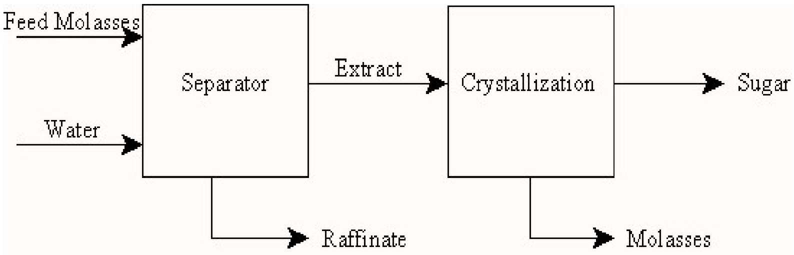
# CHROMATOGRAPHIC SEPARATOR OPTIMIZATION (ASSBT 1995)

Vadim Kochergin and Mike Kearney

Large-scale chromatographic separators have been used in the U.S. sugar industry for molasses desugarization since the mid-1980's. The technology has proven to be extremely efficient. At the present time, most U.S. sugar beet companies are using various modifications of chromatographic separators.

Separation of sucrose from non-sucrose components is based on preferential sorption of sucrose by ion-exchange resins accompanied by exclusion of non-sucrose components. Thus "excluded" components move along with the flow while adsorbed components lag behind. When only two products are collected, the sucrose rich fraction is designated "extract" and the nonsucrose fraction is designated "raffinate".



Sugar is crystallized from the extract. The concentrated raffinate is usually sold as animal feed. Chromatographic separation technology can generate a significant profit so small deviations from optimal performance can be economically detrimental.

The importance of monitoring the separator operation can be emphasized by calculating the effect that small changes in separator parameters will have on sugar production (see Table 1). Two cases were considered showing good and poor separator performance. Using current values for published sugar futures the calculations illustrate that one extract purity point decrease results in $1,700-$1,800/day loss. It appears that an extract purity decrease is more significant in the case of poor performance. The effect of separator recovery (defined as the ratio of sugar in product to sugar in feed) costs about half as much, but is still significant. Data in Table 1 also justify establishment of reliable analytical procedures to monitor true purities of both extract and raffinate.

## TABLE 1
## Example separator process at 500 tpd molasses for 330 days

| | CASE 1 (good) | | | CASE 2 (poor) | | |
|---|---|---|---|---|---|---|
| Extract purity | 92 | 91 | 92 | 88 | 87 | 88 |
| Separator recovery | 90 | 90 | 89 | 88 | 88 | 87 |
| Sugar produced, cwt/day | 3,714 | 3,638 | 3,673 | 3,322 | 3,240 | 3,284 |
| Profit Loss, $/day | 0 | 1,720 | 928 | 0 | 1,856 | 860 |
| Profit Loss $/campaign | 0 | 567,600 | 306,204 | 0 | 612,480 | 283,800 |

In order to monitor and optimize separator performance certain criteria should be established. Undoubtedly maximization of both sugar recovery and extract purity will be the ultimate performance goal. In practice various sets of parameters are to be compared. Normally higher recovery may be achieved by quality reduction, and just the opposite higher purity extract will result in sugar loss with the raffinate stream. Thus neither extract purity nor recovery can be used as sufficient criteria for optimization. This fact can be illustrated by comparing two different sets of parameters: “extract purity = 92, recovery = 90” and “extract purity = 90, recovery = 92”. Further calculations are required to evaluate which operation mode is more beneficial.

A criterion (Z-factor) was introduced[1] that is a function of performance of both separator and sugar end. The expression for Z is:

$$Z = R \times \left(1 - \frac{Me}{mE}\right)$$

where R = separator recovery/100
E = extract purity/100
M = molasses purity after extract crystallization
e = 1-E
m = 1-M

Analysis of the formula demonstrates that the Z-factor increases when sugar recovery or extract purity is increased. The Z-factor decreases at the same time if resulting molasses purity increases. This shows that the Z-factor is a very convenient number because it reflects both separator and sugar end efficiency and reaches the maximum value at maximum sugar production. Z-factor also has an important physical meaning. It may be interpreted as sugar extraction of the system that includes both the separator and the sugar end. Thus by knowing the Z-factor and the feed molasses purity one can calculate the amount of sugar produced from the following expression:

Sugar produced = Z × sugar entering the separator

With the Z-factor it is easy to compare various modes of operation.

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[1] M. Kearney, “The use of infinite series for optimizing placement and operation of chromatographic separators”, S.I.T. Meeting, Canada, May 6-9, 1990.

