BE038

# Automation system: a process innovation technology for sugar cane industry

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**Abstract**

This research presents an investigation into improving crystallization system to upgrade sugar cane production based on the DECHAROEN™ technology. The proposed system technique uses a continuous vacuum pan branded to replace the traditional batch vacuum pan without the crystal quality problems. The use of new continuous type providing technical advance and ease of full automation to affords significant improvements in, reducing loss of sucrose and expanding production capacity of the sugar mills. Results modernized using continuous vacuum pans (CVPs) were compared to data of previous processes using batch pans for verifying the effectiveness of proposed system. The used of statistical tool like percentage change, and Prognostic method to predict future operations of factors investigated. Its economic benefits were now gladly accepted in five cane sugar manufacturers in Thailand, whose crystallization process used the new DECHAROEN™ vacuum pan.

**Keywords**: Crystallization, Vacuum pan, batch, Continuous, Pan boiling, Sugar Cane

## 1. Introduction

The sugar industry processes sugar cane and sugar beet to manufacture edible sugar. More than 60% of the world's sugar production is from sugar cane, the balance is from sugar beet. Sugar manufacturing is a highly seasonal industry, with season lengths of about 6 to 18 weeks for beets and 20 to 32 weeks for cane. Sugar production is a seasonal industry with starting dates depending on climatic conditions. Raw sugar manufacture necessarily coincides

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with harvesting season, since sugar cannot be stored for any appreciable time. In Philippines, crushing season begins in October or November and lasts through May and often runs into April the study of Sugar Regulatory Administration 2016. Cane mills located in cane growing regions generally produce raw sugar, which is then refined to produce high purity, low color sugar, generally called white sugar, either at annexed refineries or at remote stand-alone refineries. Cane from different regions or different fields in the same region vary greatly in sucrose content (Rein, 2013). The good quality cane enables high sugar recoveries to be obtained while minimizing costs of production. However, good cane quality does not guarantee that the sugar mill will produce good quality raw sugar. Processing operations within the raw sugar house can have a significant effect on raw sugar quality (Puanghom, et al, 2015; Limsutthiphong & Julsereewong, 2016).

There are several characterizations for industrial consolidation and development to become more competitive in the international market such as using new materials and techniques and upgrading process technology and automation of production (Masuchun, 2013). According to Sugar Regulatory Administration (2013) one of the most problems to be considered of sugar cane industries is the quality and how to maximize the quantity of sugar crystals as it determines sugar value and affects the performance of mills, the increasingly demanding high quality sugar to optimize their own operations. Sugar producers need to understand the impact of quality issues on their production Jansen (2015). Cane sugar is sucrose which has been extracted from sugar cane, a tropical plant which produces naturally high concentrations of sweet substance the study of International Sugar Congress 2013. Crystallization process, the largest energy consumption stage of sugar cane production is operated under vacuum pans and optimal crystalline condition provides the efficient and effective raw sugar production. The vacuum pan type should be firstly determined for producing a specified size of sugar crystal from a solution containing sugar and non-sugars. The pan selection involves a number of factors related to the specific sugar boiling scheme. The crucial factors are sugar crystal quality, quantity, pan availability and economy. When two or more aspects are applicable, one usually goes with the economics first (Puanghom & Limsutthiphong, 2016

## 2. Objective

This current study aims to present the technology process solution of vacuum pan crystallization for upgrading raw cane sugar production process. To determine the quality and quantity of raw cane sugar the proposed technique employs the innovative design, DECHAROEN™ brand (CVP), to replace the conventional batch vacuum pan.

The performances of the proposed technique were observed in 5 cane sugar manufacturers in Thailand, which have installed the DECHAROEN™ CVP in their crystallization process. The lists of these factories are also included to guarantee the effectiveness of the proposed technique.

## 3. Concepts, Theories and Related Research

The highest rated capacity per day is only 15,000 TCD in the Philippines located in Bacolod City (Victorias Milling Corporation) according to Sugar Regulatory Administration (2016) while in Thailand is now producing 50,000 TCD (Masuchun & Hunsigi, 2016). Traditionally, in many off-design crystallization processes of cane sugar industry, the automatic choice has been a discontinuous (batch) pan system, which has advantage of small instrumentation cost and flexibility operation however, the batch system is well-suited to produce small amounts of raw cane sugar (Pankarnchanato, 2013). Nowadays, most cane sugar manufacturers become larger and require to improve operating efficiencies, and a continuous pan system has been proved to be more cost-effective the study of International Sugar Congress 2013.

