SPLIT & DUAL CONTINUOUS PANS- DESIGN ASPECTS FOR MAXIMIZING THE BENIFITS TO SUGAR MILLS.

M.PANDU RANGA RAO, VICE PRESIDENT – TECHNICAL
SHRIJEE PROCESS ENGINEERING WORKS LTD, MUMBAI, INDIA.

Key words: Split continuous pan, Dual continuous pan, Heat transfer coefficient.

Abstract

Split/Dual Continuous vacuum pans provides significant advantages such as complete automation & minimal supervision, steam economy, better exhaustion, uniform crystals, high rate of evaporation, high through put and maximum capacity utilization. The design concept, of Split /Dual continuous pans, has been developed by “M/S Shrijee Process Engineering Works Ltd” to ensure the above benefits to the sugar industry. The split continuous vacuum pan is having the flexibility to operate at 50% to 100% of the designed capacity in correlation with crushing rate and either side 50% of the pan can be taken for water boiling without stopping the complete pan. The dual continuous pan can be utilized for simultaneous boiling of any two massecuite or any one massecuite boiling can be stopped and other massecuite can be boiled as per the requirement. Both, split continuous pan and Dual continuous pans, are having the provision to utilize the different pressure steam simultaneously at two different sides of the calandria. These pans have been running successful for A, B and C massecuite in India and overseas.

Split/Dual continuous vacuum pans provide major advantages in achieving more effective use of installed volumetric capacity than batch pans. Additional advantages are reduced supervision, steam economy and consistency in the product massecuite. However in order to maximize the benefits, continuous pans must be operated at high sucrose deposition rates and be able to minimize the effects of any short comings such as time off line for cleaning.

This paper shall emphasize several important designs and operating criterion for maximizing the benefits from continuous pans to the sugar industry.

Introduction

Indian and overseas Sugar mills are expanding crushing capacity and looking for efficient designs of various process house equipments which can minimize steam consumption, power consumption, process losses, man power, required space for installation and better capacity utilization. To increase revenue sugar mills are adopting the Co-generation. To obtain more revenue from the co-generation, process steam & power consumption must be reduced with efficient pan designs which can boil with low pressure and temperature vapour V3/V4 from quintuple evaporators.

Split/Dual continuous pans have been designed to boil with low-pressure V3/V4 vapour from quintuple effect evaporators. These pans can reduce the high pressure steam consumption at process house and more power can be generated for export.
To achieve the highest efficiency of Split/Dual continuous pans, the following factors have been considered while designing:

1. Higher heating surface to volume ratio.
2. Massecuite flow pattern from 1st compartment to discharge compartment.
3. Proper steam/vapour distribution and proper condensate & nox gas withdrawal arrangement.
4. Vigorous circulation of massecuite.
5. Mechanical circulators for tightening zone.
6. Hydrostatic head and boiling point elevation (BPE).
7. Jigger steam provision.
8. Steam/Vapour consumption and suitable to boil with low pressure vapours.
9. Volumetric efficiency and crystal size distribution.
10. Number of compartments and individual compartments volume.
11. Feed molasses (liquor) distribution.
12. Exhaustion of product massecuite.
13. Efficient entrainment arrester.
14. Type of condenser.

Split continuous pan

Shrijee Process Engineering Works Ltd, India, has designed, supplied, and successfully commissioned the Split continuous vacuum pan with complete automation for "C" massecuite boiling with 180 m^3 working volume in 2018-19 crushing season to "LOUISIANA SUGAR CANE COOPERATIVE, Louisiana, USA. This pan is having the module **"A"** and module **"B"** Split continuous pans can be used for low-grade or high-grade massecuite boiling with minimum steam consumption at designed output. This pan has been designed to operate with V1/V2 vapour, as they don't have co-generation.

Design criterion and technical data of Split continuous pan.

The Split continuous pan is suitable to run at 100% and 50% without any drawback. The pan is cylindrical shell type having horizontal construction with "W" shape bottom portion. Calandria is an assembly of vertical tubes. The pan is having multiple compartments to ensure closer approach to plug flow of massecuite from 1st compartment to discharge compartment.

Massecuite production capacity of the pan is calculated based on average massecuite level above top tube of 350 mm. Liquor (molasses/syrup) and hot water is provided to each compartment.

Both modules are provided with separate heating steam/vapour to ensure uniform distribution throughout the calandria. Separate condensate withdrawal system has been provided for both modules. Non-condensable gas connections have been provided at appropriate location for efficient and complete removal of light and heavy gas from both modules.

Table-1, Technical and Design data of Split continuous pan of Louisiana Sugar Cane Cooperative (LASUCA), USA

Description	**Data**
Massecuite	"C" Massecuite
Capacity	67.2TPH
Seed Magma Properties:	
Brix	92%
Flow Rate	19-22.4 TPH
Crystal Size	100-120 micron
Molasses Feed:	
Brix	72-75 %
Temperature	70-75^{0}c
Outlet Massecuite Properties:	
Crystal size	200-250 micron
Brix	98-100%
Heating steam:	
Steam pressure	3.0 - 4.0 Psig(120-130kpa)
Steam temperature	103-105^{0}c
Pan Details:	
Holding Volume	180M^3
Heating Surface	1800M^2
Heating surface to volume ratio	10 M^{-1}
No. of Compartments per module	8
Tube details:	
Material	ASTM A249 TP304
Outer diameter	102 mm
Thickness	16 SWG (1.6 mm)
Length	1200 mm

The pan is of horizontal design with vertical stainless steel tubes (ASTM A249 TP304) expanded in between mild steel tube plates of 32 mm thickness. The pan is constructed as two separate modules A&B with a separate calandria with 8 compartments in each module. There is down take in parallel to the length of the pan on both sides of calandria of both modules to ensure high rate of circulation. The pan provided with an overall heating surface to volume ratio of **10m^{-1}** to operate with bled vapour from evaporators.

Table-2 Shows details of the modules A&B, number of compartments, compartment volume, number of tubes and heating surface area.