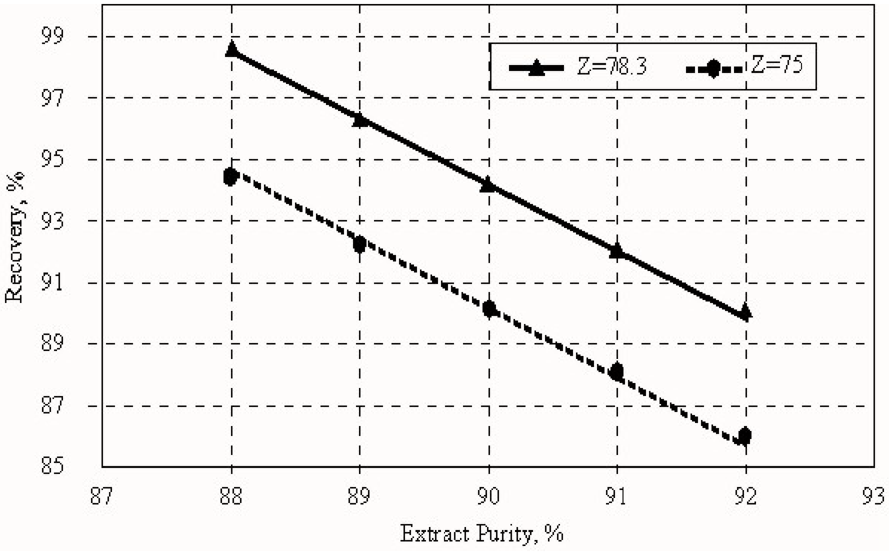
## TABLE 2

| | **Case 1** | **Case 2** |
|---|---|---|
| Extract purity | 90 | 92 |
| Recovery | 92 | 90 |
| Z-factor | 76.7 | 78.3 |

The data in Table 2 show that assuming the same molasses purity after crystallization, the amount of sugar produced from each 100 tons of sugar entering the separator will be 1.6 tons higher in Case 2.

The Z-factor concept may also be used for drawing the following important conclusion: Multiple combinations of extract purities and recoveries result in the same amount of sugar produced. Figure 1 illustrates this statement. The calculations were based on the assumption that no extract molasses was recycled and the purity of extract molasses reached 60%. Lines corresponding to constant Z values show that the same amount of sugar may be produced by operating the separator in different modes. For example 75% of the sugar will be recovered if the separator is operated at purity = 91, recovery = 88 as well as purity = 88, recovery = 94.

## FIGURE 1



The following table lists the Z-factor as a function of extract purity and recovery.

## TABLE 3
## Fraction of Molasses Sucrose Recovered as Crystallized Product (Z-factor) as a Function of Separator Recovery and Extract Purity
## (molasses=60 purity, no molasses recycle)

| **Extract Purity** | **Recovery Across the Molasses Separator** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **100** | **98** | **96** | **94** | **92** | **90** | **88** | **86** | **84** | **82** | **80** |
| 100 | 1.000 | 0.980 | 0.960 | 0.940 | 0.920 | 0.900 | 0.880 | 0.860 | 0.840 | 0.820 | 0.800 |
| 98 | 0.969 | 0.950 | 0.931 | 0.911 | 0.892 | 0.872 | 0.853 | 0.834 | 0.814 | 0.795 | 0.776 |
| 96 | 0.938 | 0.919 | 0.900 | 0.881 | 0.863 | 0.844 | 0.825 | 0.806 | 0.788 | 0.769 | 0.750 |
| 94 | 0.904 | 0.886 | 0.868 | 0.850 | 0.832 | 0.814 | 0.796 | 0.778 | 0.760 | 0.741 | 0.723 |
| 92 | 0.870 | 0.852 | 0.835 | 0.817 | 0.800 | 0.783 | 0.765 | 0.748 | 0.730 | 0.713 | 0.696 |
| 90 | 0.833 | 0.814 | 0.800 | 0.783 | 0.767 | 0.750 | 0.733 | 0.717 | 0.700 | 0.683 | 0.667 |
| 88 | 0.795 | 0.780 | 0.764 | 0.748 | 0.732 | 0.716 | 0.700 | 0.684 | 0.668 | 0.652 | 0.636 |
| 86 | 0.756 | 0.741 | 0.726 | 0.710 | 0.695 | 0.680 | 0.665 | 0.650 | 0.635 | 0.620 | 0.605 |
| 84 | 0.714 | 0.700 | 0.686 | 0.671 | 0.657 | 0.643 | 0.629 | 0.614 | 0.600 | 0.586 | 0.571 |
| 82 | 0.671 | 0.657 | 0.644 | 0.630 | 0.617 | 0.604 | 0.590 | 0.577 | 0.563 | 0.550 | 0.537 |
| 80 | 0.625 | 0.613 | 0.600 | 0.588 | 0.575 | 0.563 | 0.550 | 0.538 | 0.525 | 0.513 | 0.500 |

An example of Z-factor application is given in Table 4. Calculations are carried out for a separator processing 500 tpd 80 brix molasses. Final molasses purity after extract crystallization is assumed to be 60%. Relatively poor performance of a separator is considered.

## TABLE 4

| | | |
|---|---|---|
| Extract purity | 87 | 90 |
| Separator recovery | 87 | 81 |
| Z-factor | 67.5 | 67.5 |
| Sugar produced, cwt/day | 3203 | 3203 |
| DS molasses produced, tpd | 77 | 53 |
| DS raffinate, tpd | 158 | 182 |

Two operation modes are considered which yield the same amount of crystallized sugar. “Higher purity-lower recovery” mode seems to be more beneficial since less non-sugars will be processed through the sugar end. On the other hand if a separator is oversized molasses recycle may be considered. In such a case similar calculations may be performed using the Z-factor as a measure of separator performance.

The Z-factor has proved to be convenient criterion for monitoring the optimization of separator performance, as well as for strategic planning of system operation.

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