# IDEA ABOUT PAN BOILING


by

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# VACUUM PANS & PAN BOILING

PAN BOILING IS A UNIT OPERATION PERFORMED IN A SUGAR FACTORY TO TAKE OUT THE SUGAR FROM THE MOTHER LIQUOR THROUGH CRYSTALLIZATION. THE WORK IS ACCOMPLISHED BY BOILING THE CLARIFIED MOTHER LIQUOR IN SPECIALLY DESIGNED HEAT EXCHANGERS KNOWN AS VACUUM PANS. THE MOTHER LIQUOR IS CONCENTRATED BY BOILING UNDER VACUUM OF 25-26" OF MERCURY USING EXHAUST STEAM/VAPOURS.

AS MAY BE SEEN FROM SUBSEQUENT SLIDES, OUT OF ALL THE SUGAR LOSSES OCUURING DURING PROCESSING, MAX. LOSS OF SUGAR TAKES PLACE IN MOLASSES, HENCE, THE PAN BOILING OPERATION ASSUMES GREATER SIGNIFICANCE.

# LOSS OF SUGAR IN SUGAR FACTORY

IT OCCURS UNDER FOUR HEADS:

1. SUGAR OR POL IN BAGASSE % CANE:

IF POL% BAGASSE IS 1.6, BAGASSES %CANE IS 30

THEN POL IN BAGASSE % CANE = $\frac{1.6 \times 30}{100}$

= 0.48 -----(i)

2. SUGAR OR POL IN PRESS CAKE % CANE:

IF POL % P. CAKE IS 1.8, P. CAKE % CANE IS 3.5

THEN POL IN P. CAKE % CANE = $\frac{1.8 \times 3.5}{100}$

= 0.063 -----(ii)

## 3. SUGAR OR POL IN FINAL MOLASSES % CANE:

IF POL % MOLASSES IS 27.0, MOLASSES % CANE IS 4.5

THEN POL IN MOLASSES % CANE = $\frac{27X4.5}{100}$

= 1.215 -----(iii)

## 4. UNKNOWN SUGAR LOSS % CANE

= 0.05 -----(iv)

**SO, TOTAL LOSS OF SUGAR DURING PROCESSING:**

**SUM OF (i) TO (iv) = 1.808 OR SAY 1.81**

# INTRODUCTION TO TERMINOLOGY

1. MASSECUITE : IT IS THE MIXTURE OF SUGAR CRYSTALS AND THE MOTHER LIQUOR FORMED DURING CRYSTALLIZATION IN VACUUM PANS. ACCORDING TO THE DECREASING PURITIES THEY ARE TERMED AS A,B AND C MASSECUITES IN PLANTATION WHITE SUGAR & RAW SUGAR FACTORIES OR $R_1$, $R_2$, $R_3$ MASSECUITES IN SUGAR REFINERIES.

2. MOLASSES: IT IS THE MOTHER LIQUOR IN THE MASSECUITE WHICH IS SEPARATED FROM THE CRYSTALS BY MECHANICAL MEANS e.g. CENTRIFUGATION. GENERALLY, MOLASSES OBTAINED PRIOR TO WASHING OF CRYSTALS IS KNOWN AS HEAVY MOLASSES, WHEREAS, THAT OBTAINED AFTER APPLICATION OF WASH WATER IS KNOWN AS LIGHT MOLASSES. HEAVY MOLASSES OF A PARTICULAR MASSECUITE IS USED IN SUBSEQUENT BOILING, WHILE THE LIGHT MOLASSES IN THE SAME BOILING.

3. **SATURATED SOLOUTION** : WHEN A SUBSTANCE IS DISSOLVED IN WATER AT A PARTICULAR TEMPERATURE, AFTER DISSOLVING A CERTAIN QUANTITY, NO MORE DISSOLUTION OF SUBSTANCE IS POSSIBLE UNLESS THE TEMP. IS INCREASED. SO, THE SOLUTION IS TERMED AS "SATURATED SOLUTION" AT THAT PARTICULAR TEMP., e.g. AT 40 DEG. C ONE KG. OF WATER CAN DISSOLVE 2.334 KG. OF SUCROSE.

4. **SUPERSATURATED SOLUTION**: WHEN A SATURATED SOLUTION IS COOLED OR WHEN ITS WATER IS EVAPORATED IN SUCH A WAY THAT NO SUGAR CRYSTALS ARE FORMED, THE SOLUTION IS TERMED AS SUPERSATURATED.

5. CO-OFFICIENT OF SUPER SATURATION:

THE DEGREE OF S.S. ALSO KNOWN AS COEFFICIENT OF SUPER SATURATION MAY BE DEPICTED AS, S =

$$\frac{\text{SUCROSE\%WATER AT TEMP. T IN A S.S. SOLUTION}}{\text{SUCROSE\%WATER AT TEMP. T IN A SAT. SOLUTION}}$$

6. BOILING POINT RISE OR ELEVATION: IN A SUGAR FACTORY, IT IS NOT WATER WHICH IS BOILING BUT JUICE OR A TECHNICAL SUGAR SOLUTION. NOW THE BOILING POINT OF A SUGAR SOLUTION OR OF JUICE UNDER A GIVEN PRESSURE INCREASES WITH CONCENTRATION OR BRIX.

7. HYROSTATIC HEAD OR PRESSURE : WHEN A PRESSURE ‘P’ IS EXERTED ON THE SURFACE OF THE LIQUID, THE PRESSURE TO WHICH THE MOLECULES AT A CERTAIN DEPTH ARE SUBJECTED IS EQUAL TO ‘P’ INCREASED BY PRESSURE OF LIQUID CORRESPONDING TO THE DEPTH. IT IS VERY WELL KNOWN THAT BOLING POINT INCREASES WITH PRESSURE.

8. FALSE GRAINS: UNWANTED GRAINS FORMED DURING BOILING DUE TO VARIOUS REASONS e.g. VERY HIGH SUPER SATURATION, GRAINS ALREADY AVAILABLE IN FEED, FLUCTUATIONS IN VACUUM, COLD FEED, INSUFFICIENT GRAINS etc.

9. CONGLOMERATES : PHENOMENON OF JOINING OF SEVERAL SUGAR CRYSTALS IS KNOWN AS CONGLOMERATION AND THE BUNCH OF SUGAR CRYSTALS IS KNOWN AS CONGLOMERATE, WHICH CAUSES DETERIORATION OF SUGAR QUALITY.

