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THE NRS FOR SUGAR JUICE DELIMITING:  
RENEWED INTEREST DUE TO RECENT DEVELOPMENTS  
IN THE U.S. BEET SUGAR INDUSTRY

Xavier Lancrenon



Softening of juice, commonly referred to as deliming, was not widely used in the beet sugar industry in North America until 1985. Although a few scattered factories had used this unit operation in the past, by this time it was no longer employed by any factory. This was primarily because the existing deliming plants were old, manually operated, and required the use of sodium chloride as a regenerant in their operation--which created environmental problems. By 1985, out of some thirty-six beet sugar factories, none used deliming in their operations.

Since 1985 we see a renewed interest in deliming, clearly evidenced by four new deliming plants. All of these plants were in operation during the 1990-1991 campaign. This means that in just five years the percentage of factories using deliming went from zero percent to twelve percent. This is still far below the seventy-five to eighty percent of sugar factories in various European countries which have deliming plants in operation. It does, however, clearly indicate a trend in the North American sugar industry.

Why should today's beet sugar factory be equipped with a deliming plant? The answer to this question is simple: BECAUSE DELIMING IS PROFITABLE!

At this meeting of the ASSBT, Eric Ekern has made a presentation which focuses on the savings in chemicals obtained by a factory using deliming by the Gryllus process.

A few months ago, in a presentation at the S.I.T. meeting in Vancouver, B.C., Tom Hensheid presented the "weak catex" deliming system, stating the

following: "The benefits gained by softening thin juice are substantial. Our factories have been able to slice more beet because of the clean evaporators. Energy usage per ton of beet sliced has dropped significantly. Evaporator boilouts are history and scaling of thick juice filters no longer occurs. Pan vapors have improved, increasing sugar end capacity and allowing the use of lower vapors. The resulting benefits to our process, we feel, would pay for the installation in about four years..."

Both the Gryllus and "weak catex" systems represent a new generation of delimiting plants in North America.

In this presentation we are focusing on another alternative, which is also a member of that new breed of delimiting systems: NRS (New Regeneration System) delimiting.

Our intent is not to make an in-depth presentation of the NRS. This can be found in several publications, some of which are listed below for those wishing to make a detailed study of the process. We would, however, like to help the sugar factory manager make an evaluation of the profitability of a delimiting system in general, and demonstrate that the NRS is a good choice for a factory wishing to use ion exclusion for the recovery of sugar from beet molasses.

A. Variation in Lime Salts Content in the Beet Sugar Factory Operation

If lime salts were not a potential problem for the factory operation, no one would measure their quantity in the thin juice. Because of their significant effect, however, particularly on evaporator efficiency, everyone is carefully monitoring the lime salts in thin juice.

What are the factors which affect the lime salts in juice?

1) Agronomic Factors: Beet Growing Conditions.

Depending on the area under cultivation, beets can be irrigated or non-irrigated. The irrigated beets, of course, are less sensitive to a drought situation than the non-irrigated. The lime salts in juice from the irrigated beets have a tendency to be lower, especially during a period of drought. The use of too much fertilizer, in combination with the drought, can also adversely affect the purity of beets. Consequently, the lime salts content of the thin juice can be higher.

Table I shows the average lime salts content of thin juice at some USA factories where beets were irrigated for the last three years. Table II shows the average lime salts content of thin juice at some USA factories where the beets were not irrigated for this three year period.

From these tables we see that the lime salts content of thin juice from irrigated beets is on average lower than the lime salts content of non-irrigated beets. Factories located in non-irrigated areas will, therefore, monitor lime salts more closely than those factories in the irrigated areas.