Table 2- Details of the 180 m^3 Shrijee Split continuous pan at Louisiana Sugar Cane Cooperative, USA

Module	Compartment no.	Each compartment volume, m^3	Total volume m^3	Number of tubes	Heating surface area, m^2
A	1&8	11.30	22.60	324x2=648	230.9
	2&7	11.25	22.50	311x2=622	221.7
	3&6	11.40	22.80	326x2=652	232.3
	4&5	11.05	22.10	303x2=606	215.9
B	1&8	11.30	22.60	324x22=648	230.9
	2&7	11.25	22.50	311x2=622	221.7
	3&6	11.40	22.80	326x2=652	232.3
	4&5	11.05	22.10	303x2=606	215.9
Total	16		180	5056	1801.6

Heating surface has been calculated based on effective length of tubes between inside faces of the tube plates and mean diameter of the tubes. Working volume based on average massecuite level of 350mm above the top tube plate.

Observations on Pan Performance:

Module A was successfully commissioned on 13th November 2018 and was in operation till 12th December 2018. Module B was commissioned on 12th December 2018 and was in operation till 15th January 2019 (end of season 2018-19). In correlation with the crushing rate Louisiana Sugar Cane Cooperative (LASUCA) has commissioned the pan modules one after the other and each module was in operation for one month and no sugar accumulation or lumps formation was noticed in both modules. Boiling, quality of massecuite and production rate, were observed good from both modules. No accumulation of massecuite was observed in any compartment of both modules. There was a complete absence of lumps in the product massecuite and no blocking of tubes has occurred.

The pan has produced good quality "C" massecuite of high brix and crystal content of 35-40% with uniform size distribution.

Design considerations

1. Higher heating surface to volume ratio:

Split/Dual continuous pans are designed with heating surface to volume of $10M^{-1}$ so as to ensure high rate of heat transfer and vigorous boiling even with low pressure and temperature vapours.

2. Massecuite flow, from 1st compartment to discharge compartment:

Massecuite flow from compartment to compartment is Top-Bottom-Top in zig-zag manner. Massecuite discharges from the discharge box located at compartment no.8 of each module. There is massecuite outlet valve just below the discharge box which can be controlled as and when required. Massecuite shall be discharged into the receiver with sealing arrangement.

3. Proper steam/vapour distribution and proper condensate & nox gas withdrawal arrangement.

Separate steam/vapour entry connection was provided to A&B modules to ensure uniform distribution throughout the calandria. Steam entry to both modules has been provided with control valves to control the steam/ vapour with reference to the calandria pressure. With this provision either module can be stopped or slowdown as and when required. Proper condensate and non condensable withdrawal system have been provided to remove as soon as they formed.

4. Vigorous circulation of massecuite:

To ensure high rate of heat transfer, high rate of evaporation, high rate of crystallization, and to avoid the fine crystal generation, lumps formation, inactive zones, high rate of circulation is vital. This pan has been designed to ensure high rate of circulation so as to achieve all the above said advantages.

5. Mechanical circulators for tightening zone.

Shrijee has been designing the continuous pans with top mounted mechanical circulators for last two compartments to increase the circulation. Our continuous pans with mechanical circulators for last tow compartments have been working with V4 vapor and giving good results. However for Split continuous pan, of LASUCA, USA, has not been provided with mechanical circulators as they are using high pressure vapours.

6. Hydrostatic head and Boiling point elevation (BPE):

The effect of hydrostatic head in the continuous pan is much lesser than batch pan. The massecuite level from 1st compartment to discharge compartment is gradually reduced from 400mm at 1st compartment to 300mm at discharge compartment so as to ensure almost equal hydrostatic head in all the compartments (in order to reduce the BPE and to increase the temperature gradient) with reference to brix of respective compartments. An average massecuite level above the top tube plate is 350mm and an average total massecuite height from bottom tube plate to top of the discharge massecuite is 1550mm.

7. Jigger steam provision:

There is a provision for jigger steam with steam/vapour used at calandria. Non condensable gas from the calandria can also be used for jiggering to accelerate the natural circulation. Jigger steam shall be used as and when required with reference to the natural circulation.

8. Steam/Vapour consumption and suitable to boil with low pressure vapour:

Split/Dual continuous pans are designed to boil with low pressure vapours such as V3/V4. Separate condensate flow meters have been provided to both module to estimate the steam consumption and performance of each module. Massecuite production from each module can be calculated from the seed magma (grain) and molasses (feed liquor) totalizer. From the condensate flow and massecuite output, steam/vapour consumption per ton of massecuite produced typically ranged between 0.25 and 0.28 T.

9. Volumetric efficiency and crystal size distribution:

The crystal size distribution of seed magma, number & volume of compartments, coefficient of super saturation (it is driving force to transfer the sucrose from mother liquor to seed crystal surface) in each compartment, massecuite circulation rate, nominal residence time and level of automation shall influence the crystal size distribution in the product massecuite. The relative increase in mean crystal residence time compared to the nominal residence time is termed as the volumetric efficiency" Based on seed crystal growth from a mean size of 0.100 mm to product crystals with mean size of 0.200 mm, the sum of the average residence time for the crystals in each of the compartment is 6.5 hours. At the design production rate of 60 TPH of "C" massecuite, the nominal residence time (pan volume/product volume per hr) in the pan is 4.5 hrs and the volumetric efficiency is 1.44. (Normal range is 1.3 to 1.7)

10. Number of compartments and individual compartments volume:

Based on the type of massecuite, seed crystal size and required product crystal size, the number of compartments and volume of compartment shall be calculated. In Shrijee design of Split continuous pans all the compartments volume remains near about same and being achieved 23-25units purity drop between the massecuite and the purity of respective molasses in case of C massecuite. The coefficient of variation of crystals in the product massecuite was observed in range of 0.30 to 0.35. The discharged massecuite was subsequently cooled in cooling crystallizers and achieved good performance at the continuous centrifugals with good purity drop.