10. ENTRAINMENT : LOSS OF SUGAR WITH VAPOURS DURING BOILING. IT OCCURS DUE TO SUDDEN FLUCTUATION IN VACUUM, HIGHER LEVEL, HIGHER VAPOUR VELOCITY AND FAULTY DESIGN OF THE ENTRAINMENT CATCHER.

# ZONES OF SUPER SATURATION

1. **METASTABLE ZONE** : S.S. IS SUCH THAT ONLY EXISTING SUGAR CRYSTALS GROW & NO NEW CRYSTALS ARE FORMED.

2. **INTERMEDIATE ZONE** : S.S. IS RELATIVELY HIGHER, NOT ONLY EXISTING CRYSTAL GROW BUT THERE ARE CHANCES OF FORMATION OF NEW SUGAR CRYSTALS.

3. **LABILE ZONE** : SUPERSATURATION IS VERY HIGH AND NEW CRYSTALS ARE FORMED SPONTANEOUSLY.

THIS IS THE REASON, PAN BOILING IS CARRIED OUT IN METASTABLE ZONE ONLY & HIGHER ZONES OF S.S. ARE AVOIDED. ONLY WHEN THE GRAINING IS TO BE CARRIED OUT BY WAITING METHOD, S.S. IS TAKEN TO THE LABILE ZONE.

**SO FOR CARRYING OUT THE PAN BOILING AND PARTICULARLY FOR NUCLEATION:**

* EITHER THE CONCENTRATION/S.S. IS TO BE PUSHED VERY HIGH SO THAT IT REACHES IN LABILE ZONE AND CRYSTALLIZATION OF SUGAR TAKES PLACE. THE GRAINS SO FORMED ARE HARDENED & THEN THE STRIKE IS BUILT USING FEED MATERIAL.

* OR WE PROVIDE NUCLEUS FROM OUTSIDE IN THE FORM OF SUGAR SLURRY/DRY SEED DEPENDING UPON THE MASSECUITE TO BE BOILED KEEPING THE SUPER SATURATION IN METASTABLE ZONE, SO THAT, ONLY EXISTING CRYSTALS GROW IN SIZE. THE STRIKE IS DEVELOPED USING THE DESIRED FEED MATERIAL. SEED SLURRY IS USED FOR BOILING LOW GRADE MASSECUITES (B & C), WHEREAS, DRY SEED (FINE SUGAR FROM GRADER) IS USED FOR BOILING A MASSECUITE.

# METHODS FOR GRAIN FORMATION

1. **WAITING METHOD :** THE S.S. IS PUSHED HIGH i.e. IN THE LABILE ZONE, WHEN CRYSTAL AUTOMATICALLY APPEAR.
2. **SHOCK SEEDING METHOD :** NUCLEUS IS PROVIDED FROM OUTSIDE IN THE FORM OF ICING SUGAR.
3. **TRUE SEEDING OR SLURRY METHOD :** NUCLEUS IS PROVIDED FROM OUTSIDE IN THE FORM OF SUGAR SLURRY.

   TRUE SEEDING OR SLURRY METHOD IS CONSIDERED MOST SUPERIOR. THE SIZE OF GRAINS IN SLURRY SHOULD BE 3-5 MICRON ONLY.

# RATE OF CRYSTALLIZATION

IT DEPENDS UPON:

1. VISCOSITY- HIGHER VISCOSITY RETARDS RATE OF CRYSTALLIZATION.
2. TEMPERATURE (WHICH INFLUENCES VISCOSITY)- RATE OF CRYSTALLIZATION INCREASES WITH INCREASE IN TEMPERATURE
3. SUPER SATURATION- HIGHER THE SUPERSATURATION, HIGHER IS THE RATE OF CRYSTALLIZATION.
4. PURITY OF THE MOTHER LIQUOR- RATE OF CRYSTALLIZATION INCREASES WITH THE INCREASE IN PURITY.