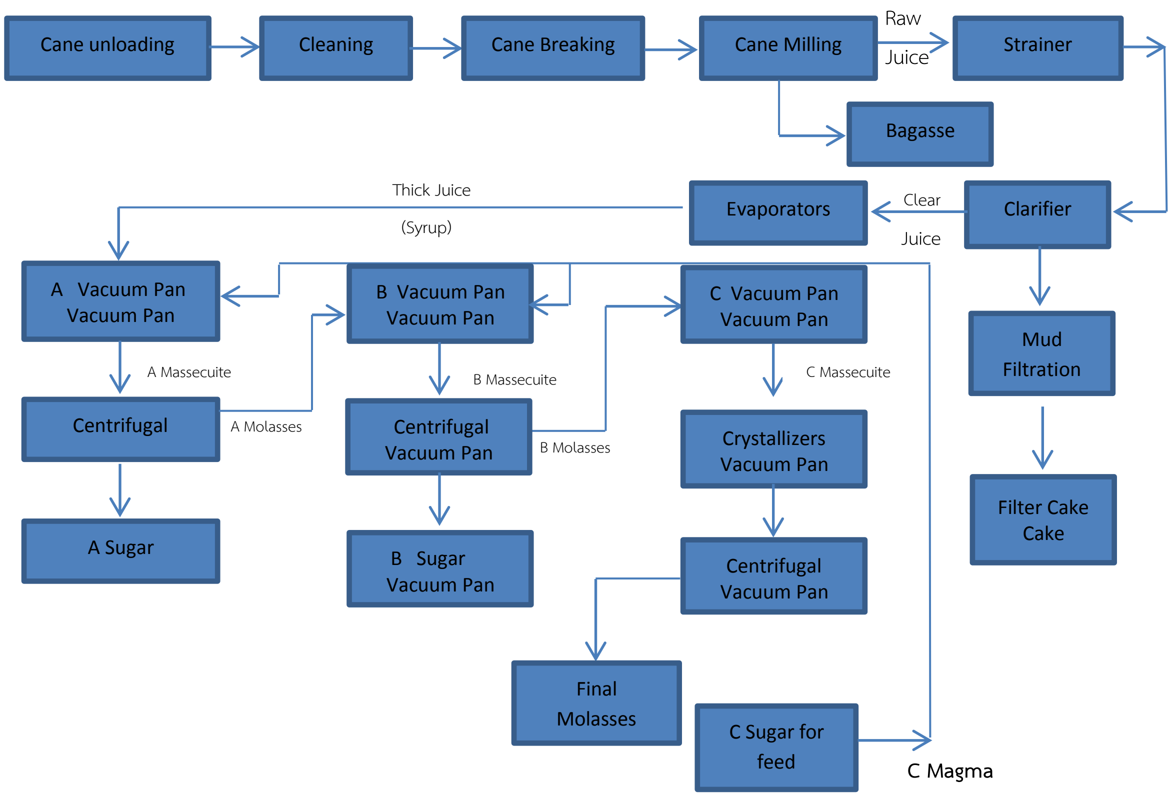


*Figure 1. Simplified process flow diagram of a typical raw cane sugar production Demier International, 2013*

Figure 1 shows a simplified process flow diagram of a raw cane sugar production, which consist of five main steps; juice extraction, defecation and clarification, evaporation, crystallization and centrifuging. The crystallization starts in the vacuum pans, which are used to produce satisfactory raw sugar crystals from syrup or molasses for refined feed stock or raw sugar export. Thus, vacuum pan design is one important factor that determines the quality of sugar crystal produced (Puanghom, 2016). In the pan boiling process under reduced pressure, the syrup (or molasses) is evaporated until it reaches the supersaturation stage. At this point, the crystallization process is initiated by seeding or shocking the solution. When the volume of the mixture of liquor crystals, known as massecuite, reaches the capacity of the pan, the evaporation is allowed to proceed until the final massecuite is formed. At this point, the contents of the vacuum pan are discharged to the centrifugal, whose function is to maximize the sugar crystal removal from the liquor.

