International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869, Volume-2, Issue-6, June 2014

Sugar crystallization in low temperatures: The theory and practice by advanced sugar crystallization control program

Yassien M.Temerk, Osama Z.El-Abdein, Ibrahim D. Abdullah, and Sherif T. Amin

***Abstract*— Most of recent advanced sugar crystallization controlling programs aims to get the highest sugar yield and quality with minimum cost. This work is the second part of advanced sugar crystallization control program project which based on mathematical model, and focusing in the sugar crystallization in low temperatures with advantages of achievement the highest productivity and quality with cost reduction. The theory based on theoretical comparison between parameters and quantities obtained from crystallization of a certain sugar grade at same conditions of end crystal content and supersaturation and two different operating temperatures by using data of the advanced crystallization control program. The theory was implemented for R1 and R4 sugar crystallization in united sugar company of Egypt USCE and obtained results simulated with that in practice and listed for analysis and discussions.**

***Index Terms*— Crystallization control, Crystallization parameters, sugar crystallization in low temperatures.**

I. INTRODUCTION

A. *Sugar crystallization process*

Crystallization in a factory takes place under vacuum and involves masses transfer and evaporation processes. Vacuum is necessary to keep the temperature at a low level to minimize color formation and the inversion or degradation of sucrose in the process.

In starting a batch boiling, liquor is concentrated until meta stable zone reached (see fig.I.1). Crystallization is initiated by adding a slurry of sugar fines and alcohol, which provides the nuclei to start crystallization. The concentration of mother liquor surrounding sugar crystals is controlled so that crystallization occurs without dissolving any crystal or forming any new nuclei (false grain). This requires the establishment of sufficient surface area and control of the feed to the pan to control mother liquor concentration.

The process has been traditionally carried out in batch vacuum pans and recently continuous systems have been introduced. In some cases, the process is started on a magma or footing which is a mixture of a liquor and a crystals from a previous seeding, thus avoiding the seeding process.

Sugar boiling is one of the most important parameters in producing sugar. There is awareness in the sugar industry regarding the importance of product quality and the cost of production. It is generally agreed that the most important parameter in crystallization control is supersaturation, followed by crystal content [1].

B. *Solubility and supersaturation: key parameters of crystallization*

a. *Solubility of sucrose in pure sucrose solution*

Sucrose is highly soluble in water. A saturated solution of sucrose contain two parts of sucrose to one part of sucrose at room temperature, and almost five parts sucrose to one part of water at 100 ºC. In order to crystallize sucrose, it is necessary to raise concentration of sucrose above that of saturated solution, and control it at the high concentration to achieve the required crystallization quality. Therefore it is important to establish the sucrose concentration at saturation under the operating conditions [2].

The saturation coefficient q sat, p is the solubility at saturation of pure sucrose in water, expressed in g sucrose/g water thus:

$$q_{sat,\ p} = w_{s,\ sat,\ p} / (100 - w_{s,\ sat,\ p}) \qquad I.1$$

The solubility coefficient SC is used to represent the ratio of the concentration of sucrose in an impure saturated solution to the concentration in a pure solution saturated at the same temperature, and defined as:

$$SC = (W_s/W_w)_{sat,\ i} / (W_s/W_w)_{sat,\ p} = q_{sat,\ I} / q_{sat,\ p} \qquad I.2$$

For a supersaturated solution, whether pure or impure, the degree of supersaturation is expressed by the supersaturation coefficient y. calculated by dividing the sucrose /water ratio of supersaturated solution by sucrose/water ratio of a saturated solution under the same conditions of temperature and purity[3]. The supersaturation coefficient indicates whether the solution is unsaturated ($y<1$), saturated ($y=1$), supersaturate($y>1$).

It is defined as: $$y = (W_s/W_w) / (W_s/W_w)_{sat} \qquad I.3$$

Manuscript received June 07, 2014.

Yassien M. Temerk, Chemistry department, Assuit University / Faculty of Science/ Assuit University, Assuit , Egypt, Mobile No. 00201227370769,

Osama Z. El-Abdein, Chemistry department, Sugar Technology Research Institute / United sugar company of Egypt USCE, Suez, Egypt, Mobile No.00201000102845

Ibrahim D. Abdulla, Chemistry department, Assuit University/ Sugar Technology Research Institute/ Egyptian Sugar and Integrated Industries Company, City Hawamdia, Egypt, Mobile No.00201122555173.

Zones of saturation for pure sucrose solution:

1) Stable zones: Sucrose solution is still under saturated, no nucleation or crystal growth occurs and any added crystals will dissolve.

2) Meta stable zone: sucrose solution is slightly supersaturated and if left in this condition no change will occur, sugar crystals added will grow.

3) Intermediate Zone: Sucrose solution is over supersaturated and new crystals will form in the presence of existing crystals.

4) Labile Zone: Solution is very unstable and spontaneous nucleation can occur.

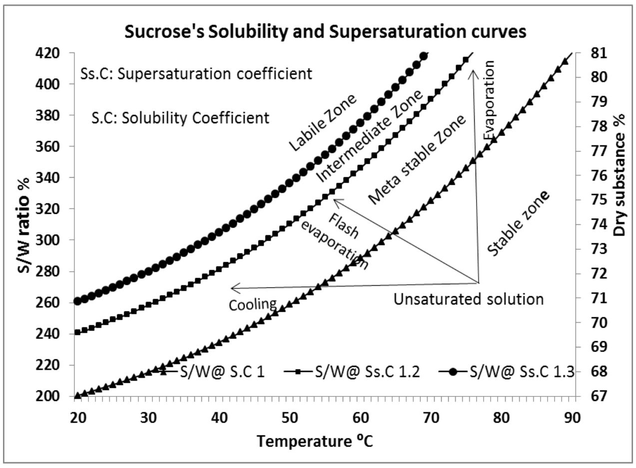


Fig. I.1. Solubility of pure sucrose in water as function of temperature by the program.