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TABLE I

AVERAGE LIME SALTS CONTENT OF THIN JUICE IN SOME U.S. BEET SUGAR FACTORIES:  
FOR IRRIGATED BEET AREAS

	1987/1988	1988/1989	1989/1990
FACTORY A	0.040	0.042	0.035
FACTORY B	0.063	0.072	0.047
FACTORY C	0.107	0.085	0.092
FACTORY D	0.056	0.045	0.078
FACTORY E	0.124	0.063	0.071
FACTORY F	0.089	0.094	0.089
FACTORY G	0.092	0.065	0.069
FACTORY H	0.092	0.091	0.078

NOTE: VALUES EXPRESSED IN CaO/100 BRIX

AVERAGE VALUE: 0.074

TABLE II

AVERAGE LIME SALTS CONTENT OF THIN JUICE IN SOME U.S. BEET SUGAR FACTORIES:

FOR NON-IRRIGATED BEET AREAS

	1987/1988	1988/1989	1989/1990
FACTORY 1	0.085	0.128	0.089
FACTORY 2	0.156	0.172	0.288
FACTORY 3	0.101	0.172	0.238
FACTORY 4	0.093	0.099	0.118
FACTORY 5	0.115	0.103	0.160
FACTORY 6	0.228	0.194	0.227
FACTORY 7	0.237	0.215	0.163
FACTORY 8	0.148	0.148	0.119
FACTORY 9	0.221	0.171	0.198
FACTORY 10	0.093	0.135	0.091

NOTE: VALUES EXPRESSED IN CaO/100 BRIX

AVERAGE VALUE: 0.157

2) Seasonal Factors

a) Storage of Beets

Storage of beets during the campaign leads to deterioration of juice quality. This is illustrated in Table III, which shows the progression of the lime salts level in thin juice for a particular factory during a beet slicing campaign:

--In this case, during the first two months of the campaign the average lime salts level is 0.06 g CaO % Brix.

--During the last two months, the average lime salts level becomes 0.17 g CaO % Brix.

This is a generally accepted phenomenon, and a beet sugar factory will expect to have more problems due to evaporator scaling at the end of the season than at the beginning.

b) Conditions Beyond the Factory's Control

Sometimes unexpected weather conditions bring dramatic changes to the lime salts level of thin juice. For example, during the 1984-1985 season, a U.S. beet sugar factory, accustomed to treating juices with a lime salts level which averaged 0.06 g CaO/100 Brix, had to cope with levels as high as 0.3 g/100 Brix, i.e., five times their usual salts level. This was due to poor beet quality, brought about by a mid-season frost followed by a thaw-out.

TABLE III

PROGRESSION OF THE LIME SALTS LEVEL IN THIN JUICE  
FOR ONE PARTICULAR U.S. SUGAR FACTORY DURING A BEET SLICING CAMPAIGN:  
(1989 - 1990)

<u>WEEK NO.</u>	<u>THIN JUICE LIME SALTS</u> <u>Gm CaO/100 Bx</u>
1	0.072
2	0.053
3	0.066
4	0.062
5	0.049
6	0.043
7	0.059
8	0.080
9	0.071
10	0.083
11	0.150
12	0.152
13	0.178
14	0.212
15	0.229
16	0.180
17	0.282



In another case, a factory treating thin juices normally having 0.2 to 0.25 g CaO/100 Brix had to face levels of 0.5 g to 0.6 g CaO/100 Brix, due to a combination of drought and disease severely damaging beet quality during the 1989-1990 season.

Needless to say, when such unexpected events occur, the use of a deliming system is particularly profitable for the factory operation.

### 3) Process Factors

It is clear that the lime salts content of the thin juice, for a given factory, is to a great degree determined by the process.

#### a) Choice of Clarification System

If a conventional clarification system, with preliming of juice, is used--which results in very good elimination of reducing sugars in the juice--the lime salts in the thin juice will be higher.

If a Dorr clarification system is used, elimination of reducing sugars is less effective, but the lime salts are lower.

b) Alkalinization of Juice to Avoid pH Drop

The addition of an alkaline agent--such as caustic soda or magnesium oxide-- to avoid a drop in pH during evaporation, also has an effect on the lime salts content of the juice. This addition is usually done routinely when the quality of the beet deteriorates.

c) Effect of a Steffen House

Using the Steffen process to recover sugar from molasses usually leads to a higher lime salts content in the juice, due to the calcium added to the juice by the Steffen's calcium saccharate. In using this process, an increase in lime salts of 0.1 g CaO/100 Brix over the normal lime salts level of the factory must be taken into consideration.