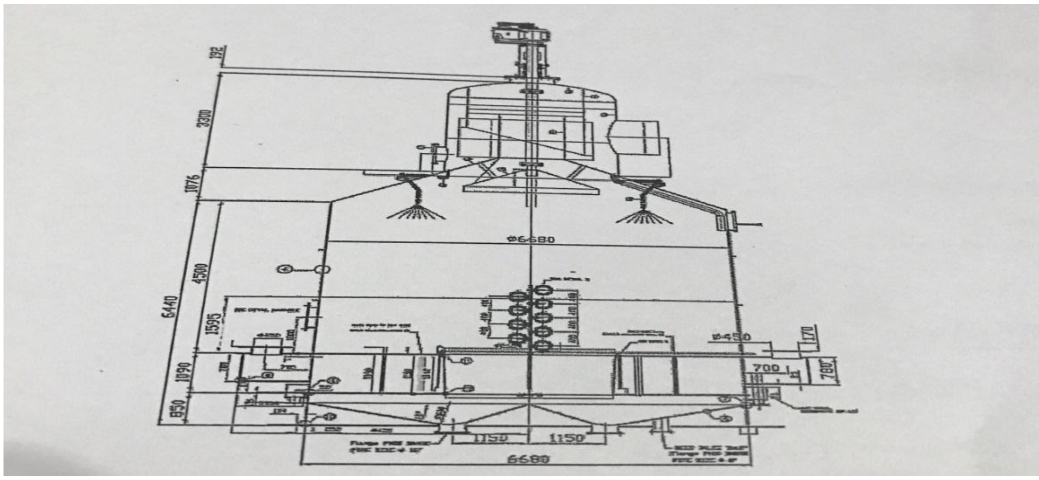

***Figure 2. One possible practical design of conventional batch vacuum pan**s*

The study conducted by International Congress of Sugar (2014). In the past decades, the manually or automatically controlled crystallization took place almost in batch units. Batch vacuum pans are commonly designed in the form of a vertical cylindrical vessel using vertical tube calandria with steam condensing on the outsides of the tubes. One of geometries widely used has single central downtake surrounded with vertical tubes (100mm in diameter and 600-1200 mm in length), straight side walls and "W" bottom (14-24°in angle). The exchange area, expressed per unit massecuite volume, is about 5 to 6 $m^2/m^3$. The downtake is sized to provide a circulation ratio, defined as the ratio of the cross sectional area of the tubes to the area of the downtake. The downtake diameter is about 30-50% of the calandria diameter. The massecuites with high viscosity require the use of large diameters to overcome the friction with the available buoyancy. Short tubes are choses for low-grade pans, while longer tubes are selected for high-grade pans. The smaller angles of the "W" bottom reduce the discharge velocity and lengthen the strike time. Two discharge valves are recommended.

Figure 2 shows one possible practical design of conventional batch vacuum pans used in cane sugar manufacturers in Thailand. With batch system, the duties of pans can be interchanged to accommodate the variation of relative quantities of A, B, and C massecuite, which depend on the time of season and cane purities. However, the batch system has many disadvantages such as high operating labor and handling costs, poor sugar quality, and requiring shunt-down time to empty, clean out and refill. In order to be an alternative of commercial Continuous vacuum Pan CVP's for cane sugar industry especially in Asia, the new horizontal CVP under DECHAROEN™ project has been originally developed by Demier group since 2013. The expected design of its development is based on the end-user' point of view (Puanghom, 2016)

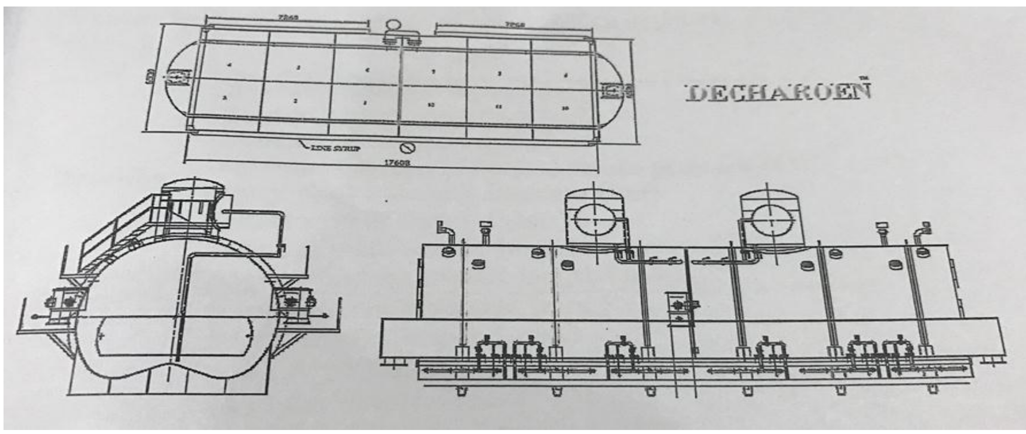


***Figure 3. DECHAROEN™ Technology CVP***

DECHAROEN™ CVP as shown in Figure 3 is one of horizontal design multiple compartment pans, which provide a number of mixed cells in series and rely on natural circulation. Its distinguish feature is the pan with double calandrias, double heating steam inlets and double vapour outlets to condenser. The double calandrias were developed for good circulating, high heat transfer rates, and uniform condition in the pan. The double steam inlets and double vapour outlets were developed for easy measuring and controlling absolute pressure and maintaining steady vacuum condition (Demier International, 2016).Good crystallization conditions within the pan, minimizing condenser load, improving steam economy (operated with Vapour 2 or even Vapour 3), and reducing sucrose loss can be thus easily achieved. Additionally, the double calandrias can be completely separated into two single calandrias, which are able to operate in different conditions, and also alternate with varying capacity (Limsutthipong, 2016).

The continuous sugar production and pan cleaning can be easily obtained. The new pan, therefore, is more available and flexible. The principal benefits are specified as the design objective are better sugar quality, higher capacity, less steam and power consumption (Puanghom & Limsutthipong, 2016).

## 4. Methodology

*Prognostic method-* is an engineering discipline focused on predicting the time at which a system or a component. Prognostics predict the future performance of a component by assessing the extent of deviation or degradation of a system from its expected normal operating conditions.