The solubility and supersaturation coefficients of pure sucrose solution by Vavrinecz [4]. Shown in (figI.1) Saturation is represented for the curve Ss.C =1 .The meta stable region of supersaturation coefficient between 1 and 1.2. In this region, sugar crystals added will grow but no new sugar nuclei will form. This is the region the crystallization should be controlled. The intermediate region lie between Sc.C1.2 and 1.3, in which the crystals will continue to grow but new nuclei will form in the presence of sugar crystals (secondary nucleation). The labile region above a supersaturation of 1.3 is, in this region nucleation will occur spontaneously (primary nucleation). Solutions of lower purity will require a higher degree of supersaturation to induce nucleation than that of high purity that has narrow zones of saturation.

For an under saturated solution at appoint below saturation curve (fig.I.1), the solution can be moved into the supersaturated region by evaporation at constant temperature or by cooling at a constant dissolved solid content.

b. Solubility of sucrose in technical solutions

Regarding sucrose solubility variation corresponding to the presence of different nonsugars, various authors, and in particular Silin[8] have studied either their effect as a whole or the effect excreted by single compounds. In general, nonsugars as whole decrease sucrose solubility at low $q_{NS/W}$ (nonsugar water ratio), and increases it at high nonsugar concentrations:

$$y_{sat} = a \times q_{NS/W} + b + (1-b) \times \exp.(-c \times q_{NS/W}) \qquad \text{I.4}$$

The values generally used in practice go back to data of Grut [5] and are compiled by Bubnik et al. [6].

C. Masseciute Crystal content CC

Besides supersaturation, which is the most important parameter of crystallization, crystal content has important role, too. The equations of crystal content in g/100g massecuite CC %Masc., and the crystal content in g/100 g massecuite solids CC % Masc. so are given in equations I.5,I.6

$$\text{CC \% Masc.} = 100 \times \frac{\text{MSc bx} \times (\text{PMa} - \text{PMol})}{\text{PMa} \times (100 - \text{PMol})} \qquad \text{I.5}$$

$$\text{CC \% Masc.} = 100 \times \frac{(\text{PMa} - \text{PMol})}{\text{PMa} \times (100 - \text{PMol})} \qquad \text{I.6}$$

Where: PMa   purity of massecuite and PMol   purity of mother liquor

The amount of crystals in the massecuite is usually a limiting factor in crystallization .The crystal content may get so high that the massecuite virtually solid and crystallization must be halted before the viscosity of massecuite gets too high.

A higher mother liquor viscosity to some extent lowers the permissible crystal content. It is therefore important to have some kind of indication on crystal content. In practice, the crystal content of massecuite should be set at the highest level that, with a high viscosity of mother liquor, will give massecuite of maximum viscosity, consistent with workability.

Table I.2. Target crystal content values for massecuite of different purities [7].

	MSC. Purity	CC%MSC. solids	CC% MSC.	Exhaustion
Refined boiling	99	64	57	-
A massecuite	85	57	52.5	67
B massecuite	68	42.5	40	61

D. Crystal size distribution CSD

The Crystal size is important in produced sugar because it usually has to meet some consumer quality specification. The most common size ranged between 0.4 to 0.8 mm. Larger crystal sizes have less surface area per unit mass easier to process in centrifugation because the quantity of surface film is less on larger crystals. However the larger surface area of smaller crystals enhances the rate of crystallization.

Crystal size distribution is also important, the more uniform crystal size distribution, the easier the centrifugal separation. Small crystals fill the gabs between larger crystals, resulting in a layer of crystal in the centrifugal which does not purge easily, also may pass through screen apertures, leading to lower molasses exhaustion.

Crystal size distribution is generally characterized by coefficient of variation CV, which is defined as:

$$CV = 100\times \sigma / dm \qquad I.7$$

Where dm is the mean crystal size and σ the standard deviation of distribution. As the crystal growths, the mean size increases so CV can be expected to decrease.

Crystal size measurement is defined in equation I.7 as the standard deviation of crystal size distribution divided by the mean and expressed as percentage. In a high grade boiling, a CV of around 30 is good, but a lower CV is easier to achieve with a larger crystal mean aperture. As alternative, a limit on the amount of fines around 5% is used as a size control parameter.

E. Batch evaporating crystallization.

In evaporating crystallization, supersaturation is produced by the evaporation of water. In the process, the dry substance content of the solution or of the crystal suspension (magma), consisting of sugar crystals and mother liquor, increases. Consequently, either the solubility limit is exceeded or the crystallization process eventually initiated by nucleation or injection of crystallizate (slurry, seed magma crystallizate), or crystals already present are induced to grow.

For energy reasons and because of thermal sensitivity of the solutions, technical sugar crystallization is carried out under reduced pressure (vacuum) in equipment specially designed for this purpose. Industrial equipment (vacuum pan) for the evaporating crystallization of sugar is operated batch wise or continuously. Batch evaporating crystallization phases are shown in fig.I.2

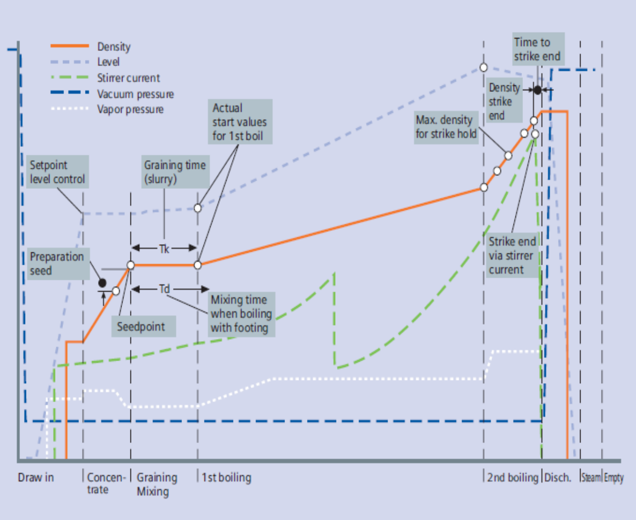


Fig.I.2. Siemens NAHMAT pan control batch evaporating Cycle

F. Why boiling in low operating temperatures is preferable?

A significant loss of sucrose can occur during crystallization operations. For this reason it is advantageous to reduce boiling temperatures to a practical and minimize residences times in crystallization. High massecuite exhaustions which reduce the total amount of massecuite to be boiled help to keep the losses to the minimum. The lower boiling temperatures also enable vapor bleeding from the evaporators to be used as heating steam in the clanadria with an adequate temp. difference for heat transfer. Most massecuite boiling occurs with massecuite temperature in the range of 63 to 70 °C (raw cane sugar). Fore refined boilings, the temperature is maintained somewhat higher to prompt the rate of crystallization. The boiling time is much reduced and elevated temperature can be tolerated cane sugar engineering 2007 [7].

