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CHROMATOGRAPHY OF THE SECOND MOTHER LIQUOR IN A NEW BEET SUGAR FACTORY:

AN ELEGANT WAY TO INCREASE THE SUGAR YIELD

AND

DECREASE THE CAPITAL COST OF CRYSTALLIZATION

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SUMMARY

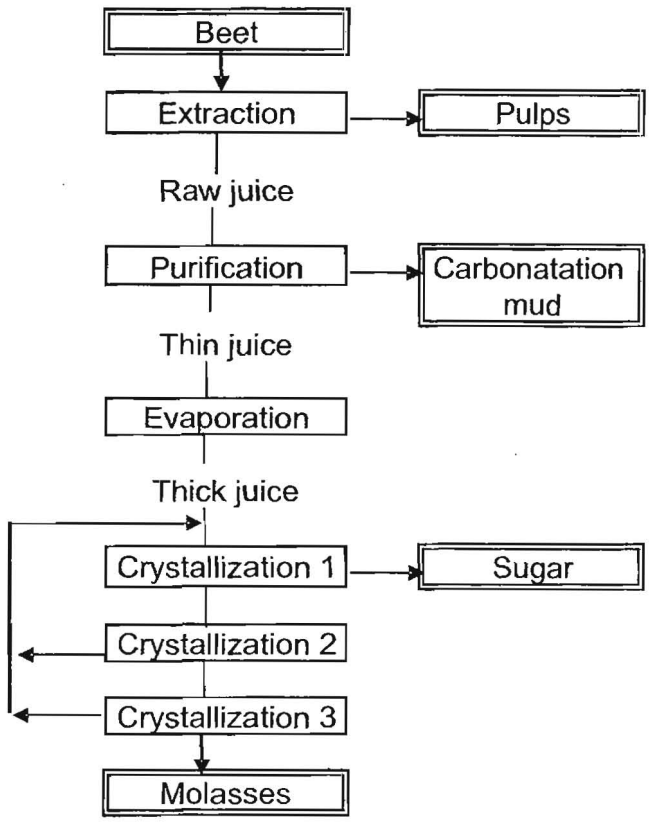
The interest of chromatography of beet molasses to increase the sugar yield in a beet sugar factory, when there is a significant difference between the price of crystal sugar and molasses is well known.

The Authors demonstrate the importance of a better integration to the process, when a new sugar factory is built: it becomes very advantageous to feed the chromatographic separator for the recovery of sugar with the second mother liquor (low green syrup). In this case, it is no longer necessary to invest in a third strike of crystallization, and it is possible to better use the equipment out of the season.

I. CHROMATOGRAPHIC SEPARATION IN THE BEET SUGAR INDUSTRY

Beet sugar factories are still being built with the conventional "three strikes" crystallization design:

Table 1: Block diagram of the conventional beet sugar factory



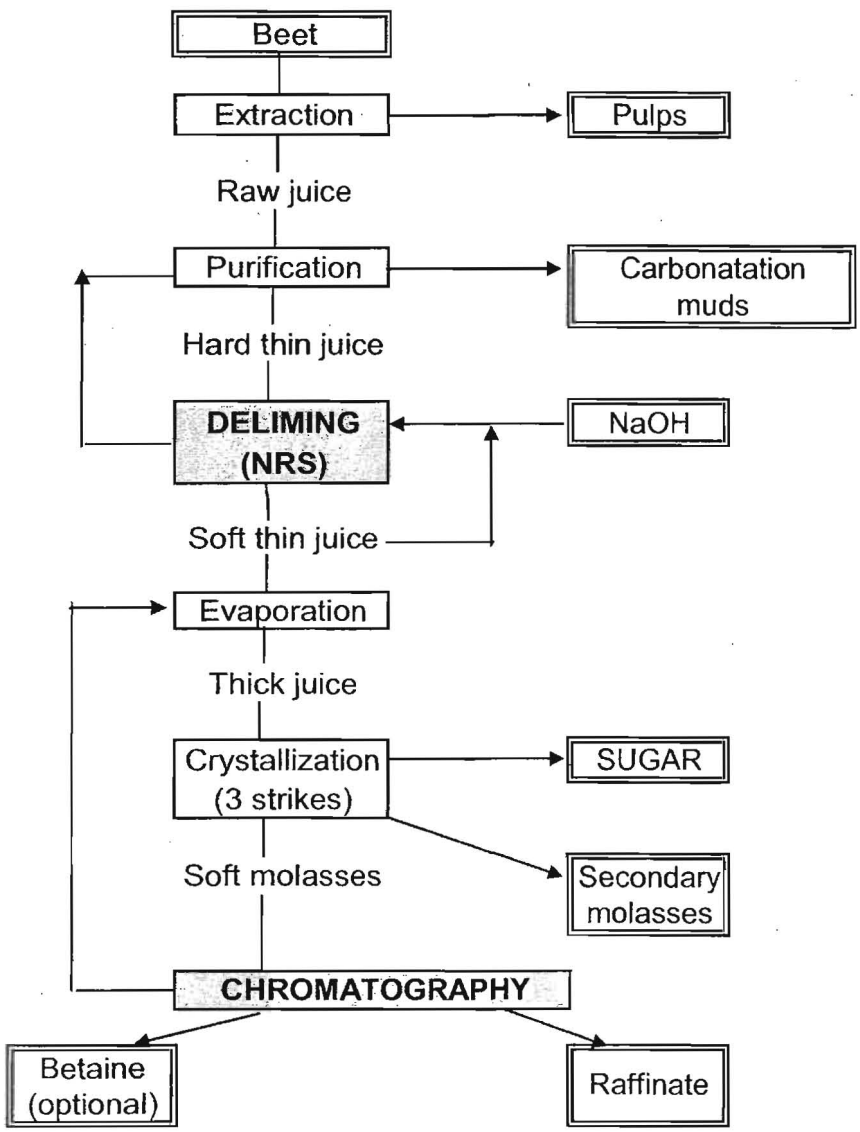
All the sugar recovered is extracted and purified from the thick juice by crystallization only. The molasses is the ultimate by-product of this process, the last mother-liquor of three successive crystallization steps. Having a purity of 58-60, it cannot be crystallized anymore, although it still contains approximately 11 to 16 % of the sugar initially present in the beet:

Table 2: Sugar balance in a conventional beet sugar factory

	% beet
Sugar in beet	17.5
Loss at diffusion	0.25
Loss at purification	0.06
Loss in molasses	2 – 2.95
Undetermined loss	0.3
Sugar produced	13.94 – 14.89
Overall yield of extraction : 79.7 – 85 %	
Sugar lost in molasses : 11.4 – 16.8 %	

Since the development of the chromatographic separation, it has become possible to desugarize the molasses by means of a complementary technology, which "step-in" where crystallization cannot be efficient anymore:

Table 3 : Beet sugar factory with thin juice deliming and molasses desugarization



The chromatographic separation of molasses allows typically recovering 90 % of the sugar in molasses, thus increasing the sugar recovery significantly:

Table 4: Sugar balance with a molasses desugarization plant

	% beet
Sugar in beet	17.5
Loss at diffusion	0.25
Loss at purification	0.06
Loss in rafinate	0.2 – 0.29
Loss in secondary molasses	0.3 – 0.4
Undetermined loss	0.3
Sugar produced	16.2 – 16.69
Overall yield of extraction : 92.5 – 95.4	
Additional sugar produced: 10.4 – 12.8 % on sugar in beet	

Compared to the conventional "all crystallization" process, this represents an additional recovery of 10.4 – 12.8 % on sugar in beet.

In view of this sizable improvement, many plants of molasses desugarization have been added to existing beet sugar factories, where the economic conditions justified this supplementary sugar extraction. (1) (2) (3)

II. INTEGRATING THE CHROMATOGRAPHIC SEPARATION TO THE BEET SUGAR PROCESS

The success of a new technology is often ensured by its degree of integration in the overall process, thus generating more or less profits to the end-users.

A typical example of this assessment can be found in the development of deliming, an ion-exchange technology that has developed over the years in the beet sugar processing.

Initially used for thin juice decalcification in order to improve the evaporators efficiency, it was generating inconvenient salty effluents until elegant and integrated processes such as the Gryllus process or the NRS process made it completely "effluent free" and well adapted to the beet sugar plant.

The NRS deliming process (4) has also the advantage of producing soft molasses, suitable to the chromatographic separation process. Therefore, integrating a "NRS" juice deliming system in a beet sugar factory will avoid the end-user to have to add in molasses pre-treatment a costly chemical softening system prior to the molasses separator. The ultimate integration of deliming is the use of raffinate from the separator for the regeneration of the deliming system (Patented Applexion/LSU Process), thus making the process also "chemical free". (5)

Table 5: Four options of integrated ion-exchange deliming processes in the beet sugar factory.