# GENERAL CLASSIFICATION OF VACUUM PANS

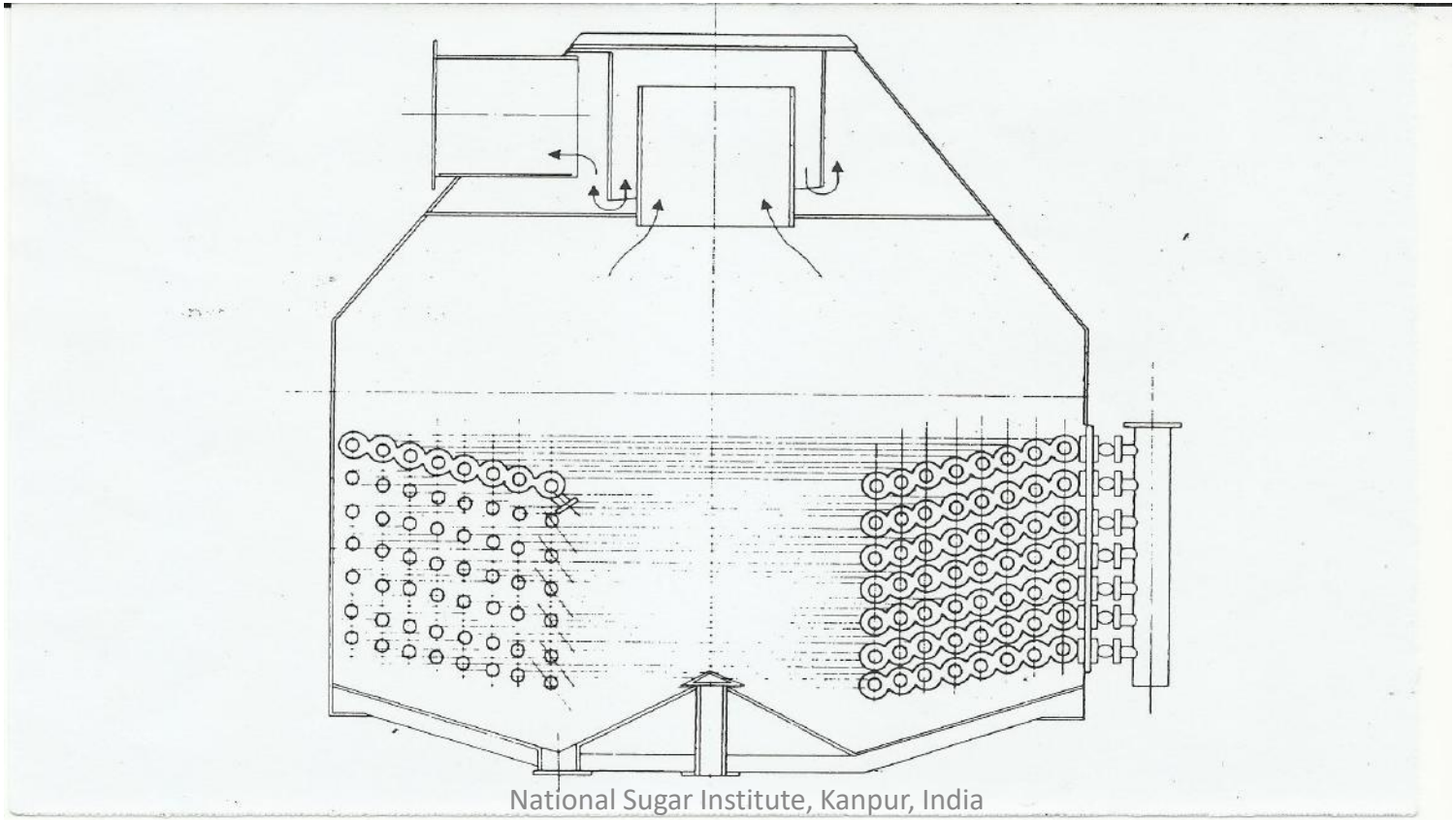
VACUUM PANS FOR SUGAR

- COIL PAN
- CALANDRIA PAN
  - FIXED CALANDRIA
    - BATCH TYPE
    - CONTINUOUS TYPE
  - FLOATING CALANDRIA#

**# some designs of floating calandria continuous pans are available but generally continuous pans are of fixed calandria type.**

# TYPES OF VACUUM PANS

**COIL PAN : IN SUCH PANS, HEATING SURFACES COMPRISES OF NO. OF SPIRAL COILS MADE OF COPPER, GENERALLY 2 OR MORE IN NUMBERS. THE DIAMETER OF THE COILS IS ABOUT 10-15 CM AND RATIO OF LENGTH TO THEIR INTERNAL DIAMETER IS 75-250 DEPENDING UPON TYPE OF HEATING MEDIA USED.**



# CALANDRIA PANS

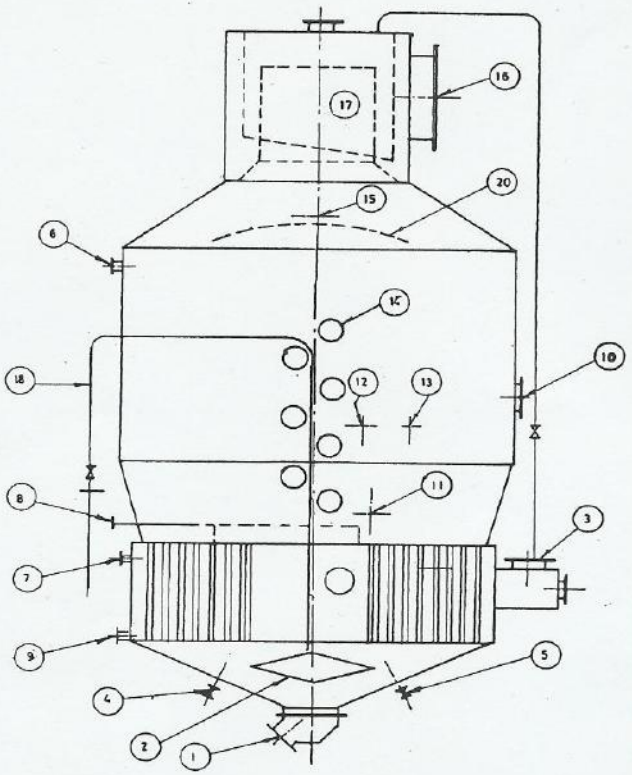
They may be categorized as :

1. **FIXED CALANDRIA PAN :** THE CALANDRIA IS ATTACHED TO THE SHELL, THE HEATING SURFACES OF WHICH COMPRISE OF STAINLESS STEEL, SS-304, TUBES. THE DIAMETER OF TUBES IS GENERALLY KEPT 101.6MM OD X 16 G AND LENGTH VARIES FROM 800-1000 MM DEPENDING UPON THE TYPE OF MASSECUITE.

   THE DIAMETER OF THE CENTRAL DOWNTAKE IS OF IMPORTANCE FOR PROVIDING ADEQUATE CIRCULATION AND IS KEPT AROUND 40-50% OF THE DIAMETER OF THE PAN OR TO BE MORE PRECISE THE AREA OF CROSS SECTION OF DOWNTAKE SHOULD BE 40-50% OF THE CROSS SECTIONAL AREA OF ALL TUBES. MAXIMUM LEVEL OF STRIKE IS ABOUT 1500MM ABOVE THE TOP TUBE PLATE SO AS TO AVOID NATURAL CIRCULATION SLACKNESS DUE TO HYDROSTATIC HEAD.

   THE RATIO OF HEATING SURFACE TO VOLUME IS IMPORTANT AND IS KEPT AROUND 6.6 SQM/CUM. SIMILARLY, THE GRAINING VOLUME OF THE PAN IS LIMITED TO AROUND 37% OF STRIKE VOLUME OF THE PAN.

# VIEW OF A FIXED CALANDRIA LOW HEAD VACUUM PAN



| S. NO | DESCRIPTION |
|---|---|
| 1. | DOSCHARGE VALVE |
| 2. | DEFLECTOR |
| 3. | EXHAUST/VAPOUR VALVE |
| 4. | CUT OVER VALVE |
| 5. | WASH OUT VALVE |
| 6. | VACCUM BREAKER VALVE |
| 7. | AMMONIA VENTING |
| 8. | PROOF STICK |
| 9. | CONDENSATE OUTLET |
| 10. | MAN HOLE |
| 11. | THERMOMETER |
| 12. | VACUUM GAUGE |
| 13. | PRESSURE GAUGE |
| 14. | SIGHT GLASS |
| 15. | LIGHT GLASS |
| 16. | VAPOUR OUTLET |
| 17. | CATCH ALL |
| 18. | FEED PIPE |
| 19. | DOWN TAKE |
| 20. | UMBERLLA |

