Chapter-4
Sugar Processing

By :Yonas D. and Kedir Y.

Department of Chemical Engineering

KiOT, Wollo University

3.1 Introduction of Sugarcane

History of sugar

- Carbohydrates,sugar and starch are major foods for humans.
- These are synthesized by plants by using carbondioxide and water from the atmosphere.
- The average person in Ethiopia consumes 32kg of sugar per year.
- It is difficult to determine when sugar first became known to humankind.
- But it probably travelled from New Guinea to India many centuries before christ.
- The sugar trade between Asia and Europe was one of the most important commercial items in the early centuries.
- Sugar was first extracted in North America in 1689 B.C. using cane from West Indies.

Cont..d

- Steam driven crushing and grinding roller mills were introduced in the later part of the Eighteenth century.
- Bone-char decolourization was employed for the first time in 1812.
- The vacuum pan was invented by Howard about 1824 B.C.
- Multiple effect evaporation was proposed about 1834.
- The first suspended centrifuge was developed by weston in 1852.
- The use of granular activated carbon and ion exchange process to remove colour and ash has become common.
- Evaporation, centrifugation and filtration are the unit operations applied in sugar making process.

Sugar Factories in Ethiopia

- Tendaho sugar Factory
- Wonji Sugar Factory
- Fincha sugar Factory
- Metehara sugar Factory
- Kuraz sugar Factory
- Tana Beles Sugar Factory

Tendaho Factory

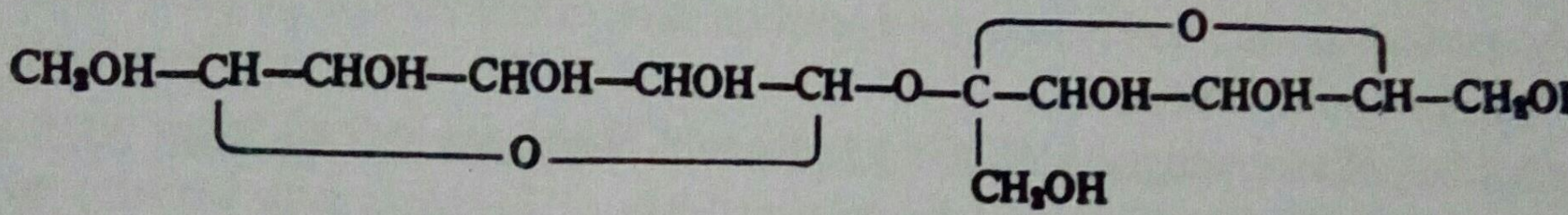
Properties of Sucrose

Sucrose

Pertinent Properties of Sucrose

Chemical formula : $C_{12}H_{22}O_{11}$ (disaccharide)

Structural formula :



Mol. wt.	342
M.P.	186°C (decomposition)
Density	1.58 gm/cc
Solubility	Very soluble in water, slightly soluble in methyl and ethyl alcohol
Forms	Powdered, granulated

Methods of Production

Classification of Processes:

i) Extraction of sugar cane to produce crystalline white sugar.

ii) Extraction of sugar cane to a dark brown sugar concentrate.

Extraction of crystalline sugar production from sugarcane:

Quantitative Requirements:

Basis: 1 ton of raw sugar(97% sucrose)