II. EXPERIMENTAL WORK

A. Scientific Selection of controlling parameters to achieve optimum efficiency at different conditions

Auto scientific selection of parameters such as liquor feed rate control (start and end boiling level, brix) from solubility and supersaturation curve of pure or impure sucrose solution using solubility's values of Vavrinecz [4], Bubnik [6] respectively and pan working volume . The derivation of seed brix, end mother liquor purity, end mother liquor brix, and end massecuite brix by Osama [9] as follow:

a. Seeding brix derivation from corresponding, SS feed purity, and S/W ratio:

If: feed purity 99 % at 75 ° C and SS 1.05, Sugar solubility S/W = 343%, seed brix (Y) =?

$$1.05 = \frac{S/W\ @SS\ 1.05}{S/W}$$

$$S/W = 1.05 \times 343 = 360.15\ \%$$

$$S/W = (\text{Sugar content} / \text{Water content}) \times 100$$

$$360.15 = \frac{(\text{feed purity} \times Y) \times 100}{(100 - Y)}$$

$$360.15\times 100 - 360.15\,Y = 99\,Y$$

$$36015 = (360.15 + 99)\,Y$$

$$Y = 36015 / 459.15$$

$$= 78.438\ \ \%$$

$$\textbf{Seeding brix} = \frac{\textbf{Corresponding S/W ratio} \times \textbf{100}}{\textbf{Corresponding S/W ratio + feed purity}}\ \% \qquad II.1$$

b. End ML purity derivation from feed liquor purity, sugar purity and CC by Ozein [9] division pattern

If: feed purity FEp= 99%, sugar purity SUp= 99.85%, and crystal content CC = 55%

Massecuite solids (Masc. solids)
100%

Sugar	ML solids
(CC × sugar purity) /100	(Masc. solids – CC)
(55 × 99.85) /100	(100 - 55)
54.9175 %	45 %

ML sugar (feed purity –Sugar) | ML non-sugar (ML solids – ML sugar)

(99 - 54.92) 44.083% | (45 – 44.08) 0.918%

ML purity = (ML Sugar /ML solids) × 100
= (44.08/45) × 100
= 97.96 %

$$\textbf{End ML purity} = \frac{\text{FEp} - (\text{CC} \times \text{SUp}/100) \times 100}{100 - \text{CC}}\ \% \qquad \text{II.2}$$

c. *End mother liquor ML brix derivation from end ML purity and corresponding sugar water ratio*

For 99% feed purity S/W = 366% at 80 ºC, S/W at SS 1.05 = 366 × 1.05 = 384.3%

ML Purity = (sugar content/ ML Brix) × 100
ML Brix = 100 – water content
Sugar content = S/W% × water content

$$\text{ML purity} = \frac{(\text{S/W} \times \text{water content})/100}{100 - \text{water content}} \times 100$$

ML purity ×100 – ML purity ×water content = S/W ×water content

$$\text{Water content} = \frac{\text{ML purity} \times 100}{\text{ML purity} + \text{S/W}}$$

ML brix = 100 – (9796.111/482.261)
= 79.69 %

$$\textbf{End ML Brix} = 100 - \frac{(\text{End ML purity} \times 100)\ \%}{(\text{End ML purity} + \text{S/W})} \qquad \text{II.3}$$

d. *End massecuite brix (let it X) derivation from end ML brix:*

$$\text{ML brix} = \frac{\text{ML solids} \times 100}{\text{ML solids} + \text{water content}}$$

$$\text{ML brix} = \frac{(\text{Masc. brix} \times \text{ML solid yield}/100) \times 100}{(\text{Masc. brix} \times \text{ML solid yield}/100) + \text{water content}}$$

$$79.6781 = \frac{(0.45\,X) \times 100}{(0.45\,X) + (100 - X)}$$

45 X = (79.6871× 0.45X) + 7968.71 – 79.6871 X
45 X = 35.8592X – 79.6781 X + 7967.81
45 X = -43.82791X +7968.71
45X +43.82791 X = 7968.71
X = 7968.71 /88.82791
= 89.709 %

End Massecuite Brix

$$= \textbf{End } \frac{\textbf{MLbx} \times 100\ \%}{(\textbf{End MLbx} - \textbf{End MLbx} \times \textbf{MLso}/100 + \textbf{MLso})} \qquad \textbf{II.4}$$

Crystallization process is a nonlinear and non-stationary process, and the main process nonlinearities are represented by the crystal growth rate, control optimization attempt to reduce the variables that impede the linearity of process [10]. The control of crystal growth rate to be proceeded in a linear rate and SS of mother liquor within Meta stable zone depends on regular liquor feed and evaporation that easily be achieved by formulating linear level /brix relationship. Fig. II.1. represents the flow chart of program control which is basically based on the tracking of SS during crystallization.