From the above one can see that the lime salts level in thin juice depends on a number of factors, some of which cannot always be controlled by the factory. Also, the level of lime salts can vary drastically--from low values to high values--during a single season, or from one season to another.

Although the level of lime salts cannot be connected mathematically to the amount of evaporator scaling (since the

scaling effect of the salts also depends on the anionic composition of the thin juice and especially the concentration in carbonates, citrates, oxalates, acetates, etc...), it is clear that for the factory, higher lime salts usually means more scaling problems with the evaporators and other equipment, such as syrup filters and crystallization .

In a modern factory looking for optimization of its energy consumption--which has become a high priority item for the factories of North America, the deliming of thin juice plays a key role.

B. Effect of Deliming on Heat Transfer Equipment Efficiency in a Beet Sugar Factory

Even in North America, where energy has been considered to be cheap--and still is, when compared with that in other areas of the world--the trend in the beet sugar industry is now toward the systematic reduction of energy costs.

The industry's first move was to convert fuel oil burning boilers to gas or coal, wherever possible, to avail itself of the cheapest source of energy.

The next step has been the serious consideration of investments to improve the energy efficiency of the factory. A deliming plant falls into this category.

If we consider the classic formula for heat transfer through a surface

area:  $Q = UxSx\Delta t$

where  $Q$  is the total heat transferred per hour

$U$  is the overall heat transfer coefficient

$S$  is the area of heat surface

$\Delta t$  is the difference in temperature across the heating surface

--we see that deliming will improve the overall heat transfer coefficient.

The following examples show how the sugar factory can benefit from this.

- 1) Example No. 1: A factory where the evaporation station is the bottleneck of the process.

Table IV shows the increase in evaporation capacity for this particular factory if the evaporators are kept clean through the deliming of thin juice. In this case, maintaining the same  $\Delta t$  for the same surface area, a 5% increase in evaporation capacity is observed.

If the evaporator is the bottleneck in the factory, the use of deliming would reduce the slicing campaign by 5%: If the campaign is normally 150 days, this would represent a reduction of seven days--and a sizeable saving to the factory.

TABLE IV

INCREASE IN EVAPORATION CAPACITY WHEN TUBES ARE CLEAN

BODIES	1	2	3	4	5
AVERAGE U BETWEEN CLEANINGS	382	379	313	158	108
U AFTER CLEANING	406	393	328	165	111
BX AT INLET	12.6	18.4	29.9	41.2	57.2
BX AT OUTLET	18.4	29.9	41.2	57.2	59.6
TONS OF WATER EVAPORATED PER TON THIN JUICE CONCENTRATED	0.315	0.263	0.160	0.041	0.0086
% U INCREASE WHEN CLEAN	6.28	3.69	4.79	4.43	2.7
ADDITIONAL TONS WATER EVAPORATED PER TON OF THIN JUICE WHEN TUBES ARE CLEAN	0.0197	0.0097	0.0076	0.0018	0.0002

TOTAL TONS WATER EVAPORATED PER TON OF THIN JUICE  
(AVERAGE EVAPORATION BETWEEN CLEANINGS): 0.7876

TOTAL INCREASE IN TONS OF WATER EVAPORATED AFTER CLEANING: 0.039

PERCENT EVAPORATION INCREASE: 5%

- 2) Example No. 2: With a clean evaporator it is possible to use lower vapor for white pan boiling.

Figure No. 1 shows a simplified heat balance in a beet sugar factory where second effect vapors are used for white pan boiling. Due to low overall heat transfer coefficient coming from lime salts scaling, the  $\Delta t$  in each effect is higher and the pressure of the third vapors is, therefore, not high enough to ensure the use of these vapors for white pan boiling. One can see that there is a 38,500 pounds per hour draw from the second vapors, 30,000 pounds of which are used for the white pan boiling.