Sugar cane: 6-10.5 tons of 10-16% sucrose content

Water : 3-4 tons

Lime : 6-10 kg

SO_2 : 12-17 kg

Plant capacity: 100-400 tons/day of sugar

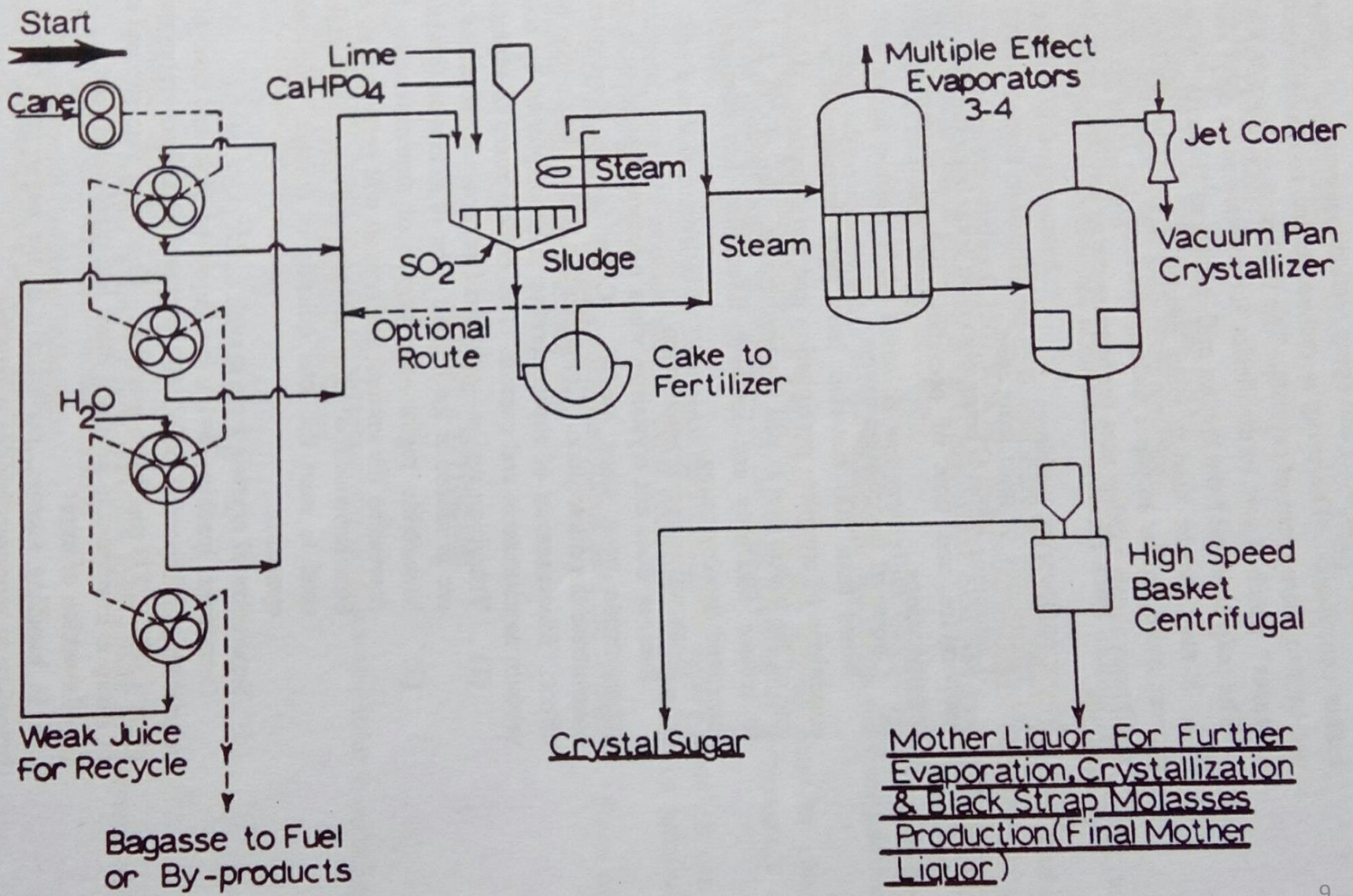
Process description

Extraction of sucrose from sugar cane consists of several processing steps.