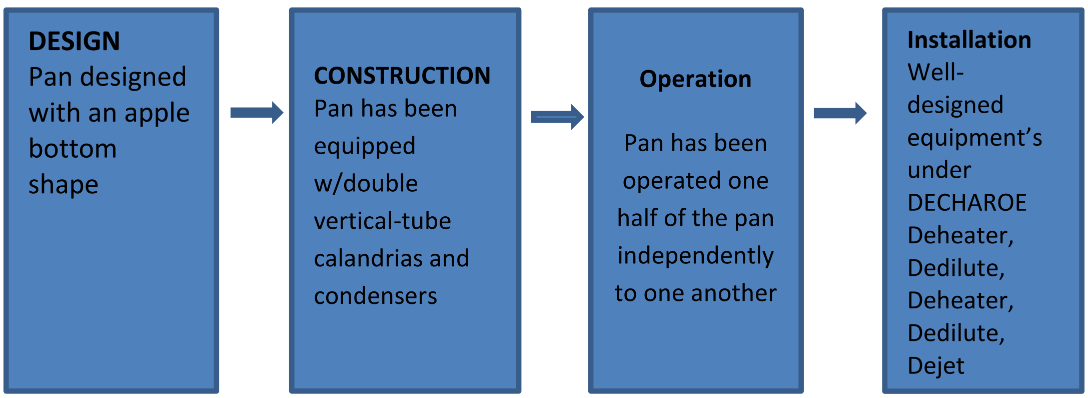


Figure 4. Process of DECHAROEN™ Technology

In order to provide crystallization process shown in Figure 4 with high efficiency and high steam economy for cane sugar industry to assess the quantity and quality of sugar, the DECHAROEN™ technology was first introduced by Demier group in 2016. Based on this technology, various cost-effective solutions to implement these experimental steps.

The study conducted by Demier group, (2016). There are three distinguishing features of this pan, which have a positive effect on both the product quality and quantity. Firstly, the pan has been designed with an apple bottom shape to provide good massecuite circulation. Second, the pan has been equipped with double vertical tube calandrias and double condensers to provide optimal crystallization conditions. Lastly, the pan has been installed with a center partition, so that one half of the pan can be operated independently of another. This characteristic offers the ability to clean one half of the pan while another half is still in operation. In addition, the DECHAROEN™ CVP's have a capability to operate with minimal steal consumption and to operate on bleed vapor 1, vapor 2, or even vapor 3 from evaporators. They also can be utilized for all A, B and C massecuite production duties in various sugar boiling schemes. Additionally, the well-designed equipments i.e., DEHEATER, DEDILUTE, and DEJET as well as the well-selected very fine seed in the form of slurry called DESEED to enhance the efficiency of crystallization process.

## 5. Statistical Treatment

*Research Locale*

Thailand has emerged as one of the largest production of sugar cane and sugar world with highest number of factories and became a potential belt area according to International Sugar Congress, 2013. The area as such as in the top on many indicators such as number of sugar factories, crushing capacity, cane crushed, cane recovery, etc. Thailand is the home area researcher, it was chosen on convenient bases as the study area for the purpose of the present investigation. Decharoen technology was sampled in five sugar factories in Southern Province of Thailand including Mitr Phol Sugar Co.,Ltd, Saraburi Sugar Co., Ltd, Khon Kaen Sugar Co., Ltd, New Roamphol Sugar Co.,Ltd, New Krung Thai Sugar Factory Co., Ltd and Sukothai Sugar Industry Co., Ltd.

*Data gathering*

Decharoen Technology was sampled in 5 sugar factories in Southern Province of Thailand including Mitr Phol Sugar Co.,Ltd, Saraburi Sugar Co., Ltd, Khon Kaen Sugar Co., Ltd, New Roamphol Sugar Co.,Ltd, New Krung Thai Sugar Factory Co., Ltd and Sukothai Sugar Industry Co., Ltd. using an appropriate design for each factory based on the cane tons capacity per day, steam requirements, ideal brand for software and space of the factory for each machineries and instruments. The researcher has decided to cover the period of one year, which starts from 2015-2016. It was considered as appropriate for the analysis of sugar factory units a period of time.

*Instrumentation*

The data draw from the questionnaire is analysis with the help of various tools and techniques. The statistical tool like percentage change is used and geographical location, area, size, age, crushing capacity, and nature of production.