OPTION	Advantages	Disadvantages
First option Regenerating with brine	• Improve evaporator efficiency	• NaCl consumption • Salty effluent
Second option Regenerating with low green (Gryllus)	• Improve evaporator efficiency • Effluent free • Chemical free	• Producing "hard" molasses
Third option Regenerating with caustic soda (NRS)	• Improve evaporator efficiency • Effluent free • Suitable to molasses desugarization	• Consuming caustic soda
Fourth option Regenerating with raffinate (Patented)	• Improve evaporator efficiency • Effluent free • Suitable to molasses desugarization • Chemical free	None of the above

Similarly to the deliming step, the chromatographic separation of sugar from non-sugar can be differently integrated in the beet sugar processing and therefore be more or less profitable to the end-user:

Table 6: Three options of integrated chromatographic separation systems in the beet sugar factory

OPTION	Advantages	Disadvantages
First option Molasses desugarization during the beet season only	• Increased sugar recovery	• Large chromatographic separator • Full size sugar boiling house
Second option Molasses desugarization year round	• Increased sugar recovery • Smaller chromatographic separator	• Full size sugar boiling house
Third option Low green syrup desugarization year round	• Increased sugar recovery • Smaller chromatographic separator • Smaller sugar boiling house	None of the above

Facing a very competitive cane sugar industry and the challenge from the corn and wheat sweeteners, the modern beet sugar industry will pursue its efforts of modernization in the following directions:

- Increasing the sugar extraction by means of chromatographic separation
- Increasing the duration of equipment operations during the year
- Balancing better the use of crystallization versus chromatographic separation : By means of a low green syrup separator, it is possible to decrease the size of the sugar boiling house and to keep the crystallization equipment where it is working the best: for the first strike and the second strike of the sugar plant. (6)

III. EXAMPLE OF A NEW BEET SUGAR FACTORY INTEGRATING A LOW GREEN SYRUP DESUGARIZATION SYSTEM

We take the theoretical example of a 7 000 t/day beet sugar factory, for which the necessary equipment for crystallization is evaluated:

- in case of using the conventional three strikes crystallization
- in case of using an integrated combination of crystallization and low green syrup desugarization by chromatography

Table 7 : Low green syrup desugarization typical performances

FEED	Purity	72 - 76
	Brix	± 60
EXTRACT	Purity	93 - 96
	Sugar recovery	92 - 95
	Brix	30 - 33
RAFFINATE	Purity	14 - 17
	Brix	4.4 - 6

Separator used : SSMB two fractions system, which can be later transformed into a NS2P three fractions for betaine recovery (F.A.S.T. Technology) (6)

Table 8 : Comparison between operations of the conventional plant and the new plant using low green syrup desugarization

CONVENTIONAL PLANT (7 000 t/day beet)

- 100 days of operation

- Producing 99 700 t sugar/year

- Producing 42 800 t molasses/year

NEW PLANT WITH LGS DESUGARIZATION (7 000 t/day beet)

- During the season (100 days)
  Producing 75 900 t sugar
  Producing 48 500 t low green syrup

- Year-round (300 days)
  Producing 66 800 t extract
  Producing 23 800 t raffinate (55 Bx)

- Extract crystallization campaign (98 days)
  Producing 36 600 t sugar
  Producing 10 900 t secondary molasses