11. Feed molasses (liquor) distribution:

Split continuous pans are being provided with efficient feed distributors located at the bottom of each compartment to ensure uniform distribution of feed material throughout the length of the compartment.

12. Exhaustion of product massecuite:

Good exhaustion (maximum sucrose transfer from mother liquor to seed crystal surface) is the primary object of pan boiling which has been considered while designing the Split continuous pans. Factors that are determining the % exhaustion are, seed crystal size & uniformity, purity of seed crystals, feed liquor purity & temperature, RS/Ash ratio, brix of feed liquor & massecuite, boiling temperature, circulation of massecuite in addition to good design of the pan. Shrijee Split continuous pan ensures above 65 %exhaustion.

13. Efficient entrainment arrester:

Split/Dual continuous pans are provided with three stage entrainment arrester to ensure zero entrainment with minimum pressure drop. The entrainment arrester system is a combination of umbrella followed by centrifugal separator followed by helmet type with proper arrangement to collect any entrained droplets.

14. Type of condenser:

The Split continuous Pan has been provided with individual condensers for module “A” and module “B”. However common condenser can also be used for both modules with isolation valves in the vapour lines going to common condenser from individual modules. Both condensers have been automated to maintain 630-660 mm of Hg vacuum as per set value with minimum injection water. Single entry condenser for module “A” and Barometric condenser (customer request) for module “B” have been provided for LASUCA pan. Module “A” was getting the above vacuum with in 3min in hot condition and module “B” was getting the same vacuum in 10 min. The injection water consumption at single entry condenser was 30-40% lesser than the Barometric condenser. Single entry condenser not required any external support such as steam ejector/water ejector/vacuum pump to extract non condensable gas, where as barometric condenser required.

Table -3 Automation:

Instrument	Type
Brix Transmitters each compartment	Conductivity with auto washing
Molasses Control Valve to each compartment	Butterfly
Molasses (liquor) flow meter	Electromagnetic
Seed magma flow meter	Electromagnetic
Seed magma and liquor flow meter	Ratio controller.
Speed control to seed magma pumps	VFD
Condensate flow meter	Electromagnetic
RTD Pt-100	0-300 Deg. F
Steam Pressure transmitter for calendria	DPT-Gauge
Steam out On/Off valve	Butterfly
Heating steam control Valve.	Butterfly
Condenser Pressure Transmitters	DPT-Absolute
Condenser water Control Valves	Butterfly

The automation is reliable and has simplified the operation to achieve good results with minimized manual interference.

Table 4 – Heat transfer coefficient of Split continuous pan

Module	Massecuite	Massecuite production/hr	Steam Consumption T/Ton massecuite	Heat transfer coefficient, kW/m^2k	
				min	max
A	C	33.6	0.25-0.28	0.20	0.25
B	C	33.6	0.25-0.28	0.20	0.25

