Technical Calculations for Sugar Works

A CONTRIBUTION TO THE CHEMICAL CONTROL OF SUGAR MANUFACTURE

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TRANSLATED FROM THE THIRD GERMAN EDITION

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PREFACE

It has been a long-cherished wish of the translator to add some valuable handbook to the short list of technical literature on the sugar industry already obtainable in the English language.

The translator presents the book to his English-speaking colleagues in the earnest hope that it may prove profitable to them.

C. J. BOURBAKIS.

LYONS, N. Y., October, 1909.

AUTHOR'S PREFACE TO THE SECOND EDITION

THE chemical control of the manufacturing process is generally practiced in modern sugar-houses, and the excellent instructions that we possess for the examination of the raw materials and manufactured products are convincing proofs of the care and attention given to this branch of the chemical science.

The numerical results obtained through the analyses possess, however, only a comparatively limited value, so long as they are not utilized for the control of the factory work, i.e., for calculating the output of the different products and for confirming the correctness and possibility of the results found. The full benefit of the chemical examination is realized and its high value made evident only by such utilization of the analytical data.

If we keep in view that, when the quantities and composition of the first massecuite and of the raw sugar are known, the quantity and composition of the syrup, consequently of the second massecuite, are fully determined—because all substances not found in the raw sugar have passed into the syrup—and also that the purity of the molasses is sufficient to enable us to calculate the quantities of sucrose recovered in the second and third sugar, we immediately understand why the knowledge of these relations and connections, that allow us to calculate unknown values from a few known data, is of the highest importance.

Since, then, in the first massecuite all other products are contained as if in ovo, it must be possible to calculate inversely and control the work when the quantities and composition of the products as well as their proportions to the massecuite are known. A keen and strictly accurate control is thus made possible.

The first attempt to introduce a rational numerical control was made by Suchomel. Subsequently Hulla, Brilka, Schneider, and Dr. Claassen have done meritorious work in establishing and developing the methods.

A manual devoted to the calculations of the control as a whole did not exist before the publication of this little work. The exhaustion of the first edition, rapid beyond all expectations, and in spite of its shortcomings, is the best proof that such a work was needed.

If the author has succeeded in turning attention towards a subject of whose great bearing every specialist who studies it will be convinced, he will consider it as the best reward for his labors.

OTTO MITTELSTAEDT.

AUTHOR'S PREFACE TO THE THIRD EDITION

Throughout this book the calculations are based on the coefficients of purity. The admissibility of such a use of the coefficients has, however, been contested in various quarters during the last few years. It is objected that the coefficient expresses only the proportion or relation between sugar and non-sugar, consequently it possesses but a purely quantitative value, while the yields chiefly depend on the quality of non-sugar.

A certain value cannot be denied to this objection. It proves right if we conceive of a product as directly separated into crystalline sugar and molasses. In such a case the possibility will exist that the melassigenic action of the non-sugar will be taken too high or too low, because the melassigenic coefficient of the non-sugar must first be determined empirically.

For all other cases, where the coefficient is utilized for the calculation of the yield, it is quite sufficient to know the quantitative distribution of the non-sugar in the obtained products. If from a given quantity of a product composed of different substances, one determined ingredient is withdrawn in greater proportion than the others, it is evident that the remaining constituents are, so to say, concentrated. The degree or extent of this concentration enables us to draw conclusions as to the quantity of that substance separated.

Furthermore, it must be stated that the criticisms published to this date are of a clearly negative character. Positive propositions that would make probable a substantial alteration or improvement of the methods now in use for calculating the yields have not been made.

The present third edition has been, in part, completely rewritten. The first sections have been considerably enlarged. These changes, it is hoped, will contribute to increase the usefulness of the book.

OTTO MITTELSTAEDT.

TABLE OF CONTENTS

TECHNICAL CALCULATIONS FOR SUGAR WORKS

FUNDAMENTAL NOTIONS

1. Sugar, Non-sugar and Coefficient. All raw materials that are used for the manufacture of sugar, the beet juices of the sugar factories as well as the raw sugars of the refineries, contain, besides sugar and water, also varying quantities of organic and inorganic substances, generally known under the collective name of *non-sugar* or *total non-sugar.*

The quantity of water contained in these raw products is of no importance for the work, as it can be cheaply diminished by evaporation in the multiple effect and the pans; on the other hand, these materials can be easily reduced to any desired degree of dilution by the addition of water.

The percentage of solids of a product, in other words, the sum of sugar and non-sugar contained in 100 parts of it, is called *dry substance*, and can be determined by two different methods:

(*a*) A weighed quantity of the product is dried in a dish at 105–110° C., till constant weight is obtained.

The percentage of dry substance in the product is then calculated from the loss of water The number thus found gives the real dry substance (Ds).

(*b*) In the second method the specific gravity of the product is found by the use of a densimeter, a hydrostatic balance, or an areometer (Brix, Balling). This method can be used only on liquid products; in the presence of non-sugar it gives numbers not perfectly correct, as these other coexisting substances influence the spindle* or the specific gravity in a different way than the pure sugar solutions, upon which the scales of the saccharometer and the tables for the calculation of the specific gravity into percentage by weight are based. For these reasons the dry substance found by this last method is termed "apparent" or Brix (B).

For normal products the amount of apparent dry substance is generally higher than the real Ds, and only with perfectly pure solutions do the two numbers coincide. Consequently for exact calculations the true dry substance must be always taken as a basis, and only in approximative estimations can B taken as equal to Ds, or the apparent dry substance be considered as real. We shall later introduce a method that makes it possible to calculate the real dry substance when knowing the apparent. (See p. 12, 13 et seq.)

The quantity of sugar contained in a product is determined only by one method, i.e., by the use of the polarimeter. As, however, in the raw beet juices there exist, besides sugar, also other dextrogyrate substances, (f.i.,

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* The addition of one per cent. lime to a sugar solution causes an increase in density of about 2.6° Brix.

asparagin,* raffinose, etc.), the sugar percentage of these products seems higher than what it really is.

The difference between the percentage of dry substance and that of sugar is called *total non-sugar.* This in its turn, is made up of inorganic bodies, also termed *ash* or *salts,* and the so-called organic non-sugar.

The inorganic non-sugar is determined by incineration of a small quantity of the product in a platinum dish with the addition of concentrated sulphuric acid, according to C. Scheibler's method. By multiplying the amount of ash so found by 0.9, the carbonates are obtained. This calculation is based upon the higher molecular weight of the sulphates as compared with that of the carbonates. The same result is obtained by subtracting the one-tenth of the sulphated ash.

The difference between non-sugar and carbonated ash gives the *organic non-sugar.*

The relations existing between the constituents of the sugar-house products can be made clear by an example:

If, for instance, the analysis of a thin juice has given 9.5 per cent. dry substance, then the quantity of water will be: $100-9.5=90.5$ per cent. If, further, the polarization indicated 8.1 per cent. sugar, the juice contains: $9.5-8.1=1.4$ per cent. total non-sugar. If, besides, the incineration shows 0.6 per cent. ash, then the organic non-sugar is calculated as equal to: $1.4-0.6=0.8$ per cent. The relation of ash to organic non-sugar is consequently

$$0.6:0.8 \quad \text{or} \quad 1:1.33.$$

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* Asparagin, as such, is levorotatory, but on the addition of lead acetate the polarization is reversed.

In order to present more simply and concisely the composition of a product, as given by the chemical analysis, certain symbols are conveniently used in imitation of those adopted in chemistry. Thus

1 part of dry substance	is denoted	by the	symbol	Ds
1 part of water	"	"	"	W
1 part of sugar	"	"	"	S
1 part of non-sugar	"	"	"	NS
1 part of ash	"	"	"	A
1 part of organic non-sugar	"	"	"	ONS

A number placed before or after the symbol shows how many weight-units of the corresponding substance are contained in the mixture.

When the percentage composition of a product is given, the sign "%" is simply placed after the whole formula.

The percentage composition of the above given juice can accordingly be written in the following form:

9.5 Ds, 8.1 S, 0.6 A, 0.8ONS %.

If, on the contrary, it is desired to indicate simply that the mixture at hand is one of fixed proportions by weight, but that its parts added do not necessarily represent a sum of 100, then the sign "Wt," parts by weight, follows the expression.

If, for instance, a syrup is composed of 25 parts of sugar together with 9 of non-sugar and 8 of water, the symbolic expression can be given as follows:

S 27.0, NS 9.0, W 8.0, Wt.

The sugar percentage of a product gives no immediate indications as to the quantity of sugar obtainable. The value of a product depends not only on the sugar it contains but also on the coexisting quantities of non-sugar; it further depends on the relation between sugar and dry substance.

The non-sugar included in the expression "dry substance" possesses the property of preventing a certain quantity of sugar from crystallizing; in other words, it has a *melassigenic* influence.

By the term "molasses"* are to be understood "the final syrups, obtained in raw-sugar houses as well as in refineries, in which such an accumulation of non-sugar has taken place that their sugar (47-50 per cent. on the weight of the molasses) cannot be obtained by farther concentration and setting apart for crystallization, not even if the mass be kept at the right concentration and under the conditions acknowledged as most favorable for the formation of crystals."

The extraction of the sugar from the molasses is only possible by special processes (precipitation, use of strontia, etc.). In these the sugar is precipitated by forming solid combinations with the strontia or lime. These compounds, known as saccharates, are then separated from the non-sugar remaining in the mother liquor.

The relation between dry substance and sugar is calculated on 100 parts of dry substance and is then termed *coefficient of purity* (P). The coefficient can as well be obtained from the proportion

$$\mathrm{Ds} : \mathrm{S} :: 100 : x,$$

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* Claassen, Centralblatt, Jahrg., 1897, No. 5, p. 1048.

and x being P,

$$P = \frac{S \times 100}{Ds}.$$

Consequently the coefficient expresses the quantity of sugar in 100 parts of a product, supposed dry.

When calculating a coefficient it is of no consequence whether the starting point is the percentage composition of the product or the proportion of the composing parts in a mixture. It is equally unimportant whether the product is liquid or solid.

Thus the coefficient of the thin juice already cited (9.5 per cent. Ds and 8.1 per cent. S) would be

$$P = \frac{8.1 \times 100}{9.5} = 82.56.$$

The coefficient of the syrup composed of 27.0 parts of sugar, 9.0 of non-sugar, and 8 of water, will be 75, because

$$P = \frac{27 \times 100}{(27 + 9)} = 75.$$

A raw sugar of 95.6 polarization and 1.67 per cent water, consequently $100 - 1.67 = 98.33$ per cent dry substance, has a coefficient of 97.22 points, for

$$P = \frac{95.6 \times 100}{98.33} = 97.22.$$

Evidently when the real dry substance serves for the calculation, the purity so found is the true (TP), while the apparent dry substance taken as a basis will give the apparent purity (AP).

It has already been said (p. 2) that the apparent dry substance, in the presence of non-sugar, is constantly higher than the real. For this reason the coefficient of apparent purity is always lower than the true.

H. Pellet, E. Gravier, J. Weisberg, Molenda, and Fr. Sachs have been prominent in the determination of the relations existing between the apparent and the true purity of the products.

Weisberg elaborated a special method for the determination of the apparent purity, and calculated a series of coefficients that give the true purity by multiplication with the apparent. Although proof of the general applicability of these coefficients has not yet been adduced, and while they are even contested in various quarters, the method will be here discussed, as it has not yet found a place in books treating on technical investigations because of its comparatively recent date.

In order to obtain the apparent coefficient Weisberg proceeds as follows: He finds the degree Brix of a solution of the normal weight of the product submitted to analysis, in 100 cc. He then calculates the sugar percentage of this normal solution, and from the Brix and sugar he obtains the apparent coefficient of purity which, multiplied by the corresponding factor of the table given on page 8, gives finally the true purity of the product.

The following example, given by the author, will make clear the technical method of determination and calculation:

Five times the normal weight ($26.048 \times 5 = 130.24$ grs.) of a massecuite, obtained according to Langen's process of crystallization, were dissolved in hot water and brought into a 500-cc. flask, which, after cooling, was filled up to the mark.

TABLE FOR CALCULATING THE TRUE PURITY FROM THE APPARENT

(According to Weisberg)

Apparent Purity.	Factor.	True Purity.	Apparent Purity.	Factor.	True Purity.
57.0	1.054	60.0	78.0	1.021	79.6
57.5	1.052	60.5	79.0	1.020	80.6
58.0	1.050	60.9	80.0	1.019	81.5
58.5	1.048	61.3	81.0	1.018	82.4
59.0	1.046	61.7	82.0	1.017	83.4
60.0	1.044	62.6	83.0	1.016	84.3
61.0	1.042	63.5	84.0	1.015	85.3
62.0	1.040	64.5	85.0	1.014	86.3
63.0	1.038	65.4	86.0	1.013	87.1
64.0	1.036	66.3	87.0	1.012	88.0
65.0	1.034	67.2	88.0	1.011	89.0
66.0	1.033	68.2	89.0	1.010	89.9
67.0	1.032	69.1	90.0	1.009	90.8
68.0	1.031	70.1	91.0	1.008	91.7
69.0	1.030	71.1	92.0	1.007	92.6
70.0	1.029	72.0	93.0	1.006	93.5
71.0	1.028	73.0	94.0	1.005	94.5
72.0	1.027	73.9	95.0	1.004	95.4
73.0	1.026	74.9	96.0	1.003	96.3
74.0	1.025	75.9	97.0	1.002	97.2
75.0	1.024	76.8	98.0	1.002	98.2
76.0	1.023	77.7	99.0	1.001	99.2
77.0	1.022	78.7	100.0	1.000	100.0

By the use of a Brix hydrometer of verified accuracy,*

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* The hydrometers are verified by the use of solutions of high-grade refined sugar in distilled water. The so-found coefficients of purity of these solutions must lie between 99.7–100.3.

graduated in tenths of a degree, the normal solution was found to be of 21.6 B. at 20° C., or, after correction, 21.8 B. at the normal temperature of 17.5° C. The corresponding specific gravity is 1.0914.

For the determination of the sugar percentage, 50 cc. of the normal solution were then introduced into a 100-cc. flask. Lead acetate was added, the flask filled to the mark, and the liquid filtered and polarized. The polarization found was 40.3°, so that the sugar contained amounts to $40.3 \times 2 = 80.6$ per cent.

The sugar contained in the normal solution must now be found from the already known S per cent. of the massecuite. One degree of polariscope reading corresponds to 0.26048 gr. of sugar in 100 cc. Hence if we multiply 80.6 by 0.26048 and then divide the product by the specific gravity of the normal solution (in this case 1.0914) we will obtain the parts of polarization corresponding to 21.8 B., or in other terms, the sugar contained in 100 parts of the normal solution,

$$\frac{80.6 \times 0.26048}{1.0914} = \frac{20.994688}{1.0914} = 19.145 \text{ per cent.}$$

For 21.8 B. and 19.145 S the apparent purity of the normal solution (which is also the purity of the massecuite) is calculated as $= 87.82$. This number, multiplied by the factor 1.011, corresponding to 88 apparent purity in Weisberg's table, gives the true purity of the product as $= 88.78$.

By desiccation it was found that the massecuite contained 9.58 per cent. water. Consequently its dry substance was $100 - 9.58 = 90.42$ per cent. This number and a polarization of 80.6 per cent. give a true coefficient of purity of 89.14 points.

The difference between the true coefficient, as found by desiccation and as obtained by Weisberg's method, does not exceed 89.14 − 88.78 = 0.36. A series of experiments arranged by the author gave but slight variations between the two methods. Schnell * also obtained satisfactory results.

For products containing at least 78 per cent. of dry substance, therefore, for massecuites and molasses, the following method can be advantageously used for the determination of the apparent purity: The normal weight, = 26.048 gr., is dissolved in boiling distilled water so far as possible free from air. The solution is brought into a flask of 100 cc., cooled by placing in cold water, and the flask finally filled to the mark. The specific gravity of the normal solution is found by the use of the Westphal balance at a temperature as near 17.5° C. as possible. If the result found is, for instance, 1.0912, the apparent dry substance can be obtained by omitting the integer 1 and moving the decimal point three places to the right = 91.2 per cent. In this method it is always presupposed, as already stated, that the analyzed product contains not less than 78 per cent. of dry substance.

The method is based upon the following facts: It is known that a solution of pure sugar, polarizing 100° and containing 26.048 grs. of chemically pure sugar, has a specific gravity = 1.100. A solution of

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* Centralblatt für die Zuckerindustrie der Welt, 1897, p. 918.

90° polarization has a specific gravity = 1.090; one of 80° = 1.080.