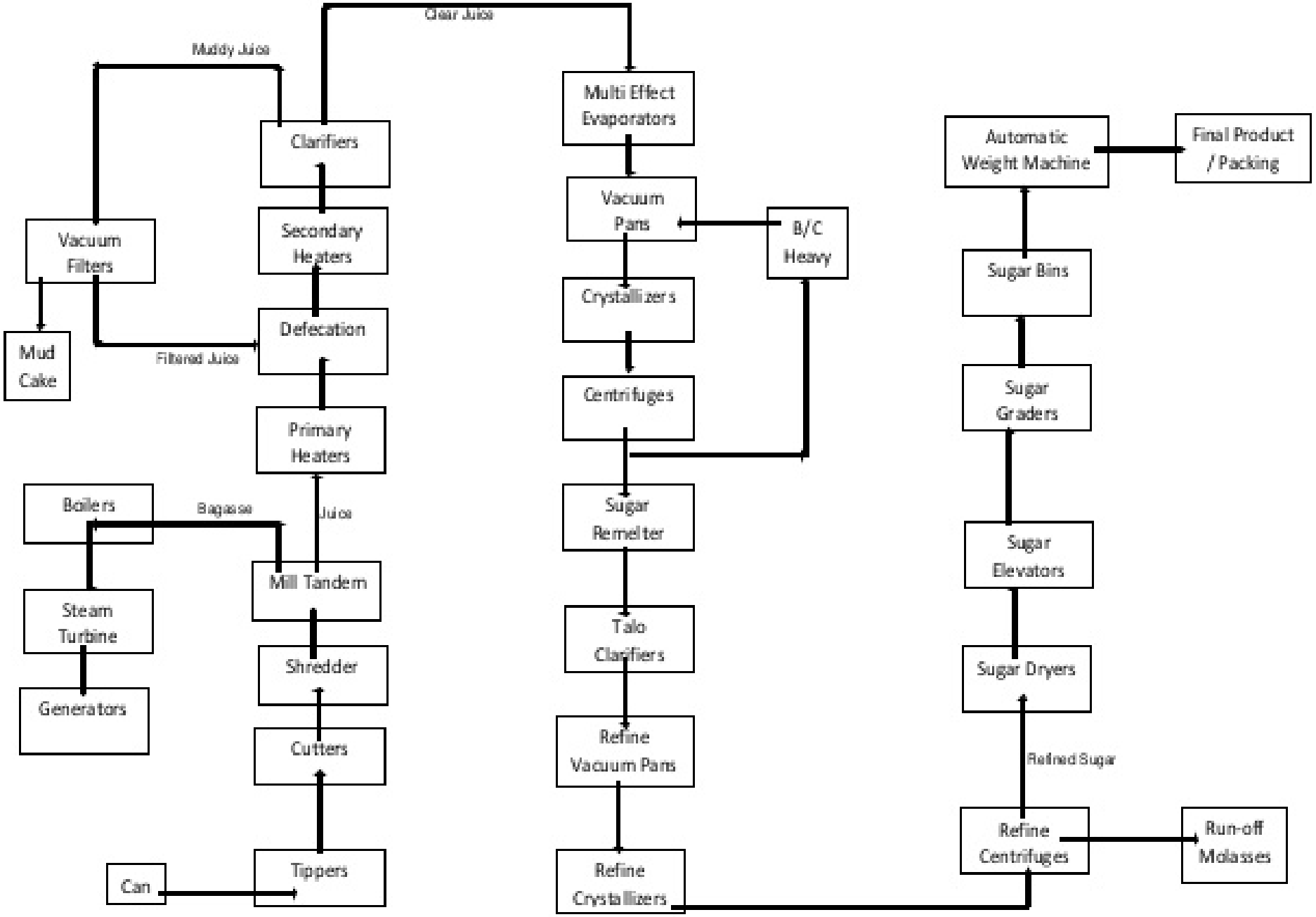
They are as follows.

i) Sugarcane harvesting, ii)Cane preparation, iii) Milling/Extraction , iv) clarification, v) Filtration, vi)Evaporation, vii) Vacuum pan, viii) Crystallization, x)Centrifugal separation, xi)Molasses exhaustion, xii)Drying of raw sugar cane.

Process Flow sheet of Sugarcane (Bergius Process)



Process flow diagram of sugar production



i) Sugarcane Harvesting

- Harvesting of sugar cane can be done either manually or mechanically.
- It has a bamboo like stalk grows to a height from 3- 5 m.
- It contains 11-15% sucrose by weight
- The approximate period of growth of the cane in Cuba is 12-15months.
- In Ethiopia, the growing season of sugar cane is 9-10 months.
- The cane is first washed to remove mud and debris
- Sometimes, burning of sugar cane field is done before manual harvesting, in order to facilitate cutting the cane for field workers.

ii) Cane preparation

- The preparation of sugar cane is a very important step which affects the extraction of juice during milling.
- Since the sugar content of the sugar cane degrades, the cane needs to be delivered to the milling station in less than 24 hours after harvesting.
- Before the cane is transferred to the crushing section, it is usually washed to remove dirt that has been transported with the cane from the harvest field.

