MATHEMATICAL MODELS OF THE SUGAR END

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Presented By

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One of the methods to improve and optimize technology and equipment is to use mathematical simulation for a process (called engineering models). Two mathematical simulation models will be presented today. These models are a vacuum pan model and a sugar end model.

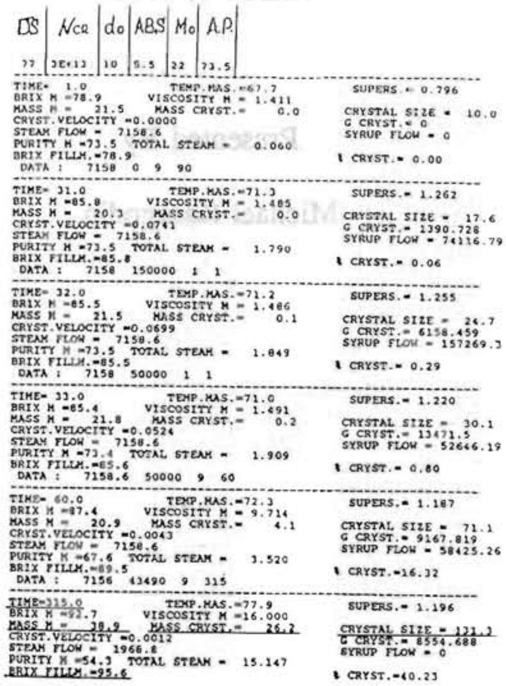
Part I

Vacuum Pan Model

1. A dynamic engineering model for the vacuum pan was developed utilizing non-linear differential equations and equations for material and energy balances.

   The computer program is able to calculate over 20 output parameters (including crystal size and brix of the fillmass) for a specified period of time. It utilizes input parameters of the process (brix of the syrup, number of crystals, initial size of the crystals, absolute pressure, mass of the charge and apparent purity of the syrup).

2. Figure 1 shows an example simulating low raw pan boiling. The apparent purity = 73.5%, and the DS = 77%. In 5 hours and 15 minutes, we can boil 65.1 tons of fillmass with the brix = 95.6, and the average crystal size = 131 micron.



```
DS | Ncr   | do | ABS | Mo | A.P.
77 | 3E+13 | 10 | 5.5 | 22 | 73.5
--------------------------------------------------------------------------
TIME= 1.0             TEMP.MAS.=67.7            SUPERS.= 0.796
BRIX M =78.9       VISCOSITY M = 1.411
MASS M =    21.5    MASS CRYST.=     0.0        CRYSTAL SIZE =  10.0
CRYST.VELOCITY =0.0000                          G CRYST.= 0
STEAM FLOW =  7158.6                            SYRUP FLOW = 0
PURITY M =73.5  TOTAL STEAM =   0.060
BRIX FILLM.=78.9                                % CRYST.= 0.00
 DATA :   7158  0  9  90
--------------------------------------------------------------------------
TIME= 31.0            TEMP.MAS.=71.3            SUPERS.= 1.262
BRIX M =85.8       VISCOSITY M = 1.485
MASS M =    20.3    MASS CRYST.=     0.0        CRYSTAL SIZE =  17.6
CRYST.VELOCITY =0.0741                          G CRYST.= 1390.728
STEAM FLOW =  7158.6                            SYRUP FLOW = 74116.79
PURITY M =73.5  TOTAL STEAM =   1.790
BRIX FILLM.=85.8                                % CRYST.= 0.06
 DATA :   7158  150000  1  1
--------------------------------------------------------------------------
TIME= 32.0            TEMP.MAS.=71.2            SUPERS.= 1.255
BRIX M =85.5       VISCOSITY M = 1.486
MASS M =    21.5    MASS CRYST.=     0.1        CRYSTAL SIZE =  24.7
CRYST.VELOCITY =0.0699                          G CRYST.= 6158.459
STEAM FLOW =  7158.6                            SYRUP FLOW = 157269.3
PURITY M =73.5  TOTAL STEAM =   1.849
BRIX FILLM.=85.5                                % CRYST.= 0.29
 DATA :   7158  50000  1  1
--------------------------------------------------------------------------
TIME= 33.0            TEMP.MAS.=71.0            SUPERS.= 1.220
BRIX M =85.4       VISCOSITY M = 1.491
MASS M =    21.8    MASS CRYST.=     0.2        CRYSTAL SIZE =  30.1
CRYST.VELOCITY =0.0524                          G CRYST.= 13471.5
STEAM FLOW =  7158.6                            SYRUP FLOW = 52646.19
PURITY M =73.4  TOTAL STEAM =   1.909
BRIX FILLM.=85.6                                % CRYST.= 0.80
 DATA :   7158.6  50000  9  60
--------------------------------------------------------------------------
TIME= 60.0            TEMP.MAS.=72.3            SUPERS.= 1.187
BRIX M =87.4       VISCOSITY M = 9.714
MASS M =    20.9    MASS CRYST.=     4.1        CRYSTAL SIZE =  71.1
CRYST.VELOCITY =0.0043                          G CRYST.= 9167.819
STEAM FLOW =  7158.6                            SYRUP FLOW = 58425.26
PURITY M =67.6  TOTAL STEAM =   3.520
BRIX FILLM.=89.5                                % CRYST.=16.32
 DATA :   7156  43490  9  315
--------------------------------------------------------------------------
TIME=315.0            TEMP.MAS.=77.9            SUPERS.= 1.196
BRIX M =92.7       VISCOSITY M =16.000
MASS M =    38.9    MASS CRYST.=    26.2        CRYSTAL SIZE = 131.3
CRYST.VELOCITY =0.0012                          G CRYST.= 8554.688
STEAM FLOW =  1966.8                            SYRUP FLOW = 0
PURITY M =54.3  TOTAL STEAM =  15.147
BRIX FILLM.=95.6                                % CRYST.=40.23
```