As now, further, a solution polarizing 100° can have the specific gravity of 1.100 only in case the sugar used has 100 per cent. dry substance, and as further a solution of 26.048 grs. of a sugar containing 90 per cent. of dry substance in 100 cc. has a specific gravity of 1.090, we can conclude by the simple rule that the decimal numbers following the point represent the amount of dry substance of the product, and that each 0.001 expresses one unit.

In case the products contain non-sugar, the dry substance found by the above given method, will be the "apparent," and the purity can be calculated into "true" by the use of Weisberg's factors.

The above treated relations between specific gravity and dry substance of the normal solution, are valid, as already said, only for products that contain over 78 per cent. of dry substance. For more liquid products the beginning of a stronger contraction causes substantial deviations from the given rule.

In the tables given on page 12 are grouped the results of some experiments conducted according to the various methods. Although executed with Dutch raw products that differ materially in their composition from the French products used by Weisberg in the course of his investigations, the difference found between the purities as obtained directly and as calculated, are so small that they can be considered as absolutely unimportant from a technical point of view.

The apparent dry substance found by Weisberg's method can be calculated if the sugar of the corresponding product be multiplied by 100 and the product divided by the apparent coefficient.

In a similar manner the true dry substance can be found from the true coefficient obtained according to Weisberg. (Compare pp. 3 and 16.)

REAL COMPOSITION OF THE PRODUCTS

(By desiccation)

	I. Rf. M. C.	II. Rf. M. C.	Raw Sugar Massecuite.	II. M. Cuite.	III. M. Cuite.	Molasses.
Polarization	92.90	90.40	80.60	66.10	58.60	48.30
Water	6.58	7.14	9.58	11.23	12.035	19.25
Dry substance	93.42	92.86	90.42	88.77	87.965	80.75
True purity	99.45	97.36	89.14	74.46	66.62	59.81

Results Found by Operating on a Normal Solution

(A) According to Weisberg's Method

Degrees Brix	22.30	22.20	21.80	21.80	21.90	20.10
Calculated, sugar . .	22.13	21.54	19.14	15.77	13.98	11.61
Ap. dry substance ..	93.62	93.20	91.78	91.33	91.80	83.60
Apparent purity	99.23	97.00	87.82	72.37	63.83	57.76
True purity	99.33	97.17	88.78	74.14	66.13	60.29
Difference	−0.12	−0.17	−0.36	−0.32	−0.49	+0.48

(B) By the Specific Gravity

Specific gravity	1.0935	1.0932	1.0912	1.0912	1.0918	1.0837
Ap. dry substance ..	93.50	93.20	91.20	91.20	91.80	83.70
Apparent purity....	99.35	97.00	88.38	72.48	63.83	57.70
True purity	99.45	97.19	89.34	74.29	66.13	60.20
Difference	0.0	−0.17	+0.20	−0.17	−0.49	+0.39

Molenda and Sachs pointed out another and more simple relation existing between apparent and true dry substance. They have shown that the non-sugar contained in the normal products has a specific gravity of about 1.11 upon the average as compared with that of the dissolved sugar. Therefore, by dividing the quantity of apparent non-sugar by 1.11 or multiplying it by 0.9, the true non-sugar is obtained. Let it be emphasized here that Sachs also, in all analyses of strongly concentrated products (massecuites, syrups), operates on their normal solution. In fact the true purities calculated according to Sachs are so close to those found by the Weisberg factors that the differences must be considered as quite trifling.

A product of an apparent purity of 60 has for instance, according to Sachs, $40 \times 0.9 = 36$ per cent. real non-sugar. The true coefficient is consequently 62.5, because

$$96:60::100:62.5.$$

The same product should be, according to Weisberg's factors (p. 8) of 62.6 true purity ($60 \times 1.044 = 62.6$).

The knowledge of the true coefficient of purity constitutes one of the most important expedients for the control of the factory work, because the output in crystalline sugar that can be expected from a product depends chiefly on the relation between sugar and non-sugar. So, for instance, it is possible, under certain circumstances, to obtain in the form of crystals the whole quantity of sugar contained in a product of 100 purity by evaporation at a very low temperature, as there is no non-sugar present that would have a hindering effect on the crystallization. The higher the percentage of non-sugar of a product, in other words, the lower its purity, the smaller will be its yield. This makes clear the necessity of as thorough an elimination as possible of the non-sugar contained in the raw products.

Although the coefficients are essentially of a quantitative character in giving indications as to the relation between sugar and non-sugar, still their importance to technicians for the information they furnish as to the quality of the products is not to be undervalued. Thus, for instance, products having a coefficient above 85 points are easily crystallizable; when boiled in a vacuum under favorable conditions they form crystals easily and quickly, while more time is required for products of a purity below 85. Masses that have a purity below 78 can no more be directly boiled to grain: they belong to the "after-products." The massecuite is boiled "blank," and only after a prolonged standing does it yield crystals of sugar of a correspondingly lower purity.

Even these lower products deposit the greater part of their sugar, so far as it can be obtained in crystalline form, easily and completely on formed crystals, if these are present in the vacuum-pan (introduction of seed grain), and if, further, the massecuites are kept in motion during the few days required by the after-crystallization. By the motion the already formed crystals are not allowed to deposit and separate from the mother liquor. The so-called "boiling to grain" of the after-products, introduced first into practice by A. Freitag, the director of the Western Sugar Refinery of Amsterdam, is undoubtedly the most important advance in modern sugar technology.

From products that have a true purity of about 60 points, generally no more sugar can be obtained in crystalline form—they constitute the "molasses."

In all cases when the coefficient is taken into account for the estimation of the value of products, it is assumed that these products do not contain any abnormal impurities or uncommon quantities of foreign dextrorotatory bodies (raffinose, dextran); also that they have not been submitted to any special or peculiar process which would cause important qualitative alterations of the nature and composition of the non-sugar, as happens by osmosis. By the osmotic treatment the easily diffusible salts are chiefly eliminated, while the organic non-sugar prevails in the osmosed syrup. These last bodies have a considerably more pronounced melassigenic influence than the salts; in fact they contribute to the rise of the resistances and consequently lower the crystallizability of the products in such a manner that the increase in the output by no means corresponds to the improvement of the purities obtained by the osmosis. In other terms, the gain in sugar is much lower than could be expected according to the improvement of the coefficients.

The methods and formulæ that utilize the coefficients of purity for the calculation of the outputs of the normal products will be given later on in the course of the book.

The expression

$$P = \frac{S \times 100}{Ds} \quad . \; . \; . \; . \; . \; . \; . \quad (1)$$

can be interpreted in the following words: "The purity is found by multiplying the sugar by 100, and dividing by the dry substance." Hence two more expressions can be derived:

$$Ds = \frac{S \times 100}{P} \quad . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

(=the dry substance is found by multiplying the sugar by 100 and dividing by the purity); and

$$S = \frac{Ds \times P}{100} \quad . \; . \; . \; . \; . \; . \; . \; . \quad (3)$$

(=when the dry substance and the purity are known, the sugar can be calculated by multiplying the dry substance by the purity and dividing by 100.)

Application of the expression (2): A massecuite of raw sugar has a purity of 90.6 and sugar 86.4 per cent. What is the dry substance percentage?

$$\frac{86.4 \times 100}{90.6} = 95.36 \text{ Ds.}$$

The massecuite contains, consequently, 100 − 95.36 = 4.64 per cent. W.

Application of the expression (3): A second massecuite contains 9.3 per cent. W. The coefficient is 73.6. What is the S percentage?

$$S \text{ per cent.} = \frac{90.7 \times 73.6}{100} = 66.75 \text{ per cent.}$$

Although the expression (1) is generally sufficient for everyday practice, still the knowledge of the two others derived from the first is often of value. Thus, for instance, the second expression is necessary for the calculation of the dry substance when we know the sugar and the true coefficient of purity found by the use of Weisberg's factors. (See p. 8.)

2. Losses in Manufacture. Next to the more or less favorable relations between total solids and sugar in the raw products, the loss in manufacture is the most important item to be considered in the calculation of the yields.

The term *sugar losses* or *manufacturing losses* denotes the quantities of sugar that are separated and lost in the by-products, or are altered by chemical causes.

The losses during manufacture can consequently be classified as:

(1) Mechanical, and
(2) Chemical, losses.

Under the latter heading are also included the "polarization losses" that are occasioned in raw-sugar factories by the presence of dextrogyrate organic non-sugar, causing the sugar percentage to seem higher than it really is, but which is partly eliminated, partly decomposed by subsequent treatment of the juices.

The sum of the mechanical and chemical losses is known as "total loss." As now in practice only the total and the mechanical losses can be determined, the difference between the two is considered as representing the chemical losses.

In order to obtain the total loss it is necessary to determine the sugar content of the raw material entering the factory, as well as of the sugar exported to the store.

For the determination of the mechanical losses the knowledge of the weights of the by-products and of their sugar percentage is also needed.

The determination of these points presents no difficulties in refineries, yet serious ones in raw-sugar factories. Claassen, Pellet, and Sachs have published very important works as to the losses taking place in these latter establishments; the study of their publications is indispensable to every sugar technician.

In this place the question of the losses can only be summed up, in a general way; we can not enter into details, but only refer to the works of the above named authorities.

The general course of the control is the following: The sugar that enters into process is calculated from the weight of the washed beets that go through the slicer, and the polarization of the cossettes coming into the diffusion cells. The sampling of these cossettes is effected by taking a handful from time to time and packing it immediately in a tight lead pot, in order to prevent evaporation. The more frequently such samples are taken the better will be the average of the sample obtained. The contents of the lead pot are carefully mixed several times daily, and the cossettes polarized. For this purpose the aqueous extraction methods of Pellet or Sachs–Le Docte are far more convenient than the alcoholic method still extensively used in Germany, because they give less room for errors.

The samples of the exhausted cossettes are taken on emptying the diffusion, in a similar manner, as when sampling the fresh cossettes. Care must be taken that the sample corresponds to the upper, middle, and lower zone of the cell. The polarization of the diffusion waste water is also needed.

As no chemical or polarization losses take place in the battery, the sugar contained in the diffusion juice must be equal to the sugar that entered the process, in the fresh cossettes, minus the accountable diffusion losses. For this reason it is advisable to take frequent samples of diffusion juice. 0.05 gm. of mercuric bichloride are brought into the sample bottle (liter capacity), as the juice is subject to rapid alteration if kept without a preservative; by this addition decomposition is entirely avoided.

From the quantity of the diffusion juice and its sugar percentage, with the addition of the ascertained mechanical losses by diffusion, the amount of sugar that entered the process is controlled and checked; this must coincide with the quantity of sugar found in the beets.

In drawing up the losses, the weight and polarization of the first and second lime cake, as well as of the first massecuite, must further be known. As it is often by no means easy to determine beyond objection the weight of these products with certainty and precision, recourse is had to indirect methods. Thus the weight of the lime cake is obtained from the quantity of lime used, while that of the first massecuite is calculated from the weight of the produced raw sugar and the measured quantity of the II massecuite. We shall have an opportunity to discuss more fully these methods in a proper place. We shall now turn specially to the losses.

A. *Mechanical Losses.* The mechanical losses in the raw-sugar houses result mainly from the elimination of the by-products; the polarization of these products can be obtained with comparative facility and certainty by chemical analysis, and the only difficulties to overcome relate to the sampling. These losses are collectively termed, "known, determinable, or accountable."

The known losses are naturally more important in the raw-sugar factories as greater quantities of by-products are produced there.

One hundred parts of beets will give 90–95 parts of wet, unpressed pulp, showing 0.35 per cent. S for ordinary roots. Consequently the loss calculated per 100 parts of beets will be 0.30 per cent. S, for

$$\frac{90 \times 0.35}{100} = \sim 0.30.^*$$

For beets containing 13.2 per cent. S, and for pulp with 0.35 per cent. S, there are lost $\sim$0.30 S per cent. beets, or on every 13.2 parts of sugar. Consequently per 100 parts of sugar:

$$13.2 : 0.3 :: 100 : x;$$

$$x = \frac{0.3 \times 100}{13.2} = 2.27 \text{ per cent.}$$

In the case given above as an example, the loss will be 0.3 S per cent. beets, or 2.27 per hundred parts of sugar.

Of course there is nothing to prevent a more complete exhaustion; still, generally, this is not to be pursued, firstly, because the juices would become abnormally dilute, so that the gain in sugar would not cover the

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* The sign $\sim$ signifies, throughout this book, nearly, about, closely.

expenses for evaporating the greater bulk of water; and, secondly, because by a far-pushed exhaustion greater quantities of non-sugar pass into the juice, causing a deterioration of the purity.

The following example shows how widely juices of the same battery differ:

Juice from the first cell:

$Ds=9.80$, $S=8.40$, $NS=1.40$, $P=85.73$;

Juice from the last cell:

$Ds=0.62$, $S=0.29$, $NS=0.33$, $P=46.60$.

Thus, while for the first diffusor, 100 parts of dry substance contained 85.73 per cent. of sugar, for the last diffusor this number was but 46.60. Still it must be said that a great part of the non-sugar contained in these juices is precipitated during the defecation and carbonation, and the juices give crystallizable massecuite.

Next to the pulp the waste water constitutes another source of mechanical loss in the diffusion battery. It is known by experience that on 100 parts of beets, about 100 parts of waste water will be produced. The average polarization being ~ 0.1 the loss represents ~ 0.1 per cent. calculated on beets.

The further course of the manufacture makes inevitable another very important loss, namely, the one occurring in the lime cakes of the carbonation.

The quantity of the produced lime cake depends on the amount of lime used, necessary for a sufficient epuration of the juices, and also, although to a less degree, on the precipitated quantities of non-sugar.

As a general average, for normal roots, the maximum juice epuration is attained by the use of 2.50 per cent. of lime. The quantity of lime cake obtained in this case is calculated as follows: From 2.50 kgs. lime (CaO) are produced 4.46 kgs. of calcium carbonate, for

$$CaO : CaCO_3 : : 2.50 : x;$$

$$56 : 100 : : 2.50 : x;$$

and

$$\frac{100 \times 2.50}{56} = 4.46.$$

As now, further, ~40–50 per cent. of the non-sugar contained in the raw juices is eliminated by the carbonation, and as 100 parts of beets give about 125 parts of diffusion juice, there are precipitated 0.78 part of non-sugar, if the juice has the composition of the above given first cell diffusion juice:

$$\frac{1.4 \times 125 \times 45}{100 \times 100} = 0.78.$$

The dry substance of the filter-press cake produced from 100 kgs. of beets, if we neglect the impurities of the lime as well as the sugar content, will hence consist of

	4.46 kgs. of calcium carbonate, and
	0.78 kg. of precipitated non-sugar
Total	5.24 kgs.

The wet, fresh lime cake contains ~50 per cent. water, so that 5.24 kgs. correspond to 10.48 of press-cake, produced by the use of 2.50 parts of lime. Hence 1 part of lime $= \frac{10.48}{2.50} = 4.2$ parts of filter-press cake. The rule can consequently be formulated that it is sufficient to multiply the quantity of lime used per 100 parts of beets by the factor 4.2 in order to obtain the amount of lime cake produced from 100 kgs. of roots.

If the lime cake contains 2 per cent. S, the per cent. loss calculated on beets will be:

$$\frac{10.48 \times 2}{100} = \sim 0.2.$$

This loss can be considerably reduced by a sufficient washing of the cake. In fact, in modernly equipped factories it is lowered one-half, i.e., to 0.1 per cent.

The mechanical loss that takes place in the filtration, or rather in the washing of the filter clothes, is estimated by Pellet at 0.05 per cent. He also calls attention to a loss overlooked heretofore. The tare of the sacks containing the sugar for delivery is assumed as equal to 1 kg., while in fact they do not weigh more than 800–820 grs. This, calculated on beets, amounts to a loss of at least 0.01 per cent.

Accordingly, for every 100 parts of beets worked the following losses take place:

	Per Cent.
In the residuums of the diffusion battery	0.30
" waste waters	0.10
" filter-press cakes	0.20
" juice filters	0.05
" tare of the sacks	0.01
Total	0.66

For beets containing 13.2 per cent. S, the mechanical loss per 100 parts of sugar is

$$13.2 : 0.66 :: 100 : x \quad x = 5 \text{ per cent.}$$

The mechanical losses occurring in the refining process amount to ∼0.5 per cent., calculated on the raw sugar worked, and are equally great for high or low polarizing raw products. It is a generally recognized fact that the mechanical losses in large refineries are lower than in smaller ones.