There may be calandria pan where diameter of body = diameter of tube plate

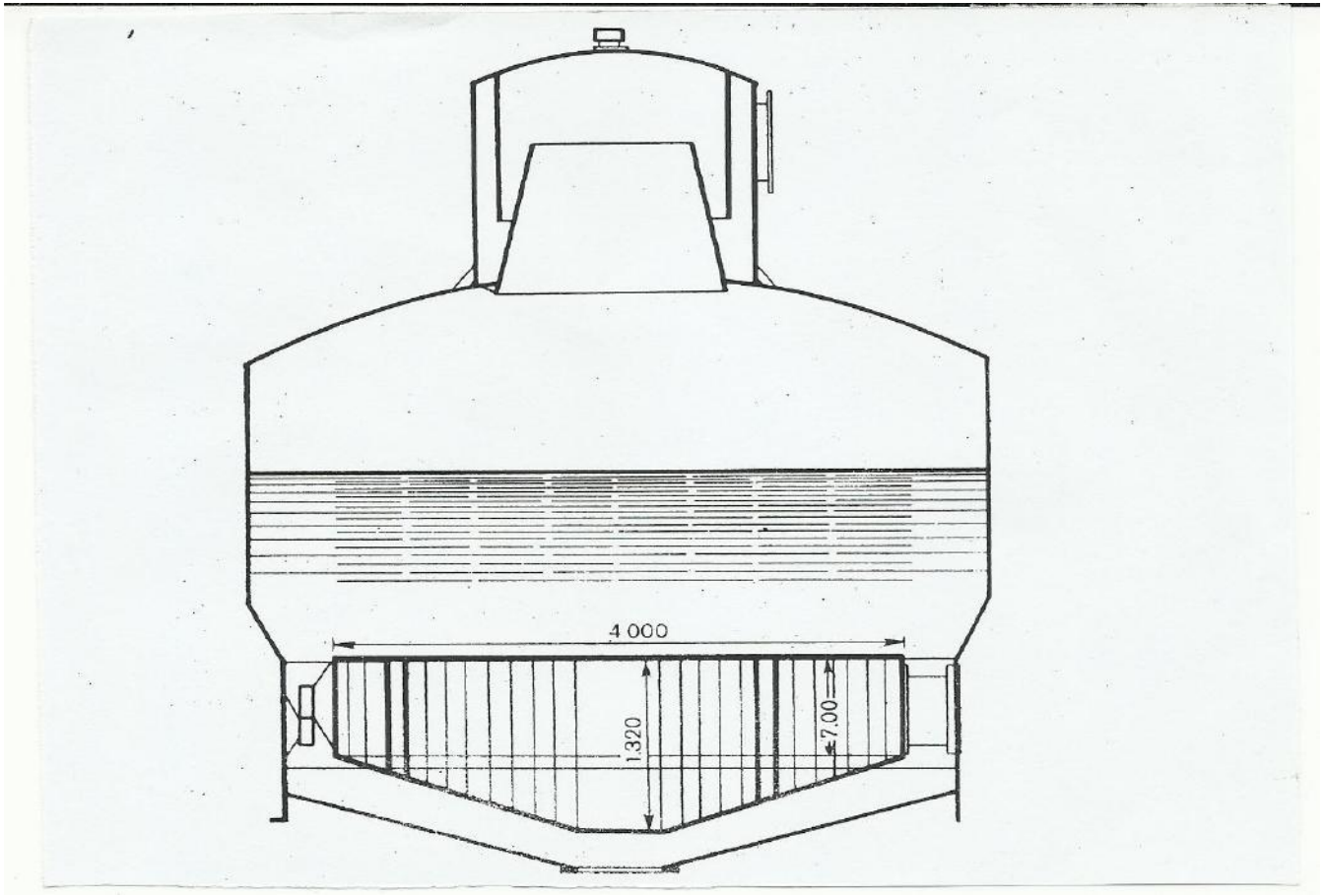
or

when diameter of body > diameter of tube plate ( $D_B = 1.15\ D_t$ ). Such pans are known as Low Head Calandria Pan as the desired massecuite quantity can be boiled at low strike height. Due to lower strike height, the hydrostatic head is lower

## 2. FLOATING CALANDRIA PAN:

THE CALANDRIA IS SITUATED AT THE CENTRE OF THE PAN. SUCH PANS ARE NO LONGER USED WIDELY. UNIQUE FEATURE OF SUCH PANS IS OF HAVING A CENTRAL WELL ALONGWITH ANNULAR SPACE FOR THE CIRCULATION OF MASSECUITE. DUE TO THE CONICAL SHAPE OF THE CALANDRIA, THE BOTTOM TUBE PLATE BEING INCLINED, THE TUBE LENGTH DIFFERS FROM PERIPHERY TO CENTRE. THE ENTRY OF STEAM IS MADE BY A PIPE ENTERING THROUGH THE CATCH-ALL AND DESCENDING VERTICALLY TO THE CALANDRIA FOR FACILITATING UNIFORM DISTRIBUTION OF STEAM IN THE CALANDRIA.