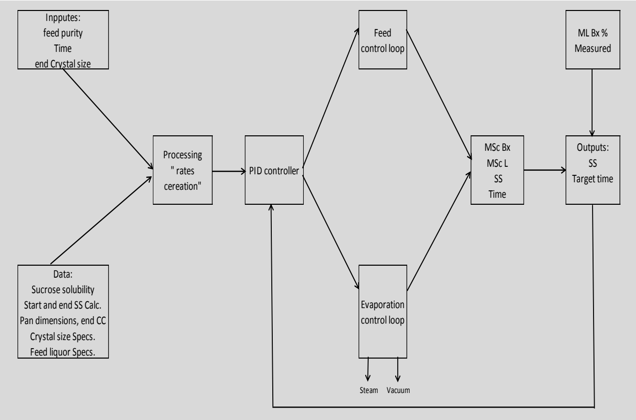


Fig. II. 1. Program control flow chart

Tble.II.1. Strike solid balance, parameters for R1 sugar crystallization 99% purity at same start, ends SS 1.05%, working temperatures, and different CC % Masc. solids by the program.

Quantity Q or parameter	60%	55%	50%
Slurry Q 9 to 650 micron ml	444.9	401.1	358.7
Seeding brix %	78.44	78.44	78.44
End Massecuite brix %	**90.77**	**89.71**	**88.64**
Massecuite Q Ton	102.6	102.1	101.6
Massecuite solids Ton	93.13	91.58	90.08
Water content Ton	9.47	10.51	11.50
Massecuite sugar Ton	92.2	90.66	89.18
Massecuite non-sugar Ton	0.93	0.915	0.90
Sugar crystals Ton	**55.88**	**50.37**	**45.04**
Evaporated water Q at72% brix of feed Ton	**26.74**	**25.11**	**23.53**
Mother liquor solids Ton	37.25	41.21	45.04
Mother liquor sugar Ton	36.4	40.37	44.21
Mother liquor non-sugar Ton	0.85	0.84	0.83
Mother liquor quantity Ton	46.73	51.72	56.54
Mother liquor purity %	**97.73**	**97.96**	**98.15**
Mother liquor brix %	**79.73**	**79.69**	**79.66**
Sugar purity %	99.85	99.85	99.85
Wash water Q to77% brix Ton	3.07	3.19	3.31
Dilution water to72 % brix Ton	3.77	4.13	4.47
Overall water quantity Ton	**6.85**	**7.33**	**7.78**

Table II.2. Strike solid balance and parameters for R1 sugar crystallization 99% purity at same 60% CC, start SS1.05%,working temperatures, and different end SS by the program.

Quantity Q or parameter	1%	1.05	1.1
Slurry Q 9 to 650 micron ml	442.1	445	447.7
Seeding brix %	78.44	78.44	78.44
End Massecuite brix %	**90.35**	**90.77**	**91.15**
Massecuite Q Ton	102.4	102.6	102.7
Massecuite solids Ton	92.52	93.13	93.69
Water content Ton	9.88	9.47	9.09
Massecuite sugar Ton	91.59	92.2	92.76
Massecuite non-sugar Ton	0.93	0.93	0.94
Sugar crystals Ton	**55.51**	**55.88**	**56.22**
Evaporated water Q at72% brix of feed Ton	**26.09**	**26.74**	**27.34**
Mother liquor solids Ton	37	37.25	37.48
Mother liquor sugar Ton	36.17	36.40	36.63
Mother liquor non-sugar Ton	0.84	0.86	0.85
Mother liquor quantity Ton	46.89	46.73	46.57
Mother liquor purity %	**97.73**	**97.73**	**97.93**
Mother liquor brix %	**78.93**	**79.73**	**80.47**
Sugar purity %	99.85	99.85	99.85
Wash water Q to77% brix Ton	2.58	3.07	3.52
Dilution water to72 % brix Ton	3.76	3.77	3.90
Overall water quantity Ton	**6.34**	**6.85**	**7.33**

From tables II.2 at same CC 60% the achieved sugar quantities nearly the same, while from cost point of view the evaporated water and overall wash water quantities raised gradually with raise end SS which need high steam and power consumption, so the best choice here is SS 1% . Form table II.1 it is cleared off course the best CC at 60% (55.88t) but highest evaporated water (26.74 t) , so the best parameters choice for purity 99 to 95 is end CC 60% and end SS 1 %, where at this condition the SS trend as shown in fig. II. 2 is still in meta stable zone, While increasing end SS than1% will leads to SS values exceeds limit value (1.2%) of Meta stable zone during boiling stage. So the best choice for purity 99 to 92% is 60% end CC, seed SS 1.05%, and end mother liquor SS is 1%.

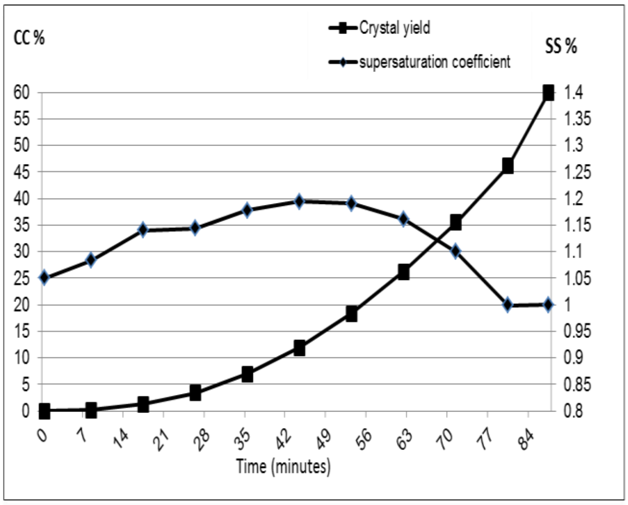


Fig.II.2. SS trend for R1 sugar crystallization 99% purity at 1.05 % seed, and 1% end boiling.

B. *Sugar crystallization in low temperatures theory*

The program efficiency to use its functional analysis property to choose the best parameters to get optimum crystallization performance as previously shown for selection the crystallization permeates, the functional analysis also used to select the optimum conditions such as the working temperature needed to get best results of sugar quantity and steam and wash water consumption. The following data analysis tables II.3, II.4 shows the crystallization is preferred to be occurred at low or high working temperatures by crystallization of R1,R4 sugar as examples at two different working temperatures with five degree difference from seed to end and at same conditions of SS, CC; 1st from 70°C to 75°C and the 2nd from 75°C to 80 °C.