Total sugar produced : 112 500 t

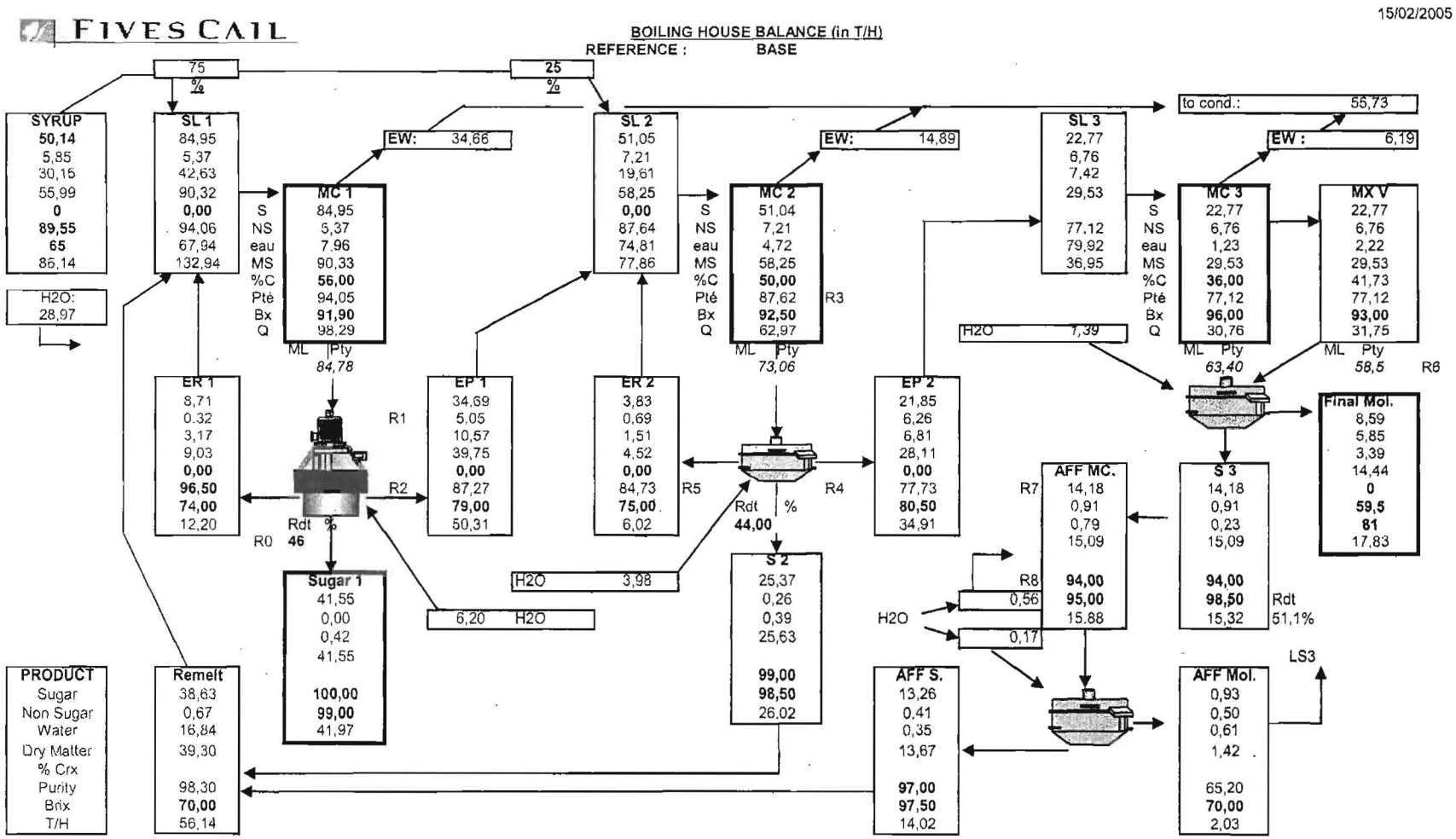
i.e. AN INCREASED SUGAR PRODUCTION OF 12 800 t

The following tables 9, 10 and 11 illustrate the material balance of the sugar boiling house in the conventional sugar plant and in the new plant with LGS desugarization.

It can be seen that the new plant with LGS desugarization is operating only with two strikes during the season.

For the extract crystallization campaign, the same equipment is used for a three strikes with raffinade crystallization, which ensures the best quality for the crystallized sugar from the extract.