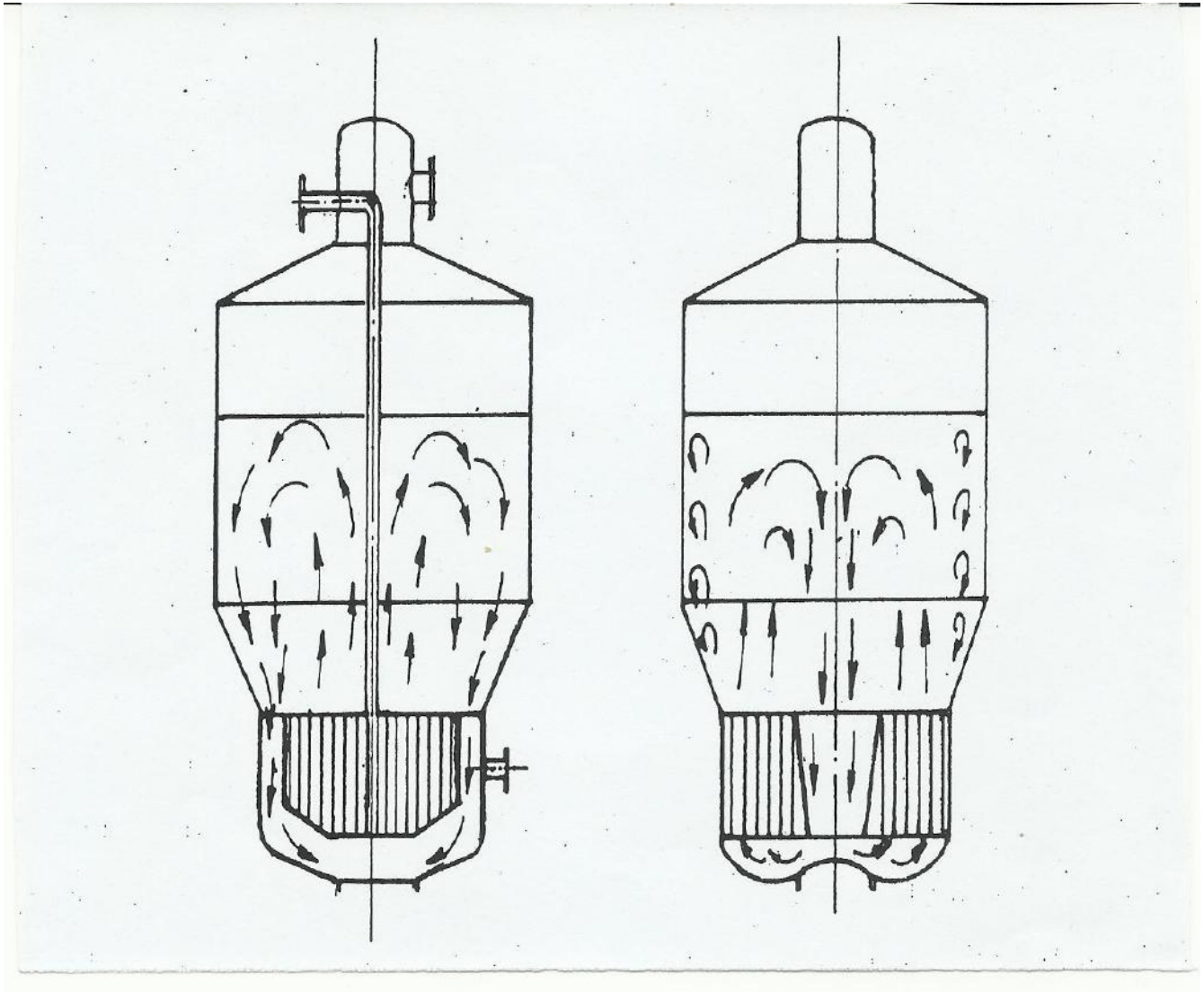
# VIEW OF A FLOATING CALANDRIA PAN



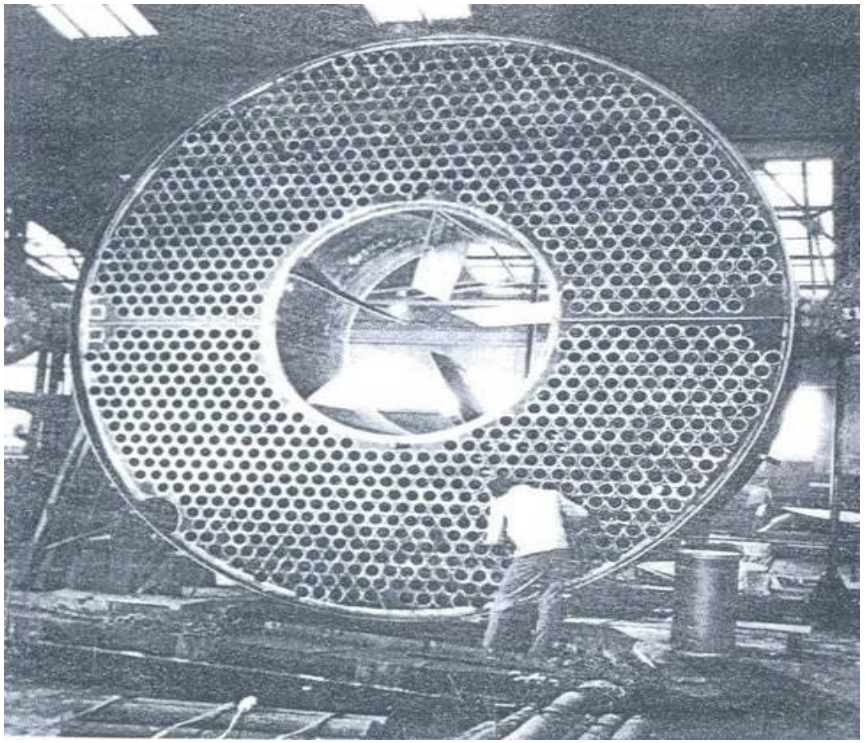

Floating Calandria Pan is also sometimes called “Segura Pan”. It has got annular downtake and steam entry at the centre. The tube length varies from centre to periphery in decreasing order. There are many maintenance issues associated with such pans and hence not used now.

# CIRCULATION PATTERNS

## (FIXED VS FLOATING CALANDRIA)



# PAN WITH MECHANICAL CIRCULATOR



**MECHANICAL CIRCULATORS ARE PROVIDED EITHER IN LOW GRADE OR REFINED SUGAR PANS TO COPE UP WITH THE REQUIREMENT OF CIRCULATION. WITH THE RISE IN STRIKE LEVEL, THE RATE OF CIRCULATION DECREASES AND THIS PHENOMENON IS PRONOUNCED IN LOW GRADE MASSECUITES DUE TO HIGHER VISCOSITIES. CIRCULATION UNDER THESE CONDITIONS IS MAINTAINED BY PROVIDING A MECHANICAL CIRCULATOR FROM THE PAN TOP TO WHICH IS ATTACHED A SCREW PUMP IMPELLER LOCATED AT THE BOTTOM OF THE DOWNTAKE. NOW A DAYS BOTTOM MOUNTED CIRCULATORS ARE ALSO AVAILABLE.**

# ADVANTAGES OF MECHANICAL CIRCULATOR

1. THE BOILING TIME REDUCES BY 25-35%.
2. STIKE LEVEL OR THE WORKING VOLUME CAN BE INCREASED.
3. EVEN AND UNIFORM GRAIN SIZE CAN BE MAINTAINED.
4. CIRCULATION RATES ARE FAIRLY MAINTAINED AND THUS CONGLOMERATE FORMATION IS MINIMIZED IN HIGH GRADE MASSECUITES AND SO IS THE COLOUR DEVELOPMENT. WHEREAS IN THE LOW GRADE MASSECUITES, THE EXHAUSTION OF MOTHER LIQUOR IMPROVES.
5. LOW PRESSURE VAPOUR CAN BE USED FOR BOILING.
6. SAVING IN STEAM CONSUMPTION DUE TO REDUCTION IN BOILING TIME.