These losses can be attributed chiefly to the sugar adhering to the sacks, and to the boneblack filtration. Some smaller losses are caused by the workmen consuming some of the white product, spilling of juices, pulverization by the saws and grinders, and by crushing or trampling. The relative quantities may be given nearly as follows:

	Per Cent.
In the raw sugar sacks	0.10
" mechanical filtration	0.05
By boneblack filtration and wash water	0.25
Consumed	0.02
By spilling, crushing, and pulverization	0.08
Total	0.50

B. *Chemical Losses.* The chemical losses can be traced to two different causes, namely, they can be explained by the presence of organic substances possessing dextrogyratory power like sucrose, but eliminated or decomposed in the course of the work; or they may be occasioned by the destructive simultaneous influence of the heat and the water on the sugar.

The sugar losses found in the first case are only apparent, while those of the latter are real. Nevertheless, both categories are included in the term "polarization losses" as being hardly distinguishable from one another, yet determinable only by means of the polarimeter.

The apparent sugar losses are met with only in the raw-sugar houses. They are often referred to as "undeterminable, unaccountable, or unknown, losses," for the reason that any effort to ascertain their proportions is attended by serious difficulties. They can be found approximately by subtracting the not fully determined real sugar loss from the total.

The total loss in the sugar-houses amounts to 1.20 per cent. on beets, of which about 0.66 per cent. are mechanical losses. As now the real sugar loss hardly runs up to 0.10 per cent. there is left: $1.20-0.66-0.10=0.44\%$ apparent chemical loss.

We shall soon show how the value 0.10 per cent., for real chemical sugar loss, is obtained. (See p. 28.)

There are reasons for believing that the total apparent sugar loss takes place during the treatment of the juices with lime, in the carbonation and defecation, while the real chemical sugar loss of 0.10 per cent. occurs during the boiling of the thick juices in the pans.

Contrary to what happens in the raw-sugar houses, where the apparent loss constitutes the main part of the chemical losses, in refineries the real sugar loss, originating from the destruction of sugar, comes to the foreground. The cause of this is that during the repeated boilings of the sugar required by the refinery process, the masses are exposed for a long time to the action of high temperature, so that part of the sugar undergoes chemical alteration.

The decompositions undergone by the sugar are very probably the following: Under the action of the high temperatures unavoidably necessary for the boiling of the juices, the sugar, by taking up water, is converted into glucose and fructose, which form the constituents of invert-sugar. The decomposition, however, advances further, a part of the invert-sugar, namely, the fructose, losing water by reason of the overheating, being transformed into products of an acid nature, and into caramel of neutral reaction. The production of the acid bodies, chiefly formic, acetic, carbonic, lactic, glucinic, and apoglucinic acids, makes it necessary to keep slightly alkaline all sugar juices destined for boiling. The alkali immediately forms neutral salts with the acids, and any inverting action of the latter is thus avoided.

By the further action of alkalies on the invert-sugar and caramel, salts of humic acid are also formed. The quantity of decomposed sugar depends on the temperature and the duration of heating. It can be assumed that for every boiling ~0.4 per cent. sugar are destroyed, calculated on the raw sugar. The method of working in refineries requires repeated boilings of the syrups and masses. On 100 parts of sugar entering the process ~85 per cent. will be boiled once, ~30 per cent. twice, ~15 per cent. three times, and ~7.5 per cent. four times, in order to obtain the whole amount of crystallizable sugar. If now ~0.4 per cent. are destroyed in each boiling, the losses will be:

In the I raffinate: $\frac{85\times0.4}{100}=0.34$ per cent.

In the II raffinate: $\frac{30\times0.4}{100}=0.12$ “

In the raw-sugar massecuite: $\frac{15\times0.4}{100}=0.06$ “

In the after product: $\frac{7.5\times0.4}{100}=0.03$ “

Total .... 0.55 “

On 100 parts of sugar, in the work of a large refinery, nearly 0.55 per cent. are destroyed and transformed into non-sugar. 95 parts of sucrose, taking up water, will give 100 parts of invert-sugar, which on continued decomposition, and further combining with alkalies, will give 105 parts of total non-sugar. From 0.55 per cent. parts of decomposed sugar there will be formed, consequently,

$$95:105::0.55:x \quad (x=\sim0.6 \text{ parts NS}).$$

The total non-sugar of the raw product entering the process is accordingly increased.

As now it is reasonable to assume in every case that the whole non-sugar contributes to the formation of molasses, regardless of whether it entered the process as such or has been subsequently formed by chemical alterations, this increase of the non-sugar by ~0.6 per cent. must be taken into account when calculating the yield.

A direct confirmation of the destruction of sugar and simultaneous formation of non-sugar is found in the change of the relation between ash and organic non-sugar in the molasses of refineries as compared with the one existing in the imported raw sugar. If no fresh formation of non-sugar had taken place, the proportion should be the same for the molasses as for the raw product, in fact, rather less organic non-sugar should be found in the molasses, as the addition of lime for alkalization increases the quantity of ash, and in addition, during the boneblack filtration the organic non-sugar is chiefly absorbed, so that its quantity should decrease. In fact, for raw sugars containing, for every one part of ash, 1.2 parts of organic non-sugar, the proportion found in the molasses advances to from 1:1.7 to 1:1.8, which proves irrefutably the formation of new non-sugar. The absorbing action of the boneblack explains why the whole quantity of newly formed non-sugar cannot be determined.

From the number 0.55 can be derived also the real loss taking place in raw sugar houses, which is =0.1 per cent., as it has been said. Namely, if on 100 parts of raw sugar 0.55 per cent. are destroyed, for beets with 13.5 per cent. S, this destruction corresponds to 0.074 per cent., or round, to 0.1 per cent.

SUMMARY

The total losses in raw-sugar factories, calculated per 100 parts of beets are:

	Per Cent.	
(*a*) *Mechanical Losses.*		
In the residuums of the diffusion	~0.30	Total ~1.20
“ waste water	~0.10	
“ lime cakes	~0.20	
“ juice filtration	~0.05	
“ tare of the bags	~0.01	
Total	~0.66	
(*b*) *Chemical Losses.*		
Apparent sugar losses	~0.10	
Real sugar losses	~0.05	
Sum	~0.55	

The total losses that occur during the refining, calculated per 100 parts raw sugar, are:

	Per Cent.
(*a*) *Mechanical Losses.*	
In the raw-sugar sacks	~0.10
“ mechanical filtration	~0.05
“ filtration on boneblack	~0.25
Consumed	~0.02
Spilled, pulverized, etc.	~0.08
Total	~0.50
(*b*) *Chemical Losses.*	
Real sugar loss	~0.55

Consequently, if a raw-sugar house works beets containing ~ 13.5 per cent. S, there can be recovered in all products, molasses included: $\sim 13.5 - 1.20 = 12.3$ per cent. S. On the other hand, a refinery working raw product of 95.5 polarization, will extract from all products, molasses included, at best, $95.5 - 1.05 = 94.45$ per cent. sucrose.*

The Yield. We have already seen in the preceding part of the book to what figures the sugar losses that take place during the refining of the raw sugar amount.

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* As a complement we may add here the account of the sugar losses occurring in sugar-cane mills, as given by H. Pellet in his communication to the VIIIth Congress of Applied Chemistry (London, May–June, 1909). According to this well-known French authority, the losses are the following:

"If we assume that the juice is extracted by mill pressure and treated by simple defecation, we can sum up the losses as follows:

(1)	Canes chewed and juice drunk by employees, etc.	0.05
(2)	Sucrose lost in press-cake	0.08
(3)	“ in bags or fillers	0.05–0.08
(4)	“ by inversion during concentration (1–2 per cent. on weight of sucrose) for canes with 13 per cent. S.	0.13
(5)	“ in condensed water	0.05
(6)	“ by entrainment from open tanks, etc	0.01
(7)	“ in sediments, cleaning of tanks, etc.	0.02
(8)	Overweight of sugar bags	0.01
(9)	Loss in mechanical filtration	0.05
(10)	Other mechanical losses throughout the mill, laboratory samples, crushing, etc.	0.05
	Total	0.53

To this must be added the sugar lost in the bagasse. In some factories over 2 per cent., in few below 0.9. Taking 1 per cent. as an average we have a total loss of 1 53 per cent. on the weight of the cane."

A complete translation of Mr. H. Pellet's important communication can be found in the "Sugar Planters' Journal" of Louisiana, Vol. 39, No. 40.—(TRANSLATOR).

In connection with that question another item must be discussed as directly related to the losses, namely, the, for the manufacturers, very important question of the output of the raw sugars in white, consumable merchandise.

The raw sugar is a half-finished product. Its mechanical, but chiefly chemical, impurities, as well as the sugar alteration taking place in the course of the refining, result in that only a certain percentage of the chemically pure, optically determined sugar can be gained in the form of white product. The quantity of white consumable product obtained from 100 parts of a raw sugar is termed its "yield" or "refining value."

The yield of a raw sugar depends chiefly on its higher or lower sugar and non-sugar percentage, but it is further influenced by the mechanical and chemical losses. The non-sugar introduced with the raw material or formed during the course of manufacture, impedes the crystallization of a portion of sugar; in fact, one part of non-sugar retains 1.5 to ~ 1.9 parts of sugar, so that the purity of the refinery molasses varies between 60 and ~ 65.5, for

$$2.5 : 1.5 :: 100 : 60,$$

$$2.9 : 1.9 :: 100 : \sim 65.5.$$

The purity will be higher or lower depending mainly upon the non-sugar content of the raw product. If the content is high, molasses of a low coefficient will be obtained; on the contrary, if little non-sugar is contained, the coefficient will be high.

The yield of a raw product can, hence, be found by subtracting from its polarization the inevitable total losses taking place in normal work, besides the quantities of sugar retained by the total non-sugar of the introduced product, and by the NS newly produced by chemical losses.

We shall later describe a method allowing the calculation approximately of the yield of any raw sugar on the basis of similar considerations. The method now in use for the determination of the yield rests on an entirely different basis, which we shall soon discuss. Meanwhile some more general explanations are necessary to make it well understood.

The reason of the high importance which the notion of the yield has for the vendor as well as for the buyer, is due to the fact that while it serves as a basis in the determination of the value of the raw sugar, it, on the other hand, marks how much the practical refiner expects to recover from the raw product, by any and all means, a paid-for yield, in the form of white merchandise. Hence it follows that while the production of a sugar showing the highest possible value, by the application of the practically admitted yield calculation, is to the interest of the raw-sugar manufacturer, the refiner on his part prefers such products that yield the most according to his own experience. Both parties have but one common wish—how to apply the calculation of the yield to their case and interest. In spite of many efforts, it has not yet been possible to find a method of calculation satisfactory to all. The fundamental difficulties that must be overcome, arise from the impossibility of attaining and maintaining in small experiments the conditions existing in factory work. Besides this, even in experiments conducted on a larger scale, the decisive factors are subject to such fluctuations that they can advance no strong claims to practical value. Thus, for instance, to point out one of these factors, it is inconceivable that the treatment of the after products can be conducted in small researches as can be done in a continuous factory work.

The method used in international commerce for the determination of the yield was introduced in the year 1863, by Monnier, at that time chemist of the Say Refinery. It is based on the fact that an almost fixed relation between sugar and salts had been observed in the molasses of that refinery, and that every 1 part of salts present corresponded to 5 parts of sugar. Monnier determined the ash by direct incineration of the products without any addition, and consequently obtained all inorganic substances in the form of carbonates.

Monnier concluded from his researches that the salts constitute the melassigenic element, and that 1 part of salts prevents 5 parts of sugar from crystallizing, and retains them in the molasses. For the determination of the yield, the found amount of ash was therefore multiplied by 5 and the numbers so obtained were subtracted from the optically determined sugar percentage.

This method was known as "calculation of the yield from the ash coefficient." To understand this method it is important to add that Monnier included in the coefficient 5 all mechanical and chemical losses, as clearly shown by his expressions:

"In case * the actual yield does not coincide with the

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* See also Dr. A. Herzfeld: "Ueber die Zweckmässigste Art der Werthschätzung des Rohzuckers," Zeitschrift des Vereins für Rübenzuckerindustrie, März, 1892, S: 125.

theoretical, the reason would be due to abnormal losses, because of defective washing of the filters or improper treatment of the charcoal. Both these causes, in a work conducted in a faulty manner, can result in losses exceeding one per cent. of the raw sugar used. If the work has been properly conducted, the weight of the refined sugar plus the weight of the molasses must be equal to the weight of the sugar used."

Hereby it must be observed that at the time Monnier introduced his method of calculating the yield by the ash coefficient, the raw sugar factories produced only sugars known as "raw sugars for export" with 94–96 per cent. polarization and 88–90 per cent. yield. As, besides this, all juices at that time were filtered through boneblack, it can be assumed that they contained normal quantities of non-sugar, in other words, that the proportion 1.0 salts:1.25 organic substances was not exceeded. But later on, as the course of manufacture was changed, and the boneblack was superseded by sulphurous acid, there were produced repeatedly raw sugars with a relation between ash and organic non-sugar as high as 1.0:1.7 instead of the formerly prevailing 1.00:1.25 to 1.00:1.50. From raw sugars of such composition it has been made evident by experience that the yield calculated according to the ash cannot be obtained.

Furthermore, raw sugars later appeared on the market with a high polarization and small ash percentage. These sugars had to be treated according to the ash-yield, although in this case as well, the theoretical calculation always left the manufacturer in the lurch. The far-reaching consequences of the unlimited use of the ash-yield had not been sufficiently appreciated. Monnier is not to be blamed for all these cases, as he could not foresee them. He accomplished an important service in the domains of practical sugar chemistry, by establishing the first method of calculating the yield: a method permitting the drawing of conclusions as to the practical output of a raw sugar from its chemical composition, something that was considered as utterly impossible up to that time.

As to Monnier's statement that in normal work the weight of the white merchandise plus the weight of the molasses must be equal to the weight of the worked raw product, it is clear that this can be the case only when the molasses contain more water than what corresponds to the raw sugar, because otherwise all mechanical losses should have been avoided. In factory work a loss of 0.5–1.5 per cent. on the mass of the raw sugar takes place if there are produced strongly concentrated molasses.

The principal error of Monnier was that he considered the salts as the melassigenic element. The fact that at least an equal melassigenic action should be ascribed to the organic non-sugar was then soon made clear. Nevertheless the "ash-yield" maintained its position, and has been generally accepted since C. Scheibler modified the very inconvenient and tedious older method of direct combustion, by moistening the product with concentrated sulphuric acid before incineration.

According to Scheibler's "sulphated ash" method, all inorganic substances are obtained in the form of sulphates, and are calculated into the corresponding quantity of carbonates by multiplication by the factor 0.9. The subsequent calculation of the yield is effected according to Monnier.

Let it be remarked here that Scheibler expressed himself very decisively against the general use of the ash coefficient. He even made the remarkable proposition, entirely contrary to Monnier's, to multiply the organic non-sugar by 4 and subtract the product from the polarization. On the other hand, Stammer and Weiler proposed to take as a starting point the total non-sugar.

The "ash-yield" held rule for the shortest time in its own native country, France. After Pagnoul proved that the prevailing relation in the molasses of that time was 1 ash:4.1 sugar, the calculation of the yield was accordingly changed. In the future, four times the weight of ash, 1.5 per cent. as manufacturing loss, and twice the amount of any present invert-sugar, were to be subtracted from the polarization.

Apart from the last thoroughly jutsified rule, the French yield is very favorable to the refiner, because, as it has been proved, under the governmental control of the factories in Holland, by this method of calculation, when working normal export sugar, it yields consumable merchandise by 0.35 per cent. higher than can be theoretically expected.

As to the factor 2 for the invert-sugar, let it be here emphasized once more that it is by no means too high. Molasses from raw beet-sugar, rich in glucose, usually have high coefficients, while the quality of the product is greatly impaired by the pronounced coloration caused by the action of the alkalies on the invert-sugar.

In Germany, in spite of the long labors of Scheibler, no advance has been made as to the question of yield. Scheibler's method of successive washings gave unsatisfactory results, because by its use only the sugar in a crystalline form contained in the raw material can be determined; and, furthermore, there is danger that sugar from the saturated alcoholic solution employed deposits on the crystals, which, indeed, occurs very easily. The Charlottenburg experiments, conducted by Scheibler as well, gave no tangible results, so that for the lack of a better method the ash-yield continued to be used with a prevalence hardly interrupted, and only for a short time, by the proposed "non-sugar yield."

