cake
Filtrate
Decolourisation and / or
Ion exchange
Filtration
Filter cake
Crystallization (vacuum pan)
molasses
Centrifngation
mother
liquor
sugar crystals
Drying with not air
Screening and grading
Refind sugar (>99.5% sucrose)
Packing


Raw water
Ca(HCO3)
Mg(HCO3)2
CaSO4
MgSO4
CaCl2
NaCl
SiO2 · H2O
Strong acid cation resin
CO2 removal unit (as required)
CO2 · H2O
H2SO4
HCl
SiO2 · H2O
Strong base anion resin
Treated water
Ca
R- Mg
Na
SO4
R- Cl
HSiO3
HCO3


Inlet Water
Cation Exchange Bed
Anion Exchange Bed
Cation Free Water (Low pH)
Demineralized Water (Neutral pH)

2.5. Grades: -

The grades of sieved sugar are warranted as per instructions of Government of India. These are governed by N.S.I. (National Sugar Institute) every year, sugar standards are supplied to sugar factories for usual colour comparision and sieve analysis is also prescribed for every grade. At present, in all sugar is bagged for six grades, namely:

a) Large 30, large 29

b) Medium 30, medium 29

c) Small 30, and small 29.

Large, medium and small signify for the grain size and 30, 29 are measurement of visual whiteness.

2.6. Bagasse: - The fibrous portion of cane remains behind after extraction of juice is called bagasse. It is an important by-product from cane sugar mill. It finds applications in many areas.

i) Since the average fuel value of ash-free dry bagasse is 8300 Btu/lb, it is primarily used as fuel for the generation of steam in sugar factory. Some factories generate electricity from bagasse.

ii) It is used as a raw-material for the pulp, paper, paperboard and wall board industries.

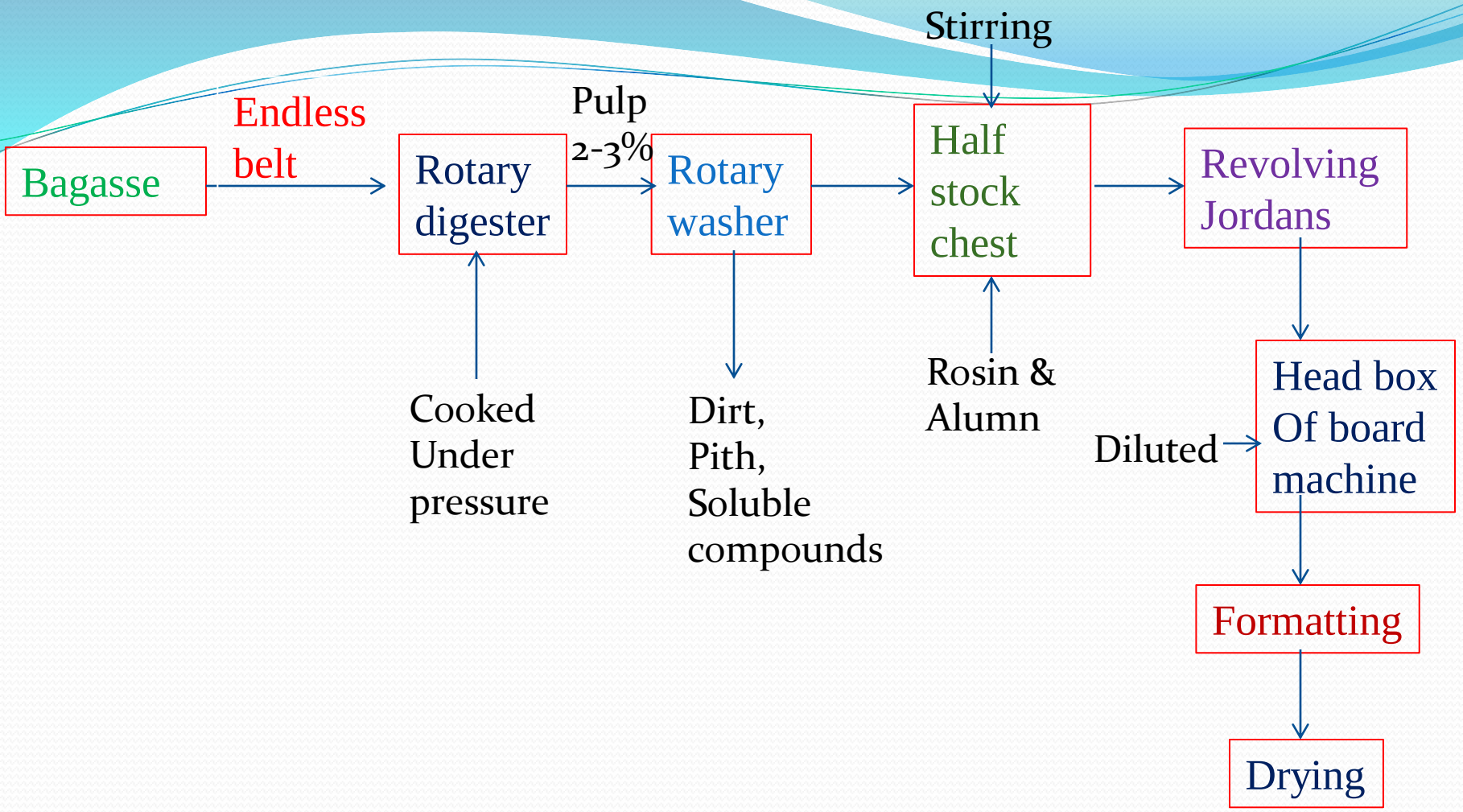
iii) Pith is separated by gravity separators from bagasse and used in the manufacture of explosives.