Figure 1.

The results from this model are very close to the results of the actual process. The model can be used as an engineering verification of different process strategies. This is done by changing input parameters. For example, by changing the number of crystals, we can see how the crystal size and batch time will change.

As an example, we wanted to determine the effect on crystal size and boiling time resulting from addition of a vacuum pan. With the help of the model, we realized we needed to increase the number of crystals from $3*10^{12}$ to $6*10^{12}$ and decrease the steam flow by 50%. As a result of this, we would receive approximately the same amount of fillmass (63.2 T) with the same brix (95.7), Figure 2. The average crystal size increased to 221 microns (by 90 microns), and the process time increased by 4 hours from 5 hours 15 minutes to 9 hours 15 minutes.

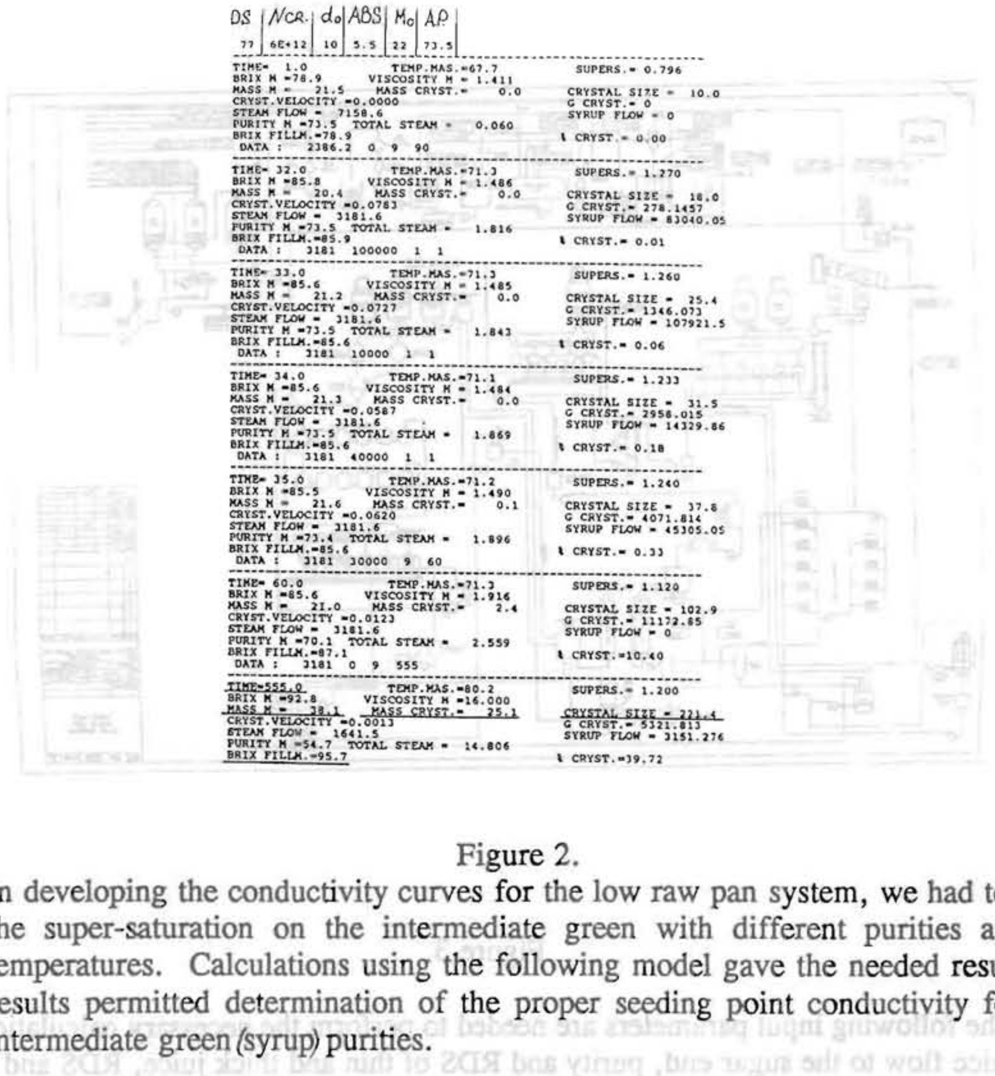


Figure 2.

In developing the conductivity curves for the low raw pan system, we had to determine the super-saturation on the intermediate green with different purities at the same temperatures. Calculations using the following model gave the needed results. These results permitted determination of the proper seeding point conductivity for different intermediate green (syrup) purities.

Many other examples have been evaluated with good results. This engineering model of vacuum pan boiling can be helpful in evaluating process improvement.

Part II

Sugar End Model

1. This model can be used for analyzing different technological schemes and capacity changes in the sugar end.

   The model is based on the sugar end material balance and includes all process flows and sugar end equipment (Figure 3).

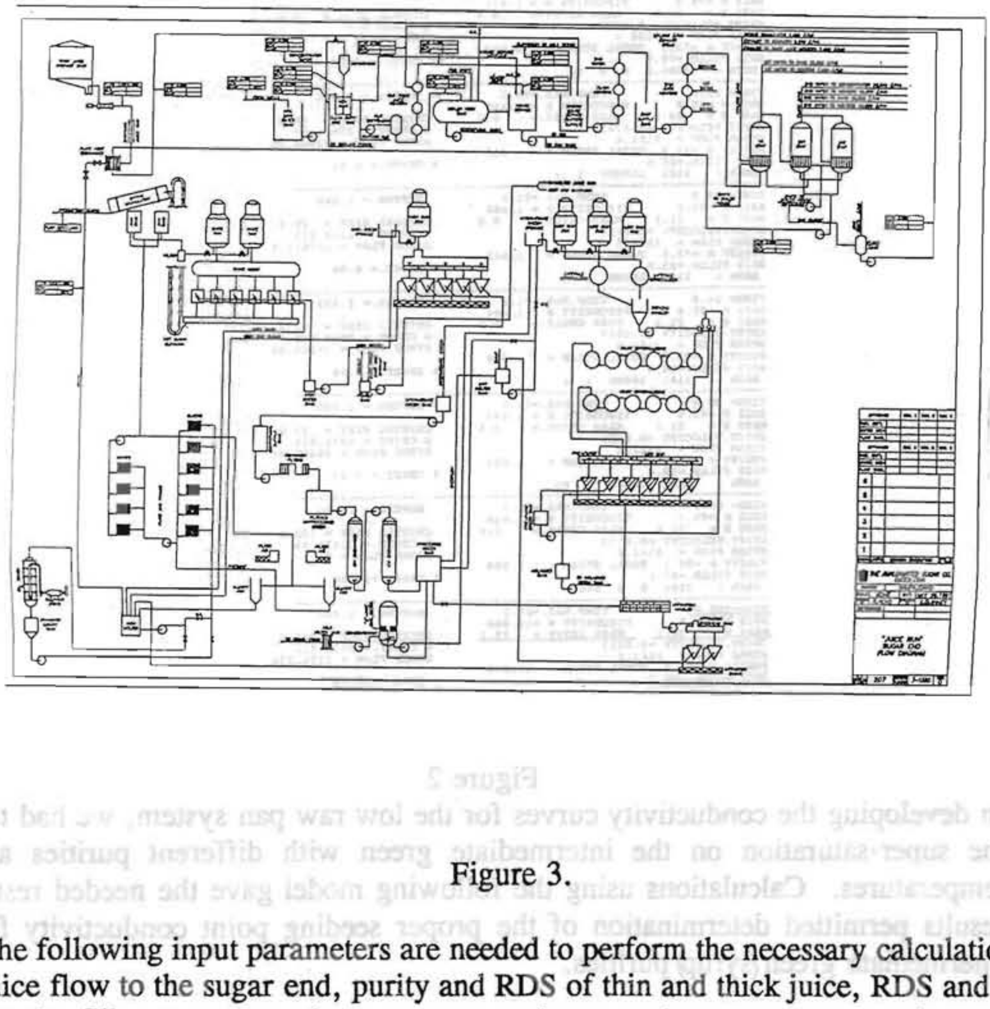


Figure 3.