Table II.3. Parameters and quantities of R1crystallization 99% at two different working temperatures 70 to75 and 75 to 80 °C of same CC:60%, SS 1.05% for seed and 1% end boiling, pan volume 70m3, color in 180 IU, and 90% color removal.

Quantity Q or parameter	70 to 75	75 to 80
Seed brix %	**77.51**	**78.44**
End mother liquor brix %	**77.62**	**78.7**
End massecuite brix %	**89.66**	**90.23**
End mother liquor Q Ton	46.9	46.23
End mother liquor Q at 73 % brix	56.6	56.56
Specific gravity of end massecuite b	1.45	1.44
Massecuite Q in ton	101.5	100.8
Total feed liquor Q in ton	130	129.9
Total evaporation Q in ton/cycle	**28.51**	**29.13**
End mother liquor color in IU	481	487.9
Sugar Q in ton after centrifugal/cyc	**49.96**	**49.93**
Wash water Q to syrup brix 73%	4.79	5.42
Cycle time in hours	**1.88**	**2**
Cycles /day	**12.76**	**12**
Sugar Q/day form one pan in ton	**637.5**	**599.2**

Gain in sugar quantity from one pan cycles = 38.3 ton/day
Wash water save for pan /day with same cycles =7.56 ton /day Evaporation water saving for pan with same cycles= 7.44 ton/day

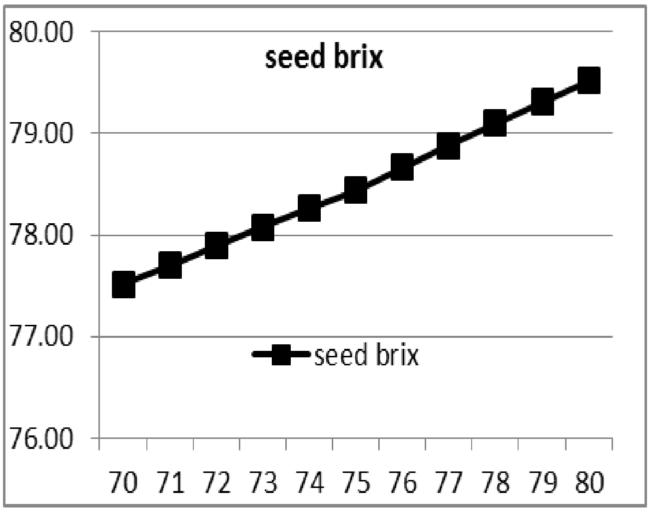


Fig.II.3.Temperature effect on seed brix value of R1 sugar crystallization 99%purity at SS1.05%.

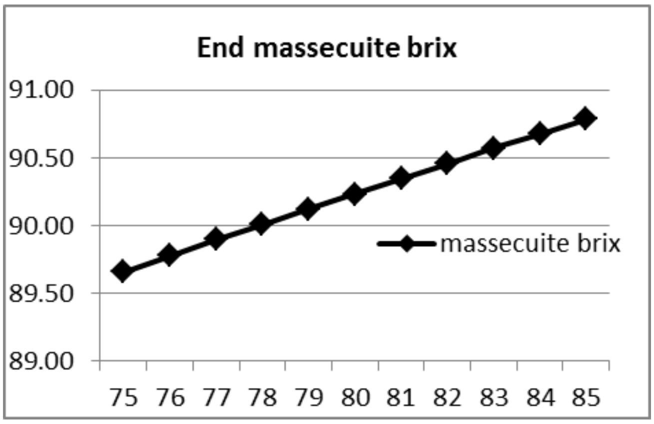


Fig.II.4.Temperature effects on end massecuite brix for R1 sugar crystallization 99% at 60% CC.

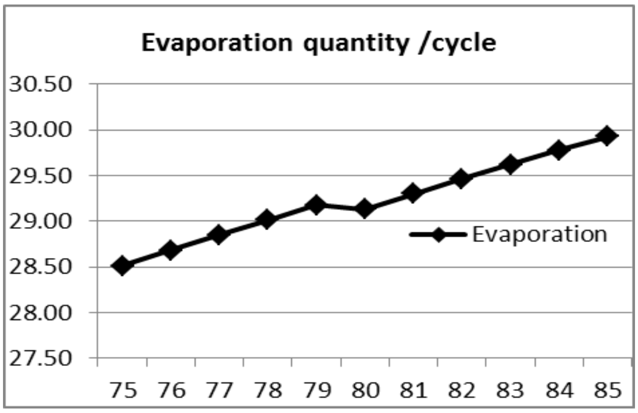


Fig.II.5.Temperature effect on evaporated water quantity for R1 sugar crystallization 99% purity and at 60% CC.

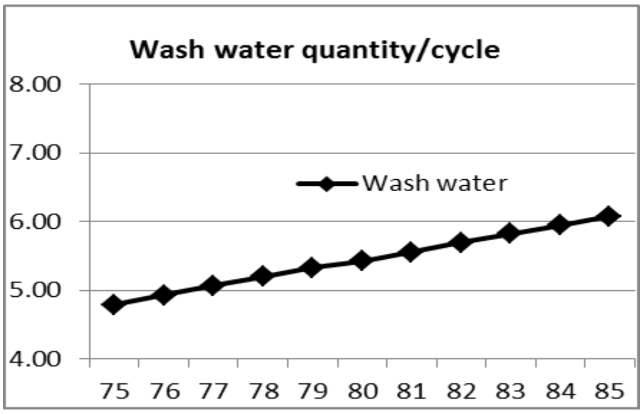


Fig.II.6.Temperature effect on wash water quantity for R1 sugar crystallization 99% purity and at 60% CC.