iv) It is also used as manure and cattle feed. The compost of bagasse contains K = 0.3%, P2O5 = 0.005%, N = 0.4%.

v) ά-Cellulose obtained from bagasse acts as a basis for rayon and explosives.

vi) We can obtain furfural and activated carbon, plastics and bagasse concrete from bagasse.

vii) A high quantity wax has also been extracted from bagasse.



Preparation of Cellotex

2.7. Preparation of Celotex: -

Celotex is an insulating and building board material manufactured from bagasse. The bagasse is introduced into rotary digesters by means of endless belt and cooked there under pressure in order to make the fibres pliable and sterilized, to loosen the sticking material and to dissolve organic material. The resulting pulp in a 2-3% suspension is then pumped to specially design rotary washers, in order to remove dirt, soluble compounds and some pith. The washed pulp is then conveyed to half stock chests, where it is stirred with powerful agitators with rosin and alum to remove any irregularities. This process is called sizing. The fibres are refined to give optimum fine size in conical revolving Jordans. The refined fiber in the form of about 2% suspension is fed to the head box of the machine. In the head box it is diluted to about 0.5% and then fed into forming screens and then led to pressed fibre and finally to press roll.

The sheets are pressed together to give the required thickness. It is then dried in a drier, heated with super heated steam or gas. As the product leaves the drier, it is at once sprayed with water, in order to bring it up to its normal water content (about 8%). The board is finally cut and fabricated.

Sugar Industry in Maharashtra and India: -

Sugar Industries in Maharashtra: -

One of the chief crops manufactured in Maharashtra is sugarcane, with a host of sugar industries been set up over the years. Sugarcane is the primary cash crop among farmers of the western Maharashtra region. The sugarcane is mostly sold to sugar mills for sugar production. The Sugar industry in Maharashtra is highly popular in the cooperative sector, as farmers own a portion in the sugar factories.

At present there are 173 cooperative sugar factories in operation. Sugar mills in Maharashtra produced just over 100,000 tons of sugar in 2017-18 seasons with innovative technologies being implemented in the Maharashtra sugar industry.