Table 12 and 13 indicate the quantities and capacities of the main equipment necessary for the sugar boiling house in both cases.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BOILING HOUSE BALANCE (in T/H)
REFERENCE : BASE
15/02/2005
75 %
25 %
to cond.: 55,73
SYRUP
50,14
5,85
30,15
55,99
0
89,55
65
86,14
H2O: 28,97
SL 1
84,95
5,37
42,63
90,32
0,00
94,06
67,94
132,94
EW: 34,66
MC 1
S 84,95
NS 5,37
eau 7,96
MS 90,33
%C 56,00
Pté 94,05
Bx 91,90
Q 98,29
ML Pty
84,78
SL 2
51,05
7,21
19,61
58,25
0,00
87,64
74,81
77,86
EW: 14,89
MC 2
S 51,04
NS 7,21
eau 4,72
MS 58,25
%C 50,00
Pté 87,62
Bx 92,50
Q 62,97
R3
ML Pty
73,06
SL 3
22,77
6,76
7,42
29,53
77,12
79,92
36,95
EW : 6,19
MC 3
S 22,77
NS 6,76
eau 1,23
MS 29,53
%C 36,00
Pté 77,12
Bx 96,00
Q 30,76
ML Pty
63,40
MX V
22,77
6,76
2,22
29,53
41,73
77,12
93,00
31,75
ML Pty
58,5
R6
H2O 1,39
Final Mol.
8,59
5,85
3,39
14,44
0
59,5
81
17,83
ER 1
8,71
0,32
3,17
9,03
0,00
96,50
74,00
12,20
R1
R2
R0 46
Rdt %
EP 1
34,69
5,05
10,57
39,75
0,00
87,27
79,00
50,31
ER 2
3,83
0,69
1,51
4,52
0,00
84,73
75,00
6,02
R5
R4
EP 2
21,85
6,26
6,81
28,11
0,00
77,73
80,50
34,91
Rdt %
44,00
AFF MC.
14,18
0,91
0,79
15,09
94,00
95,00
15,88
R7
R8
0,56
0,17
H2O
S 3
14,18
0,91
0,23
15,09
94,00
98,50
15,32
Rdt
51,1%
Sugar 1
41,55
0,00
0,42
41,55
100,00
99,00
41,97
6,20 H2O
H2O 3,98
S 2
25,37
0,26
0,39
25,63
99,00
98,50
26,02
AFF S.
13,26
0,41
0,35
13,67
97,00
97,50
14,02
AFF Mol.
0,93
0,50
0,61
1,42
65,20
70,00
2,03
LS3
PRODUCT
Sugar
Non Sugar
Water
Dry Matter
% Crx
Purity
Brix
T/H
Remelt
38,63
0,67
16,84
39,30
98,30
70,00
56,14

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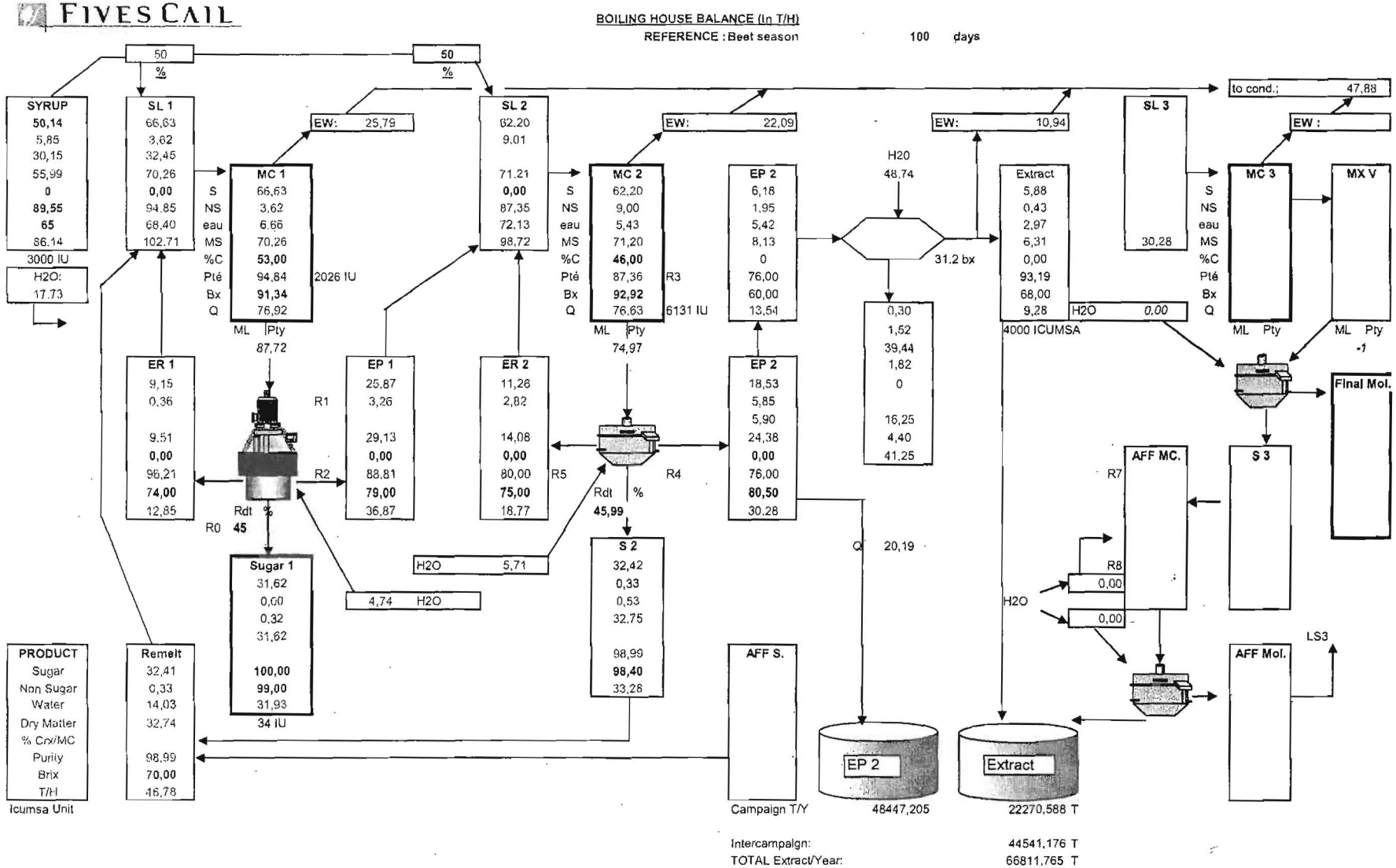