Table II.4. Parameters and quantities of R4crystallization 92% at two different working temperatures 70 to75 and 75 to 80 °C of same CC 60%, SS 1.05% for seed,1% end boiling, pan volume 70m3, color in 1700 IU, and 90% color removal.

Quantity Q or parameter	70 to 75	75 to 80
Seed brix %	**78.13**	**79.27**
End mother liquor brix %	**81.27**	**82.34**
End massecuite brix %	**91.56**	**92.1**
End mother liquor Q Ton	46.06	45.73
End mother liquor Q at 73 % brix	58.19	58.54
Specific gravity of end massecuite br	1.46	1.46
Massecuite Q in ton	102.2	102.2
Total feed liquor Q in ton	128.2	128.9
Total evaporation Q in ton/cycle	**25.98**	**26.74**
End mother liquor color in IU	4892.5	4895.6
Sugar Q in ton after centrifugal/cycl	51.37	51.68
Wash water Q to syrup brix 73%	7.08	7.73
Cycle time in hours	**2.58**	**2.75**
Cycles /day	9.3	8.72
Sugar Q/day form one pan in ton	**477.7**	**451**

Gain in sugar quantity from one pan cycles = 26.7 ton/day
Wash water save for pan day with same cycles = 5.67 ton /day
Evaporation water saving for pan with same cycles= 6.63 ton/day

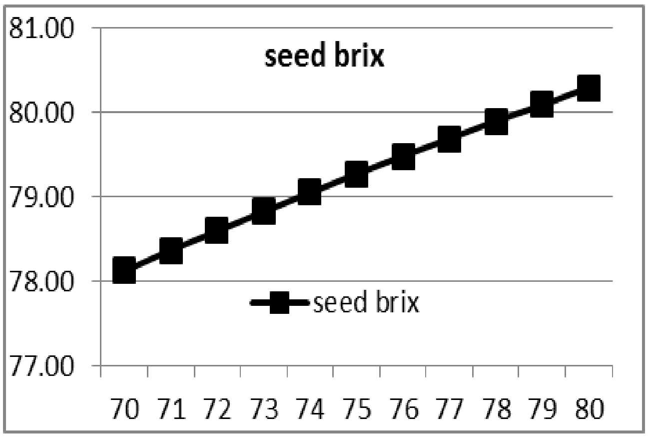


Fig.II.7. Temperature effect on seed brix end value of R4 sugar crystallization92% purity at SS1.05%.

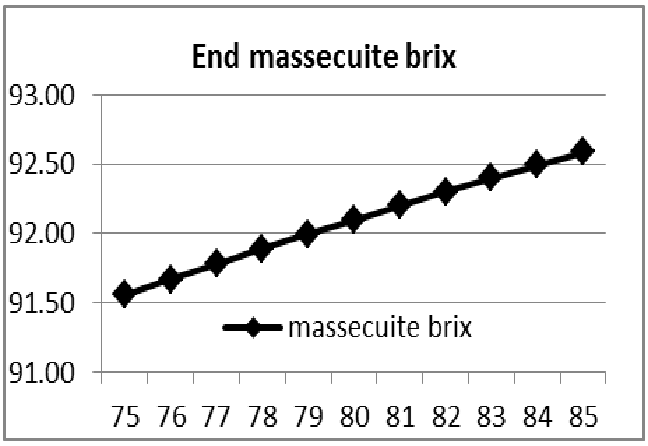


Fig.II.8.Temperature effect on massecuite brix for R4 sugar crystallization 92% purity and at 60% CC.

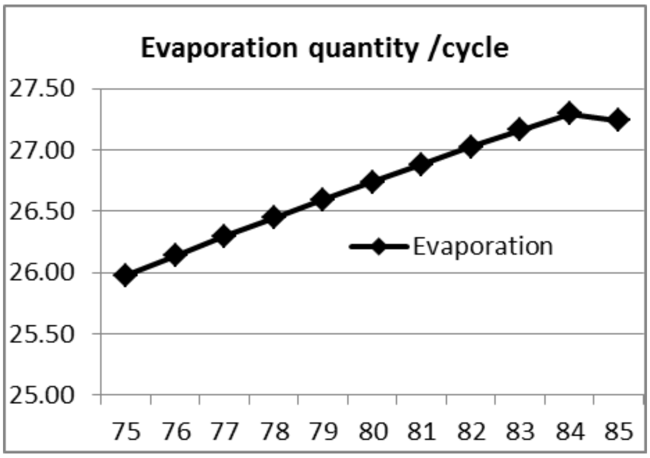


Fig.II.9. Temperature effect on quantity of evaporation for R4 sugar crystallization 92% purity and at 60% CC.

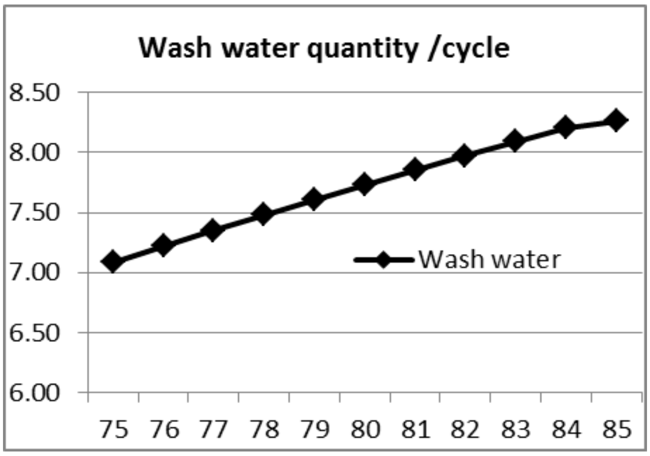


Fig.II.10. Temperature effect on wash water quantity for R4 sugar crystallization 92% purity and at 60% CC.