Installing a deliming plant in this factory will reduce the  $\Delta t$  at each effect, thereby increasing the pressure of the third-effect vapors for the same evaporation capacity. These vapors, instead of the second vapors, can then be used for white pan boiling. In Figure 2, the same factory has modified its heat balance to use third vapors for white pan boiling. An increase in evaporator efficiency is observed, the Brix of standard liquor being raised from 66 (before the modification) to 71 (after modification). Also, the necessary vapor for the white pan boiling (22,500 pounds/hour) is now taken from the third vapors. This results in a lower consumption of exhaust steam: a 6.5% saving in the factory's steam consumption.

For a 150-day campaign, with steam at a cost of \$7.00/ton, the annual saving in steam reduction alone is \$94,500.00.

FIGURE 1 : HEAT BALANCE IN A BEET SUGAR FACTORY  
WHERE SECOND EFFECT VAPOR IS USED  
FOR WHITE PAN BOILING

FIGURE 1

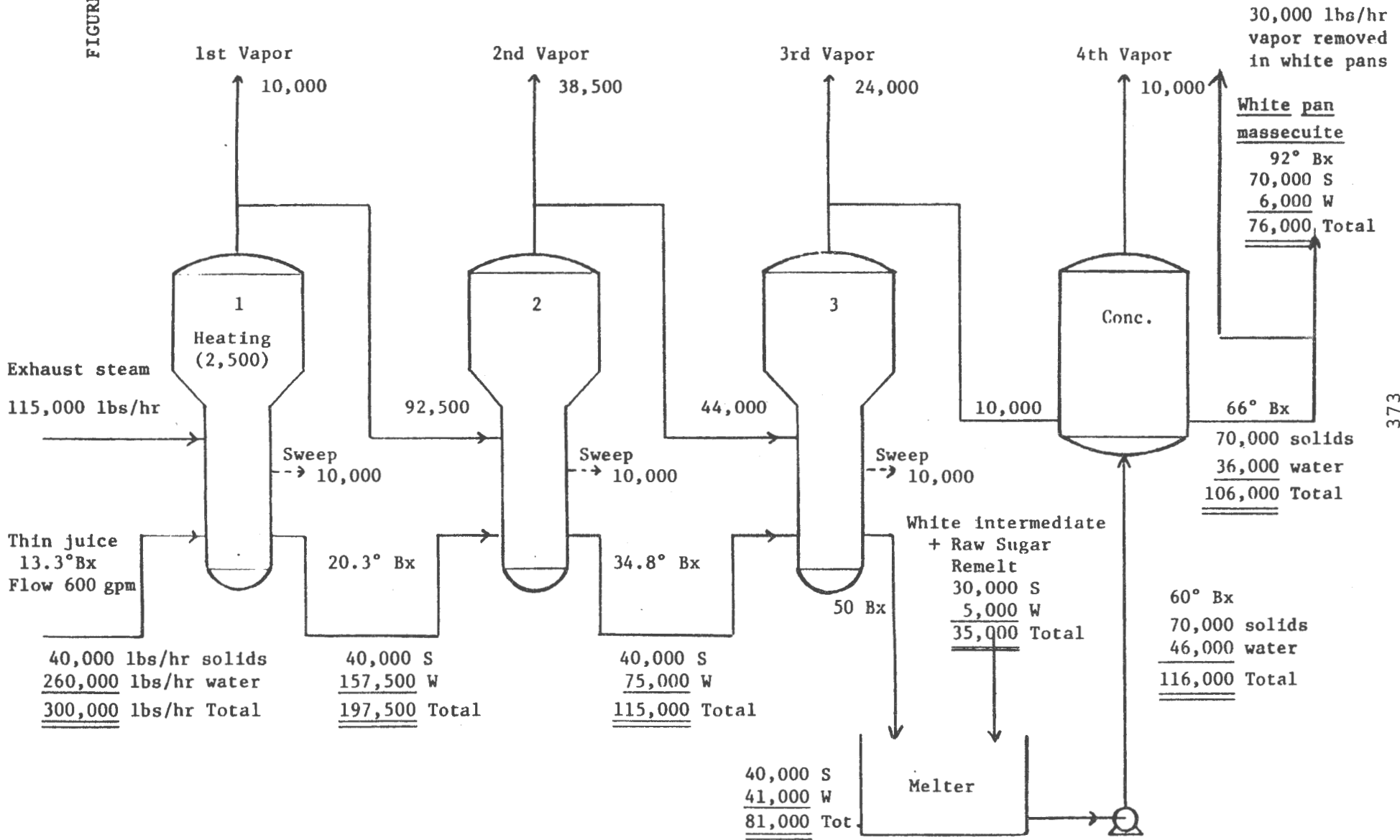
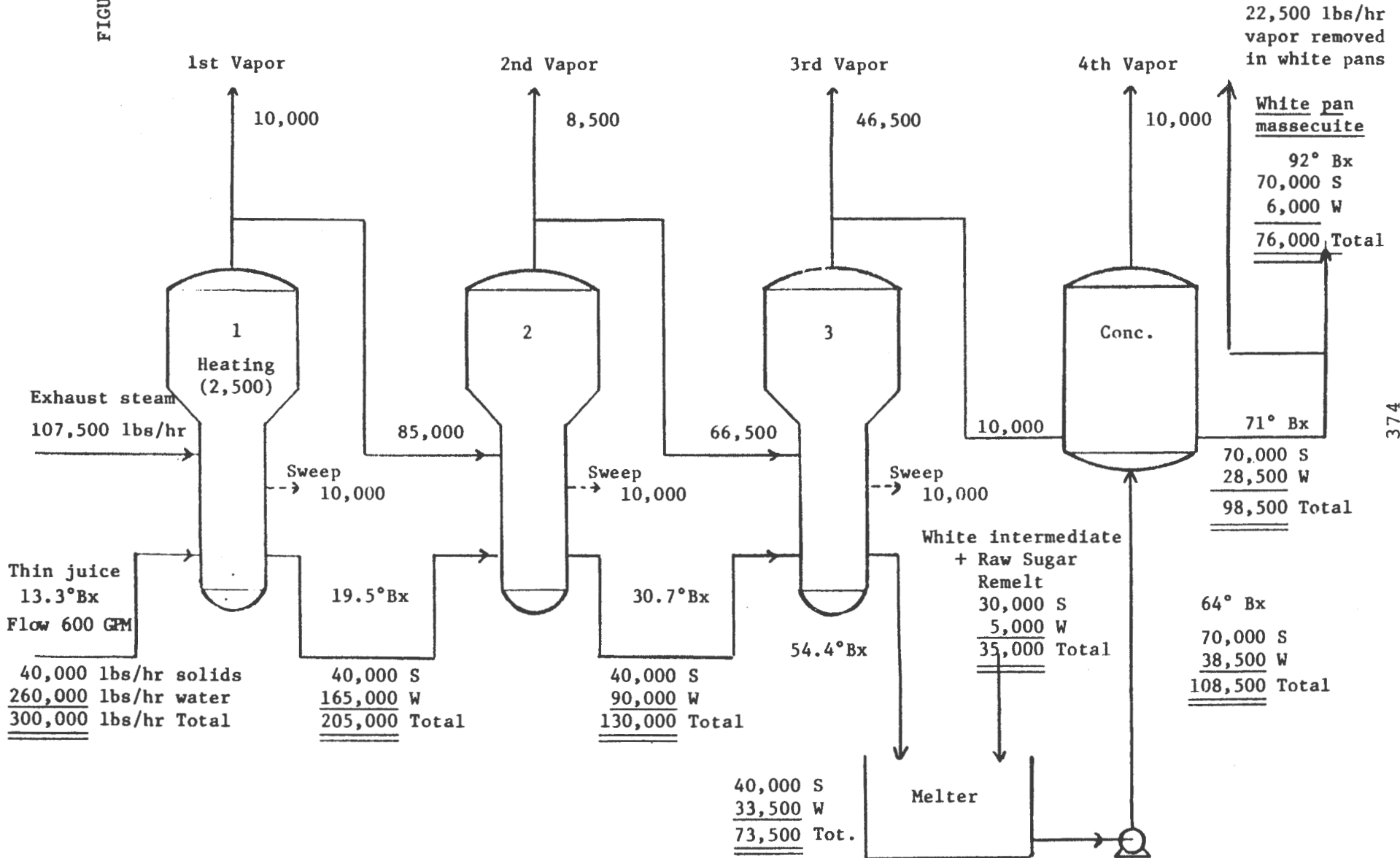