## 6. Results and Discussion

### A. Quantity

MITR PHOL SUGAR – 18, 000 TCD

Table 1. Comparison results of the quantity of raw sugar

| Quantity | Batch pan (Before) | Standard Proposed technique of New CVP (After) | Results (Percentage change) | Remarks |
|---|---|---|---|---|
| Steam requirement for 65 °Bx syrup feed | 56.2 | 38.3 | 31.85% | Decrease |
| Steam requirement for 60 °Bx syrup feed | 72.04 | 48.6 | 32.54% | Decrease |
| Cooling water requirement for condenser ($m^3/hr$) | 50Vv[1] | 40 Vv[1] | 20% | Decrease |
| Mother Liquor exhaustion (%) | 59 | >62 | 5.08% | Increase |
| Purity drop (%) | 19 | >21 | 10.53% | Increase |
| Crystal content (%) | 46 | 49 | 6.52% | Increase |
| Crystal size distribution | 27 | <26 | 3.7% | Decrease |

[1] $V_V$ *is the volume flow rate of inlet vapour of condenser*

SARABURI SUGAR-18,000 TCD

Table 2. Comparison results of the quantity of raw sugar

| Quantity | Batch pan (Before) | Standard Proposed technique of New CVP (After) | Results (Percentage change) | Remarks |
|---|---|---|---|---|
| Steam requirement for 65 °Bx syrup feed | 60.5 | 38.3 | 36.69% | Decrease |
| Steam requirement for 60 °Bx syrup feed | 75.08 | 48.6 | 32.27% | Decrease |
| Cooling water requirement for condenser ($m^3/hr$) | 65Vv[1] | 40 Vv[1] | 38.46% | Decrease |
| Mother Liquor exhaustion (%) | 56 | >62 | 10.71% | Increase |

| Quantity | Batch pan (Before) | Standard Proposed technique of New CVP (After) | Results (Percentage change) | Remarks |
|---|---|---|---|---|
| Purity drop (%) | 17 | >21 | 23.53% | Increase |
| Crystal content (%) | 40 | 49 | 11.36% | Increase |
| Crystal size distribution | 28 | <26 | 7.14 | Decrease |

*[1]$V_V$ is the volume flow rate of inlet vapour of condenser*

KHON KAEN SUGAR-18,000 TCD

**Table 3. Comparison results of the quantity of raw sugar**

| Quantity | Batch pan (Before) | Standard Proposed technique of New CVP (After) | Results (Percentage change) | Remarks |
|---|---|---|---|---|
| Steam requirement for 65 °Bx syrup feed | 70 | 38.3 | 45.29% | Decrease |
| Steam requirement for 60 °Bx syrup feed | 80 | 48.6 | 39.25% | Decrease |
| Cooling water requirement for condenser ($m^3$/hr) | 60Vv[1] | 40 Vv[1] | 33.33% | Decrease |
| Mother Liquor exhaustion (%) | 53 | >62 | 16.98% | Increase |
| Purity drop (%) | 15 | >21 | 40% | Increase |
| Crystal content (%) | 39 | 49 | 11.36 | Increase |
| Crystal size distribution | 28 | <26 | 7.14% | Decrease |

*[1]$V_V$ is the volume flow rate of inlet vapour of condenser*

NEW KRUNG THAI SUGAR-18,000 TCD

**Table 4. Comparison results of the quantity of raw sugar**

| Quantity | Batch pan (Before) | Standard Proposed technique of New CVP (After) | Results (Percentage change) | Remarks |
|---|---|---|---|---|
| Steam requirement for 65 °Bx syrup feed | 57.2 | 38.3 | 33.04% | Decrease |
| Steam requirement for 60 °Bx syrup feed | 74.04 | 48.6 | 34.36% | Decrease |
| Cooling water requirement for condenser ($m^3$/hr) | 60Vv[1] | 40 Vv[1] | 33.33% | Decrease |
| Mother Liquor exhaustion (%) | 56 | >62 | 10.71% | Increase |
| Purity drop (%) | 18 | >21 | 16.67% | Increase |
| Crystal content (%) | 44 | 49 | 11.36% | Increase |
| Crystal size distribution | 27 | <26 | 3.7% | decrease |

*[1] $V_V$ is the volume flow rate of inlet vapour of condenser*

SUKOTHAI SUGAR CO LTD-18,000 TCD

**Table 5. Comparison results of the quantity of raw sugar**

| Quantity | Batch pan (Before) | Standard Proposed technique of New CVP (After) | Results (Percentage change) | Remarks |
|---|---|---|---|---|
| Steam requirement for 65 °Bx syrup feed | 60.5 | 38.3 | 36.69% | Decrease |
| Steam requirement for 60 °Bx syrup feed | 76.04 | 48.6 | 36.09% | Decrease |
| Cooling water requirement for condenser ($m^3$/hr) | 76Vv[1] | 40 Vv[1] | 47.37% | Decrease |
| Mother Liquor exhaustion (%) | 55 | >62 | 12.73% | Increase |
| Purity drop (%) | 16 | >21 | 31.25% | Increase |
| Crystal content (%) | 44 | 50 | 13.64% | Increase |
| Crystal size distribution | 27 | <28 | 3.7% | decrease |