About 2.5 crore people in rural Maharashtra depend on the sugar season to earn their livelihoods and the sugarcane industry provides direct employment to about 1.65 lakh workers. Besides this, about eight lakh workers are engaged in harvesting and transport operations, for six months. However the excessive production of sugar at global level and the subsequent price crash has led to sugar factories not being able to pay the farmers the money in time.

The Maharashtra sugar industry has been contributing nearly 40% of India's total sugar production. Maharashtra Sugar Industry is one of the most notable and large-scale sugar manufacturing sectors in the country. The rate of growth of sugar manufacturing has been massive over the past few years. The latest statistics of sugar production in Maharashtra indicates that this state is doing better than the other states.

The presence of this industry has led to development of rural places, from which the sugarcane is drawn to factories, including an improved road network, transportation facilities, medical facilities, education facilities, and banking.

"The current unprecedented situation due to the outbreak of COVID-19 has impacted global sugar prices," said ISMA, adding that the impact could be temporary. While no sugar mill has reported closure due to the spread of COVID-19, the lockdown has affected sugarcane cutting. The COVID-19 impact has also reduced sugar offtake from sugar mills. In western Maharashtra, farmers are worried at the fear of corona virus that has the gripped cane cutters. The spread of the virus has reduced sugar intake from sugar mills, which will, going forward, result in financial problems for these firms.

Most popular sugar factories in Maharashtra:

Adivasi S.S.K. Navapur Nandurbar Vibhag Ltd. (Tal. Navapura, Dist. Nandurbar).

Chhatrapati Sambhaji Raje Sakhar Udyog Ltd. (Sambhajinagar, Aurangabad).

2.8.2. Sugar Industries in India: -

India has been the chief sugar producing country in the world. In India, Sugar industry is the second largest industry after textile industry in major agro industries. The cane sugar industry of India spread over vast regions of the country. It occupied an important place in the economic and social life of the country in view of the wealth generated as well as the employment provided to lakhs of people in rural areas of the country. Sugarcane is thus processed in India for producing three types of sweetening agent's viz., Gur, Khandsari Sugar and Vacuum pan crystal white sugar, for direct consumption, as well as for manufacture of sweets by indigenous methods.

The sugar production in the country during the sugar year October 1990 to September 1991 went up by 10.58 lakh tonnes to 20.16 lakh tonnes according to a press release issued on 17 Nov. 1991 by Indian Sugar Mills Association (I.S.M.A.).

Now, there are 624 sugar factories in the country as on 31-03-2009. There sector wise break up is as follows:

Profile of Sugar industry

Sector	No. of sugar factories
Private	245
Public	62
Cooperatives	317
Total	624

As per 2010-11	
Area of cultivation	4.98 million hectares
Cane production	346.00 Million tones
Sugar production	24.20-24.50 Million tones

In 2010-11, sugarcane was planted in 4.98 million hectares across the country, of which 1 million hectares was in Maharashtra and over 2 million hectares in Uttar Pradesh, official estimates show. Uttar Pradesh and Maharashtra are the two largest sugarcane producing states in the country, accounting for more than 80% of the annual crop production. There are 74 sugar factories in U.P., 45 in Maharashtra, 26 in Bihar, 15 in Karnataka and 15 in Tamilnadu. The industry gives employment to 3,50,000 persons.

Sugar industry is highly seasonal industry, with season lengths of about 6-18 weeks for beets and 20-32 weeks for canes.

India entered in the world market as exporter of sugar in 1957. Since then this industry is earning foreign exchange for the country. Sugar was decontrolled from 1978 to 1979. Government again reintroduced the policy of partial control of sugar with dual price system after 1979, which is still continuing. Under this policy, sugar is to be sold as levy sugar (controlled price) and sugar is to be sold in open market (without any price control).

In India the yield of sugar cane per acre and percentage recovery of sugar are low. Indian sugar factories have low milling efficiency and recovery of sugar from sugar cane is very low. But, the manufacture of paper from bagasse, alcohol from molasses would enable the factories to recover the cost of conversion of cane into sugar.

Thank *You*.