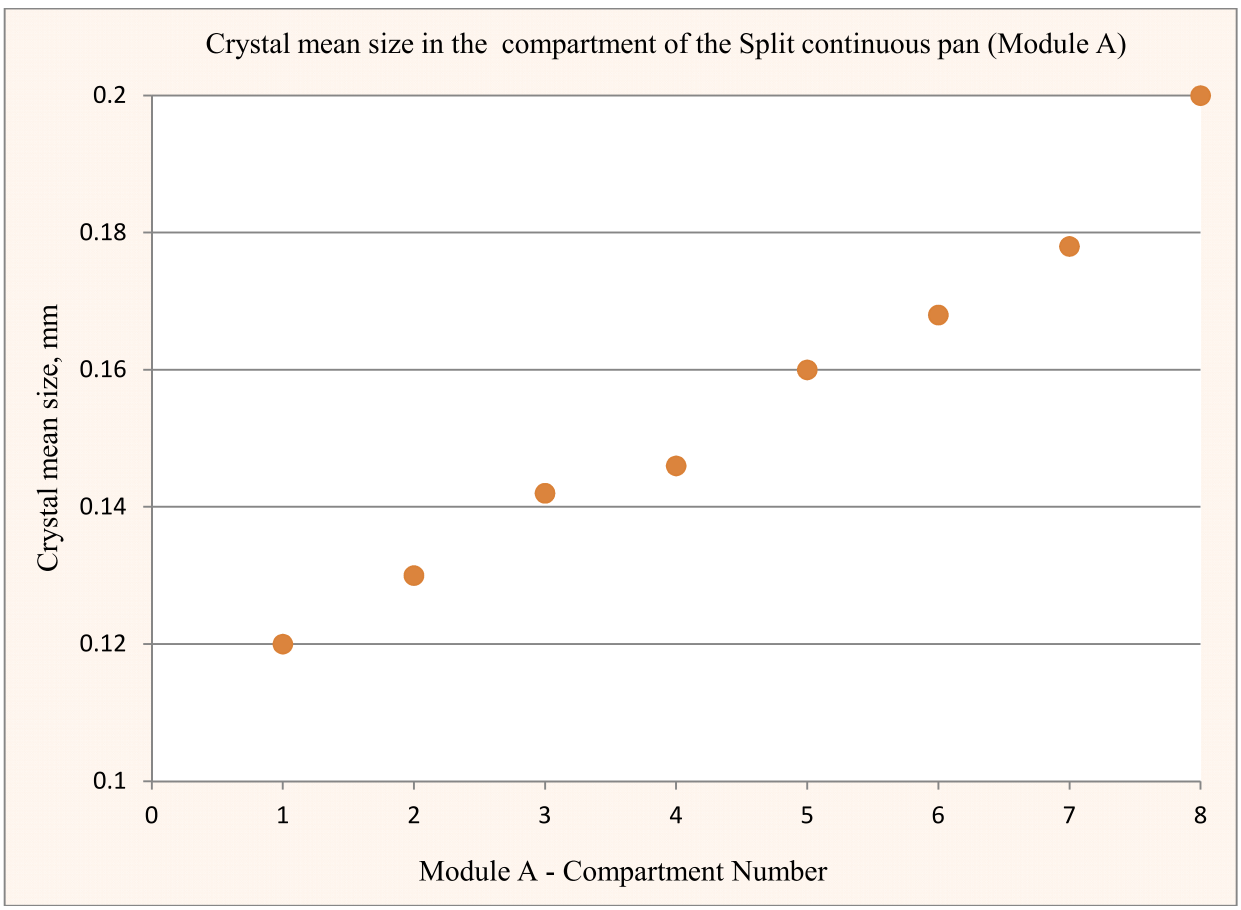
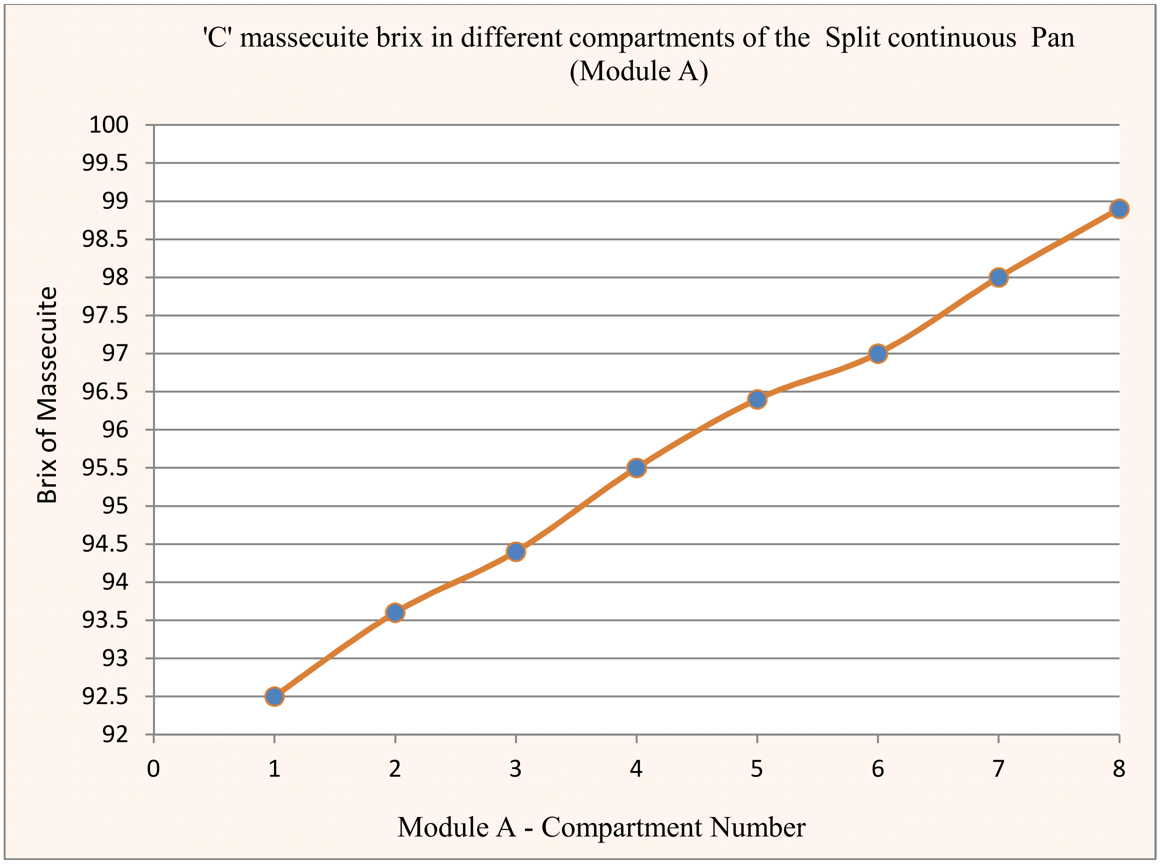


Figure -1



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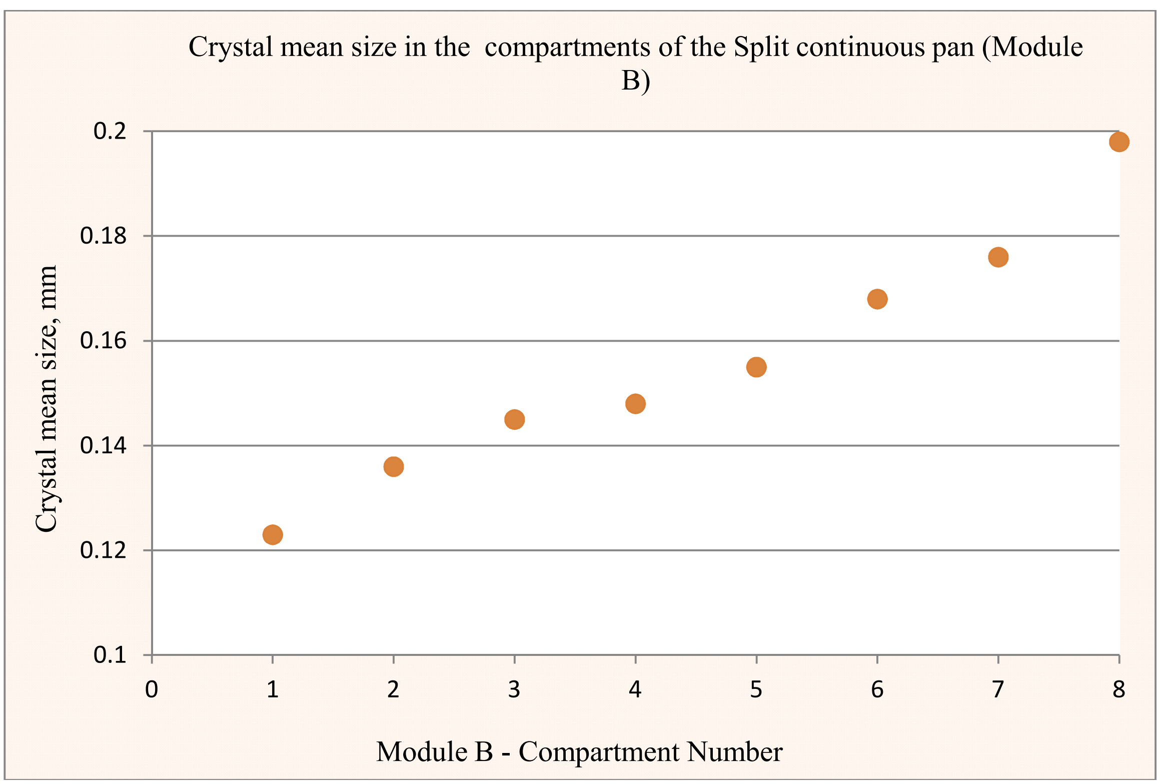