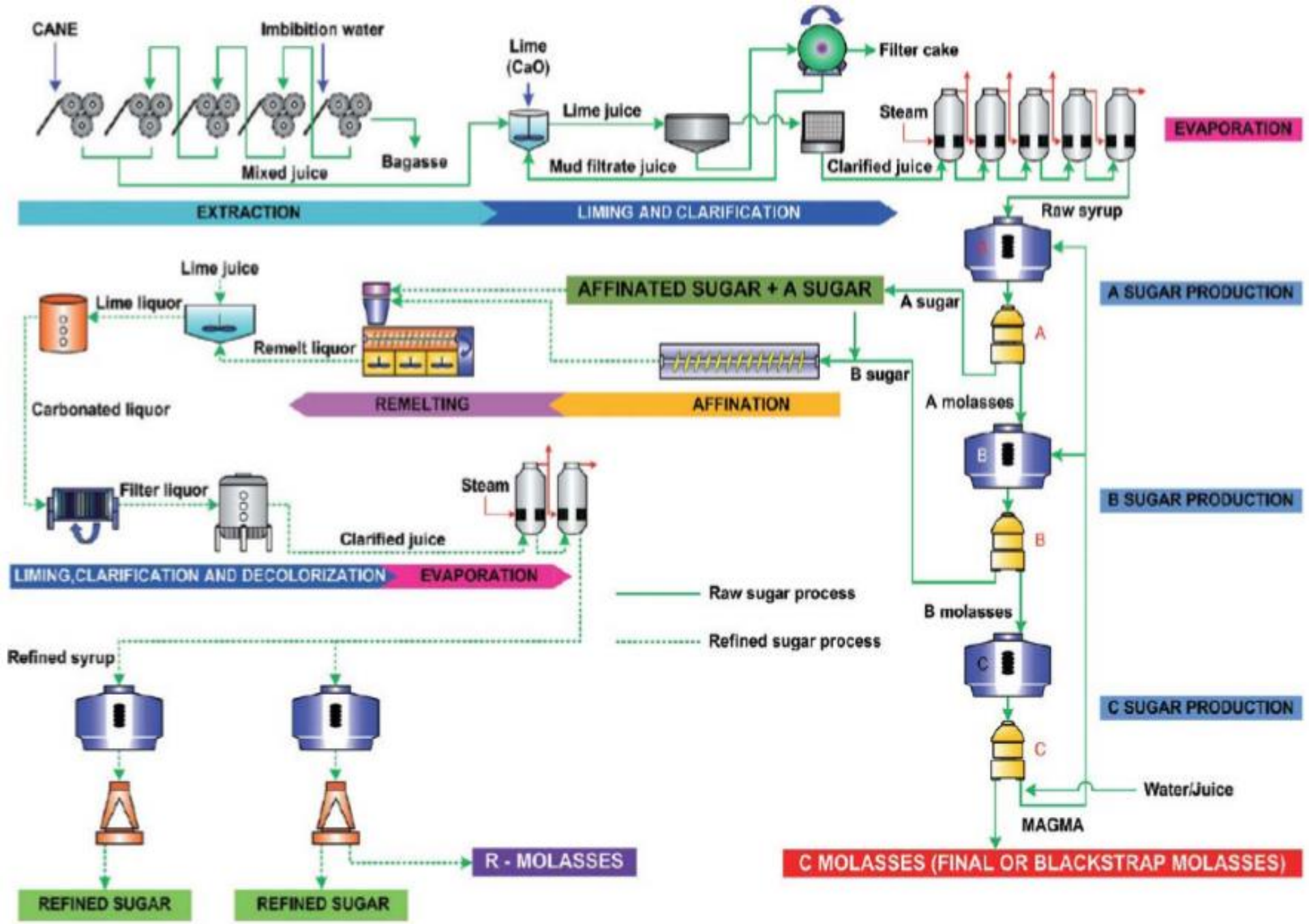
iii) Extraction

- The next step is to chop up the washed cane in preparation for crushing.
- This step is skipped if the sugarcane was harvested by machines because it is usually the harvester that cuts the cane stalks into pieces.
- These chopped up cane stalks are then crushed and milled to extract the sugar juice.
- Baggase is produced as a by-product which is usually sent to boilers for burning.
- The equipment for milling can involve milling rollers, rotating knives, and shredders (which require additional energy and equipment).
- For the extraction of the juice from the cane, a process called imbibition is used

- ✓ This is a process where water or juice is added in counter current (see figure) in order to extract juice as it travels from mill to mill.
- ❑ The juice that leaves the final mill is called mixed juice and its typical sugar content is 15 % (wt %).
- ❑ Bagasse contains 46-52% moisture, 43-52% fiber and some ash (sand and grit from the field.
- ❑ A typical sugar cane physical composition can be 12-14% fiber which generates 25- 30 tons of bagasse (50% moisture content) per 100 tons of cane and 10 tons of sugar.
- ❑ During the milling process, cane juice is produced which is the main input for sugar production and ethanol.
- ❑ Not all sugar mills produce sugar and ethanol together.

iv) Clarification

- First the juice is preheated
- The milk of lime is added to the juice and heated.
- These large tanks are called clarifiers or continuous settlers or thickeners.
- This juice is treated by passing sulphur dioxide gas through it.
- This is known as sulphitation process.
- Then SO_2 is next bubbled through the juice until the pH is 7.0 to 7.1
- This provides maximum flocculation of impurities
- Here, SO_2 also acts as a bleaching agent
- This sulphated juice is then preheated again