*[1] $V_V$ is the volume flow rate of inlet vapour of condenser*

Table 1-5 (QUANTITY) summarizes the comparison results it is evident that the steam requirements for 65 °Bx drop to (31.85%, 36.69%,45.29%, 33.04%, 36.69%) and 60 °Bx syrup feed drop to (32.54%, 32.27%, 39.27%, 39.25%, 43.36%, 36.09%) respectively the major parameters according to Cane Sugar Handbook, John Wiley, USA, 2015 for footing the pan with raw syrup of the single stage and two-stage production C-seed is 38 (65 °Bx) and 66 (60 °Bx), and the cooling requirement also drops to (20%,38.46%,33.33%,33.33%,47.37%) which is around 35-40 V**v**[1] returns through gravity channel and it is pumped to the condenser. This cold water will be then passed to the condenser for cooling purpose. Proposed system will be able to cool the condenser cooling water to lower temperature. The power required for spraying the water will be saved. It also expected because of low temperature of cooling water rate of condensation of cooling water will be more and it will create more vacuum in the evaporator and pans. This will lower down the boiling point in the evaporator and it will reduce steam consumption and ultimately result in bagasse saving. As the particulate matter in gases is reduced due to scrubbing system, it will reduce the pollution at the factory site. As the temperature of cooling water is less the quantity of water required for condensing vapours will also is less (Chouhan & Chandrakar 2014).The main objective in sugar pan boiling is to achieve the highest yield of crystals from massecuite and correlatively the lowest drop in purity and high mother liquor exhaustion. The purity drop of a proposed system (>21) and (>62) for mother liquor exhaustion will result to better sugar quantity and quality by massecuite purity of >21 and volume flow rate of >62. Crystal content of (47 -50 company data) of a proposed system was achieved and a maximum requirements for crystal distribution is 47 above average and crystal size distribution requirements of <28. Careful observations of variations of the work led to investigations of efficiency of vacuum pumps, condenser water supply, steam supply, temperatures of boiling's, boiling time, quantity and quality of grain, early establishment of metastable super saturation in every boiling, highest concentration of Brix possible without causing loss of time in striking, and even the steaming of pan and also feeding of massecuites cooling in crystallizers. At the curing station: routine check of speed of centrifugal, quantity of steam and water used, check of possible perforated screens, proper separation of molasses and sugar washings (Turner, 2015)

It is proposed to estimate the saving in power by this arrangement.

**B. Quantity**

**Table 1. Comparison results of quality raw sugar of about 99°Z gathered from MITRL PHOL Co.Ltd based on Decharoen Brand.**

| Quality | Before | After Improvement | Results (Percentage Change) | Remarks |
|---|---|---|---|---|
| Purity of syrup (%) | 83.37 | 82.63 | 0.89% | Decrease |
| Purity of A massecuite % | 85.33 | 58.21 | 31.78% | Decrease |
| Purity of A molasses % | 67.86 | 66.54 | 1.95% | Decrease |
| Crystal content of A massecuite % solids | 54.36 | 55.80 | 2.65% | Increase |
| Exhaustion of A massecuite % | 63.70 | 65.45 | 2.75% | Increase |
| Purity drop for A boiling | 17.47 | 18.67 | 6.87% | Increase |
| Purity of B massecuite % | 71.92 | 71.27 | 0.9% | Decrease |
| Purity of B molasses % | 47.96 | 47.34 | 1.29% | Decrease |
| Crystal content of B massecuite % solids | 46.04 | 47.44 | 3.04% | Increase |
| Purity drop for B boiling | 23.96 | 23.93 | 0.13% | decrease |
| Purity of C massecuite % | 55.41 | 54.69 | 1.3% | Decrease |
| Purity of C molasses % | 34.10 | 31.52 | 7.57% | Decrease |
| Crystal content of massecuite % solid | 32.34 | 32.37 | 0.09% | Increase |
| Purity drop for C boiling | 21.31 | 22.17 | 4.04% | Increase |
| Boiling house recovery % | 82.61 | 83.13 | 0.63% | Increase |
| Yield (%C.C.S) | 87.86 | 90.05 | 2.49% | Increase |
| Losses in the final molasses % | 9.52 | 8.46 | 11.13% | Decrease |
| Total losses % | 21.79 | 20.64 | 5.28% | Decrease |
| Steam used (kg/ton cane) | 456.05 | 402.88 | 11.66% | Decrease |
| Electrical power used (kWh/ton cane) | 17.46 | 16.34 | 6.41% | Decrease |