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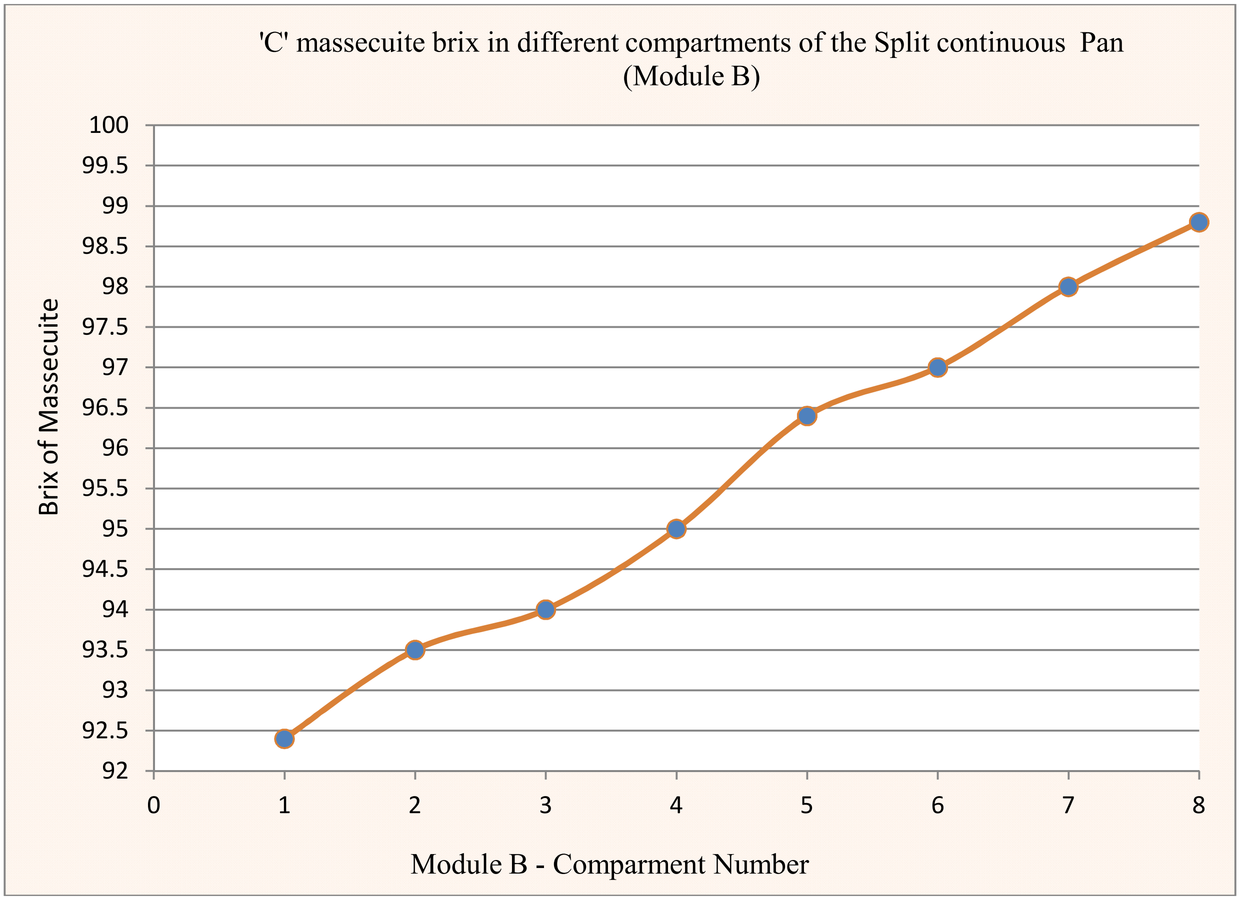


Figure – 4

Dual Continuous Pan for simultaneous boiling of 'B' & 'C' Massecuite.

Design criterion and technical considerations of "Dual continuous pan" are almost similar to that of Split continuous pan as explained above. However the holding volume, residence time, heating surface and compartment size & volume are different for modules of "B" and "C" massecuite.

Shrijee Process Engineering works Ltd, has designed, supplied, and successfully commissioned the "Dual continuous pan" with complete automation for simultaneous boiling of "B" and "C" massecuite with $42M^3$ and $48M^3$ working volume to produce 20TPH of "B" Massecuite and 15TPH of "C" Massecuite respectively, to M/S Natem Suagrs Ltd, India in 2015-16 crushing season.

Individual steam/vapour entry was provided for modules of B&C massecuite with individual condensate withdrawal system. This pan has been designed to operate with V3 vapour for "B" Massecuite and V2 vapour for "C" massecuite.

Automation:

Identical automation has been provided for B&C massecuite and the level of automation is similar to that of Split continuous pan as given in Table-3 above.

Condenser:

The Dual continuous Pan has been provided with common single entry condenser of capacity suitable to handle total vapour from “B” and “C” massecuite boiling. Isolation valves have been provided in the vapour lines from B&C boiling going to common condenser. Condenser has been automated to maintain 630-660 mm of Hg vacuum as per set value with minimum injection water consumption.