About the year 1890 there were produced in Germany many sugars showing a relation between organic sugar and ash as high as 1.5–1.7 ONS:1.0 A instead of the normal 1.25:1.00. The consequence was that the ash-yield paid on similar sugars could not be obtained, as there were produced larger quantities of molasses than by working normal sugars. As a remedy for this inconvenience, a new method was established in the year 1893 by the Union of German Refiners. According to this new method all sugar refineries of Germany were bound to buy their sugar and calculate their yield by multiplying the total non-sugar by the factor $2\frac{1}{4}$ and subtracting the product from the polarization. It was hoped that in this way values would be obtained expressing what output could really be expected, better than by the ash coefficient; at the same time no serious differences would be found for normal first products. By "normal first product" is understood a raw sugar containing 1.25 parts of ONS per 1 part of ash. For sugars having this proportion between A and ONS the calculation of the yield by the non-sugar should coincide with the "ash-yield," because by the ash coefficient there would be:

$$1 \text{ ash} \times 5 = 5 \text{ parts},$$

and by the "non-sugar method,"

$$1 \text{ ash} + 1.25 \text{ org. NS} : 2.25 \text{ total NS},$$
$$2.25 \times 2\tfrac{1}{4} = 5.0625 \text{ parts},$$

or, in both cases, ~5 parts to be subtracted from the polarization.

The high expectations attached by the German refiners to the "total non-sugar yield" have in no way been fulfilled, and for the following reasons: As it can be proved by a simple calculation, the non-sugar yield is advantageous to the buyer only if the relation of the ash to the organic non-sugar turns out higher than 1:1.25. But if the relation decreases, even slightly, say to 1:1.2, the refiner pays for the raw sugar, according to the non-sugar yield, more than according to the ash-yield; and what is still more unpleasant, the theoretical output can by no means be obtained from raw products of a similar composition, as has been very often proved by actual factory experience.

It seems that the fresh formation of non-sugar by destruction of sugar, a very important factor in all cases, has been entirely overlooked when establishing the non-sugar coefficient. This new formation is nearly the same whether working high or low sugars, judged by the "non-sugar yield." When calculating the yield from the total non-sugar and the factor $2\frac{1}{4}$, the total NS must amount to a certain figure, such as to give, when multiplied by the factor, a number high enough to include the total mechanical and chemical losses. This happens only when the non-sugar amounts to at least 2.25 per cent., so that the number to be subtracted from the polarization is $2.25 \times 2\frac{1}{4} = 5$. Otherwise the theoretically calculated yield is not practically possible, because the melassigenic action of the newly formed non-sugar is now noticeable in all its extent.

Under these conditions it was to the interest of the raw-sugar manufacturers to produce, if practicable, only sugars containing but little non-sugar, because the estimation of their value would be more favorable. By a prolonged action of the lime in the defecation, and a careful treatment of the juices in the carbonation, they succeeded indeed in solving the problem, and the raw sugars with a high percentage of non-sugar disappeared completely from the market.

Now the remarkable case developed that the German refiner paid more for his raw sugar than did his competitors in the world's market, where the ash-yield was valid as before, without a compensation of any kind, not even theoretically, because often the calculated yield could by no means be actually obtained.

Evidently this discredited completely the "non-sugar yield" method, and a return was again made to the "ash-yield," and the more willingly as the quality of the sugar found on the market promised substantial advantages from this change of system.

The history of the "non-sugar yield" must be looked upon as very instructive. The same laws that rule nature are equally valid in the life and ways of men; for every power coming into action a counter-power enters into play at the same time, and every pressure is necessarily followed by a counter-pressure.

When discussing the calculation of the yield from the non-sugar, we have seen that it gives really serviceable results only under certain assumptions; that, in other terms, it furnishes correct results only for a determined category of sugars. The same thing happens with the "ash-yield." We have seen that the composition of the raw sugars rendered desirable an alteration of the method of calculating the yield, and in such a way that the whole non-sugar contained could be taken into account—as the ash alone was not sufficient. But this is equally insufficient under quite other conditions. The conditions that have been noted on page 38 in regard to the "non-sugar yield" apply to the "ash-yield" as well. Here, too, it is necessary that the ash of the raw sugar attains a certain figure, such that the ash factor, five, can include all mechanical and chemical losses. Experience has shown that the ash must amount to one per cent. at least if the yield calculated on the ash is to be actually obtained. As in the case of the non-sugar method, here, too, five parts must be subtracted from the polarization, so that the ash-yield may correspond to the necessary conditions. All this indicates that the ash-yield also is correct only for a completely limited and known category of raw sugars, namely, for the so-called normal export raw sugars, that have an ash-yield varying between 88–90 per cent. and a relation of A:ONS not higher than 1:1.25.

This explains as well the fact that in many refineries the yields practically obtained are very close to those theoretically calculated. "The general average of the raw sugars of many factories taken collectively, simply corresponds closely to the conditions that would make a normal raw sugar according to the ash-yield."

If, then, the ash-yield is of no value when applied to raw sugar containing less ash than one per cent., it follows that it is completely useless for the determination of the refining value of the so-called "sand sugars," such as are produced in Russia and France.

The sand sugars are raw sugars of a higher purity that have already been submitted to a preliminary purification in the raw-sugar houses, in that by means of water or steam washing they are freed from the coating of mother syrup inclosing the crystals.

According to the official report of the Imperial Russian Technical Society of Kiew, only sand sugar is refined in Russia. The raw sugar has the following composition:

	Per Cent.
Saccharose	99.650
Ash	0.073
Water of organic non-sugar	0.277
	100.000

From 100 parts of this sugar are obtained 100.29 per cent. of refined sugar, emballage included, and 2.282 per cent. molasses of 76° Balling.

The 100.29 parts of refined sugar contain:

Sucrose	96.9581
Paper	3.0503
Threads	0.2817
	100.29

The molasses contain:

Sucrose	48.2
Ash	4.5
Invert-sugar	17.0
Water and organic non-sugar	30.3
	100.0

Consequently on every 99.65 parts of sucrose contained in 100 parts of the worked raw product, there are obtained:

Sucrose in form of refined sugar	96.9581
Sucrose in the molasses	1.0990
	98.0571

Loss: $99.6500 - 98.0571 = 1.5929$.

The loss of sucrose, according to the figures of this report, is rather high. This is due most probably to the fact that the polarization of the molasses is found lower than what it really is, because of the levorotatory invert-sugar they contain (17 per cent.). In any case, the figures showing the average output of all Russian factories are of no small importance for the further development of the question of yields.

The figures given in the report show at once the complete unreliability and irrationality of the ash as well as the non-sugar method of calculating the yields, when dealing with raw sugar of a composition different from that of the normal export sugars. Thus, for instance, the ash method would give for a sugar of the above composition a refining value of:

$$99.65 - (5 \times 0.073) = 99.285 \text{ per cent.},$$

while on the basis of the non-sugar calculation a practical output of:

$$99.65-(2.25\times 0.25)=99.087 \text{ per cent.},$$

would be expected, if the total NS of the sand sugar be taken as $=0.25$ per cent. This last supposition is justified by the knowledge that such sugars usually contain 0.1 per cent. of water.

Both methods of calculating the yield are found consequently to be 2% too high. As we have already stated, the reason must be ascribed to the fact that the empirical coefficients used by both methods are valid only for a very limited category of sugars.

It should then be considered as a real progress if it were made possible to establish a more thorough method giving substantial fundamental data for the calculation of the yield of even the most widely different products. This would not seem to be a completely unsolvable problem, if the cases considered here, in connection with the discussion of the losses in the refineries, be taken as starting point.

If the mechanical and chemical losses of a factory are known, and the average purity of the molasses produced also, the output in white consumable merchandise can be easily calculated from the composition of the raw material worked and the above-mentioned factors.

We have already discussed the average losses in refining (see p. 29). We have seen that the mechanical losses amount to ~ 0.5 per cent., the chemical to ~ 0.55 per cent., and that, further ~ 0.6 per cent. of new non-sugar is formed. If we admit that the working of normal export sugar gives molasses of 60 purity, while sand sugars give molasses of a true purity 65.8, we can calculate the yields as follows:

1. **Export Sugar.** 95.6 polarization, 1.2 per cent. ash, 1.5 per cent. organic non-sugar, 1.7 per cent. water. Purity of molasses = 60. Each part of non-sugar retains consequently $\frac{60}{40} = 1.5$ parts of sugar in the molasses.

REFINING VALUE

	Per Cent.
Polarization	95.60
Losses: Mechanical = 0.50 Chemical = 0.55	1.05
	94.55

TOTAL NON-SUGAR

In the raw product	2.70
From chemical losses	0.60
	3.30

There are thus obtainable in the form of white merchandise:

$$94.55 - (3.30 \times 1.5) = 89.6 \text{ per cent.}$$

The "practical method" used here has the advantage that it can as well be employed for after-products, without any change, which, as is well known, is not the case with the ash method of calculation.

This calculation can be mathematically expressed as follows:

$$Y = P - 1.05 - (0.6 + NS)\ 1.5,$$

or after abbreviation,

$$Y = P - 1.95 - (NS \times 1.5).$$

This formula is applicable for raw sugars containing at least two per cent. total non-sugar.

In the formula

Y = the yield of the raw sugar;
P = its polarization; and
NS = its total non-sugar.

2. Russian Sand Sugar. 99.65 per cent. polarization, 0.073 ash, 0.177 organic non-sugar, 0.1 water, 65.8 purity of the molasses. Each part of non-sugar retains consequently $\frac{65.8}{34.2} = 1.924$ parts of sucrose in the molasses.

REFINING VALUE

		Per Cent.
Polarization		99.650
Losses: Mechanical	0.50	
Chemical	0.55	1.050
		98.60

TOTAL NON-SUGAR

In the raw product	0.25
From chemical losses	0.60
	0.85

It follows that there must be obtained in the form of marketable white product:

$$98.60 - (0.85 \times 1.924) = 96.966 \text{ per cent.}$$

The actual output was, as we have seen, 96.9581 per cent., the difference therefore is but ~0.008 per cent., technically unimportant, while the difference with the ash and non-sugar yields is ~2 per cent.

Accordingly, the formula for calculating the yield of sand sugars is as follows:

$$Y = P - 1.05 - (0.6 + NS)1.924.$$

This formula differs from the one given for sugars of low yield merely in the higher melassigenic coefficient of the non-sugar.

Now, when it is ascertained by experience that the melassigenic coefficient is nearly 1.5 for sugars of low yield and 1.924 for sand sugars, it must be admitted that sugars having a yield lying between these two limits (90–99) must have coefficients ranging between 1.5 and 1.914. The difference that serves as a basis may be divided in about the following manner:

Polarization of the Raw Sugar.	Non-sugar, Per Cent.	Coefficient for the Imported and Newly Formed NS (% NS + 0.6).	Approximative Yield of the Raw Sugar.
95.0–95.5	2.2	1.5	89.7–90.2
95.6–96.0	2.1–1.8	1.55	90.3–91.2
96.1–96.5	1.5	1.6	91.8–92.2
96.6–97.0	1.00	1.65	92.8–93.2
97.1–97.5	0.75	1.70	93.8–94.2
97.6–98.0	0.50	1.75	94.6–95.0
98.1–98.5	0.40	1.80	95.2–95.6
98.6–99.5	0.30	1.90	95.8–96.7
Over 99.5	0.25	1.924	~97.0

It is hardly to be doubted that these remarks, with a few modifications, can serve as a basis for a method to determine beforehand the yield; a method in every respect superior to those devised so far. However, another difficulty to be removed, would arise from the fact that the chemical composition of a raw sugar does not furnish us with data fully sufficient to judge of those physical, imponderable qualities that confer upon a good sugar its superiority over lower products. Those qualities, the determination of which evades the balance, are: Light color, and strong, uniform and well-formed grain. They can be attained collectively and with relative facility in the manufacture of the raw sugars by the following means: Use of sufficient lime in the defecation, rational conduct of the carbonation and filtration, sufficient alkalinity of the thick juices (0.02 per cent. CaO), and above all a properly conducted boiling in the pan.

Thick juices of too high a concentration must be avoided, 60° Brix being considered as a maximum. In case syrups from the centrifugals are to be drawn into the pan, which does not impair the quality of the raw sugar, as is often represented, they must be diluted with waste water or thin juice, submitted to mechanical filtration, if necessary, with addition of a small quantity of lime cake, and drawn into the pan about the end of the boiling. By the dilution the viscosity is completely destroyed, as the viscosity is due to nothing else but over-saturation of the solution with sugar. Furthermore, by the dilution the energy of crystallization is greatly increased, the sugar gains the molecular mobility necessary for overcoming the resistance to crystallization, while at the same time an easier displacement of the non-sugar and coloring substance is attained. In this way it is possible to obtain, besides first raw sugars of good quality and light color, also syrups of such a low purity that the extraction of their sugar is certain to succeed in one single operation, and this in but a few days.

The view to which many raw sugar manufacturers seem to incline, namely, that the quality of the products is of a quite secondary importance and that the quantity is the only decisive factor, is a very questionable one, which sooner or later will cause great damage to its adherers.

In every case, as a complement to the determination of the yield, first raw sugars must fulfil another condition, consisting in this: The crystals, after the layer of syrup that covers them is removed, must be white. The simplest method of determining this property is by bringing about 100 grs. of raw sugar in a funnel provided with a sieve, and covering it with a colorless solution of sugar of ∼67.5 per cent. This solution displaces the syrup layer and the real color of the crystals appears. If this is white, the raw sugar can be considered as suitable for refining purposes, regardless of its origin; if, on the contrary, a first product of beet juices, shows yellow crystals by the above treatment, it must be considered as unsuitable, or be valued at a lower price. The cited test must be considered as a characteristic means of recognizing sound raw sugars.

The hitherto discussed notions of the coefficient of purity, losses in the course of manufacture, and yield, form the foundations of all technical calculations. In the following part of the book we shall have the opportunity to see their manifold application in the extended control of the sugar house.

At the same time, and conjointly, we will give the methods of general calculation. Their knowledge is of the greatest importance to every member of the technical staff, as it enables him to solve all problems relating to the work quickly and easily.

GENERAL METHODS OF CALCULATION

1. To Find the Absolute Weight of a Product of Known Volume and Specific Gravity. The unit of cubic measure is the cubic meter, cu.m. or m^3.

1 m^3 water = 1000 liters = 1000 kilograms (kgs.);
1 m^3 water = 10 hectoliters at 100 liters or 100 kgs. each;
1 m^3 juice (massecuite, etc.) = sp.gr. × 1000 = weight of the mass in kgs.;
1 m^3 juice (massecuite, etc.) = sp.gr. × 10 = quintals of mass. (1 quintal = 100 kgs.)

Example. 12.84 cu.m. of thick juice of 51.2 Brix will weigh (the specific gravity corresponding to 51.2 Brix in the tables being 1.23943).

$$12.84 \times 1.23943 \times 1000 = 15.914 \text{ kgs.}^3$$

or

$$12.84 \times 1.23943 \times 10 = 159 \text{ Q. } 143.$$

Example. 59.3 m^3 of II massecuite of 88° Brix, weigh (the specific gravity corresponding to 88 Brix is $= \sim 1.47$),

$$59.3 \times 1.47 \times 1000 = 87.171 \text{ kgs.}$$

or

$$59.3 \times 1.47 \times 10 = 871 \text{ Q. } 71.$$

2. To Find the Dry Substance, or the Weight of the Massecuite, when the Weight of the Juice is Known. The weight of the apparent dry substance (Wt Ap Ds) contained in a known quantity of a product is found from the proportions:

$$100 : \mathrm{B} :: \text{weight of the product} : x,$$

or

$$\frac{\mathrm{B} \times \text{weight of the product}}{100} = \text{Wt Ap Ds.} \quad . \quad (4)$$

Example. To find the weight of apparent dry substance contained in 15.914^3 kgs. of juice of 51.2 per cent. B:

$$\frac{15.914^3 \times 51.2}{100} = 8148^1 \text{ kgs.}$$

From the weight of apparent dry substance (Wt B) contained in a given quantity of a product, can be calculated the quantity of massecuite of a known water percentage that will be produced (Wt Mc), if the weight of dry substance be multiplied by 100 and the product divided by the Brix of the massecuite (B Mc):

$$\frac{\text{Wt B} \times 100}{\text{B Mc}} = \text{Wt massecuite.} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Example. What quantity of massecuite of 92.8 B, consequently 7.2 per cent. water, will be produced from 8148^1 kgs. of dry substance?

$$\frac{8148^1 \times 100}{92.8} = 8780 \text{ kgs. massecuite.}$$

The weight of the massecuite can be obtained directly from the weight of the juice (Wt j) by multiplying the weight by the Brix of the juice and dividing the product by the Brix of the massecuite:

$$\text{B Mc} : \text{B j} : \text{Wt j} : x,$$

$$\frac{\text{B j} \times \text{Wt j}}{\text{B Mc}} = \text{Wt massecuite.} \quad . \quad . \quad . \quad (6)$$

Example. 159.143 kgs. juice at 51.2° Brix if boiled to a massecuite of 92.8 Brix, will give:

$$\frac{51.2 \times 159.143}{92.8} = 87.800 \text{ kgs. massecuite.}$$

If in the above equations the true dry substance found by desiccation be put in the place of the apparent (Brix) obtained by spindling, the resulting number will give the real weights instead of the apparent.