CANE
Imbibition water
Mixed juice
Bagasse
Lime (CaO)
Lime juice
Mud filtrate juice
Filter cake
Clarified juice
Steam
EVAPORATION
EXTRACTION
LIMING AND CLARIFICATION
Raw syrup
Lime juice
Lime liquor
Remelt liquor
AFFINATED SUGAR + A SUGAR
A sugar
B sugar
A SUGAR PRODUCTION
A
A molasses
REMELTING
AFFINATION
Carbonated liquor
Filter liquor
Steam
Clarified juice
B
B SUGAR PRODUCTION
LIMING,CLARIFICATION AND DECOLORIZATION
EVAPORATION
Raw sugar process
Refined sugar process
B molasses
C
C SUGAR PRODUCTION
Refined syrup
Water/Juice
MAGMA
R - MOLASSES
C MOLASSES (FINAL OR BLACKSTRAP MOLASSES)
REFINED SUGAR
REFINED SUGAR

- separation of impurities from the juice by adding flocculants which will react with organic material and precipitation of non-sugar debris (mud) will follow
- colloidal and suspended impurities are coagulated, most of color is also removed during lime treatment
- The sludge is further filtered through filter press and then disposed off as solid waste (press mud).
- The filtered clear juice is preheated before taken to evaporator

v)Filtration/vacuum filtration

- Continuous Rotary drum vacuum filters are used to recover the sugar from the settled out mud.
- The underflow mud are processed on a continuous rotary press to recover sugar solution.
- This is passed either forward to the evaporator(or) backward to the thickener again if it is not clear.
- The filter cake constitutes 1-4% of the weight of cane is used for fertilizer.

vi) Evaporation

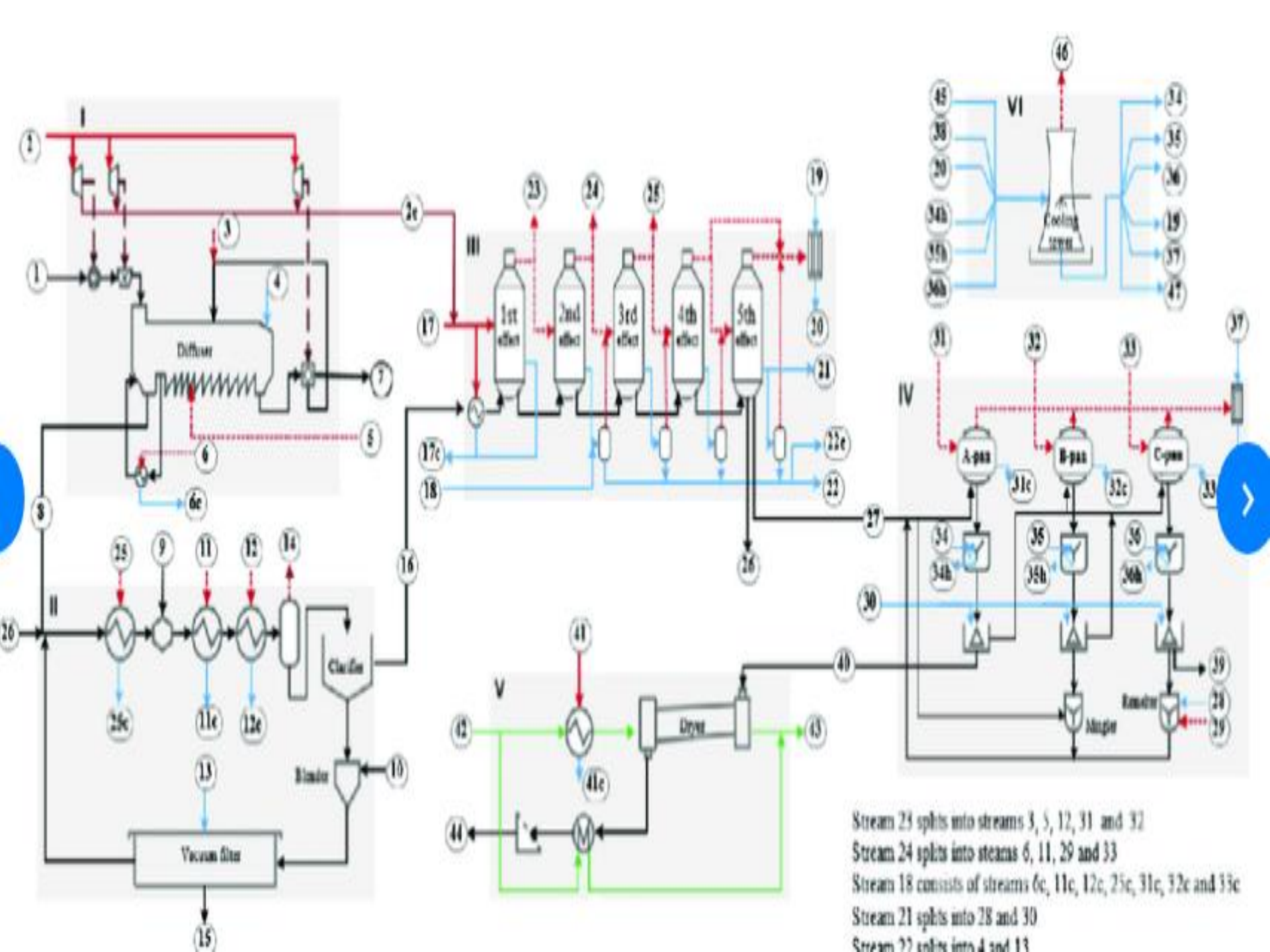
- The clarified juice from the third preheated is concentrated from 80-85% water to 40% water.
- It is processed in a 4 or 5 Effect evaporator.
- Sucrose does not crystallize when a saturated solution is reached.
- Calendria- type evaporators are used to concentrate the dilute juice.
- A clarified juice of high lime content is evaporated to 40% water in triple effect evaporators.
- At very high vacuum conditions crystallization is completed in a vacuum pan unit