Table-5, Technical and Design data Dual continuous pan of Natem sugars Ltd, India

Description	**Data**	
Massecuite	B Massecuite	C Massecuite
Capacity	20 TPH	15 TPH
Seed magma properties		
Brix	90%	92%
Flow Rate	5-6 TPH	4-5 TPH
Crystal Size	150 micron	100 micron
Molasses Feed:		
Brix	70-72 %	72-75 %
Temperature	70-75^{0}C	70-75^{0}C
Outlet Massecuite Properties:		
Crystal size	300 micron	200 micron
Brix	95-96%	98-100%
Heating steam:		
Steam pressure	12.246 – 13.65 PSIA	17.7 – 18.7.0 PSIA
Steam temperature	95-98 ^{0}C	103-105^{0}C
Pan details		
Holding Volume	42 m^3	48 m^3
Heating Surface	420 m^2	480 m^2
S / V Ratio	10m^{-1}	10m^{-1}
No of Compartments	12	12
Tube Material	ASTM A249 TP304	ASTM A249 TP304
OD	102 mm	102 mm
Thickness	1.6 mm	1.6 mm
Length	1000 mm	1000 mm
No of tubes	1432 Nos.	1636 Nos.

Table 6- Details of Dual continuous pan, Natem sugars Ltd, India

CVP	Compartment Number	Each compartment/ volume, m^3	Total volume m^3	Number of tubes	Heating surface area, m^2
B	1&12	3.46	6.92	119x2=238	69.81
	2&11	3.46	6.92	119x2=238	69.81
	3&10	3.46	6.92	119x2=238	69.81
	4&9	3.46	6.92	119x2=238	69.81
	5&8	3.46	6.92	119x2=238	69.81
	6&7	3.70	7.40	121x2=242	70.98
Total	12		42	1432	420
C	1&12	4.21	8.42	148x2=296	86.82
	2&11	4.12	8.24	141x2=282	82.72
	3&10	3.91	7.82	130x2=260	76.26
	4&9	3.91	7.82	130x2=260	76.26
	5&8	3.91	7.82	130x2=260	76.26
	6&7	3.94	7.88	139x2=278	81.54
Total	12		48	1636	480M^2

Heating surface calculated base on effective length of tubes between inside faces of the tube plates and mean diameter of the tubes. Working volume based on average massecuite level of 350 mm above the top tube plate.

Observations on Pan Performance:

Dual continuous pan has been successfully commissioned 16 March 2016 and have been in operation for 35days till 2015-16 seasons closer. No sugar accumulation or lumps formation was noticed either in "B" boiling side or in "C" boiling side. Boiling, quality of massecuite and production rate has been observed as good. No accumulation of settled massecuite and blockage of tubes have been observed in any compartment of both modules. The product massecuite is free from lumps.

Steam consumption has been estimated at 0.3 to 0.35T/Ton of massecuite and 0.25-0.28T/Ton of massecuite for B massecuite and C massecuite, respectively. Injection water consumption at common condenser has reduced up to 20-25% compared to individual condensers for same output of B&C massecuite.

The pan has been producing good quality "B"&"C" massecuite of high brix and crystal content of 40-45% of "B" massecuite and 35-40% of "C" massecuite with uniform size distribution.

Table7 – Heat transfer coefficient of Dual continuous pan, Natem Sugars Ltd, India

Massecuite	Massecuite Production T/hr	Steam Consumption T/Ton massecuite	Heat transfer coefficient, kW/m^{2}k	
			min	max
B	20	0.30-0.35	0.30	0.38
C	15	0.25-0.28	0.20	0.25