3. Reduction of Thin Juices of a Known Specific Gravity or Brix, to Thick Juices or Massecuites, and Inversely. (According to Hugo Jelinek.) In the following formulæ:

Wt_1 = the weight of the thinner or less heavy juice in kgs.;
Sp_1 = the specific gravity or spindling (B) of the same juice;
Wt_2 = the weight of the thicker, or heavier juice, or massecuite;
Sp_2 = the specific gravity or B of the heavier juice, or massecuite;
W = water to be evaporated in kgs.

The calculations are effected according to the following formulæ:

$$Wt_1 = \frac{Wt_2 \cdot Sp_2}{Sp_1}; \quad . \quad . \quad . \quad (7) \qquad Sp_2 = \frac{Sp_1 \cdot Wt_1}{Wt_2}; \quad . \quad (8)$$

$$Sp_1 = \frac{Wt_2 \cdot Sp_2}{Wt_1}; \quad . \quad . \quad . \quad (9) \qquad Wt_2 = \frac{Wt_1 \cdot Sp_1}{Sp_2}; \quad . \quad (10)$$

$$W = Wt_1\left(1 - \frac{Sp_1}{Sp_2}\right). \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Examples. (Equation (7)). 8780.3 kgs. of a massecuite must be calculated back into weight of thick juice of 51.2 B.

$$\frac{8780.3 \times 92.8}{51.2} = 15914.3 \text{ kgs.}$$

The volume of the juice can equally be found by dividing the weight by the specific gravity:

$$\frac{15914.3}{1.23943} = 12{,}840 \text{ liters, or } \frac{12{,}840}{1{,}000} = 12 \text{ m}^3 \text{ } 840.$$

(Equation (8)). To find the Sp_2, in other terms the Brix of a massecuite, from the following data:

15914.3 kgs. of thick juice of 51.2 B have given, after boiling, 8780.3 kgs. massecuite. What is the Brix of the massecuite?

Inserting these values in the formula, we find

$$\frac{51.3 \times 15914.3}{8780.3} = 92.8 \text{ Brix.}$$

(Equation (9)). 15914.3 kgs. of a thick juice have given, after boiling, 8780.3 kgs. of massecuite at 92.8 Brix. What was the Brix of the thick juice?

$$\frac{8780.3\times 92.8}{15914.3}=51.2 \text{ Brix.}$$

(Equation (10)). 15914.3 kgs. of thick juice of 51.2 Brix have been boiled to a massecuite of 92.8 Brix. What quantity of massecuite must be produced?

$$\frac{15914.3\times 51.2}{92.8}=8780.3 \text{ kgs.}$$

(Equation (11)). How many kilograms of water must be evaporated in order to obtain a massecuite of 92.8 Brix from 15914.30 kgs. of thick juice of 51.2 Brix?

$$W=15914.3\left(1-\frac{51.2}{92.8}\right);$$

$$1-\frac{51.2}{92.8}=\frac{92.8-51.2}{92.8}=\frac{41.6}{92.8}.$$

Then

$$W=15914.3\times\frac{41.6}{92.8}=7134 \text{ kgs. W.}$$

4. The Composition of an Aqueous Product being Known, to Find the Percentage Composition of its Dry Substance. A massecuite has the following composition:

$$S=88.0,\quad NS=6.2,\quad W=5.8 \text{ per cent.}$$

What is the composition of its dry substance?

The quantity of sugar will be found from the equation:

$$94.2 : 88 = 100 : x,$$

$$x = \frac{88 \times 100}{94.2} = 93.418 \text{ per cent. S.}$$

The calculation of the sugar contained in 100 parts of dry substance is consequently nothing else than the determination of the coefficient of purity.

It follows that the non-sugar content of dry substance will be:

$$100 - 93.418 = 6.582 \text{ per cent.}$$

5. Calculation of the Percentage Composition of an Aqueous Product when the Composition of its Dry Substance or its Purity is Known.

What is the composition of a thick juice with 58 per cent. dry substance, if its purity is 90.8?

The purity of the dry substance is 90.8. We find the sugar contained in the juice by the use of the formula (3):

$$\frac{90.8 \times 58}{100} = 52.664 \text{ per cent. sugar.}$$

And in the same manner the non-sugar contained in the juice:

$$\frac{9.2 \times 58}{100} = 5.336 \text{ per cent. NS.}$$

The coefficient of the thick juice must be equal to the sugar percentage of dry substance:

$$P = \frac{52.664 \times 100}{58} = 90.8.$$

6. Calculation of the Percentage Composition of a Product when the Quantities of its Ingredients are Known, by Weight.

A syrup is composed of 27 parts of sugar, 9 parts of non-sugar, and 8 parts of water. What is the percentage composition of this syrup?

On mixing the above-named substances there are produced $27+9+8=44$ parts of syrup. In these 44 parts of syrup are contained 27 parts of sugar, consequently:

$$44:27::100:x=\frac{27\times 100}{44}=61.363 \text{ per cent. S.}$$

In a similar way is calculated the percentage of NS:

$$44:9::100:x \quad (x=20.454 \text{ per cent. NS}).$$

Then the amount of water will be:

$$100-(61.363+20.454)=18.183 \text{ per cent.}$$

The coefficient of purity must be the same in both cases; this constitutes the simplest test of the accuracy of the calculation. Thus:

$$\frac{27\times 100}{36}=75 \quad \text{and} \quad \frac{61.363\times 100}{81.817}=75.$$

7. The Composition of an Aqueous Product being Known, to Recalculate for a Different Water Percentage.

The syrup resulting from the curing of a IId massecuite has the following composition:

$$S=49.4, \quad NS=26.6, \quad W=24.0 \text{ per cent.}$$

What will be the composition of a IIId massecuite of 10 per cent. W boiled from this syrup?

The syrup has $49.4+26.6=76.0$ per cent. dry substance and the massecuite that must be boiled will have $100-10=90$ per cent. Ds. Consequently:

$$76:49.4::90:x \quad (x=58.5).$$

The massecuite will contain 58.5 per cent. S.

$$\frac{26.6\times 90}{76}=31.5 \text{ per cent. NS.}$$

$$(\text{Otherwise}=\text{Ds}-\text{S}=\text{NS}, \quad \text{or} \quad 90-58.5=31.5.)$$

The purity of the syrup and massecuite being the same, =65, the calculation of the composition of the latter is correct.

8. Formulæ for the Calculation of the Outputs of Massecuites.—Massecuites contain and can be separated into two parts or constituents differing from one another by their state of aggregation; namely, into crystalline sugar and a syrup containing more or less sugar according to the purity of the mass, the so-called green syrup. The output in crystalline sugar will be the higher, the less sugar passes into the green syrup, and will decrease with the increase of the sugar contained in the syrup.

In other words, the sugar output that can be obtained from a massecuite is inversely proportional to the purity of the syrup.

We see that the relation between sugar output and coefficient of the syrup is quite fixed; this knowledge evidently enables us to calculate the output of the massecuites at the centrifugals.

The simplest conceivable case would be the one in which the massecuite would separate exactly into chemically pure crystalline sugar of 100 coefficient—we will call it briefly crystalline sugar and denote it by k—and in a green syrup of a determined purity. In this case the whole amount of non-sugar of the massecuite would have passed into the syrup, retaining at the same time a perfectly determined quantity of sugar, this quantity depending on the purity of the syrup.

The problem, however, is more complicated when the centrifugated sugar itself contains non-sugar, as usually happens. For this reason we shall consider next the determination of the quantity of crystalline sugar contained in a massecuite.

A. *Calculation and Direct Determination of the Crystalline Sugar contained in a Massecuite.* Suppose a massecuite has the following composition:

$$S=86.6, \quad NS=7.4, \quad W=6.0 \text{ per cent}$$

100 parts of the mass then contain 7.4 parts of non-sugar; for a syrup coefficient of say 73, these 7.4 parts NS will retain in the syrup:

$$7.4\times\frac{73}{27}=20 \text{ per cent.}$$

of the sugar contained in the massecuite, if the separation of the mass into chemically pure crystalline sugar and a syrup of such a low purity be supposed as practically feasible.

As we have seen, the coefficient of a product represents the quantity of sugar contained in 100 parts of its dry substance. If the purity of the green syrup is 73, there are contained in 100 parts of dry substance $100-73=27$ parts of non-sugar, and consequently in this case 1 part of NS requires $\frac{73}{27}$ parts of sugar for the formation of the syrup, so that the 7.4 parts NS of the massecuite will correspond to 20 parts of sugar.

Now, as the massecuite contains 86.6 per cent. S there will be left, or theoretically obtainable,

$$86.6-20=66.6 \text{ per cent. S.}$$

We can express the relations found above by the following formula:

$$Gp=\frac{NS \times GP}{100-GP}, \quad . \quad . \quad . \quad . \quad . \quad (12)$$

i.e., the quantity of sugar that passes in the syrup from 100 parts of a massecuite, can be found if the non-sugar passing to the syrup be multiplied by the purity of the syrup, and the product be divided by the difference, 100 − purity of the syrup (or the NS per cent. of the syrup dry substance).

Gp = polarization of the syrup;
NS = non-sugar passing into the syrup;
GP = purity of the syrups.

The total non-sugar of the massecuite may taken in the calculation only on the condition that the centrifugated sugar is chemically pure.

If we substitute the symbols in the formula (12) by the given values, we obtain:

$$Gp = \frac{7.4 \times 73}{100 - 73} = 20 \text{ per cent.}$$

The crystalline sugar contained in the massecuite is then found according to the formula:

$$k = Mc\,p - \frac{NS \times gP}{100 - gP}, \qquad \ldots\ldots \quad (13)$$

where Mc p denotes the polarization of the massecuite.

$$k = 86.6 - \frac{7.4 \times 73}{100 - 73} = 66.6 \text{ per cent.}$$

This method of calculating the crystalline sugar of a massecuite from the polarization of the mass and the purity of the syrup has been given by Schneider. Based on his formula, he compiled the table on the following page, which makes evident the dependence of the crystalline sugar on the composition of the massecuite and the purity of the green syrup.

This table is found in Scheibler's "Neue Zeitschrift für Rübenzucker-Industrie," Vol. XXVIII, 1892, p. 16.

It can be seen from the table that for an equal percentage of water and an unchanged purity of the syrup, the quantity of crystalline sugar contained in the massecuite is increased by ~1.6 per cent. for an increase in the purity of the massecuite by half a degree, while an increase of the syrup purity by 0.5 corresponds to a

100 PARTS OF THE MASSECUITE CONTAIN

Purity of the Syrup.				70.0		70.5		71.0		71.5	
S	NS	W	P	Crystalline Sugar.	Sugar Dissolved in the Syrup.	Crystalline Sugar.	Sugar Dissolved in the Syrup.	Crystalline Sugar.	Sugar Dissolved in the Syrup.	Crystalline Sugar.	Sugar Dissolved in the Syrup.
82.75	11.25	6.0	88.0	56.40	26.32	55.76	29.96	55.11	27.61	54.42	28.30
83.19	10.81		88.5	57.97	25.21	57.36	25.83	56.72	26.47	56.07	27.12
83.66	10.34		89.0	59.63	24.00	58.96	24.70	58.34	25.32	57.72	25.94
84.13	9.87		89.5	61.10	23.03	50.54	23.59	59.96	24.17	59.37	24.76
84.60	9.40		90.0	62.67	21.90	62.13	22.47	61.59	23.01	61.02	23.58
85.07	8.93		90.5	64.23	20.84	63.73	21.34	63.23	20.54	62.67	22.40
85.54	8.46		91.0	65.80	19.74	65.32	20.22	64.83	20.71	64.31	21.23
86.01	7.99		91.5	67.37	18.64	66.91	19.10	66.46	19.55	65.96	20.05
86.48	7.52		92.0	68.95	17.55	68.17	18.31	68.07	18.41	67.20	19.22
87.02	6.98		92.5	70.78	....	....	....	69.68	....	....	....
87.50	6.50		93.0	72.19	....	....	....	71.29	....	....	....

100 PARTS OF THE MASSECUITE CONTAIN

Purity of the Syrup.				72.0		72.5		73.0		73.5	
S	NS	W	P	Crystalline Sugar.	Sugar Dissolved in the Syrup.	Crystalline Sugar.	Sugar Dissolved in the Syrup.	Crystalline Sugar.	Sugar Dissolved in the Syrup.	Crystalline Sugar.	Sugar Dissolved in the Syrup.
82.75	11.25	6.00	88.00	53.71	29.01	52.98	29.74	52.22	30.50	51.43	31.29
83.19	10.81		88.5	55.39	27.80	54.69	26.50	53.96	29.23	52.21	30.98
83.66	10.34		89.0	57.07	26.59	56.40	27.26	55.70	27.96	54.98	28.68
84.13	9.87		89.5	58.75	25.38	58.11	26.02	57.44	26.69	56.75	27.38
84.60	9.40		90.0	60.43	24.17	59.82	24.78	59.18	25.42	58.53	26.07
85.07	8.93		90.5	62.11	22.96	61.53	23.54	60.93	24.14	60.30	24.77
85.54	8.46		91.0	63.78	20.76	63.23	22.31	62.67	22.87	62.07	23.47
86.01	7.99		91.5	65.46	20.55	64.94	21.07	64.41	21.60	63.85	22.16
86.48	7.52		92.0	67.14	19.34	66.66	19.82	66.15	20.33	65.62	20.86
87.02	6.98		92.5	68.82	....	....	....	....	....	....	....
87.50	6.50		93.0	70.50	....	....	....	....	....	....	....

decrease of the crystalline sugar per cent. massecuite by 0.6 per cent.

The knowledge of the amount of crystalline sugar contained in a massecuite is of importance to the sugar technician as forming a basis for the control of the work of the boiling-pans and centrifugals. On the other hand, the output in crystalline sugar, other things being equal, i.e., the composition of the massecuite being the same, depends on the execution of the technical part of the work. In relation to these points we shall give here two more methods, by Sidersky–Paris, and by Vivien, for the direct determination of the crystalline sugar.

The method of Sidersky is founded on the assumption that crystalline sugar is chemically pure, consequently that it contains no ash, and that all salts forming the ash of the massecuite (AMc) pass into the syrup and form its ash (AG). Therefore, if we determine the ash percentage of the massecuite and the ash percentage of green syrup, the quantity of syrup contained in the massecuite will be given from the expression:

$$\mathrm{AG}:\mathrm{AMc}::100:x. \quad . \quad . \quad . \quad . \quad . \qquad (14)$$

Consequently the amount of sugar in crystalline form contained in the massecuite will be:

$$100 - x.$$

If, for instance, the massecuite already taken as example contains 3.28 per cent. ash and the green syrup 9.82, we have:

$$9.82:3.28::100:x \quad (x = 33.4 \text{ per cent. syrup}).$$

It hence follows that the massecuite contains:

$$100 - 33.4 = 66.6 \text{ per cent. } k.$$

(See Scheibler's "Neue Zeitschrift für Rübenzuckerindustrie," 1892, Vol. XXVIII, p. 161.)

Vivien uses the following method for the direct deternation of crystalline sugar in the massecuites: To 200 grs. of massecuite he adds a solution of two parts of white sugar in one part of water, and brings the mixture in a funnel provided with a fine wire gauze of the kind used for the centrifugals. The massecuite is washed by pouring over it new quantities of the sugar solution, till the crystals are pure white. The solution is then aspirated off as much as possible and the cleansed massecuite is weighed. Thus is obtained the weight of the crystals, plus the weight of the solution adhering to them.

The moisture is then determined in 10 grs. of massecuite. From the percentage of water is calculated the weight of the solution by a simple multiplication by 3 because 1 part water = 3 parts sugar syrup.

If, for instance, 200 grs. massecuite have given after washing, 165.4 grs. crystals + sugar syrup, and if 10 grs. of the mass contain 0.648 gr. water, the total quantity of contained water will be:

$$\frac{0.648 \times 165.4}{10} = 10.71 \text{ grs. water;}$$

$$10.71 \times 3 = 32.3 \text{ grs. sugar solution.}$$

As we have been working on 200 grs. of massecuite, 100 massecuites will contain:

$$\frac{165.4-32.1}{2}=66.6 \text{ grs. dry crystals.*}$$

We come now to the calculation of the outputs that are to be obtained from massecuites when the centrifugated products are not chemically pure.

B. *Calculation of the Yield from the Dry Substance and Polarization of the Massecuite and Syrup.* Let us denote by x the amount of sugar that will be obtained from 100 parts of massecuite. Then the quantity of green syrup given by 100 parts of the massecuite will be $100-x$, if the massecuite be centrifuged without washing.