# CONTINUOUS PANS

**IT IS THE TYPE OF VACUUM PAN IN WHICH MASSECUITE BOILING IS CARRIED OUT CONTINUOUSLY WITH HAVING THE NEED OF STOPPING FOR DISCHARGING THE MASSECUITE & RESTARTING THE PAN. IT MAY BE:**

1. **HORIZONTAL CONTINUOUS PAN : The lay out of the tubes is horizontal.**
2. **VERTICAL CONTINUOUS PAN : The lay out tubes is vertical.**

**The Horizontal Continuous Pans may be categorized into:**

1. **Pans in which massecuite is inside the tubes and heating media outside.**
2. **Pans in which massecuite is outside the tubes and heating media inside the tubes.**

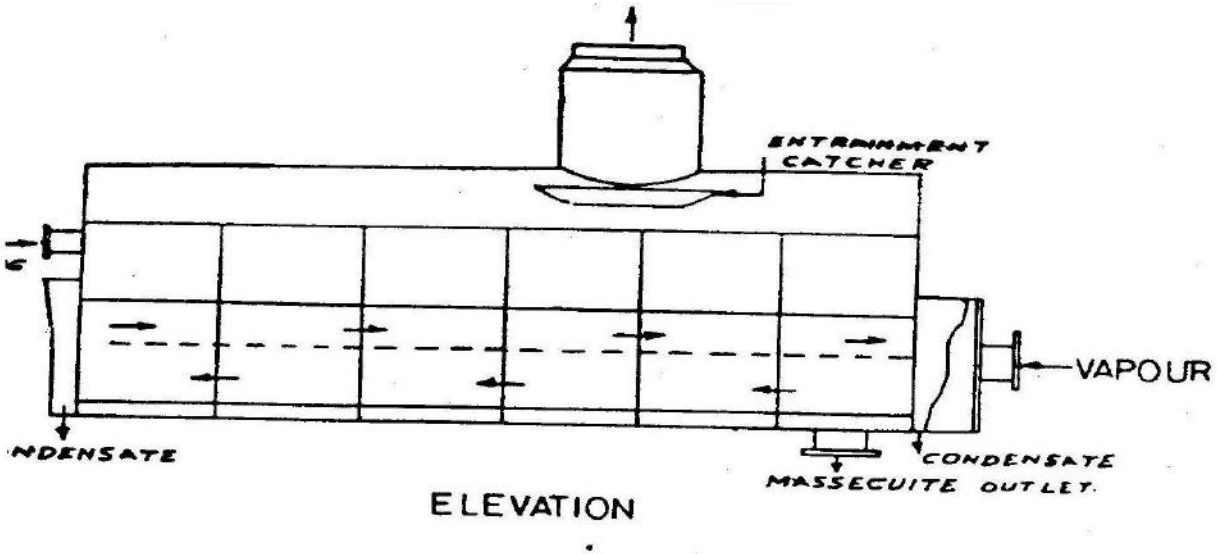
The continuous pans are multi-compartment type and while horizontal pans contain 10 or more compartments, 4 or more compartments are provided in vertical pans.

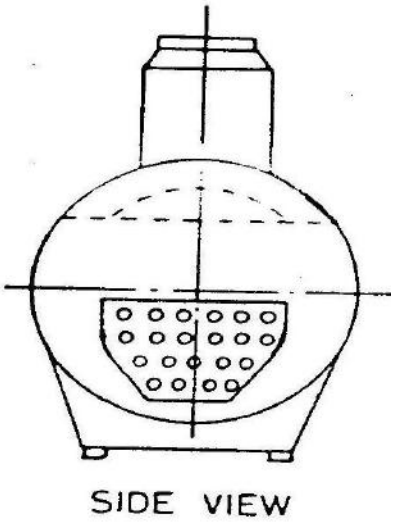
The important feature of these pans is higher heating surface to volume ratio (approx 10 sqm/cum) and lower massecuite height above the top tube plate, generally 300-400 mm only.

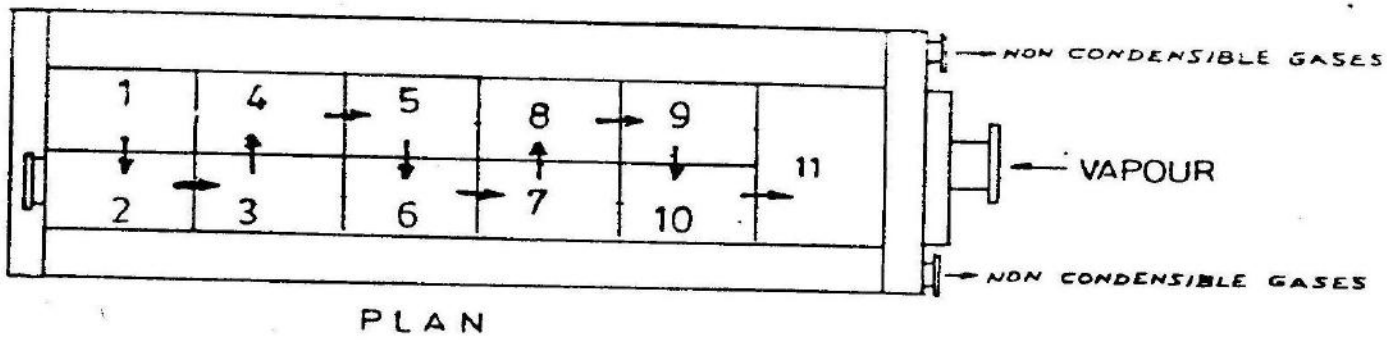
Most the continuous pans are provided with many automatic controls viz. feed magma control, conductivity based super saturation control in different compartments and level control etc.

In some continuous pans, non condensable gases or low pressure vapours are injected in the pan itself to improve circulation of the boiling mass. This is known as “Jigger Steam”.