The following input parameters are needed to perform the necessary calculations: Thick juice flow to the sugar end, purity and RDS of thin and thick juice, RDS and % crystals for the fillmasses, Quentin process sugar losses and non-sugar removal as well as beet slice rate.

As a result of calculations, you will receive all the output data for the sugar end parameters, starting from the thin juice and finishing with the molasses and low raw sugar. This includes the mass, amount of sugar and non-sugars in the products (in tons/100 tons beets), sugar content, dry solids and apparent purity (Figure 4).

SUGAR END EVALUATION PROGRAM

INPUT DATA FOR SUGAR END BALANCE :

THICK JUICE MASS flow = 24.7 tons/100 tons beets
THICK JUICE PURITY = 91.4
THICK JUICE RDS = 69.8
THIN JUICE RDS = 15.2
THIN JUICE PURITY = 89.7
RDS OF FILLMASS 1 = 91.2
% OF CRYSTALS IN FILLMASS = % CRYSTALLIZATION (FROM LEDGER)*RDS*AP/10000
% OF CRYSTALS IN FILLMASS 1 = 49.3
RDS OF FILLMASS 2 = 92.2
% OF CRYSTALS IN FILLMASS 2 = 41.9
RDS OF FILLMASS 3 = 95.2
RDS OF CRYSTALLIZERS = 93.8
% OF CRYSTALS IN CRYSTALLIZERS = 43.3
RDS OF AFFINATION FILLMASS = 91.4
% OF CRYSTALS IN AFFINATION FILLMASS = 41.5
NS REMOVAL ACROSS THE QUENTIN SYSTEM = .08 tons/100 tons beets
SUGAR LOST IN THE QUENTIN SYSTEM = .02 tons/100 tons beets
RDS OF INTERM. GREEN AFTER CONCENTRATOR = 74
TONS OF BEETS SLICED PER DAY = 5820

OUTPUT FOR SUGAR END BALANCE

N	THE NAME OF THE PRODUCT	MASS	SUG	SOLIDS	NSUG	SC	DS	PURITY
		TONS/100 TONS BEETS				%		
1	THIN JUICE	2.70	0.37	0.41	0.04	13.63	15.20	89.70
2	THICK JUICE	24.70	15.76	17.24	1.48	63.80	69.80	91.40
3	STANDARD LIQUOR	39.16	26.67	28.53	1.86	68.10	72.85	93.48
4	FILLMASS 1	31.28	26.67	28.53	1.86	85.25	91.20	93.48
5	HIGH GREEN	14.65	9.89	11.56	1.67	67.47	78.88	85.53
6	HIGH WASH	3.34	2.34	2.53	0.19	70.22	75.81	92.63
7	WHITE SUGAR	14.44	14.44	14.44	0.00	99.97	99.98	99.99
8	FILLMASS 2	12.54	9.89	11.56	1.67	78.64	92.20	85.53
9	INTERM.GREEN	7.20	4.43	6.01	1.58	61.55	83.50	73.72
10	HIGH RAW SUGAR	5.60	5.45	5.54	0.09	97.39	99.04	98.34
11	PROCESSED GREEN	8.28	4.43	6.13	1.70	53.44	74.00	72.22
12	FILLMASS 3	6.44	4.43	6.13	1.70	68.75	95.20	72.22
13	CRYSTALLIZERS	5.71	3.69	5.35	1.66	64.69	93.80	58.25
14	PREPURGE SUGAR	0.78	0.73	0.77	0.04	93.81	99.05	94.71
15	PREPURGE GREEN	1.44	0.73	1.25	0.52	50.47	86.65	58.25
16	MOLASSES	3.61	1.51	3.02	1.51	41.78	83.66	49.94
17	LOW RAW SUGAR	3.15	2.92	3.11	0.19	92.64	98.74	93.82
18	AF.FILLMASS	6.64	5.06	6.07	1.01	76.13	91.40	83.29
19	AF.GREEN	3.63	2.15	3.10	0.95	59.20	85.30	69.40
20	AF.SUGAR	3.01	2.91	2.97	0.07	96.54	98.75	97.76

CRYSTAL LOSSES (PASSED THROUGH AND MELTED) IN THE CENTRIFUGES (tons/day):

WHITE C/F : WITH HIGH GREEN - 93.5
WITH HIGH WASH - 82.7
HIGH RAW C/F : 15.7
LOW ROW C/F : 13.7

THE PROGRAM WAS PREPARED BY MICHAEL KARAGODIN (TASCO).