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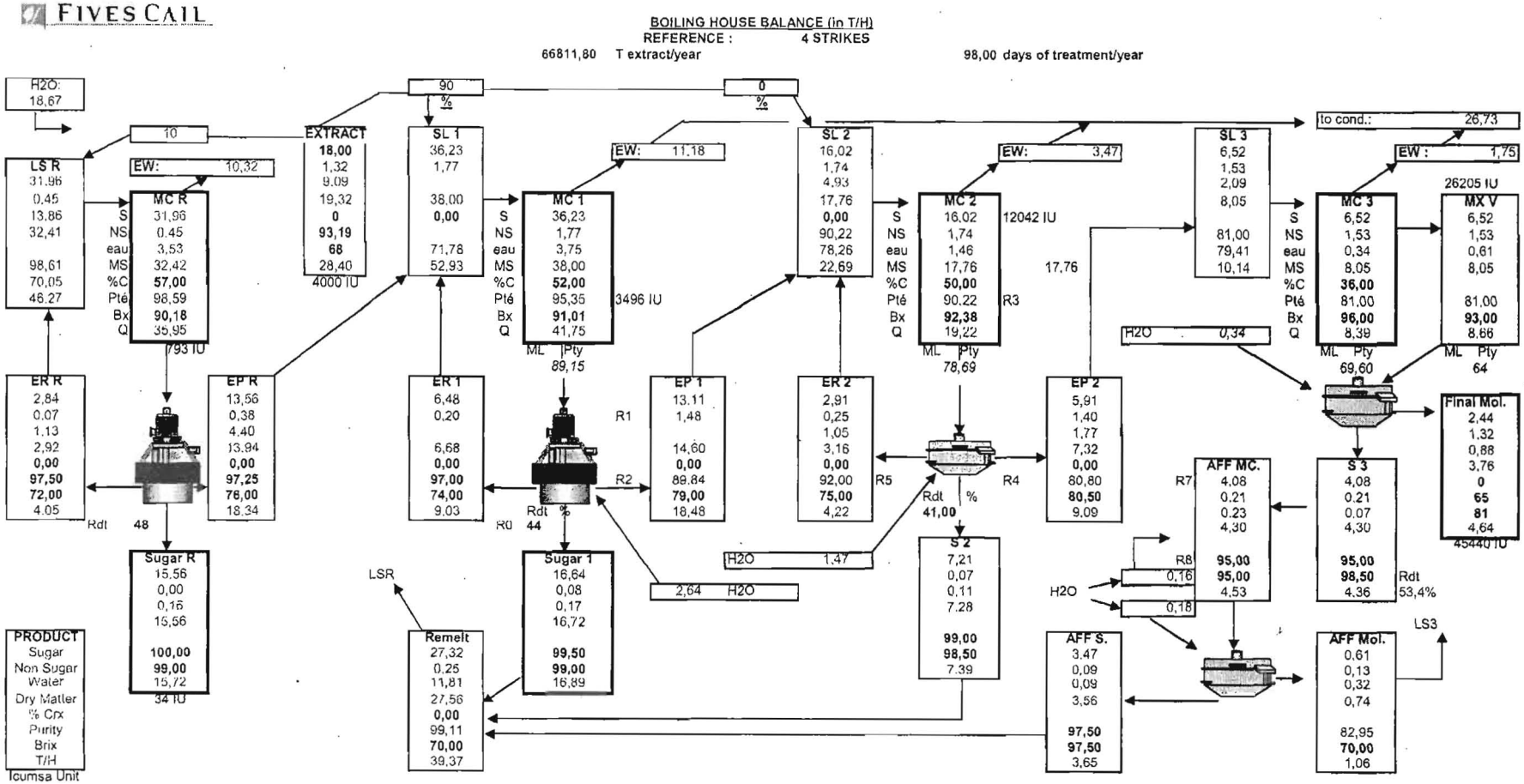