vii) Vacuum Equipment

- The basic goal of the vacuum pan operation is to produce sugar crystals of a specified size from a solution containing sugar and non- sugars.
- The first crystallisation takes place in the vacuum pans, where part of the sucrose dissolved in the standard syrup crystallises as the water in the juice evaporates.
- Crystallization is initiated by adding a slurry of sugar fines and alcohol, which provides the nuclei to start crystallization.
- In starting a batch boiling, liquor is concentrated until meta stable zone reached
- The vacuum pan becomes full of what is know as the A-massecuite which is formed by crystallised sucrose, sucrose and non-sugars dissolved in a solution known as mother liquor.

Cont..d

- All the pans operate in vacuum conditions, in order to lower the boiling point of the products being processed in them and thus prevent thermal decomposition of the sucrose (loss of sucrose).
- The concentration of mother liquor surrounding sugar crystals is controlled so that crystallization occurs without dissolving any crystal or forming any new nuclei


I
II
III
IV
V
VI
Diffuser
1st effect
2nd effect
3rd effect
4th effect
5th effect
A-pan
B-pan
C-pan
Dryer
Vacuum filter
Cooling tower
Stream 25 splits into streams 3, 5, 12, 31 and 32
Stream 24 splits into steams 6, 11, 29 and 33
Stream 18 consists of streams 6c, 11c, 12c, 25c, 31c, 32c and 33c
Stream 21 splits into 28 and 30
Stream 22 splits into 4 and 13

viii)Crystallization

- The mixture of syrup and crystals(massecuite) is dumped into a crystallizer.
- It is the horizontal agitated tank equipped with cooling coils.
- Crystallization is done in batch wise operation.
- Here additional sucrose deposits on the crystals already formed and crystallization is completed.

x) Centrifugal separation

- The massecuite is then centrifuged to separate the sugar from molasses.
- Centrifugal machine improved to yield and time of separation of sugar crystals.
- Centrifugal machine speed is 1800-2400 rpm speed.
- Viscosity control & surface tension of syrup is important.