Figure 4.

C/F EVALUATION

INPUT DATA:

GREEN 1 PURITY = 85.5
RDS OF GREEN 1 = 78.9
HWASH PURITY = 92.6
RDS OF HW1 = 75.8
WHITE SUGAR PURITY = 99.989
GREEN 2 PURITY = 73.7
RDS OF GREEN 2 = 83.5
HR SUGAR PURITY = 98.3
MOLASSES PURITY = 49.9
RDS OF MOLASSES = 83.7
LR SUGAR PURITY = 93.7

NEW VALUES :

SUGAR LOSSES (%)	NSUG FILM ON THE CRYSTALS (%)	WATER (%)
SLOSGR1= 9.2001	FILM1= 10.1111	%WFM1= 1.970715
SLOSHW1= 6.140001	FILMHW1= .8801	%WHW1= 1.700813
SLOSGR2= 4.922	FILM2= 5.5101	%WFM2= 2.108051
SLOSGR3= 10.26	FILM3= 9.300001	%WFM3= 4.122668
	FILM AF= 6.565	

FOR NEW VALUES :

OUTPUT FOR SUGAR END BALANCE

N	THE NAME OF THE PRODUCT	MASS	SUG	SOLIDS	NSUG	SC	DS	PURITY
		TONS/100 TONS BEETS				%		
1	THIN JUICE	2.70	0.37	0.41	0.04	13.63	15.20	89.70
2	THICK JUICE	24.70	15.76	17.24	1.48	63.80	69.80	91.40
3	STANDARD LIQUOR	39.16	26.67	28.53	1.86	68.10	73.85	93.48
4	FILLMASS 1	31.28	26.67	28.53	1.86	85.25	91.20	93.46
5	HIGH GREEN	14.65	9.89	11.56	1.67	67.48	78.90	85.53
6	HIGH WASH	3.34	2.34	2.53	0.19	70.22	75.80	92.63
7	WHITE SUGAR	14.44	14.44	14.44	0.00	99.97	99.98	99.99
8	FILLMASS 2	12.54	9.89	11.56	1.67	78.86	92.20	85.53
9	INTERM.GREEN	7.20	4.43	6.01	1.58	61.56	83.50	73.73
10	HIGH RAW SUGAR	5.60	5.45	5.54	0.09	97.39	99.04	98.34
11	PROCESSED GREEN	8.28	4.42	6.13	1.71	53.41	74.00	72.18
12	FILLMASS 3	6.44	4.42	6.13	1.71	68.71	95.20	72.16
13	CRYSTALLIZERS	5.71	3.69	5.36	1.66	64.64	93.80	58.18
14	PREPURGE SUGAR	0.78	0.73	0.78	0.04	93.80	99.05	94.70
15	PREPURGE GREEN	1.44	0.73	1.25	0.52	50.41	86.65	58.16
16	MOLASSES	3.60	1.50	3.01	1.51	41.74	83.70	49.87
17	LOW RAW SUGAR	3.16	2.92	3.12	0.20	92.52	98.72	93.72
18	AF.FILLMASS	6.64	5.05	6.07	1.02	76.08	91.40	83.24
19	AF.GREEN	3.63	2.15	3.10	0.95	59.12	85.30	69.30
20	AF.SUGAR	3.01	2.91	2.97	0.07	96.54	98.75	97.75

CRYSTAL LOSSES (PASSED THROUGH AND MELTED) IN THE CENTRIFUGES (tons/day):

WHITE C/F : WITH HIGH GREEN - 93.5
WITH HIGH WASH - 82.7
HIGH RAW C/F : 15.7
LOW ROW C/F : 13.7

Figure 5.

This calculation will also give the amount of crystallized sugar losses in the centrifugal.

To evaluate centrifugal behavior, additional input parameters must be provided, including purity and RDS of the greens after the centrifugation. Crystal loss through centrifugation can then be determined (crystals coming through the screen and melting) as well as non-sugars left on the crystal surface and water used in the centrifugals (Figure 5). From these values the new output data is calculated.