The temperature effects on seed brix value changes at same 1.05 %SS value shown in figures II.3, II.7, where there is an 2 degree increase in seed brix value for every 10 degree increase in temperature, and figures II.4, II.8 showing approximately increase 1.5 degree in end massecuite brix with every 10 degree increase in temperature at same CC. Also figures II.5, II.9 showing one ton increase in evaporation quantity for every 10 degree increase in end temperature, figures II.6, II.10 also showing approximately 1.3 ton increase in wash water quantity for every 10 degree increase in end temperature.

From tables II.3, II.4 it is concluded that there is high steam and wash water consumption and low sugar production in the crystallization at high temperature than that obtained by crystallization at lower working temperature under same working conditions of SS , end CC. Also with production of same sugar quantity there is 7.5 ton/day save in steam and wash water quantity for one pan cycles of R1 sugar crystallization, and 5.6 ton/day save in steam and 6.6 ton/day save for wash water quantity for R4 sugar crystallization. So sugar crystallization at low temperature is preferred to produce optimum sugar quantity and quality with lowest cost.

III. RESULTS AND DISCUSSIONS

Practical implementation data for batch evaporating crystallization of R1, and R4 sugar under low temperatures in USCE:

The program was semi implemented for crystallization of R1 and R4 sugar at batch vacuum pan of 70 m3 and 105 Ton capacity and Siemens NAHMAT controlling system. The implementation theory was inputting all parameters needed for the crystallization of every sugar type by using program's parameters and utilization feeding curve points option for introduction of feed rate controller parameters of the program. The same scenario implemented typically as the program except the online monitoring of SS, CC, and MA and corrections, where there is no refractometer device for measuring the mother liquor brix. The obtained results of CC and crystals quality simulated with the both actual results in USCE and reference values of every strike.

Tabl.III.1. parameters and quantity for practical R1 sugar Crystallization cycle in low working temperatures 14/5/2014

Quantity Q or Parameters	R1	In USCE
Feed brix %	68.1	68
Feed liquor purity %	99.1	99.2
Slurry Q in mm	400	400
Actual seed brix % set value	**77.5**	**78.5**
Seed temperature ° c	**71**	**75**
End Massecuite temperature ° c	**76.2**	**80**
End boiling brix % set value	86.8	88
Calculated evaporated water Q in to	**31.9**	**32.6**
SS of both seed and end boiling %	1.05	1.05
Cycle time in minutes at same feed b	**130**	**140**
Steam pressure bar g of 1st and 2nd	0.8	0.8
Vacuum mbar a in 1st and 2nd boili	200	240
Sugar color in IU (standard < 20)	18	19
Measured end massecuite brix %	**89.7**	**90**
Measured CC % Masc. Solids %	**54.7**	**55**
Measured CV (standard 35%)	**37.6**	**38**
Measured MA (standard>0.65mm)	**0.70**	**0.62**
Measured sugar dust (standard 3%)	**3**	**3.5**

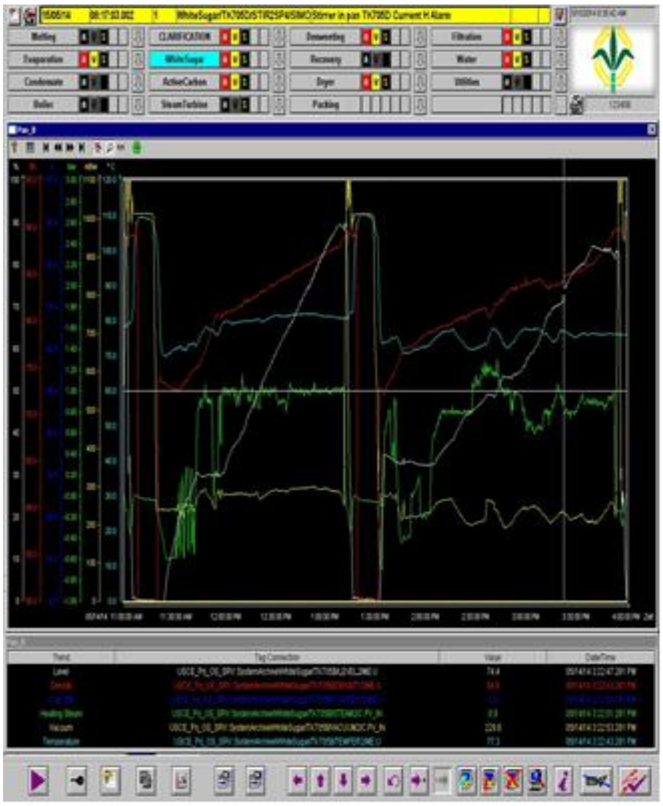
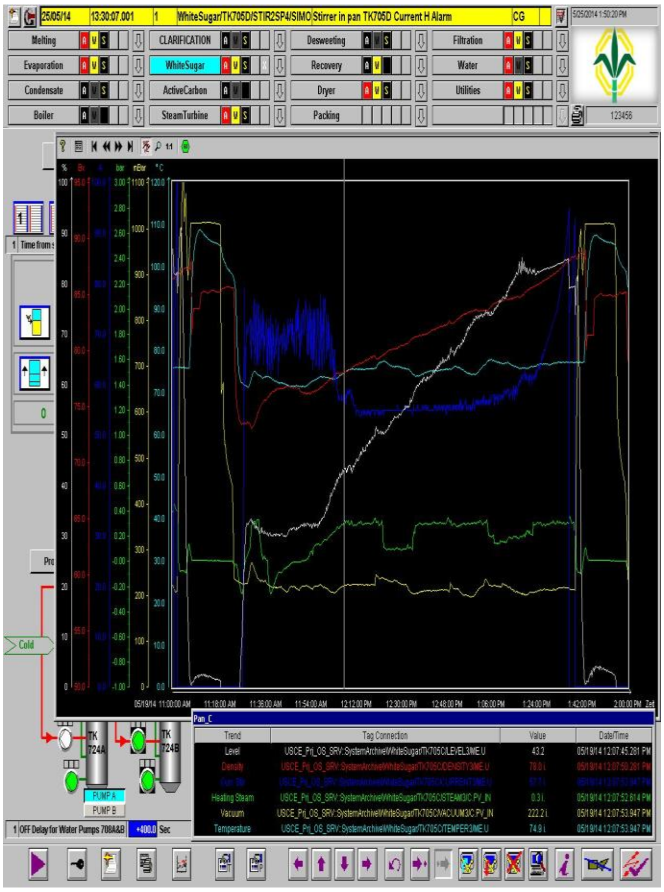


Fig.III.1. Practical R1 sugar crystallization cycle trends in low temperatures day 14/5/2014 (cycle 1.40 to 3.50 pm, 2nd trend)

Table.III.2. parameters and quantity for practical R4 sugar crystallization in low working temperatures cycle 16/4/2014.