** Purified and crystallized sucrose (saccharides) with a polarization not less than 99.7 °Z*

**Table 2. Comparison results of quality raw sugar of about 99°Z gathered from SARABURI Co.Ltd based on Decharoen Brand.**

| Quality | Before | After Improvement | Results (Percentage Change) | Remarks |
|---|---|---|---|---|
| Purity of syrup (%) | 84.50 | 82.63 | 2.21% | Decrease |
| Purity of A massecuite % | 88.33 | 58.21 | 34.1% | Decrease |
| Purity of A molasses % | 69.86 | 66.54 | 4.75% | Decrease |
| Crystal content of A massecuite % solids | 50.36 | 55.80 | 10.8% | Increase |
| Exhaustion of A massecuite % | 60.70 | 65.45 | 7.83% | Increase |
| Purity drop for A boiling | 15.47 | 18.67 | 20.69% | Increase |
| Purity of B massecuite % | 71.92 | 70.27 | 2.29% | Decrease |
| Purity of B molasses % | 47.96 | 46.34 | 3.38% | Decrease |
| Crystal content of B massecuite % solids | 46.04 | 47.44 | 3.04% | Increase |
| Purity drop for B boiling | 22.96 | 23.93 | 4.09% | Decrease |
| Purity of C massecuite % | 55.41 | 52.69 | 4.91% | Decrease |
| Purity of C molasses % | 34.10 | 30.52 | 10.5% | Decrease |
| Crystal content of massecuite % solid | 32.34 | 32.37 | 0.09% | Increase |
| Purity drop for C boiling | 21.31 | 23.17 | 8.73% | Increase |
| Boiling house recovery % | 82.61 | 85.13 | 3.05 | Increase |
| Yield (%C.C.S) | 87.86 | 92.05 | 4.77 | Increase |
| Losses in the final molasses % | 9.52 | 7.46 | 21.64% | Decrease |
| Total losses % | 21.79 | 20.64 | 5.28% | Decrease |
| Steam used (kg/ton cane) | 456.05 | 400.88 | 12.1% | Decrease |
| Electrical power used (kWh/ton cane) | 17.46 | 15.34 | 12.14% | Decrease |

**Purified and crystallized sucrose (saccharides) with a polarization not less than 99.7 °Z.*

**Table 3. Comparison results of quality raw sugar of about 99°Z gathered from KHON KAEN Co.Ltd based on Decharoen Brand.**

| Quality | Before | After Improvement | Results (Percentage Change) | Remarks |
|---|---|---|---|---|
| Purity of syrup (%) | 86.37 | 82.63 | 4.33% | Decrease |
| Purity of A massecuite % | 87.33 | 58.21 | 33.34% | Decrease |
| Purity of A molasses % | 67.86 | 65.54 | 3.42% | Decrease |
| Crystal content of A massecuite % solids | 54.36 | 56.80 | 3.54% | Increase |
| Exhaustion of A massecuite % | 63.70 | 67.45 | 5.89% | Increase |
| Purity drop for A boiling | 17.47 | 19.67 | 12.59% | Increase |
| Purity of B massecuite % | 70.92 | 70.27 | 0.92% | Decrease |
| Purity of B molasses % | 47.96 | 46.34 | 3.38% | Decrease |
| Crystal content of B massecuite % solids | 46.04 | 48.44 | 5.21% | Increase |
| Purity drop for B boiling | 24.96 | 23.93 | 4.13% | Decrease |
| Purity of C massecuite % | 57.41 | 54.69 | 4.74% | Decrease |
| Purity of C molasses % | 36.10 | 31.52 | 12.69% | Decrease |
| Crystal content of massecuite % solid | 32.34 | 34.37 | 6.28% | Increase |
| Purity drop for C boiling | 21.31 | 24.17 | 13.42% | Increase |
| Boiling house recovery % | 82.61 | 85.13 | 3.05% | Increase |
| Yield (%C.C.S) | 87.86 | 95.05 | 8.18% | Increase |
| Losses in the final molasses % | 9.52 | 8.46 | 11.13% | Decrease |
| Total losses % | 21.79 | 20.64 | 5.28% | Decrease |
| Steam used (kg/ton cane) | 456.05 | 401.88 | 11.88% | Decrease |
| Electrical power used (kWh/ton cane) | 17.46 | 14.34 | 17.87% | Decrease |

**Purified and crystallized sucrose (saccharides) with a polarization not less than 99.7 °Z.*

**Table 4. Comparison results of quality raw sugar of about 99°Z gathered from NEW KRUNGTHAI Co.Ltd based on Decharoen Brand.**