The program also gives the capacity evaluation of equipment. After inputting the capacities of the vacuum pans, crystallizers, and dryer into the program, you will receive information about the number of pans and centrifugals required for the current thick juice flow to the sugar end.

It also shows how often to drop the pans, crystallizer retention time and the amount of granulated sugar that will be produced.

The engineering model compares favorably to the real data and can be used in different ways.

Example 1: You can analyze the non-sugar recycle (Figure 4 Column 4), which is equal to 1.86 - (1.48 + 0.04) = 0.34 T/100 T beets or 22.4%.

Example 2: You can figure out how much sugar crystals are recovered in the centrifugals if you improve the centrifugal behavior or technology (Figure 5).

Example 3: You would be able to analyze the result of changing the number of vacuum pans or centrifugals (Figure 6- for Plant C). Let's say, we are going to increase the number of low raw pans from 2 to 3. The program would show that if you did not increase the total mass flow of the thick juice, you would have to increase the batch time by four hours. And using the math model for the vacuum pans, you will see it will increase the average size of the crystal by 90 microns. This will lead to lower molasses purity.

```
                    CAPACITY  EVALUATION
                    --------------------
      INPUT DATA FOR PAN, CENTRIFUGALS AND CRYSTALLIZERS :

CAPACITY (IN TONS): OF THE WHITE PAN -       56.86091
                    OF THE HIGH RAW PAN -    60.63702
                    OF THE LOW RAW PAN -     50.74355
                    OF THE CRYSTALLIZER -    29.28364
HOW MANY CRYSTALLIZERS WILL BE OPERATED -    12
THE WHITE C/F CAPACITY (TONS/HOUR) -         12.64
             HIGH RAW C/F CAPACITY -         6.082
              LOW RAW C/F CAPACITY -         2.6
           AFFINATION C/F CAPACITY -         8.05
 THE CAPACITY OF THE DRYER (TONS/HOUR) -     35

           THE RESULTS OF CAPACITY EVALUATION :
           ------------------------------------
PANS/DAY REQUIRED:

                    WHITE -     32.0
                    HIGH RAW - 12.0
                    LOW RAW -    7.4

A PAN DROP OCCURING EVERY ---------- HOURS

                    WHITE -     0.75
                    HIGH RAW - 1.99
                    LOW RAW -   3.25

NUMBER OF PANS REQUIRED:

                    WHITE (1.5 HOURS BATCH) -      2.0
                    HIGH ROW (4.0 HOURS BATCH) -   2.0
                    LOW RAW (6.5 HOURS BATCH) -    2.0
                    LOW RAW (10.0 HOURS BATCH) -   3.0

NUMBER OF CENTRIFUGALS REQUIRED:
                     WHITE -      6.0
                     HIGH RAW -   5.0
                     LOW RAW -    6.0
                     AFFINATION- 2.0

CRYSTALLIZER AVERAGE RETENTION TIME
ASSUMES 2 HOURS REQUIRED FOR CLEANING ETC.
AVERAGE RETENTION TIME (HOURS) =20.5

TOTAL HOURS IN CRYSTALLIZERS -  38.0

NUMBER OF DRYERS REQUIRED -  1.0

SUGAR RECOVERY ACROSS THE SUGAR END - 91.6

GRANULATED  SUGAR  PRODUCED (cwt/day) =16810.4
```

Figure 6.