Table 12: Equipment for the sugar boiling house

Conventional beet sugar factory 7,000 t b/d				
Product	T product/h	Equipment	Size	Nbr
MC1	98.3	• Pans • Crystallizers • Centrifugals • *SB centrifugal	70 m^3 90 m^3 1750 kg/p 1750 kg/p	3 2 3 1
White sugar	42	Dryer/cooler	50 t/h	1
MC2	63	• Pans • Crystallizers • Centrifugals • *SB centrifugal	70 m^3 120 m^3 FC 1550 FC 1550	4 2 2 1
MC3	30.8	• Pans • Vertical crystallizers • Centrifugals • *SB centrifugal	70 m^3 120 m^3 FC 1550 FC 1550	3 1 3 1
BUDGET SUGAR BOILING HOUSE : k Euro			30,000	

* SB = Stand By

Table 13: Equipment for the sugar boiling house with LGS chromatography

Beet sugar factory 7,000 t b/d									
Beet campaign					Extract campaign				
Prod	Product t/h	Equipment	size	Nbr	Product	Product t/h	Equipment	size	Nbr
MC1	76.9	Pans Crystallizers Centrifugals *SB centrifugal	55 m^3 120 m^3 1250 kg/p 1250 kg/p	2 2 4 1	MCR	35.9	Pans Crystallizers Centrifugals *SB centrifugal	55 m^3 120 m^3 1250 kg/p 1250 kg/p	2 1 2 1
					MC1	41.7	Pans Crystallizers Centrifugals	55 m^3 120 m^3 1250 kg/p	2 1 2
W S	31.9	Dryer/cooler	40 t/h	1	W S	15.7	Dryer/cooler	40 t/h	1
MC2	76.7	Pans Crystallizers Centrifugals *SB centrifugal	55 m^3 120 m^3 FC 1250 FC 1250	5 2 4 1	MC2	19.2	Pans Crystallizers Centrifugals *SB centrifugal	55 m^3 120 m^3 FC 1250 FC 1250	2 1 1 1
					MC3	8.7	Pans Crystallizers Vertical crystallizer Centrifugals *SB centrifugal	55 m^3 120 m^3 250 m^3 FC 1250 FC 1250	2 1 1 2 1
BUDGET SUGAR BOILING HOUSE : k Euro							23,000		

Savings compared to conventional = 7,000 k Euro or approx. 40 % of the LGS chromatography system.

Using the LGS desugarization process in the beet sugar factory is generating a capital cost saving for the investment of the sugar boiling house estimated to 7 million Euros.

This represents approximately 40 % of the total capital cost necessary for the LGS desugarization system.

This can be very helpful for the decision of the final end-user to proceed with this modern technology, which will allow the recovery of an additional 12 800 t of sugar per year

CONCLUSION

Low Green Syrup desugarization to increase the yield of sugar extraction should be considered as an option for every new project of beet sugar factory:

- It will increase the sugar production by more than 10 %.
- It will decrease the capital cost of the new sugar boiling house
- It will contribute to a better use of the equipment installed, with longer operating periods
- It represents a good balance between crystallization of high purity syrups and chromatography of low purity syrups for the beet sugar process.

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