FIGURE 2 : HEAT BALANCE IN A BEET SUGAR FACTORY  
WHERE THIRD EFFECT VAPOR IS USED  
FOR WHITE PAN BOILING

FIGURE 2





3) General Considerations for Improvements in Energy Efficiency through Delimiting

From the simplified examples given above it is clear that a study should be made of each specific factory; however, the following general considerations do apply:

a) Boilouts

Delimiting eliminates or greatly reduces the number of boilouts of evaporator bodies.

These boilouts are costly for the beet sugar factory in many ways:

- They slow down the general pace of evaporation.
- They require intensive and skilled labor.
- They require chemicals which are not only costly, but create disposal problems.
- They result in faster corrosion of the heat transfer elements due to chemical attack.

b) Access to New Thin Film Technology for Heat Transfer

Operating with juices or syrups which are "clean", with no risk of scaling the heat exchange surface, lends itself to the use of plate heat exchanger technology. This technology offers better thermal performance than tubular heat exchanger technology and permits reduction of product contact time at high temperature, resulting in a better quality of sugar.

c) Other Considerations

Although they are not directly connected to energy improvement, we would like to point out some of the other profit-yielding improvements to be expected from deliming:

- Reduction in consumption of anti-scaling agents.
- Improvement in filtration rates for syrups.
- Higher quality sugar due to less calcium related turbidity.

Although it is difficult to calculate some of the benefits brought to the factory by deliming, it is always possible to demonstrate its profitability.

C. NRS Deliming: A Good Choice for Factories Which Want to Recover Sugar from Molasses by Ion Exclusion

1. Principle of the NRS System (See Figure 3)

This system, developed by Akzo and promoted by Rohm & Haas, uses strong cationic resins in the sodium form for deliming juice.

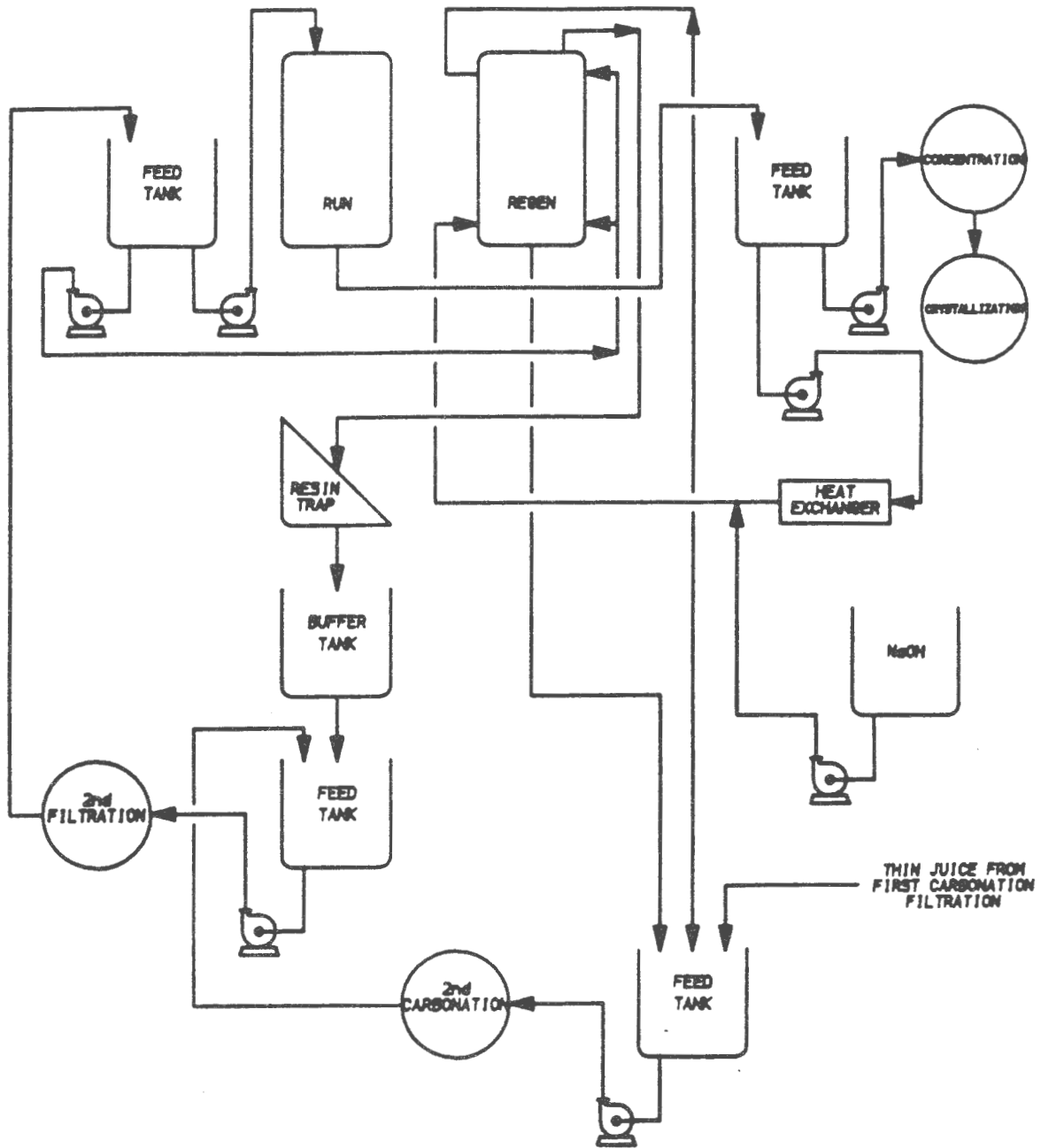
The calcium from thin juice is exchanged in the resin for sodium ions; the emerging juice is thus very low in calcium.