It is evident that the whole dry substance of the massecuite as well as its sugar must now be found again in the obtained products.

Ninety-four per cent. dry substance of the massecuite taken as example in A give:

66.6 per cent. crystals = 66.6 dry substance,
and 20 sugar + 7.4 non-sugar = 27.4 "
Total .... 94.0 "

The sugar of the massecuite will be divided into:

66.6 per cent. crystals of 100 polarization = 66.6
20.0 f in the green syrup = 20.0
Total .... = 86.6%

---

* See Scheibler's "Neue Zeitschrift für Rübenzuckerindustrie," Vol. XXXIII, 1894, p. 119.

Every 100 parts of dry substance of the massecuite are then separated into x parts of dry substance of the sugar and $(100-x)$ parts dry substance of the syrup.

In the same way 100 parts of massecuite polarization are separated into x parts of sugar polarization and $(100-x)$ parts of syrup polarization.

We have therefore the equations:

$$100\,\mathrm{McDs} = x \times \mathrm{SDs} + (100-x)\,\mathrm{GDs},$$
$$100\,\mathrm{Mcp} = x \times \mathrm{Sp} + (100-x)\,\mathrm{Gp}.$$

Mc = massecuite;
Ds = dry substance;
S = sugar;
G = syrup;
p = polarization.

Consequently the chemical examination of the massecuites and of the green syrups furnishes us with two new methods of determining the output of a massecuite.

Let us take a massecuite of the following composition:

$$\mathrm{S}=86.6,\quad \mathrm{NS}=7.4,\quad \mathrm{W}=6.0 \text{ per cent.},$$

separated into a raw sugar of 98.2 Ds and a green syrup of 82.0 Ds. Introducing these values in the formula, we find:

$$\begin{aligned} 100\,\mathrm{McDs} &= x \times \mathrm{SDs} + (100-x)\,\mathrm{GDs}. \\ 100 \times 94 &= x \times 98.2 + (100-x)\,82 \\ 9400 &= 98.2 \times + 8200 - 82x \\ -8200 &= -82x \\ \hline 1200 &= 16.2x \\ x &= \frac{1200}{16.2} = \sim 74 \text{ per cent. output.} \end{aligned}$$

We can consequently reduce the formula to the following abbreviated form:

$$x=100\frac{\text{McDs}-\text{GDs}}{\text{SDs}-\text{GDs}}. \quad . \quad . \quad . \quad . \quad . \qquad (15)$$

The calculation is conducted in an entirely similar way if we suppose that our massecuite of 86.6 polarization is separated into raw sugar at 96 polarization and syrup of 60°. By introducing these values in the formula:

$$100\ \text{Mcp}=x\times\text{Sp}+(100-x)\text{Gp},$$

we have

$$\begin{aligned}100\times86.6&=96x+(100-x)60\\ 8660&=96\times+6000-60x\\ -6000&=\ -60x\\ \hline 2660&=\ 36x\\ x&=\frac{2660}{36}=\sim74\%\ \text{output}\end{aligned}$$

The equation can then be reduced to the following form:

$$x=100\frac{\text{Mcp}-\text{Gp}}{\text{Sp}-\text{Gp}}. \quad . \quad . \quad . \quad . \quad . \qquad (16)$$

C. *Calculation of the Yield of Massecuites from the Purities of Massecuites and Syrup.* All equations given in former chapters are based on the supposition that the massecuite is directly separated into sugar and syrup. If, however, this is not the case, but water was used for washing the massecuite, then the above given formulæ are no longer valid, for the reason that 100 parts of massecuite do not give 100 parts of products as in the former case, but the resulting sum of sugar and syrup will be increased by the quantity of water employed for washing. If such a dilution has taken place, then the yield of the massecuite can only be calculated from the sucrose contained in 100 parts of the sugar and of the syrup, in other words, from their coefficients of purity.

It is easily understood that the relation existing between polarization of sugar, syrup, and massecuite must exist as well between the polarizations of the dry substances of these products.

If 100 parts of dry substance of a massecuite give x parts of dry sugar, then $100-x$ parts of dry substance pass into the syrup.

One hundred parts of dry substance of a massecuite contain, then, the amount of sucrose that is expressed by the coefficient of purity of the massecuite (McP). These 100 parts (100 McP) must be imagined as separated into x parts of sugar, or x times the coefficient of the sugar (xSP), and $100-x$ parts going to the syrup, or $100-x$ times the purity of the syrup $(100-x)$GP.

We have, then, the equation:

$$100\,\text{McP} = x\text{SP} + (100-x)\,\text{GP}.$$

By abbreviating the formula hence results:

$$x = 100\frac{\text{McP} - \text{GP}}{\text{SP} - \text{GP}}.$$

All calculations based on this formula will, it is evident, give the yield considered as "dry" sugar.

As now the yield in moist product is directly proportional to the quantity of dry substance of the massecuite (McDs) but inversely proportional to the dry substance of the sugar (SDs), the right side of the equation must be multiplied by McDs and divided by SDs. The formula then takes the following form:

$$x = 100 \frac{\text{McDs}(\text{McP} - \text{GP})}{\text{SDs}(\text{SP} - \text{GP})} . \quad . \quad . \quad . \quad (17)$$

In this form the formula can be used for all calculations of yield, and naturally also for cases where dilution took place. If the dry substance of the massecuite is 94 per cent., its coefficient 92.13, the purity of the syrup 73, of the sugar 97.74, and the dry substance of the sugar 98.2, we find:

$$x = 100 \frac{94.0(92.13 - 73.0)}{98.2(97.73 - 73.0)},$$

$$x = \frac{100 \times 94 \times 19.13}{98.2 \times 24.73} = 74 \text{ per cent. yield.}$$

Using these formulæ as a basis, the tables on pages 71 and 72 are calculated, showing the output in Ist, IId, and IIId sugar of massecuites with ascending purities.

Similar calculations for massecuites of a constantly increasing purity are of great value in practical work, because they afford a knowledge of what advantages can be expected from an increase of the purity of the massecuites, and respectively a decrease in the purity of the syrup.

The increase of the purity of the massecuite by one unit causes, for the first products, an increase of the output by $\sim$3.5 per cent. raw sugar, and for after-products $\sim$3.0 per cent.

The lowering of the syrup purity by one unit increases the output by 0.7 per cent., on an average, for first products, but for massecuites of after-products by 2.0–3.0 per cent.

D. *Calculation of the Sugar Contained in a Massecuite when the Crystalline Sugar and the Polarization of the Syrup are Known.* Calculation of the syrup polarization when the polarization of the sugar and of the massecuite are known.

Before we bring to a close our remarks as to the yields of the massecuites, let us introduce one more equation, the purpose of which is to show how to find the amount of the syrup of a given polarization that can convert a quantity of crystalline sugar of 100 polarization to a raw sugar of another given lower sugar percentage.

As we have already seen, a massecuite of 86.6 per cent. S and 6.4 per cent. NS contains 66.6 per cent. K. On the other hand, we have found that the same sugar centrifugated so as to obtain a raw sugar, gives, for a polarization of 96° of the raw product and a syrup polarization of 60, about 74 per cent. output.

Let us now face the question: What amount of syrup of 60 polarization is needed in order to convert 66.6 parts of crystalline sugar (100 pol.) into raw sugar of 96°? This can be calculated according to the following formula:

$$G = K\,\frac{100 - Sp}{Sp - gp} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (18)$$

where G denotes the quantity of green syrup;

K the crystalline sugar;

Sp the polarization of the raw sugar;

Gp the polarization of the syrup.

If we introduce the given values in the formula we find:

$$G = 66.6 \times \frac{100 - 96}{96 - 60} = 7.4.$$

Consequently there are needed 7.4 parts of syrup of 60 per cent. S in order to change 66.6 parts of K into $66.6 + 7.4 = 74$ parts of raw sugar polarizing 96°.

This equation is deduced from the following considerations: If we call x the necessary quantity of syrup, this will contain $\frac{60x}{100}$ parts of sugar. The raw sugar obtained will therefore contain $66.6 + \frac{60x}{100}$ parts of sugar.

On the other hand, we know that the raw product consists of 66.6 parts K and x parts syrup.

The total quantity of sucrose contained in the raw sugar (of 96° polarization) will be consequently:

$$\frac{(66.6 + x)100}{96}.$$

Hence we come to the equation

$$66.6 + \frac{60x}{100} = \frac{(66.6 + x)96}{100},$$

and

$$6660 + 60x = 6393.6 + 96x \quad (x = 7.4).$$

The polarization of the syrup can now be found from the polarization of the massecuite and of the sugar, from the formula:

$$Gp = \frac{100\,MCp - xSp}{100 - x},$$

where x denotes the sugar percentage obtained from the massecuite, in the centrifugals.

TABLE I

FOR THE CALCULATION OF THE RAW-SUGAR OUTPUT (95.5 POLARIZATION, 2 PER CENT. WATER) OBTAINED FROM Ist MASSECUITES WITH 6 PER CENT. WATER

Purity of the Syrup.		70.0	70.5	71.0	71.5	72.0	72.5	73.0
		100 PARTS OF MASSECUITE GIVE RAW SUGAR						
Purity of the massecuite	90.0	69.8	69.3	68.8	68.3	67.7	67.2	66.6
	90.5	71.5	71.0	70.5	70.1	69.6	69.1	68.5
	91.0	73.2	72.8	72.4	71.9	71.4	70.9	70.4
	91.5	74.9	74.6	74.2	73.7	73.3	72.9	72.4
	92.0	76.7	76.3	76.0	75.6	75.2	74.8	74.4
	92.5	78.4	78.1	77.8	77.5	77.1	76.7	76.3
	93.0	80.2	79.9	79.6	79.3	78.9	78.6	78.3

TABLE II

FOR THE CALCULATION OF THE OUTPUT IN SECOND SUGAR (92 POL., 2.5 PER CENT. WATER) OBTAINED PROM MASSECUITES WITH 10 PER CENT. WATER

Purity of the Syrup.	63.0	64.0	65.0
100 PARTS MASSECUITE GIVE PARTS OF SUGAR			
For a massecuite purity of 70.0...	20.6	18.2	15.7
“ “ 71.0...	23.5	21.3	18.8
“ “ 72.0...	26.5	24.3	22.0
“ “ 73.0...	29.4	27.3	25.1
“ “ 74.0...	32.4	30.4	28.3
“ “ 75.0...	35.3	33.4	31.4

TABLE III

FOR THE CALCULATION OF THE OUTPUT IN THIRD SUGAR (89 POL., 3 PER CENT. WATER) OBTAINED FROM MASSECUITES WITH 10 PER CENT. WATER

Purity of the Syrup.	59.0	60.0	61.0
	100 PARTS OF MASSECUITE GIVE PARTS OF SUGAR		
For a massecuite purity of 63.0...	11.3	8.7	6.0
" " 64.0 ..	14.1	11.6	9.0
" " 65.0...	16.9	14.5	12.0
" " 66.0...	19.8	17.5	15.0
" " 67.0...	22.7	20.4	18.1
" " 68.0...	25.5	23.4	21.1

9. Calculation of the Quantity of Syrup Drawn into the Ist Massecuite. In many sugar houses as well as in refineries working according to Langen's method, syrup from the centrifugals is drawn into the first pan during the boiling. The question now arises, how can we calculate the true Ist massecuite obtained directly from the beet juices if a determined quantity of syrup has been drawn into the pan, and how, inversely, can the quantity of syrup drawn be found by calculation.

The first part of the problem is easily solved by taking as basis and starting-point of the calculation the dry substance of the ready-boiled massecuite and that of the drawn syrup. If, for instance, we have 4000 kgs. massecuite, with 6 per cent. water and 91.4 purity, these will represent:

$$\frac{4000 \times 94}{100} = 3760 \text{ kgs. dry substance,}$$

with

$$\frac{3760 \times 91.4}{100} = 3436.6 \text{ kgs. sugar}$$

and $3760 - 3436.6 = 323.4$ kgs. non-sugar

If during the boiling 360 kgs. of syrup of 78 per cent. dry substance were taken in, these will correspond to

$$\frac{360 \times 78}{100} = \sim 280 \text{ kgs. dry substance.}$$

If the purity of the syrup was 74, there have been added to the massecuite:

$$\frac{280 \times 74}{100} = 207.2 \text{ kgs. of sugar,}$$

and 72.8 kgs. of non-sugar.

If we subtract these figures from those of the ready massecuite, we obtain: 3229.4 S and 250.6 kgs. NS that form the dry substance of the directly obtained massecuite. These 3480 kgs. of dry substance calculated to a massecuite of 6 per cent. W give:

$$\frac{3480 \times 100}{94} = \sim 3700 \text{ kgs. Mc.}$$

Its coefficient of purity must be 92.8, because

$$3480 : 3240 :: 100 : 92.8.$$

The calculation, however, is more complex when the quantity of the drawn syrup is unknown. In this case we must proceed by the following course of reasoning:

If the decomposition of sugar that takes place during the boiling be not taken into account, then that part of the massecuite which originates from the juices must have the same purity as the juices it was boiled from (ThP = thick juice purity). The coefficient of the final massecuite (McP) will depend on the purity (GP) and quantity of the drawn syrup.

From the above given relations must be found the quantity of syrup contained in the massecuite.

If we call x the quantity of syrup in 100 parts of dry substance of the massecuite, there will be contained in it $100 - x$ dry massecuite originating from the beet juices.

One hundred parts of the finished massecuite contain in dry form the quantity of sugar expressed by the purity (McP). 100 McP must then be equal to $100 - x$ parts of dry substance with the purity of the thick juice (ThP) plus x parts of dry substance (coming from the syrup) with a coefficient (GP). We obtain consequently the equation:

$$100\ \mathrm{McP} = (100 - x)\mathrm{ThP} + x\mathrm{GP}.$$

This can conveniently be abbreviated and transformed as follows:

$$x = 100\frac{\mathrm{ThP} - \mathrm{McP}}{\mathrm{ThP} - \mathrm{GP}}. \quad . \quad . \quad . \quad . \quad . \qquad (20)$$

If, for instance, the coefficient of the thick juice is 92.8, of the massecuite 91.4, and of the drawn syrup 74, by introducing these values in the equation we obtain the dry substance originating from the syrup and contained in 100 parts of the massecuite (supposed dry), as equal to 7.4467, because

$$x = 100\,\frac{92.8 \times 91.4}{92.8 \times 74} = \frac{100 \times 1.4}{18.8} = 7.4467.$$

One hundred parts of the dry substance of the massecuite contain therefore 7.4467 per cent. dry substance originating from the syrup, and $100 - 7.4467 = 92.5533$ per cent. of dry substance coming from the thick juice.

If the syrup had 78 per cent. dry substance, then the quantity of syrup would be:

$$78 : 100 :: 7.4467 : x = 9.54 \text{ per cent.}$$

If the finished massecuite had 6 per cent. water, consequently 94 per cent. dry substance, there are contained in it:

$$\frac{92.5533 \times 94.0}{100} = \sim 87.0 \text{ per cent.}$$

dry substance from the beet juices, and

$$\frac{7.4467 \times 94.0}{100} = \sim 7.0 \text{ per cent.}$$

dry substance from the syrup.

The massecuite that contains 6 per cent. W is then composed of 92.55 per cent. of massecuite produced by concentration of the beet juices, and 7.45 per cent. of massecuite due to the syrup, because

$$94 : 87 = 100 : 92.55,$$
$$94 : 7 = 100 : 7.45.$$

There is nothing left now but to prove this calculation to be correct.

The 87 per cent. of dry substance originating from the beet juices, of 92.8 purity, contain:

$$\frac{87 \times 92.8}{100} = 80.736 \text{ parts of sugar}$$

and $$\frac{87 \times 7.2}{100} = 6.264 \text{ parts of non-sugar.}$$

On the other hand, the 7.0 per cent. of dry substance due to the syrup which has 74 purity, consists of

$$\frac{7 \times 74}{100} = 5.18 \text{ parts of sugar}$$

and $$\frac{7 \times 26}{100} = 1.82 \text{ parts of non-sugar.}$$

If we add the sugar and non-sugar, calculate the purity according to the familiar methods and find the purity of the finished massecuite to be 91.4, it will mean that the foregoing calculations are correct:

$$\begin{array}{rcr} 80.736 \text{ S} & \text{and} & 6.264 \text{ NS.} \\ +5.180 \text{ ``} & \text{``} & 1.810 \text{ ``} \\ \hline 85.916 \text{ S} & & 8.084 \text{ NS.} \end{array}$$

$$85.916 + 8.084 = 94 \text{ Ds.}$$

$$94 : 85.916 = 100 : x,$$

$$x = 91.4.$$

10. Calculation of the Quantity of Syrup which, added to a Raw Sugar, will give a Mixture of a Fixed Water Content. How much syrup of 76 per cent. Ds is needed to change 100 parts of a raw sugar with 2 per cent. W into a magma with 10 per cent. W?