Quantity Q or Parameters	R4 cycle	In USCI
Feed brix %	73.7	73.7
Feed liquor purity %	91.8	92
Slurry Q in mm	500	500
Actual seed brix % set value	**78.5**	**79.5**
Seed temperature ° c	**72.9**	**75**
End Massecuite temperature ° c	**76.5**	**81**
End boiling brix % set value	88	88.5
Calculated evaporated water Q in ton	**23.3**	**23.9**
SS of both seed and end boiling %	1.07	1.07
Steam pressure bar g of 1st and 2nd b	0.3	0.3
Vacuum mbar a in 1st and 2nd boilin	200	260
Measured end massecuite brix %	**90.5**	**91**
Cycle time in minutes	**135**	**165**
Sugar color in IU(standard < 100)	**88**	**95**
Measured CV (standard 35%)	**37.7**	**37**
Measured MA (standard>0.65mm)	**0.52**	**0.45**
Measured sugar dust (standard 3%)	**2.8**	**3.5**



Trend	Tag Connection	Value	Date/Time
Level	USCE_Prj_OS_SRV::SystemArchive\WhiteSugar\TK705C\LEVEL3ME.U	43.2	05/19/14 12:07:45.281 PM
Density	USCE_Prj_OS_SRV::SystemArchive\WhiteSugar\TK705C\DENSITY3ME.U	78.0 i.	05/19/14 12:07:50.281 PM
[illegible]	[illegible]	[illegible]	[illegible]
Heating Steam	USCE_Prj_OS_SRV::SystemArchive\WhiteSugar\TK705C\STEAM3IC.PV_IN	0.31 i.	05/19/14 12:07:52.614 PM
Vacuum	USCE_Prj_OS_SRV::SystemArchive\WhiteSugar\TK705C\VACUUM3IC.PV_IN	222.2 i.	05/19/14 12:07:53.947 PM
Temperature	USCE_Prj_OS_SRV::SystemArchive\WhiteSugar\TK705C\TEMPER3ME.U	74.9 i.	05/19/14 12:07:53.947 PM

Fig.III.2. Practical R4 sugar crystallization cycle trends in low temperatures, day 19/5/2014 (cycle 11.25 am to 1.40pm).

The results of R1 and R4 crystallization listed in tables III.1, III.2 showing better results of cycles under low temperatures than that occurred under higher working temperatures, and represented in better sugar quality of MA for R1 sugar 0.7mm vs. 0.62 and 0.52 vs0.45 for R4, dust percent, lower sugar color 1 degree color reduction for R1 and 7 degree for R4 sugar, and 10 minutes reduction in cycle time for R1 sugar crystallization and 30 minutes for R4 sugar crystallization, while both CV> standard. Also the measured end massecuite brix is 0.5 degree lower than that boiled under high temperatures and reduction of 0.6 ton in evaporated water quantity calculated at same feed liquor brix than that obtained with crystallization under high temperatures.

IV. CONCLUSION

The usage of an advanced program for sucrose crystallization control to detect all required parameters and data of R1 and R4 sugar crystallization occurred under different working temperatures. Comparison between results obtained from the crystallization under two sets of temperatures from start seeding to crystallization end ; 1st under 70 to 75° C and the 2nd such as occurring in the practice from 75 to 80°C. The theory implemented for crystallization of R1 and R4 in united sugar company of Egypt USCE company, excellent results of sugar productivity, quality, and cost saving achieved with the application and simulation with the actual results in the field.

REFERENCES

[1] Rozsa.L. (2003) Sensor selection: Still an issue in sugar crystallization control. Prod. Philippine Sugar Technologist's Convention, Bacolod City, Philippines.

[2] Charles D.F. (1960): Solubility of pure sucrose in water. Int. sugar i.62, 126-131.

[3] Van der poel P.W.: Schiweck H.: Schwartz T. (1998): Sugar Technology beet and cane sugar manufacturing. Verlage.Dr.Albert Bartens KG – Berlin.

[4] Vavrinecz, G. (1978/79): Sugar Technol. Rev.6.117-129.

[5] Grut, E.W(1936/1973): Z. Zuckerind. Czechoslovak. Rep. 61,345-453.

[6] Bubnik, Z.; Kadlec, P.; Urban, D.; Bruhns, M (1995): Sugar Technologists Manual. Dr. Albert Bartens, Berlin, 207-22.

[7] Peter Rein(2007):Cane Sugar Engineering. Verlage.Dr.Albert Bartens KG – Berlin.

[8] Silin, P.M. (1963): Assem. Comm. Int. Techn.Sucr.12, 253-263.

[9] Osama Z. El-Abdein, Yassien M. Temerk, Ibrahim D. Abdullah, Sherif T. Amin (2014): Design and Evaluation of a Full Control Program for Sucrose Crystallization Based on Soft Sensor Approach. International Journal of Engineering and Advanced Technology (IJEAT), ISSN: 2249 – 8958, Volume-3, Issue-3, February 2014.

[10] P .Lauret, H. Boyer and J. C. Gatina (2000): Hybrid modelling of a sugar boiling process Laboratoire de Génie Industriel, Faculte des Sciences, Université de La Réunion,15 Avenue René Cassin- BP 71515 S.