After the resin has been exhausted with calcium, it must be regenerated.

This regeneration is performed with soft thin juice, cooled to a

FIGURE 3

INTEGRATION OF THE N.R.S. SYSTEM  
IN THE SUGAR FACTORY



temperature of 40° C, followed by the addition of caustic soda. The sodium from the caustic soda is exchanged for the calcium of the resin, and this calcium leaves the reactor with the juice of regeneration in the form of a soluble calcium saccharate, which is returned to carbonation.

The calcium removed from the thin juice finally ends up in the filter cake of carbonation.

Figure 4 shows typical curves of regeneration.

This unique process has the following advantages:

2. Advantages of the NRS process.

a) No juice dilution - No sugar loss.

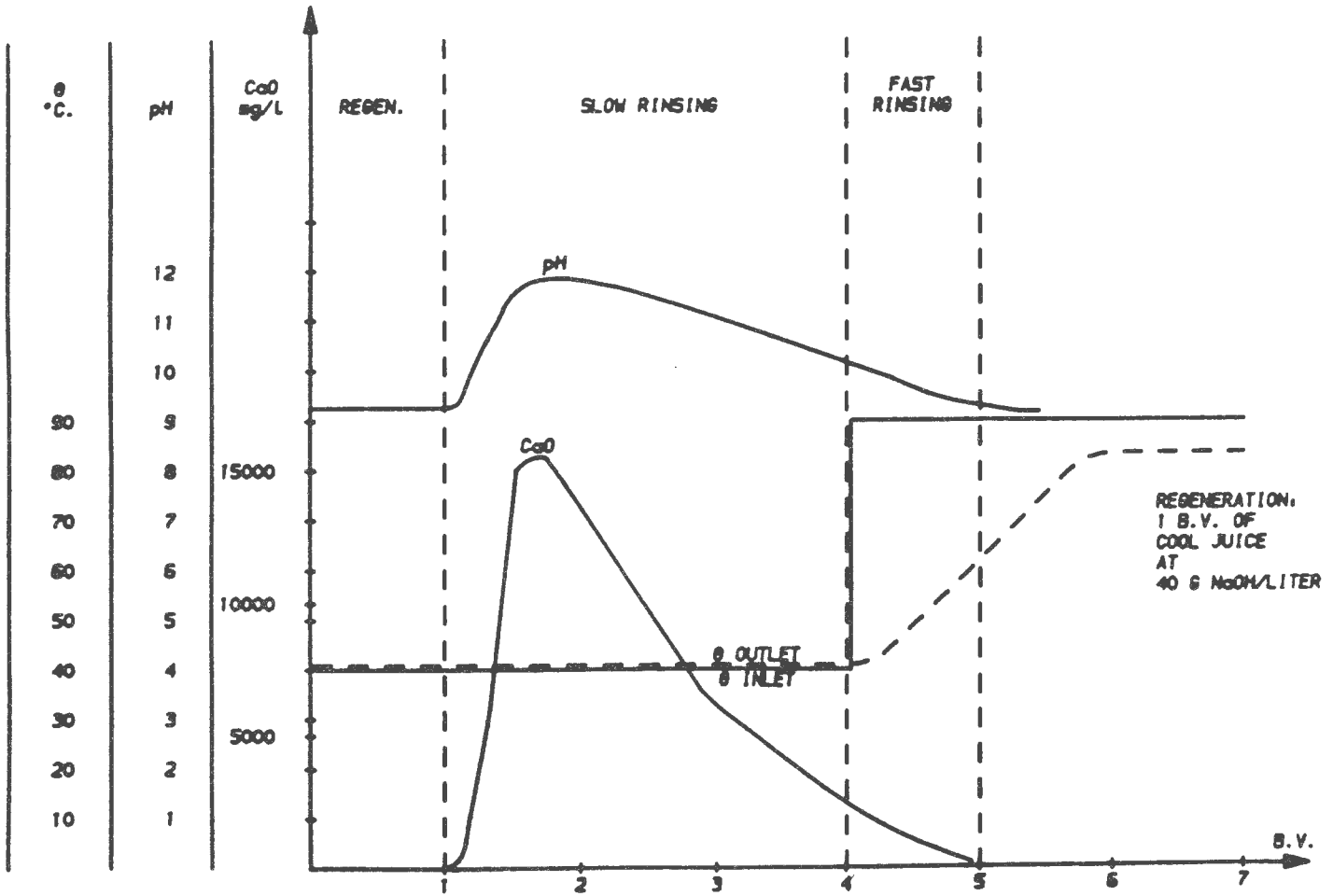
Since the reagent (caustic soda) is added to the juice and not to water (as is the case with other systems, such as brine or sulfuric acid regeneration), no dilution of juice occurs, and no loss of sugar due to sweetening on/sweetening off.

b) No production of waste effluent: No waste disposal problem.

In the NRS process the only waste stream is the calcium carbonate precipitated at the carbonation station, which ends up in the filtration cake of the carbonation filters. No

FIGURE 4

REGENERATION BY N.R.S. PROCESS



other effluent is anticipated, since all operations involved with the ion exchange reactors are made with juice recirculated in the factory.

c) Production of soft molasses suitable for the ion exclusion process, for recovery of sugar from molasses.

At the present time in the United States, this may just be one of the best incentives for installing an NRS process in a beet sugar factory. Currently the economics of sugar recovery from beet molasses via ion exclusion make this procedure especially attractive here in the U.S. We are seeing the development of a number of new projects to increase the yield of sugar extracted from beets by employing this technology.

One of the requirements for an ion exclusion process to run properly is a low level of calcium in the molasses--on the order of 0.04 g CaO/100 Brix. One way of achieving this is to install ahead of the ion exclusion process a sophisticated system for eliminating calcium in the concentrated molasses. Such a pre-treatment is costly and will produce the undesirable waste effluents.

The alternative: Installation of a softening station using the NRS at the factory producing the molasses to be treated.

The softening of thin juice in the factory will not only be the best way to obtain molasses at low calcium level by an effluent-free process, it will also be profitable to the factory, as indicated above--over and above the profit generated by the ion exclusion process.

In conclusion, we highly recommend the use of the NRS for any beet sugar factory whose future plans include an ion exclusion system.

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