The raw sugar contains $100-2=98$ per cent. Ds; after the addition of the syrup it must contain $100-10=90$ per cent.

If we call the quantity of the syrup x, this quantity will contain $\frac{76x}{100}$ parts of dry substance. One hundred parts of raw sugar and x parts of syrup, will contain, consequently, $98+\frac{76x}{100}$ Ds. After mixing we will obtain a total weight of $100+x$ of 90 per cent. Ds or $\frac{(100+x)90}{100}$ parts of dry substance. We come then to the equation:

$$98+\frac{76x}{100}=\frac{(100+x)90}{100},$$

$$9800+76x=9000+90x,$$

$$x=\frac{800}{14}=57{\cdot}143;$$

57·143 parts of syrup must hence be added.

The equation can be reduced to the following abbreviated form:

$$x=100\frac{\mathrm{SDs}-\mathrm{mDs}}{\mathrm{mDs}-\mathrm{gDs}}, \quad . \quad . \quad . \quad . \quad . \quad . \qquad (21)$$

where SDs = the dry substance of the raw sugar;
mDs = " " mixture;
GDs = " " syrup.

Evidently the formula can be used as well when massecuites are to be diluted to a determined degree.

If water is used for the dilution, the addition is calculated per 100 parts of sugar, massecuite or syrup, as follows:

Let us call SDs, McDs, or GDs the dry substance percentage of the product to be diluted, according to whether it is a raw sugar, a massecuite, or a syrup. Let us also call mDs the dry substance percentage of the mixture, and x the amount of water that must be added to 100 parts. $(100+x)$ parts of the mixture must then contain:

$$\frac{(100+x)\text{mDs}}{100}$$

parts of dry substance; they must be equal to the dry substance contained in the undiluted product = (SDs, McDs, or GDs). We have, then, the equation:

$$\text{SDs(McDs or GDs)} = \frac{(100+x)\text{mDs}}{100};$$

whence

$$x = 100\,\frac{\text{SDs} - \text{mDs}}{\text{mDs}}. \quad . \quad . \quad . \quad . \quad . \qquad (22)$$

Example. One hundred parts of a massecuite containing 96 per cent. Ds are to be diluted to 93 per cent. Ds. How much water must be added for this purpose?

$$x = 100\,\frac{96-93}{93} = \frac{300}{93} = 3.226.$$

100 Mc + 3.226 W = 103.226 mixture, at 93 per cent. Ds

$$= \frac{103.26 \times 93}{100} = 96.0.$$

11. Calculation of the Quantity of Sugar Needed in order to impart a Higher Purity to a Syrup of a Known Coefficient. It may prove necessary while working the after-products by modern methods to inject second sugars into a syrup for the purpose of increasing its energy of crystallization. Naturally, only that part of the syrup must be thus ameliorated, which will serve for the formation of the grain. The quantity of sugar to be injected is found as follows:

If we denote by mP the coefficient of the whole (= purity of the mixture), by GP and SP, the purities of the syrup (GP) and sugar, then by using the formula:

$$x = 100 \frac{\text{mP} - \text{GP}}{\text{SP} - \text{GP}},$$

we find the percentage of dry substance of the mixture due to the injected sugar.

If, for instance, the coefficient of the mixture is 80, while that of the syrup is 73 and of the sugar 91.75, the percentage of dry substance originating from the sugar is calculated thus:

$$x = 100 \frac{80 - 73}{91.75 - 73} = 37.3.$$

Consequently 100 − 37.3 = 62.7 per cent. of the Ds is due to the syrup.

If, now, further, the syrup is of 60 Brix, the quantity of sugar to be added for each 100 parts of the syrup is obtained from the relation:

$$62.7 : 60 :: 37.3 : x,$$
$$x = \frac{60 \times 37.3}{62.7} = 35.7.$$

The correctness of the calculation is verified as follows:

One hundred parts (weight) of a syrup of 60 per cent. Ds and 73 purity contain:

$$\frac{60 \times 73}{100} = 43.8 \text{ parts of sugar.}$$

and

$$60 - 43.8 = 16.2 \text{ parts of NS,}$$

35.7 parts of sugar of 89° polarization, 8 parts NS, and 90.75 purity, contain:

$$\frac{35.7 \times 89}{100} = 31.8 \text{ parts sugar,}$$

and $35.7 - 31.8 = 2.96$ parts non-sugar. The dry substance of the whole (=mixture) consists therefore of:

$$43.8 + 31.8 = 75.60 = \text{parts of sugar,}$$

and $16.2 + 2.96 = 19.16 =$ parts of non-sugar

Total, 94.76 = parts of dry substance.

We have, then,

$$94.76 : 75.60 :: 100 : x,$$
$$x = 80 (= \text{the purity of the mixture}).$$

THEORETICAL CALCULATION OF THE WORK OF A RAW-SUGAR FACTORY

All figures that will be given in the following calculations are taken in round numbers, which will account for small differences that may be noticed.

The destruction of sugar that takes place during the boiling in the pan is purposely neglected. The main loss, that happens while boiling the thick juices to massecuites, cannot be separated or distinguished from the losses of polarization; the losses during the subsequent boilings are but small.

Let us suppose that the factory has worked, in one week's time, 2,600,000 kgs. beets with 13.6 per cent. S, which corresponds to $\frac{2,600,000 \times 13.6}{100} = 353,600$ kgs. of sugar.

There have been obtained 372,300 kgs. of massecuite, consequently, calculated on beets, 14.32 per cent., because

$$2,600,000 : 372,300 :: 100 : x = 14.32.$$

The massecuite contained 86.4 per cent. sucrose. Therefore, in all,

$$\frac{372,300 \times 86.4}{100} = 321,600 \text{ kgs.}$$

Apparent loss $= 353,600 - 321,600 = 32,000$ kgs. This loss (losses of polarization included) calculated on beets, amounts to

$$2,600,000:32,000::100:x=1.23 \text{ per cent.}$$

Or, on the sugar that entered the course of manufacture:

$$353,600:32,000::100:x=9 \text{ per cent.}$$

1. Calculation of the First Massecuite. The obtained massecuite had the following composition:

$$S=86.4, \quad NS=7.8, \quad W=5.8, \quad P=91.6.$$

From the massecuite there was obtained a raw sugar of 95.6 and a syrup of 59.14 polarization. What was the output in the centrifugals and what the weight of raw sugar given by 372,300 kgs. massecuite?

Introducing these values in the expression (16) we find

$$x=100\frac{86.4-59.14}{95.6-59.14}=74.77 \text{ per cent.}$$

100 parts of massecuite have given 74.77 parts of sugar, then the 372,300 kgs.:

$$\frac{372,300\times 74.77}{100}=278,370 \text{ kgs. raw sugar.}$$

What percentage of the sugar contained in the massecuite has been recovered in the first product?

The massecuite has given a yield of 74.77 per cent. of a raw sugar polarizing 95.6, hence

$$\frac{74.77 \times 95.6}{100} = 71.48 \text{ per cent.}$$

of the total sugar of the massecuite has been recovered in the Ist product; it follows that $86.40 - 71.48 = 14.92$ per cent. have passed into the after-products.

If we admit that, in round figures, we obtained 74.8 per cent. raw sugar of

95.6 S, 2.73 NS, 1.67 W, 97.2 P,

what will be the composition of the green syrup?

74.80 parts of raw sugar contain:

$$\frac{74.80 \times 95.6}{100} = 71.509 \text{ S}, \quad \frac{74.80 \times 2.73}{100} = 2.042 \text{ NS},$$

$$\frac{74.80 \times 1.67}{100} = 1.249 \text{ W}.$$

The massecuite contained:

$S = 86.4 \quad NS = 7.8 \quad W = 5.8$

Passed in the raw sugar:

$S = 71.509 \quad NS = 2.042 \quad W = 1.249$

Left in the syrup (Wt):

$S = 14.891 \quad NS = 5.758 \quad W = 4.551$

It follows that the percentage composition of the syrup must be: 59.14 per cent. S, 22.86 per cent. NS, 18.0 per cent. W, because 25.18 parts of syrup contain 14.891 parts sugar, consequently, 100 syrup will contain:

$$\frac{14.891 \times 100}{25.18} = 59.14 \text{ per cent.}$$

In a similar way are calculated the NS and W percentage. The coefficient of the syrup is $=72.1$. The IId massecuite must then have the same purity if the sugar decomposition, which in this case is almost insignificant, be not taken into account.

2. Calculation of the IId Massecuite. How many cubic meters of IId massecuite have been produced from 372,300 kgs. of Ist massecuite, if we suppose that the syrup has been boiled to a massecuite of 12 per cent. W, and what was the composition of that second massecuite?

From 100 parts of massecuite:

14.891 parts of sugar

and 5.758 parts of non-sugar.

Consequently, 20.649 parts of dry substance

have passed in the syrup. 372,300 kgs. give therefore:

$$\frac{372,300 \times 20.65}{100} = \sim 76,800 \text{ kgs. of dry substance that pass}$$

in the IId massecuite.

With a content of 12 per cent. W, the IId massecuite will weigh:

$$\frac{76,800 \times 100}{88} = 87,200 \text{ kgs.}$$

The specific gravity corresponding to 88 Brix is ~ 1.47. The 87,200 kgs. will then occupy a volume of

$$\frac{87,200}{1.47} = 59,300 \text{ liters or } 59.3 \text{ m}^3.$$

If the factory proposes to centrifuge its second product after leaving it stand for eight weeks to crystallize, it must have at its disposal a room having a capacity of ~ 480 m^3 in which to store the IId massecuites.

It may be assumed that as a grand average in working 10,000 kgs. beets per hour, and for a work day of twenty hours, the daily production of IId massecuite will be ~ 5 m^3.

The composition of the massecuite is calculated from the composition of the syrup, as has been explained in a preceding chapter. The syrup contained 18 per cent. W -59.14 per cent. W, and 22.86 per cent. NS. Consequently with 12 per cent. of W, the composition of the massecuite will be:

$$\begin{aligned} 82:59.14::88:x &= 63.46 \text{ per cent. S.} \\ 82:22.86::88:x &= 24.54 \text{ per cent. NS.} \\ &+12.00 \text{ per cent. W.} \\ &\overline{100.00} \end{aligned}$$

What will be the output of the second massecuite of 72.1 purity, if the centrifugated sugar has 92.6 polarization, 3 per cent. water, therefore 95.25 purity, and if the coefficient of the molasses is 64?

Calculating according to the equation (17) we find

$$x = 100\,\frac{88(72.1-64)}{97(95.25-64)} = 23.51 \text{ per cent.}$$

What weight of second sugar must be obtained by the treatment of 2,600,000 kgs. beets, and what percentage of the sucrose of the Ist massecuite will be contained in the second sugar?

$$\frac{87,200 \times 23.51}{100} = 20,500 \text{ kgs. sugar.}$$

The second product contains 92.6 per cent. sucrose, hence it follows that there wil be recovered

$$\frac{20,500 \times 92.6}{100} = \sim 18,900 \text{ kgs. sucrose}$$

in the form of second sugar.

From 372,300 kgs. of Ist massecuite we obtain then 18,900 kgs. of sucrose in the second sugar. This corresponds to

$$372,300 : 18,900 :: 100 : x = 5.07 \text{ per cent.}$$

How can now be calculated the composition of the second syrup? The analysis of the IId massecuite has given:

S = 63.4, NS = 24.54, W = 12.0 per cent.;
deduct S = 21.77, NS = 1.03, W = 0.7 per cent.

that have passed in the 23.51 parts of second sugar. Consequently, there is left in the syrup:

41.69 S, 23.51 NS, 11.3 W (weight).

Its composition will then be:

$$\frac{41.69 \times 100}{76.5} = 54.5\% \text{ S}, \quad \frac{23.51 \times 100}{76.5} = 30.7\% \text{ NS},$$
$$10 - (54.5 + 30.7) = 14.8\% \text{ W}.$$

Indirect calculation of the weight and composition of the Ist massecuite from the raw sugar and the IId massecuite:

When working the massecuite according to modern methods it is impossible to determine the quantity of the first massecuite by direct weighing. In such cases the data needed are obtained by adding the quantities of dry substance contained in the Ist raw sugar and in the IId massecuite (this later product measured), and calculating on the water percentage found by the analysis of the Ist massecuite.

Thus, in our example, we have produced 278,500 kgs. of first raw sugar containing 1.67 per cent. water, therefore 98.33 per cent. dry substance, in all then

$$\frac{278{,}400 \times 98.33}{100} = 273{,}750 \text{ kgs. Ds.}$$

We obtained 59.3 m^3 of IId massecuite of 88 Brix, consequently 87,200 kgs., corresponding to

$$\frac{87{,}200 \times 88}{100} = 76{,}750 \text{ kgs. Ds.}$$

Therefore the total $= 273{,}750 + 76{,}750 = 350{,}500$ kgs. dry substance.

If the Ist massecuite contains 5.8 per cent. water, and consequently 94.2 per cent. Ds, then the 350,500 kgs. of dry substance correspond to a weight of:

$$\frac{350{,}500 \times 100}{94.2} = \sim 372{,}100 \text{ kgs. massecuite I.}$$

The difference in this case amounts to:

$$372{,}300 - 372{,}100 = 200 \text{ kgs.}$$

In practice, the differences found are of course higher. Nevertheless, the use of this method is advisable, the more so, as even by direct weighing of the massecuite, differences of 1–2 per cent. are frequently found.

In a smiilar way, by reasoning inversely, we can calculate the composition of the Ist massecuite from the analyses of the raw sugar and of the IId massecuite, 278,400 kgs. of first raw sugar at 95.6 per cent. sucrose and 2.73 per cent. NS contains:

$$\frac{278,400 \times 95.6}{100} = \sim 266,100 \text{ kgs. sucrose}$$

and

$$\frac{278,400 \times 2.73}{100} = 7,600 \text{ kgs. of non-sugar.}$$

On the other hand, 87,200 kgs. of IId massecuite with B 46 per cent. S and 24.54 per cent. NS contain:

$$\frac{87,200 \times 63.46}{100} = \sim 55,300 \text{ kgs. sucrose}$$

and

$$\frac{87,200 \times 24.54}{100} = 21,400 \text{ kgs. non-sugar.}$$

The total will be:

In the raw sugar:	266,100 kgs. S and	7,600 kgs. NS.
In the IId massecuite:	55,300 kgs. S and	21,400 kgs. NS.
	321,400 kgs. S and	29,000 kgs. NS.

It follows that the coefficient of the massecuite which contained originally these substances was:

$$350,500 : 321,400 :: 100 : x \quad (x = 91.7).$$

The coefficient found directly was 91.6. The difference then in this case does not exceed 0.1.

3. Calculation of the IIId Massecuite. The syrup of the second product had the following composition:

$$S = 54.50, \quad NS = 30.7, \quad W = 14.8 \text{ per cent.}$$

If it be boiled to a massecuite of 10 per cent. water, its composition will be:

$$S = 57.60, \quad NS = 32.4, \quad W = 10.0 \text{ per cent.}$$

From 87,200 kgs. of IId massecuite there have been produced 20,500 kgs. of second sugar. The balance, 56,700 kgs. forms the syrup of 85.2 per cent. $Ds = \sim 56,900$, that will give

$$\frac{56,900 \times 100}{90} = \sim 63,200 \text{ kgs. of IIId massecuite}$$

with 10 per cent. water.

What will be the yield per cent. of this massecuite in third sugar, if the sugar polarizes 89.0 and the molasses be of 60 purity?