# View of a Continuous Horizontal Pan

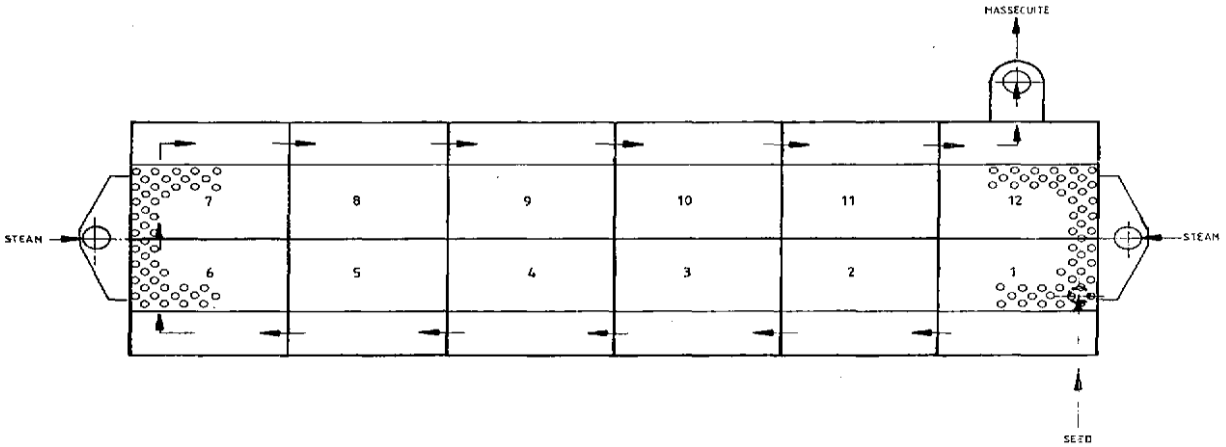


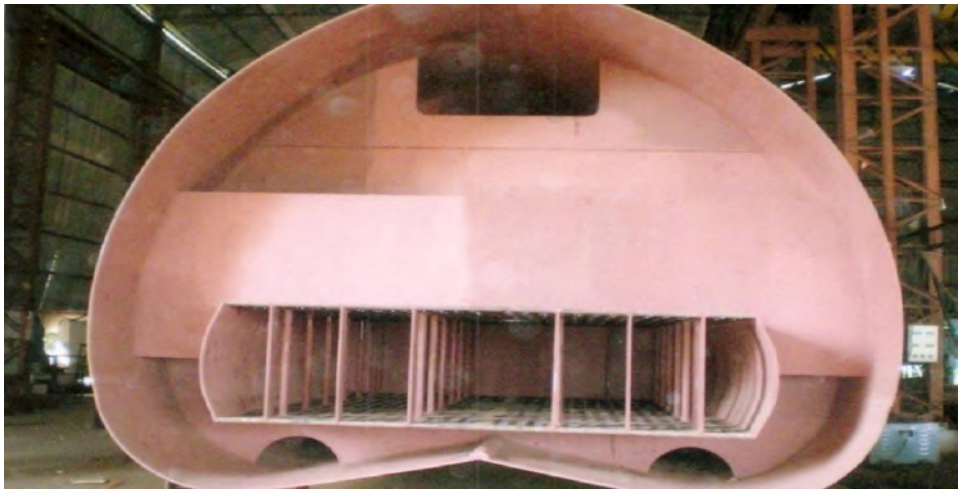



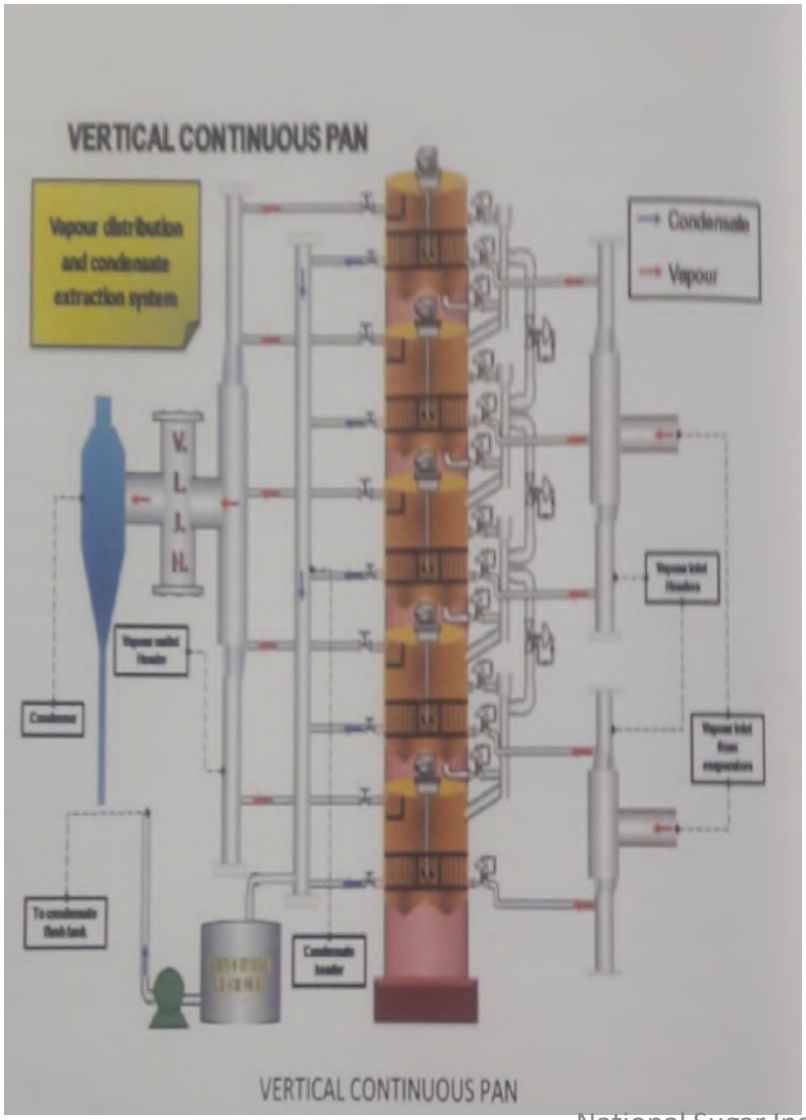

FCB - KCP CONTINUOUS PAN

# ….other horizontal continuous pans



# View of Continuous Vertical Pan




# ADVANTAGES OF THE CONTINUOUS PANS

1. For the same nominal volume, the capacity of continuous pans is about one half times that for batch pans.
2. Low pressure vapour from evaporators can be more effectively used without fluctuations in steam demand and also effecting steam economy. The evaporator and boiler stations achieve steady working with out peaks and valleys in steam requirement. Evaporator from which vapours are drawn for pan boiling achieves steady working.
3. Comparable or better exhaustion of molasses has been achieved in continuous pans as compared to batch operation.