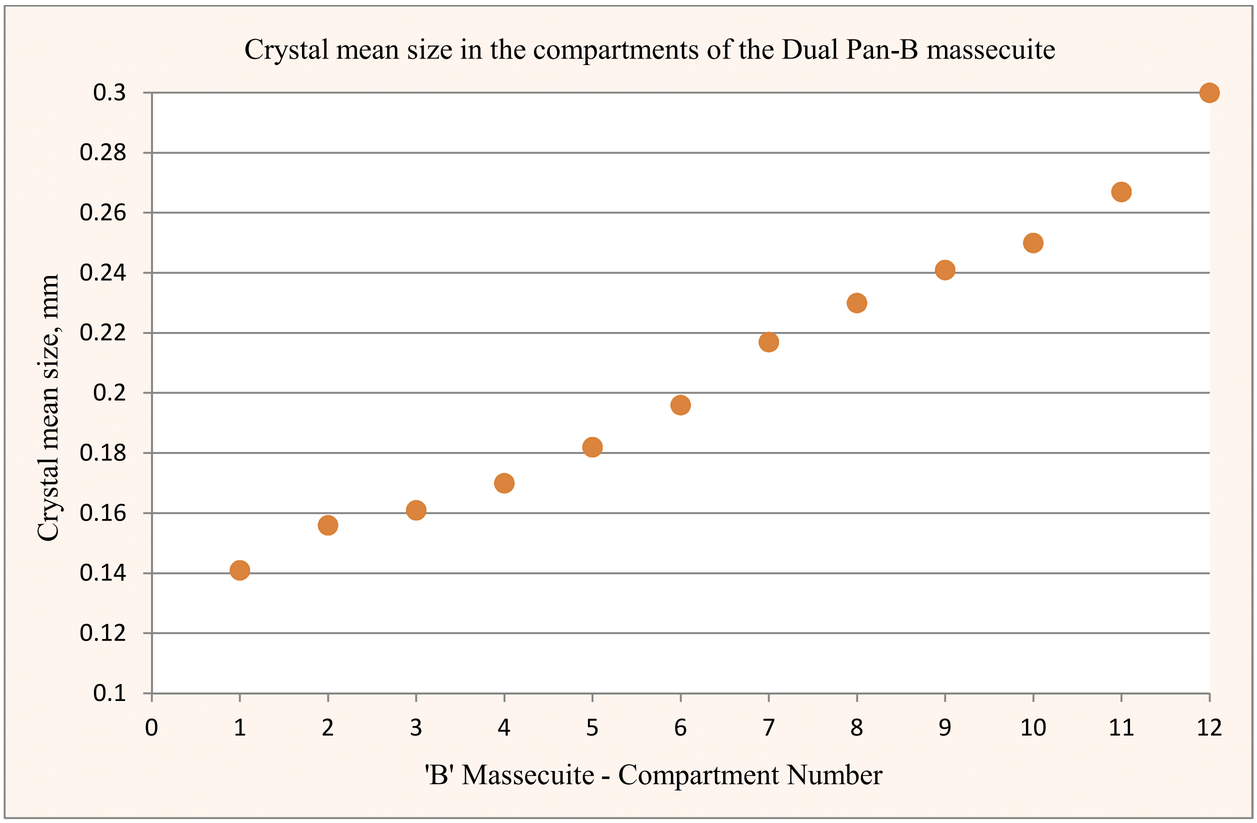
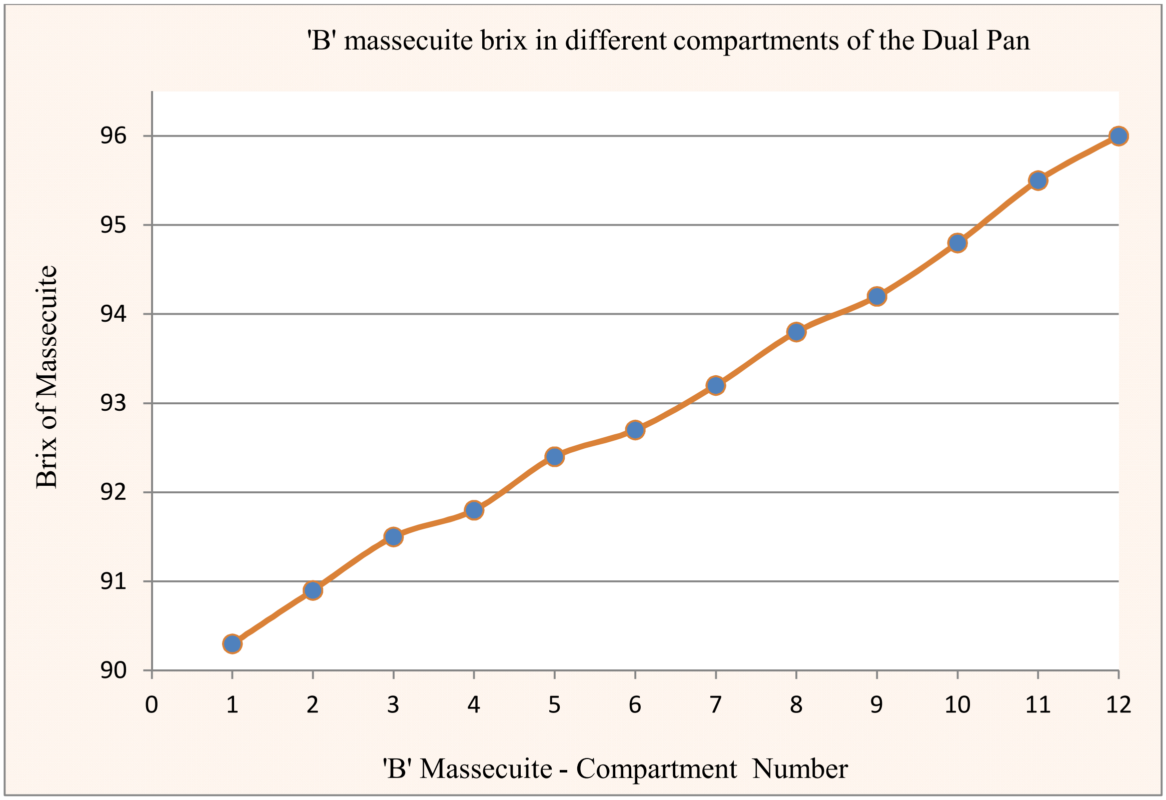


Figure - 5



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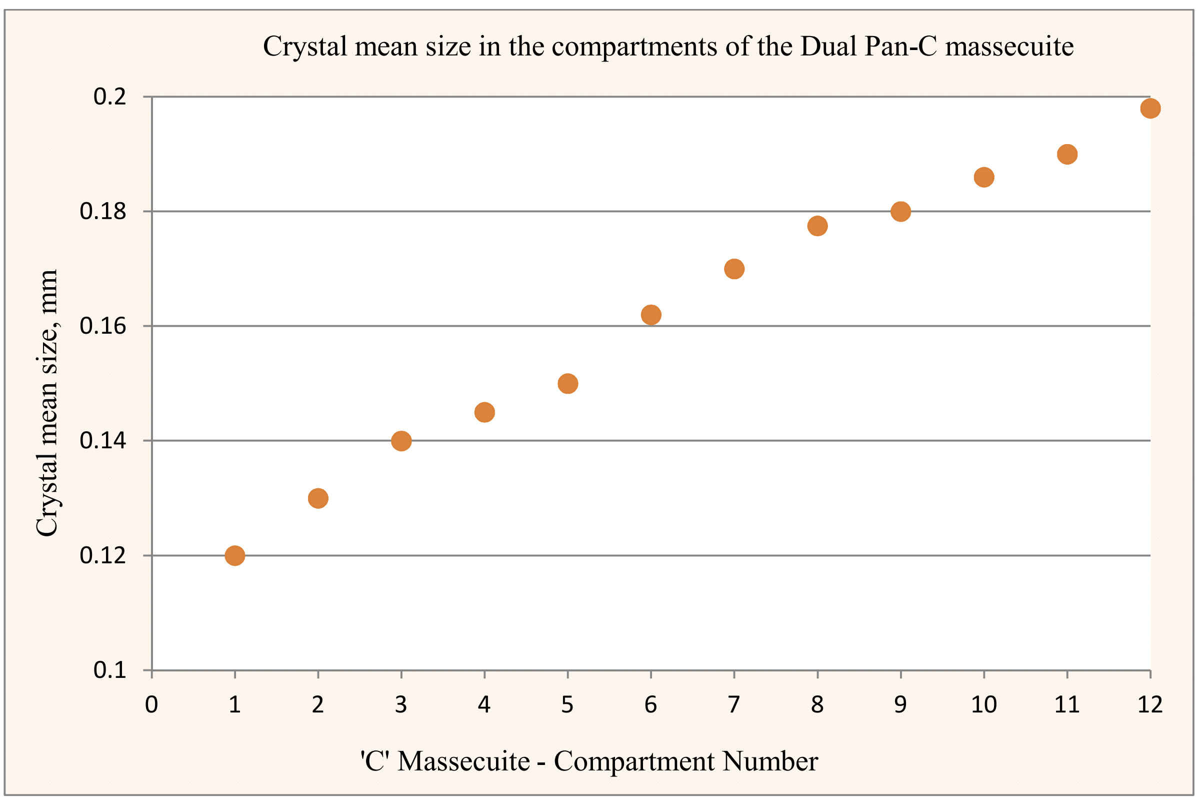