Example 4: If you increase the slicing capacity of the plant by 30% (Plant A) and use the low raw pans with the same batch time (8.3 hours). Then, you would need to increase accordingly by 1 the number of white, high raw and low raw pans, and the number of centrifuges should be changed by 3 for the low raw and white, by 1.5 for high raw and by 1 for affination. Number of holding tanks will be increased by 4 (Figure 7 & 8).

```
                 CAPACITY  EVALUATION
                 --------------------
     INPUT DATA FOR PAN, CENTRIFUGALS AND CRYSTALLIZERS :

CAPACITY (IN TONS): OF THE WHITE PAN -     86.97298    ( 1800 cub feet )
                    OF THE HIGH RAW PAN -  95.02126    ( 1870 cub feet )
                    OF THE LOW RAW PAN -   88.24062    ( 1740 cub feet )
                    OF THE HOLDING TANK -  36.88913    ( 875 cub feet )
HOW MANY HOLDING TANKS WILL BE OPERATED -  6
THE WHITE C/F CAPACITY (TONS/HOUR) -       13.707
          HIGH RAW C/F CAPACITY -          6.104
           LOW RAW C/F CAPACITY -          3.563
        AFFINATION C/F CAPACITY -          5.706
 THE CAPACITY OF THE DRYER (TONS/HOUR) -   53.61

        THE RESULTS OF CAPACITY EVALUATION :
        ------------------------------------
PANS/DAY REQUIRED:

                  WHITE =     34.0
                  HIGH RAW = 12.3
                  LOW RAW =   8.7

A PAN DROP OCCURING EVERY ---------- HOURS

                  WHITE =     0.71
                  HIGH RAW = 1.95
                  LOW RAW =   2.75

NUMBER OF PANS REQUIRED:
                                        BEET SLICED - 8765 t/day (100%)
                  WHITE (2.2 HOURS BATCH) =      3.0
                  HIGH ROW (4.0 HOURS BATCH) -   2.0
                  LOW RAW (8.3 HOURS BATCH) -    3.0
                  LOW RAW (11.0 HOURS BATCH) =   4.0

NUMBER OF CENTRIFUGALS REQUIRED:

                  WHITE =     9.0
                  HIGH RAW =  8.0
                  LOW RAW =   9.0
                  AFFINATION= 4.0

         HOLDING  TANKS
AVERAGE RETENTION TIME (HOURS) = 6.9

TOTAL HOURS WITH CRYSTALLIZERS =  12.4

NUMBER OF DRYERS REQUIRED =  1.0

SUGAR RECOVERY ACROSS THE SUGAR END = 86.1

GRANULATED  SUGAR  PRODUCED (cwt/day) =25725.7
```

Figure 7.

```
                 CAPACITY  EVALUATION
                 --------------------
     INPUT DATA FOR PAN, CENTRIFUGALS AND CRYSTALLIZERS :

CAPACITY (IN TONS): OF THE WHITE PAN -     86.97298    ( 1800 cub feet )
                    OF THE HIGH RAW PAN -  95.02126    ( 1870 cub feet )
                    OF THE LOW RAW PAN -   88.24062    ( 1740 cub feet )
                    OF THE HOLDING TANK -  36.88913    ( 875 cub feet )
HOW MANY HOLDING TANKS WILL BE OPERATED -  10
THE WHITE C/F CAPACITY (TONS/HOUR) =       13.707
          HIGH RAW C/F CAPACITY =          6.104
           LOW RAW C/F CAPACITY =          3.563
        AFFINATION C/F CAPACITY =          5.706
 THE CAPACITY OF THE DRYER (TONS/HOUR) =   53.61

        THE RESULTS OF CAPACITY EVALUATION :
        ------------------------------------
PANS/DAY REQUIRED:

                  WHITE =     43.8
                  HIGH RAW = 15.9
                  LOW RAW =  11.3

A PAN DROP OCCURING EVERY ---------- HOURS

                  WHITE =     0.55
                  HIGH RAW = 1.51
                  LOW RAW =   2.13

NUMBER OF PANS REQUIRED:
                                        BEET SLICED = 11300 t/day (130%)
                  WHITE (2.2 HOURS BATCH) =      4.0        4.0
                  HIGH ROW (4.0 HOURS BATCH) -   2.7        3.0
                  LOW RAW (8.3 HOURS BATCH) =    3.9        4.0
                  LOW RAW (11.0 HOURS BATCH) -   5.2        5.0

NUMBER OF CENTRIFUGALS REQUIRED:

                  WHITE =     11.6      12
                  HIGH RAW = 10.3       11
                  LOW RAW =   11.6      12
                  AFFINATION= 5.2       5

         HOLDING  TANKS
AVERAGE RETENTION TIME (HOURS) = 8.9

TOTAL HOURS WITH CRYSTALLIZERS =  16.3

NUMBER OF DRYERS REQUIRED =  1.3

SUGAR RECOVERY ACROSS THE SUGAR END = 86.1

GRANULATED  SUGAR  PRODUCED (cwt/day) =33166.0
```

Figure 8.