| Quality | Before | After Improvement | Results (Percentage Change) | Remarks |
|---|---|---|---|---|
| Purity of syrup (%) | 84.37 | 82.63 | 2.06% | Decrease |
| Purity of A massecuite % | 86.33 | 58.21 | 32.57% | Decrease |
| Purity of A molasses % | 66.86 | 66.54 | 0.48% | Decrease |
| Crystal content of A massecuite % solids | 52.36 | 55.80 | 6.57% | Increase |
| Exhaustion of A massecuite % | 62.70 | 65.45 | 4.39% | Increase |
| Purity drop for A boiling | 16.47 | 18.67 | 13.36% | Increase |
| Purity of B massecuite % | 72.92 | 71.27 | 2.26% | Decrease |
| Purity of B molasses % | 48.96 | 47.34 | 3.31% | Decrease |
| Crystal content of B massecuite % solids | 45.04 | 47.44 | 5.33% | Increase |
| Purity drop for B boiling | 24.96 | 23.93 | 4.13% | Decrease |
| Purity of C massecuite % | 56.41 | 54.69 | 3.05% | Decrease |
| Purity of C molasses % | 35.10 | 31.52 | 10.2% | Decrease |
| Crystal content of massecuite % solid | 32.34 | 32.40 | 0.19% | Increase |
| Purity drop for C boiling | 20.31 | 22.17 | 9.16% | Increase |
| Boiling house recovery % | 82.61 | 84.13 | 1.85% | Increase |
| Yield (%C.C.S) | 87.86 | 93.05 | 5.91% | Increase |
| Losses in the final molasses % | 9.52 | 6.46 | 32.14% | Decrease |
| Total losses % | 21.79 | 18.64 | 14.46% | Decrease |
| Steam used (kg/ton cane) | 456.05 | 401.85 | 11.88% | Decrease |
| Electrical power used (kWh/ton cane) | 17.46 | 16.34 | 6.41% | Decrease |

**Purified and crystallized sucrose (saccharides) with a polarization not less than 99.7 °Z.*

**Table 5. Comparison results of quality raw sugar of about 99°Z gathered from SUKOTHAI Co.Ltd based on Decharoen Brand.**

| Quality | Before | After Improvement | Results (Percentage Change) | Remarks |
|---|---|---|---|---|
| Purity of syrup (%) | 86.37 | 82.63 | 4.33% | Decrease |
| Purity of A massecuite % | 88.33 | 58.21 | 34.1% | Decrease |
| Purity of A molasses % | 68.86 | 66.54 | 3.37% | Decrease |
| Crystal content of A massecuite % solids | 52.36 | 55.80 | 6.57% | Increase |
| Exhaustion of A massecuite % | 62.70 | 65.45 | 4.39% | Increase |
| Purity drop for A boiling | 16.47 | 18.67 | 13.36% | Increase |
| Purity of B massecuite % | 72.92 | 71.27 | 2.26% | Decrease |
| Purity of B molasses % | 48.96 | 47.34 | 3.31% | Decrease |
| Crystal content of B massecuite % solids | 45.04 | 47.44 | 5.33% | Increase |
| Purity drop for B boiling | 24.96 | 23.93 | 4.13% | Decrease |
| Purity of C massecuite % | 56.41 | 54.69 | 3.05% | Decrease |
| Purity of C molasses % | 35.10 | 31.52 | 10.2% | Decrease |
| Crystal content of massecuite % solid | 31.34 | 32.37 | 7.78% | Increase |
| Purity drop for C boiling | 20.31 | 22.17 | 9.16% | Increase |
| Boiling house recovery % | 82.61 | 83.13 | 0.63% | Increase |
| Yield (%C.C.S) | 87.86 | 90.05 | 2.49% | Increase |
| Losses in the final molasses % | 11.52 | 8.46 | 26.5% | Decrease |
| Total losses % | 21.79 | 20.64 | 5.28% | Decrease |
| Steam used (kg/ton cane) | 456.05 | 401.88 | 11.88% | Decrease |
| Electrical power used (kWh/ton cane) | 19.46 | 16.34 | 16.03% | Decrease |

**Purified and crystallized sucrose (saccharides) with a polarization not less than 99.7 °Z.*

Table 1-5 (QUALITY) summarizes the comparison results of a proposed technique to provide more efficient crystallization has been describe. For comparison purpose, the purities of raw syrup, A molasses, and B molasses to produce the high quality C seed with 64-65 purity are 83%, 67% and 50%, respectively.

The graining volume of the pan up to the level of the top tube plate is 38% of the pan strike volume. It shown that the proposed technique provides more efficient crystallization with higher exhaustion and higher purity drop in the A boilings and lower purity in the final molasses. Additionally, the steam and electrical power requirements drop to 11.66% and 6.41% Office of the Cane and Sugar Board (OCSB) 2015. It is evident that utilizing the proposed technique produces the raw sugar with acceptable characteristics.

## 7. Conclusion

The improving cane sugar crystallization has been presented in this research. The proposed technique uses the new continuous vacuum pan to replace the conventional batch pan. Improving results observed from five cane sugar manufacturers in Thailand verify that using the new pan branded DECHAROEN ™ is efficient. The innovative design offers continuous production and enhances both quality and quantity of sugar crystallization.

*Key benefits are:*

1. Efficient personnel utilization- **Training & Development**
2. High sugar recovery- **Production rates of 50%-120% of the design rate**
3. Product consistency- **High sugar recovery rate of 99.99%**
4. Low maintenance and repair costs- **Total saving due to installation is P25M over P15M investment**
5. Higher revenues and profits- **Revenues rose by 49.5% in 9 months to P 3.11 Billion in 2016**
6. Low energy consumption- Saving **cost of electrical power per crushing season is P3M**
7. Operability or suitability- **Continuous operation of the pan**

## 8. REFERENCES:


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