Figure - 7

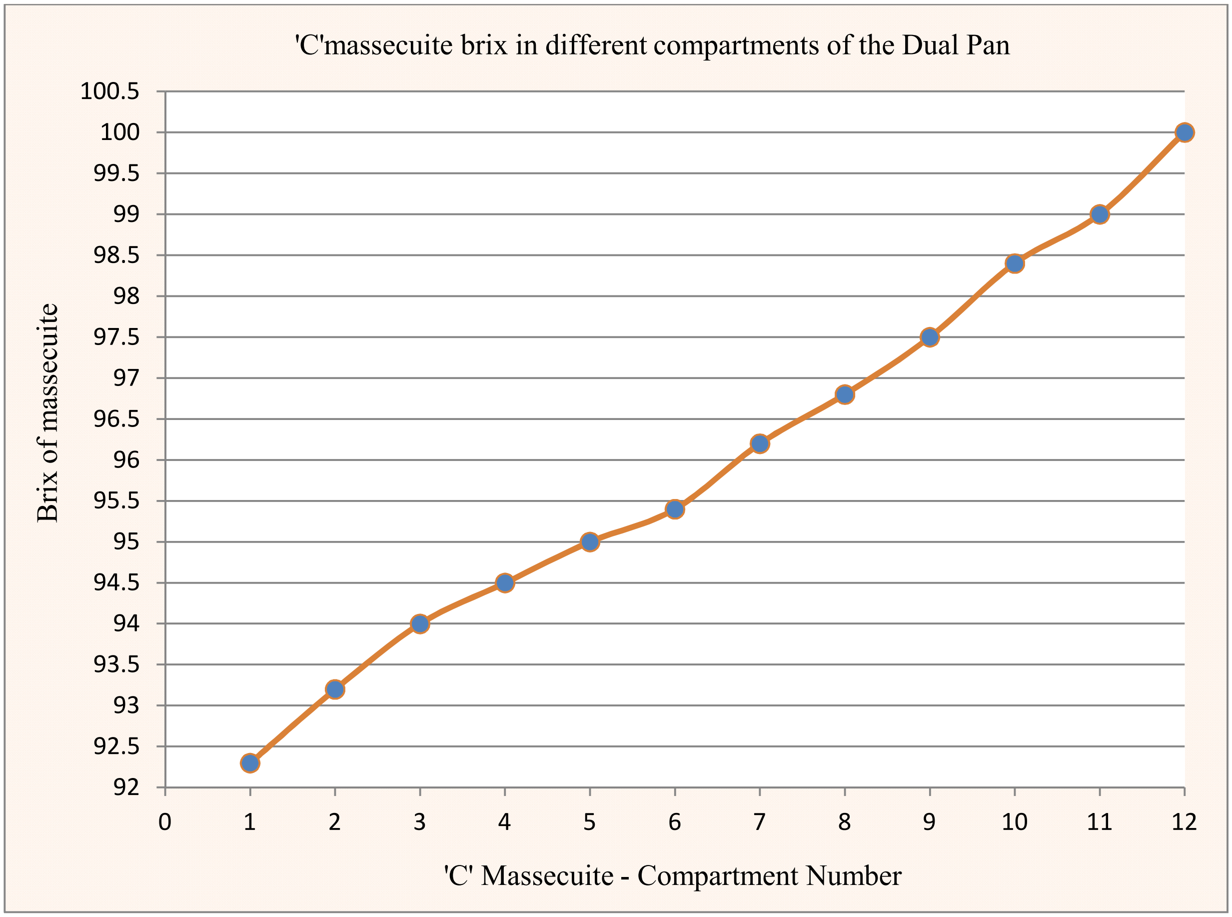

Figure - 8

Advantages of Split/Dual continuous pans:

- Flexibility to operate complete pan or 50% of the pan (in case of split pan) in correlation with crushing rate.
- Flexibility for simultaneous boiling of two grades of massecuite or any one massecuite can be stopped and one can be boiled (in case of Dual pan).
- Can be operated with low pressure and temperature vapours and steam saving.
- Lesser steam consumption.
- Reduction in injection water up to 20-25%, and reduction of power consumption at injection water pumps.
- High through put with consistency.
- Complete automation and lesser skilled man power requirement
- Lesser boil out time and flexibility to boil out either side of 50% of pan.
- Lesser space for installation.

Conclusion:

Split and Dual continuous pans are the best option to save the thermal energy, electrical energy, space for installation, skilled operating man power, and injection water and to increase the productivity with good consistency, which are significant for the profitability of sugar industry. Split/Dual continuous pans are good equipments for crystallization of all grades of massecuite. Shrijee has been designing the continuous pans with mechanical circulators for last two compartments to ensure the good boiling with V3/V4 vapours from quintuple effect evaporators for process steam saving.

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