Example 5: These mathematical models could be used for cane sugar production as well. If a raw sugar plant has a three boiling system on "magma" and we want it to be converted to white sugar production. In this case, the model will help to evaluate how to do it, using the same number of vacuum pans and increasing the number of centrifugals (Figure 9 & 10).

```
                 CAPACITY  EVALUATION
                 --------------------
     INPUT DATA FOR PAN, CENTRIFUGALS AND CRYSTALLIZERS :

CAPACITY (IN TONS): OF THE  A - PAN  =     96.63665    ( 2000 cub feet )
                    OF THE  B - PAN  =     101.427     ( 2000 cub feet )
                    OF THE  C - PAN  =     101.426     ( 2000 cub feet )
                    OF THE CRYSTALLIZER -  238.3098    ( 4971 cub feet )
HOW MANY CRYSTALLIZERS WILL BE OPERATED -  3
THE  A - C/F  CAPACITY (TONS/HOUR) -       7.76
     B - C/F  CAPACITY =                   5.39
     C - C/F  CAPACITY -                   2.11
     AFFINATION C/F CAPACITY -             0
 THE CAPACITY OF THE DRYER (TONS/HOUR) -   35

        THE RESULTS OF CAPACITY EVALUATION :
        ------------------------------------
PANS/DAY REQUIRED:

                  A - PAN =     9.6
                  B - PAN =     4.8
                  C - PAN =     4.7

A PAN DROP OCCURING EVERY ---------- HOURS

                  A - PAN =    2.49
                  B - PAN =    4.96
                  C - PAN =    5.12

NUMBER OF PANS REQUIRED:

                  A - PAN (5.0 HOURS BATCH) =      2.0
                  B - PAN (9.9 HOURS BATCH) =  2.0
                  C - PAN (10.2 HOURS BATCH) =   2.0

NUMBER OF CENTRIFUGALS REQUIRED:

                  A - C/F  =     5.0
                  B - C/F  =     3.8
                  C - C/F  =     9.4

     VERTICAL CRYSTALLIZERS
AVERAGE RETENTION TIME (HOURS) =24.0

TOTAL HOURS WITH HOLDING TANKS =  31.2

NUMBER OF DRYERS REQUIRED =  1.0

SUGAR RECOVERY ACROSS THE SUGAR END = 91.3

GRANULATED  SUGAR  PRODUCED (cwt/day) =13349.0
```

Figure 9.

```
                 CAPACITY  EVALUATION
                 --------------------
     INPUT DATA FOR PAN, CENTRIFUGALS AND CRYSTALLIZERS :

CAPACITY (IN TONS): OF THE  A - PAN  =     96.63665    ( 2000 cub feet )
                    OF THE  C - PAN  =     101.426     ( 2000 cub feet )
                    OF THE  4 - PAN  =     96.53324    ( 2000 cub feet )
                    OF THE  5 - PAN  =     96.63665    ( 2000 cub feet )
                    OF THE CRYSTALLIZER =  238.3098    ( 4971 cub feet )
HOW MANY CRYSTALLIZERS WILL BE OPERATED =  2
THE WHITE C/F CAPACITY (TONS/HOUR) =       7.76
     C - C/F  CAPACITY =                   2.11
     AFFINATION C/F CAPACITY =             5.39
     4 - C/F  CAPACITY =                   7.76
     5 - C/F  CAPACITY =                   7.74
 THE CAPACITY OF THE DRYER (TONS/HOUR) -   35

        THE RESULTS OF CAPACITY EVALUATION :
        ------------------------------------
PANS/DAY REQUIRED:

                  A - PAN =    11.1
                  C - PAN =   5.2
                  4 - PAN =   8.9
                  5 - PAN =   3.2

A PAN DROP OCCURING EVERY ---------- HOURS

                  A - PAN =    2.17
                  C - PAN =  4.62
                  4 - PAN =  2.70
                  5 - PAN =  7.39

NUMBER OF PANS REQUIRED:

                  A - PAN (3.0 HOURS BATCH) =     3.3 (4.3 HOURS BATCH) =    2.0
                  C - PAN (10.2 HOURS BATCH) =   2.2  (9.2 HOURS BATCH) =   2.0
                  4 - PAN (2.5 HOURS BATCH) =  0.9    (2.7 HOURS BATCH) =  1.0
                  5 - PAN (5.0 HOURS BATCH) =  0.7    (7.4 HOURS BATCH) =  1.0

NUMBER OF CENTRIFUGALS REQUIRED:

                  A - C/F =   5.7
                  C - C/F =  10.4
                  AFFINATION= 3.3
                  4 - C/F =   4.6
                  5 - C/F =   1.7

     VERTICAL CRYSTALLIZERS
AVERAGE RETENTION TIME (HOURS) =21.7

TOTAL HOURS WITH HOLDING TANKS =  28.3

NUMBER OF DRYERS REQUIRED =  1.0

SUGAR RECOVERY ACROSS THE SUGAR END = 93.2

GRANULATED  SUGAR  PRODUCED (cwt/day) =13081.7
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Figure 10.

As you can see from these examples, the engineering models presented are powerful tools used to analyze and improve beet and cane sugar factories and refineries.

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