4. Greater uniformity in operation with respect to crystal size and exhaustion is obtained.
5. Number of units like condenser and other pan ancillaries are reduced and thus maintenance costs are much less.
6. Injection water is requirement is less and so is the requirement of energy for injection pumps.
7. Continuous system lends its well to control of operation .
8. Labour cost is reduced.

# PAN BOILING SCHEMES

Following considerations are made in deciding the boiling scheme:

1. Purity of juice and in turn that of syrup.
2. Type & quality of sugar to be produced.
3. Target purity of final molasses.
4. Type of equipment available at crystallization and centrifugation station.
5. Competency of the manpower.

Generally, 3 (A,B & C) or 3 ½ (A,B,C1 and C) massecuite boiling scheme is adopted. In few cases where it is desired to make very good quality sugar (large crystals with low colour value) without any increase in final molasses purity, pan boiling is further modified by boiling A, A1, B, C1 and C massecuites.

# More About Pan Boiling

**Following is recommended to be maintained for efficient pan boiling :**

## Boiling time of various massecuites (Single Pan):

A massecuite : 2- 2 ½ hours

B massecuite : 4-5 hours

C massecuite : 6-8 hours

## Average brixes and purities of various massecuites :

A massecuite : 92-93 & 84-88

B massecuite : 96-97 & 66-70

C massecuite : 100-101 & 50-55

## Average crystal size in low grade massecuites:

B massecuite : 0.30 -0.35 mm

C massecuite : 0.18-0.20 mm

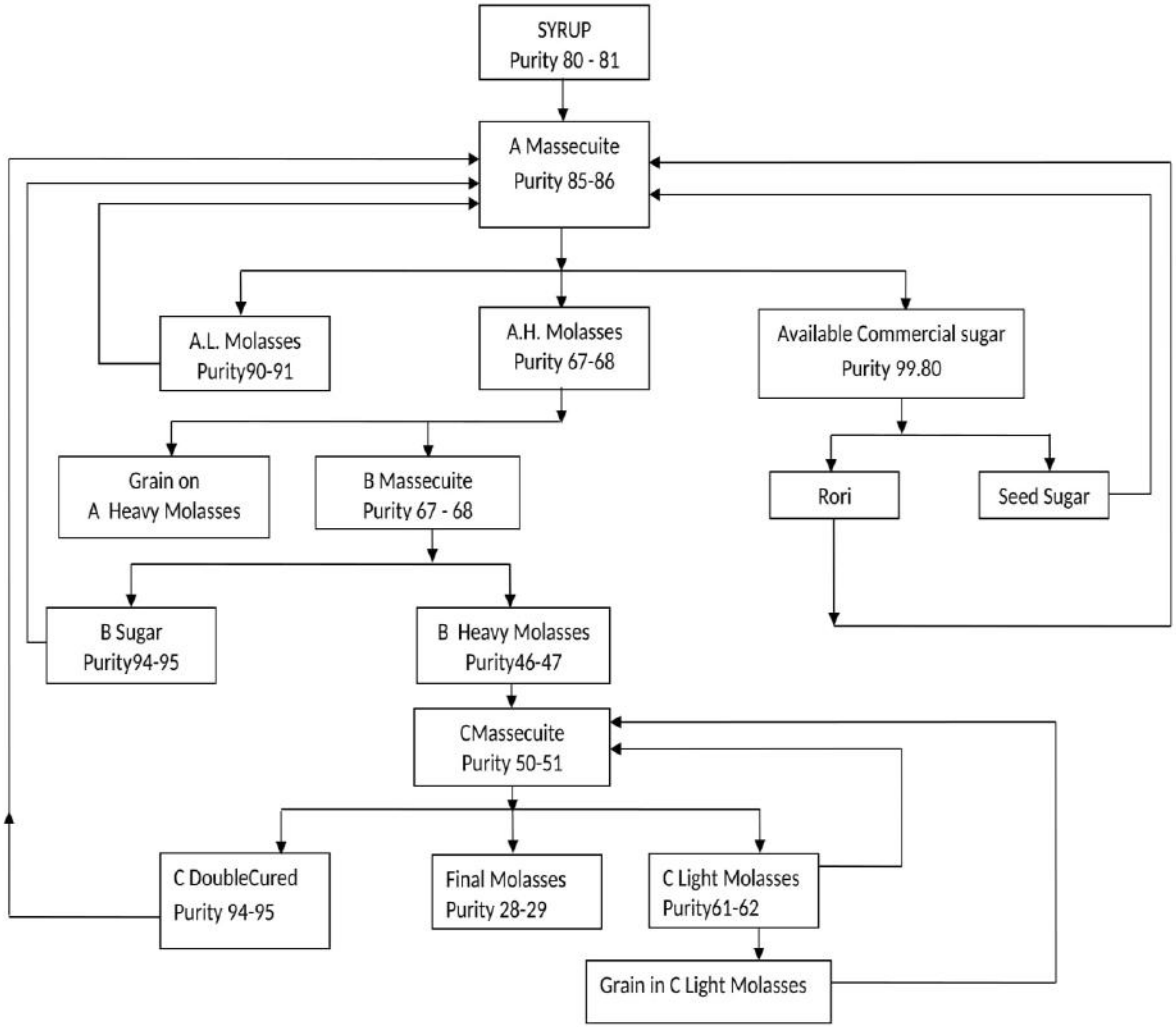
## Average Crystal% massecuite:

**A massecuite : 50-55**
**B massecuite : 40-45**
**C massecuite : 30-35**

For achieving higher exhaustion of mother liquor thus to have lower purity of final molasses, following is to be practiced:

1. Grain in case of low grade boiling should be properly hardened by using movement water.
2. The feed of molasses should be conditioned i.e. brix about 65 and temperature 65-70 deg. C & for the purpose molasses conditioners should be used.
3. Use of movement should also be made before dropping the C massecuite pan, if batch pans are used.
4. Nutsch purity should be monitored at the time of dropping of C massecuite pan so as to have idea about efficiency of pan boiling. For the purpose nutsch apparatus should be used.

## 3 MASSECUITE PAN BOILING SCHEME FOR PLANTATION WHITE SUGAR



# $3\frac{1}{2}$ MASSECUITE PAN BOILING SCHEME FOR PLANTATION WHITE SUGAR