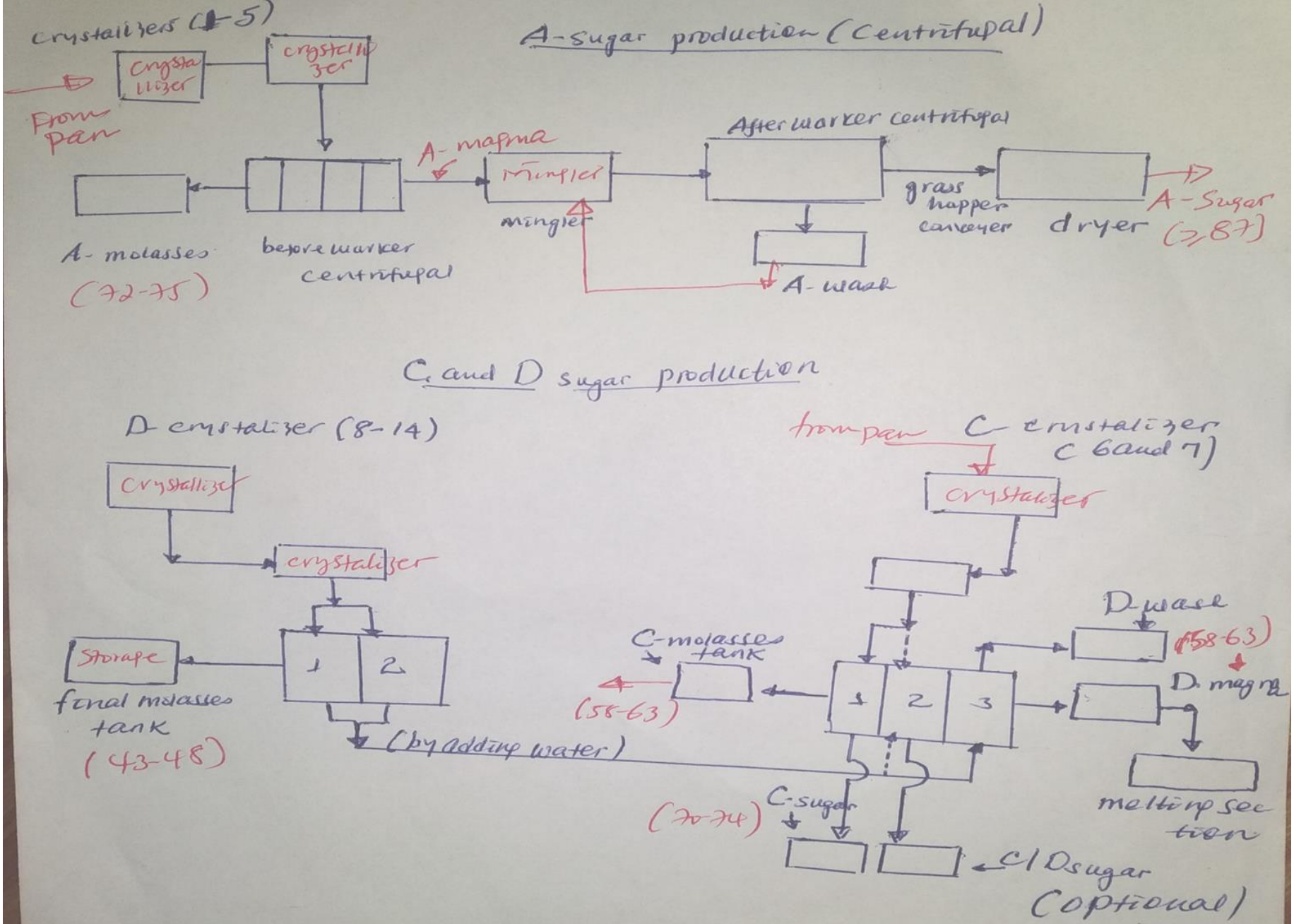


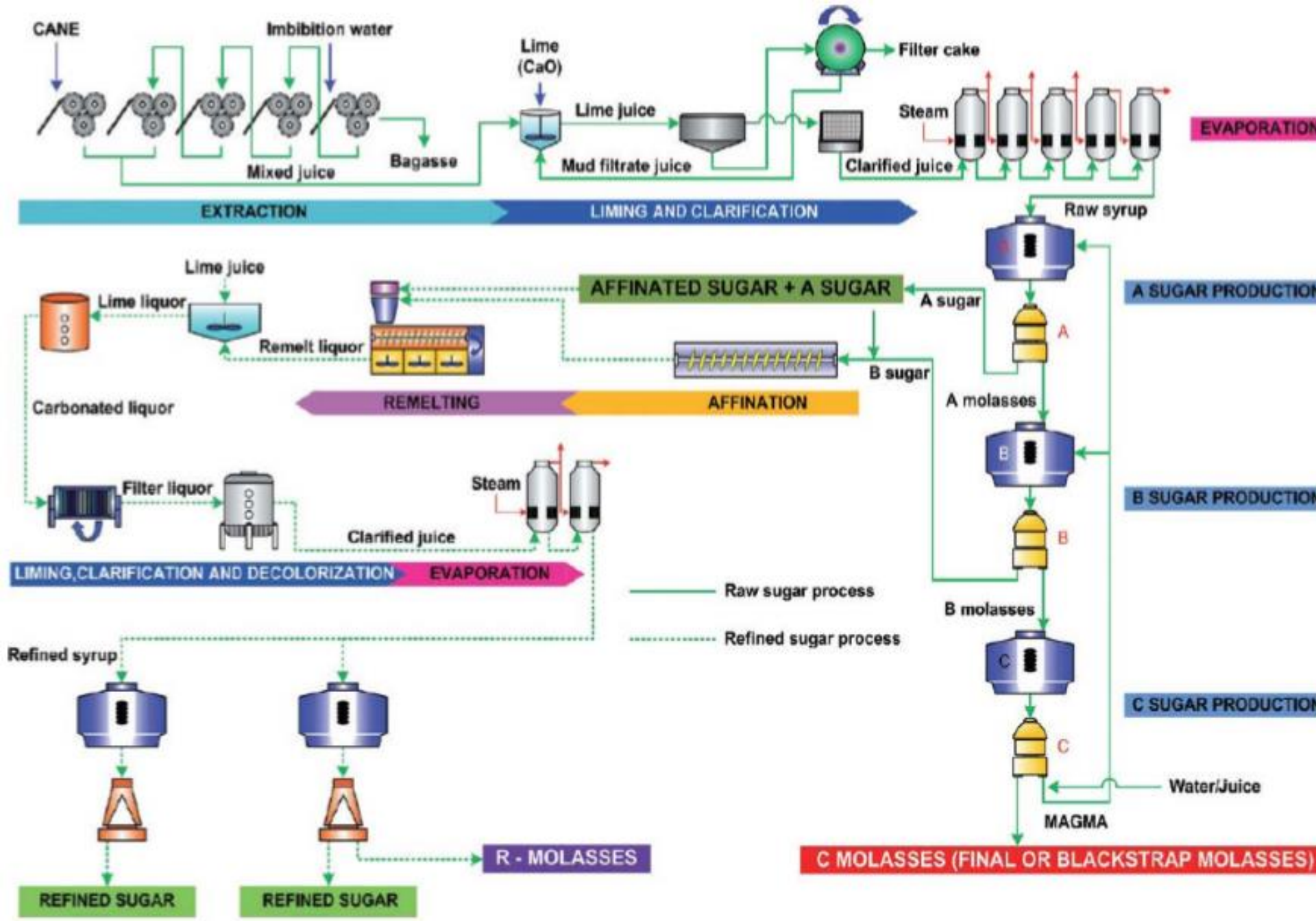
Fig-A Sugar A, C sugar and D magma production in Centrifugal.

xi)Molasses Exhaustion

- The final mother liquor is known as “blackstrap molasses”.
- It is sent to distilleries for Ethyl alcohol production.
- The molasses is used as a source of carbohydrates for cattle feed and also for Citric acid production.

Xii) Drying of raw sugar

- Finally the wet sugar crystals are dried in the vacuum drier unit(or)granulator.
- It is a horizontal rotating drum about 2m in diameter and 8m in length.
- The dried crystals pass over a series of screens where they are graded according to size.
- The white sugar containing approximately 97.8%sucrose.
- It is shipped in bulk and outside the country.


CANE
Imbibition water
Bagasse
Mixed juice
Lime (CaO)
Lime juice
Mud filtrate juice
Filter cake
Clarified juice
Steam
EVAPORATION
EXTRACTION
LIMING AND CLARIFICATION
Raw syrup
Lime juice
Lime liquor
Remelt liquor
AFFINATED SUGAR + A SUGAR
A sugar
B sugar
A SUGAR PRODUCTION
A
A molasses
REMELTING
AFFINATION
Carbonated liquor
Filter liquor
Steam
Clarified juice
B
B SUGAR PRODUCTION
B
LIMING,CLARIFICATION AND DECOLORIZATION
EVAPORATION
Raw sugar process
Refined sugar process
B molasses
C
C SUGAR PRODUCTION
C
Water/Juice
MAGMA
Refined syrup
R - MOLASSES
C MOLASSES (FINAL OR BLACKSTRAP MOLASSES)
REFINED SUGAR
REFINED SUGAR

Bagasse

- The pulp expelled from the last mill in sugar processing is known as “Bagasse”.
- It is used as steam boiler fuel.
- It is also used to make insulating board for building construction.
- Other uses of “Bagasse” are as fertilizer,cattle feed and for paper making.

Raw sugar Quality

- The level of Technology in the Indian sugar industry is quite very high in the world.
- A number of developing countries including Ethiopia, Kenya and South Africa have borrowed the Indian sugar Technology.
- Powdered sugars are made by grinding granulated sugar in mills with high quality.
- High quality cube and tablet sugars are also prepared by mixing few types of granulated sugars with a white syrup.

By-products of the sugar Industry

- Molasses, bagasse and press mud are the major by-products of the sugar industry.
- 70% of molasses are used for Ethyl alcohol production.
- Press mud is used in the farms as manures.
- Bagasse is used as a boiler feed.

Overview of sugar Production

Thank you