The composition of the massecuite is $S = 57.6$, $NS = 32.40$, $W = 10.0$ per cent. The total non-sugar passes into the molasses of 60 purity. For the formation of syrup there are needed $\frac{32.4 \times 60}{40} = 48.6$ parts sugar. The crystalline sugar will be, consequently:

$$k = 57.6 - 48.6 = 9.0 \text{ per cent.}$$

In order to be able to proceed with the calculation according to the formula (18), we must know the polarization of the syrup:

Massecuite: $S=57.6$, $NS=32.4$, $W=10.0$ per cent.
Subtracting k: 9.0,

The sugar contains: $S=48.6$ $NS=32.4$, $W=10.0$ (weight)

The polarization of the syrup will then be:

$$\frac{48.60\times 100}{91.0}=53.4 \text{ per cent.}$$

Introducing these values in the expression (18) we obtain the quantity of syrup of 53.4 polarization which can convert 9 parts of k into raw sugar of 89 polarization.

$$x=9\,\frac{100-89}{89-53.4}=2.78.$$

We can prove the correctness of the calculation in the following manner:

2.78 syrup with 53.4 per cent. S contains:

$$\frac{2.78\times 53.4}{100}=1.48 \text{ parts sucrose.}$$

$$9.0\text{k}+1.48=\ldots\ldots\ldots\ldots\ldots\ldots=10.48 \text{ S.}$$

On the other hand, 11.78 parts of raw sugar of 89 polarization contains:

$$\frac{11.78\times 89}{100}=\ldots\ldots\ldots\ldots\ldots\ldots=10.48 \text{ S.}$$

Since 100 IIId massecuite give a yield of 11.78 per cent. of raw sugar 63,200 kgs. must give $\frac{11.78\times 63{,}200}{100}=\sim 7440$ kgs. The polarization of this sugar being 89°, there are recovered $\frac{7440 \times 89}{100} = 6620$ kgs. sucrose in the form of third product. The balance, $63,200 - 7440 = 55,760$ kgs., forms the molasses of 53.4 polarization. These latter contain therefore,

$$\frac{55,760 \times 53.4}{100} = \sim 29,780 \text{ kgs. sucrose.}$$

From 372,300 kgs. of Ist massecuite, we have thus obtained 6620 kgs. of sucrose in the form of third sugar; this corresponds to

$$372,300 : 6620 :: 100 : x \quad (x = \sim 1.8 \text{ per cent.})$$

and 29,780 kgs. of molasses, or,

$$372,300 : 29,780 :: 100 : x = \sim 8.0 \text{ per cent.}$$

SUMMARY

Calculated on 100 parts of massecuite, the quantities of sucrose recovered in the different products can be set down as follows:

The massecuite contained 86.4 per cent. S. There are obtained:

In the first product:	71.48 per cent.
In the second product:	5.10 “
In the third product:	1.80 “
Left in the molasses:	8.00 “

The same results calculated on beets would be as follows (372,300 kgs. Ist massecuite out of 2,600,000 kgs. beets):

In the first product:

$$2,600,000 : 37,230 :: 71.48 : x = 10.24 \text{ per cent. S.}$$

Similarly:

In the second product =0.73 per cent. S
In the third product =0.26 " "
In the molasses =1.13 " "

2,600,000 of beets give:

I raw sugar = 278,400 kgs. = 10.708 per cent.
II " = 20,500 kgs. = 0.790 "
III " = 7,500 kgs. = 0.290 "
Total....... 11.788 per cent.

For the production of 100 kgs. of raw sugar of all products there are then needed $\frac{10,000}{11.788} = \sim 850$ kgs. beets. And there are left 55,760 kgs. molasses or = 2.14 per cent.

In a similar way, as we have calculated above, the products of one week's run, it is possible, by the same principles, to find the quantities of products of the entire run, in a purely theoretical way, from the summary of the weekly averages.

Finally, a method can be here introduced, employed by Dr. Claassen for calculating inversely the purity of the Ist massecuite from the quantities of the products obtained and their composition. This calculation is, undoubtedly, eminently helpful for the factory control.

Calculated on beets, there must be recovered: 10.708 per cent. Ist sugar, 0.790 per cent. IId, 0.290 IIId, and

2.14 per cent. molasses. The chemical composition of these products is as follows:

I raw sugar:	S=95.6,	NS= 2.73,	W= 1.67	per cent.
II "	S=92.6,	NS= 4.40,	W= 3.00	"
III "	S=89.0,	NS= 7.70,	W= 3.30	"
Molasses:	S=53.4,	NS=35.60,	W=11.00	"

We obtain, in the first product, calculated on beets:

$$\frac{10.708\times 95.6}{100}=10.237\%\ \text{S and}\ \frac{10.708\times 2.73}{100}=0.292\ \text{NS.}$$

If the same method of calculation be applied to the other products, and the quantities of sugar and non-sugar be added, from the total dry substance and the total sugars we can find the purity of the massecuite, because it is evident that by mixing the dry substance of all products we reconstitute the Ist massecuite (dry).

The calculation gives:

I product:	10.237	per cent.	S	0.293	per cent. NS
II "	0.730	"	S	0.035	"
III "	0.250	"	S	0.022	"
Molasses:	1.142	"	S	0.762	"
Total....	12.359	per cent.	S	1.112	per cent. NS,

or 12.359+1.112=13.471 per cent. total dry substance.

Consequently the purity of the massecuite should be:

$$13.471:12.359::100:x=91.7.$$

The purity of the original massecuite was 91.6.

If in the above calculation the quantities of sugar and non-sugar that pass into the molasses be neglected, the average purity for all raw sugars would be found to be equal to ~97.0 because

$$11.567:11.217::100:x, \qquad (x = \sim 97.0).$$

If we admit 2.5 to be the average water percentage of all sugars, the percentage of composition of such an average product* would be: 94.5 per cent. S, 3.0 NS, 2.5 W.

$$100:97 = 97.5:x = 94.5.$$

By the use of the methods already given for the determination of the yield, there can now be found the quantity of white product suitable for the market and obtainable from 100 parts of beets.

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* The composition of this average sugar is used in connection with the formula (17) for estimations of fluctuating products, for instance, of the quantities of raw sugar contained in the juices and the massecuites.

CALCULATION OF THE WORK OF A REFINERY

Just as we have found the composition of the different products and the output of the raw sugar massecuites, we must be able to calculate the work of a refinery by simple conclusions regarding the quantity and quality of the raw products entering the course of manufacture, and by the introduction of some general values in our equations. An essential difference will nevertheless result from the fact that the quantities of sugar decomposed during the boiling must be taken into account.

The raw sugars differ from the massecuites as to the quantities of green syrup contained; the latter contain a greater amount of syrup, to which they owe their semi-fluid condition. By the centrifugals the massecuite is separated into crystalline raw sugar and a syrup of a fairly constant composition, showing a purity of 70–73. A part of the syrup, however, remains adhering to the grains if the mass be not submitted to a special treatment. For normal raw-sugars the grains consist of almost chemically pure sugar (cane sugar or sucrose). The yellowish color, as well as the characteristic non-sugar contained in the raw sugars, are due to the thin coating of syrup that covers the grain. This may be proved by a simple test: if the sugar be brought into a funnel loosely stopped with cotton, and a saturated pure sugar solution (67–68 per cent.) be poured over it, almost white grains of sugar will be left in the funnel, as the solution mechanically removes not only the excessive quantities of non-sugar, but also the coloring matter as made evident by the tint imparted to the solution. The solution takes the place of the syrup. If the sugar grains, after a sufficient treatment, still show a yellowish coloration, the raw rugar is not to be considered as first product and its price must be fixed lower accordingly.

The operation of separating the syrup adhering to the crystals is called "washing," and when especially applied to the raw sugars, "affinage." In practice the raw sugar is brought in the centrifugals mixed with the syrup of affinage, so that the process of affining takes place in the centrifugal. The washing is done while the centrifugal runs at full speed. As washing substance, an almost saturated sugar solution is used, but often, also, water or steam.

The syrup used for the washing can exercise a purifying action only in case it has a higher purity than the syrup covering the grains. When washing with water or steam greater losses of crystalline sugar take place, as the water, or the condensed steam become saturated with sugar. It must, however, be remarked that when washing with syrup, dissolved sugar is used, which nevertheless is of an inferior value than the portion of crystalline sugar dissolved by the water.

The affinage enables the refiner to obtain a separation of the raw sugar as soon as it enters the course of manufacture, into a high-priced crystalline sugar and a syrup that can be directly worked for the after-products. In this way he avoids the disadvantage of allowing the total non-sugar to reach the first product and to unfavorably influence its quality, as it is precisely those constituents of the syrup that contain the coloring matter which gives rise to a more pronounced coloration during the boiling of an alkaline liquid.

In the process of Steffen the affinage takes place in open vessels provided with perforated bottoms. The raw sugar is washed systematically with a series of syrups of constantly increasing purity. Consequently it is rather a method of affining than of refining. The washing by syrups is also called "liquoring."

The syrups employed in this process are kept in a special apparatus. This apparatus is a large, open, round tank, built of strong sheet iron, separated by radial partitions into as many compartments or cells as there are syrups to be used in covering.

The composition of the different syrups is about the following:

Cell No.	1	B. 76.2	S 53.2	P 69.8
"	2	B. 75.8	S 53.9	P 70.9
"	3	B. 75.4	S 54.6	P 72.4
"	4	B. 75.0	S 55.3	P 73.7
"	5	B. 74.2	S 56.0	P 75.5
"	10	B. 72.2	S 59.2	P 82.0
"	15	B. 70.2	S 62.2	P 88.6
"	20	B. 68.2	S 65.2	P 95.6
"	27	B. 67.6	S 66.4	P 98.5

The composition of the syrups of the cells not given in the above table is intermediary between the values cited. Finally there are added a few syrups of about 67.5 B. and 99.6 purity.*

If we consider a raw sugar of 95.6 polarization, 1.2 per cent. ash, 1.44 per cent. non-sugar, 1.76 per cent. water, formed from crystalline sugar and a green syrup or 70, or 71, 72, 73 purity, we find that the total non-sugar contained in the mass corresponds to 2.64 per cent. The K will then be (according to equation (13)):

For 70 purity:

$$95.6 - \frac{2.64 \times 70}{100 - 70} = 89.44.$$

For 71 purity:

$$95.6 - \frac{2.64 \times 71}{100 - 71} = 89.127.$$

For 72 purity = 88.82, for 73 = 88.462 per cent.

It follows that, other things being equal, a raw sugar will be the better the less syrup adheres to its grains. But if the coefficient of the syrup is below 70, it may easily happen that the sugar is yellowish, because the external layers of the crystals contain coloring.

Such a separation of the raw sugar is, unfortunately, only theoretically possible. In practice neither chemically pure crystalline sugar nor syrups of so low purities are obtained. The resulting syrups generally have a purity of 75–76, while the affined sugar still contains 0.1–0.2 per cent. salts and a corresponding quantity of organic non-sugar—in our case 0.12–0.24 per cent. If we admit with Sidersky that the crystalline sugar itself contains no ash, then the ash of the affined sugar can only

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* See Deutsche Zuckerindustrie, 1893, No. 9, p. 371, etc Das Steffen'sche Wash-verfahren.

be due to the small quantities of syrup, and the proportion between ash and organic non-sugar will be the same as in the raw sugar submitted to affination.

Let us suppose that the affined sugar still had, for a polarization of 98.1°, 0.15 per cent. ash. It will then contain 0.18 per cent. of organic non-sugar, but its water will be 1.57 per cent. and its purity ~99.6. If the coefficient of the raw sugar was 97.31 and that of the centrifugated syrup 76, the output at the centrifugals, for 100 parts of raw sugar, will be, according to the equation (17) 90.12, for

$$x = 100\frac{98.24(97.31-76.0)}{98.43(99.60-76.0)} = 90.12 \text{ per cent.}$$

These 90.12 parts of affined sugar at the rate of 1.57 per cent. W will contain:

$$100:1.57::90.12:x = 1.415 \text{ parts W.}$$

Furthermore, they will contain $90.12-1.415=88.705$ parts of dry substance, which will consist of 88.35 parts of sugar and 0.355 of non-sugar. The equation (3) gives:

$$S = \frac{88.705 \times 99.6}{100} = 88.35.$$

If the sugar so affined be dissolved (with addition of a small quantity of lime) so that a syrup of 60 B and 40 per cent. water be obtained, for dissolving the 90.12 parts of sugar, there will be required ~60 parts of water, for

$$60:40::90.12:x = \sim 60.$$

One hundred parts of raw sugar will give consequently $90+60=150$ parts of syrup (=clairce).

The percentage composition of this syrup must be the following, according to the equation (3):

$$S=59.76, \quad NS=0.24, \quad W=40.0,$$

because

$$S=\frac{60\times 99.6}{100}=59.76, \text{ etc.}$$

If this "clairce," after adequate filtration, be boiled to a massecuite of 7 per cent. water, there will be obtained from 88.705 parts of dry substance (equation [5]):

$$\frac{88.705\times 100}{93}=95.38 \text{ parts massecuite.}$$

During the boiling a destruction of 0.4 per cent. sugar might occur, which would cause the coefficient of purity to sink from 99.6 to about 99.2.

The altered quantity of sugar will then be:

$$\frac{88.35\times 0.4}{100}=0.3534 \text{ parts sugar.}$$

The 88.35 parts of sugar will be reduced consequently to ∼88 parts, while the total non-sugar will be, of course, increased by ∼0.35. The total dry substance is hardly influenced by this alteration, and hence we obtain:

$$88.705:88::100:x=99.2.$$

One hundred parts of worked raw sugar have given 95.38 per cent. of massecuite with 99.2 purity (=first raffinate massecuite). The composition of this massecuite must be the following:

$$S = 92.25, \quad NS = 0.75, \quad W = 7.0 \text{ per cent.},$$

(according to the equation (3)

$$S = \frac{93.0 \times 99.2}{100} = 92.25, \text{ etc.}).$$

If this massecuite was cast into molds to drain and the syrup drained off indicated 97.5 purity, we can imagine the massecuite as separated into chemically pure crystalline sugar and the syrup mentioned. By introducing these values in the equation (13) we obtain:

$$k = 92.25 - \frac{0.75 \times 97.5}{100 - 97.5} = 92.25 - 29.25 = 63.0 \text{ per cent.}$$

One hundred parts of Ist rf. massecuite give consequently 63 of white sugar.

We have seen that 100 parts of raw sugar give 95.38 parts of massecuite; from 100 parts of raw sugar we recover consequently:

$$\frac{95.38 \times 63.0}{100} = 60.0894 \text{ per cent.}$$

sucrose in the Ist rf. massecuite.

Of the 88 parts of sugar contained in the Ist rf. massecuite:

$$88.00 - 60.0894 = 27.0116 \text{ parts}$$

pass into the syrup.

To this syrup are added a small quantity of lime and water sufficient to reduce its concentration to 60° Brix. The liquid is then to be submitted to a second filtration and boiled to IId rf. massecuite. If a destruction of 0.4 per cent. S takes place again, there will be destroyed, calculated on raw sugar,

$$\frac{27.0116 \times 0.4}{100} = \sim 0.1 \text{ per cent. S,}$$

and recovered in the massecuite:

26.9166 parts sugar;

0.3550 parts NS due to the raw sugar;

0.3500 parts NS due to the S destroyed during the first boiling;

0.1000 parts NS due to the S destroyed during the second boiling.

Consequently, in all 27.7166 parts of dry substance, the coefficient will then be:

$$27.7166 : 26.9166 :: 100 : x = 97.1.$$

If for this IId massecuite we admit again 7 per cent. of water, 27.7166 of dry substance will produce:

$$\frac{27.7166 \times 100}{93} = \sim 27.80$$

parts of IId rf. massecuite, which for a coefficient 97.1 will have the following composition:

$$S = 90.3, \quad NS = 2.70, \quad W = 7.0 \text{ per cent.,}$$

because, according to the equation (3), we have

$$\frac{97.1 \times 93.0}{100} = 90.3, \text{ etc.}$$

If this massecuite be treated in the same manner as the Ist rf. massecuite (filled in molds, etc.) and if the green syrup shows 93.0 purity, the output of the massecuite in white sugar will be: (Y = yield.)

$$Y = 90.3 - \frac{2.70 \times 93}{100 - 93} = 54.43.$$

Taking into account that we produced 29.80 of IId rf. massecuite from 100 parts of raw sugar, we find that we recover:

$$\frac{29.80 \times 54.43}{100} = 16.22 \text{ per cent. sucrose}$$

in the second refined product.

There remain in the syrup:

$26.9166 - 16.22 = 10.6966$ parts of sugar, and
0.8050 parts of non-sugar.

Total...... 11.5016 parts of dry substance

of 93 purity, for

$$11.5016 : 10.6966 :: 100 : x = 93.0.$$

This syrup is to be diluted to 60° Brix and treated as previously described.

If we examine more closely the coefficient of this second syrup, we see that it approaches the purities of the raw thick juices. We shall also have to consider if we cannot advantageously inject into this syrup the raw sugar given by the after-products.

The composition of a second raw sugar obtained from a massecuite boiled to grain, and submitted to crystallization in motion for several days, is the following as a grand average:

$$P=94.33, \quad S=91.5, \quad NS=5.5, \quad W=3.0 \text{ per cent.}$$

By comparing the coefficients we see that we can unquestionably combine the treatment of a product of such composition with the work of the second refinery syrups. The purity of the latter being 93, the syrup will be improved by the injection of sugar of 94.3 purity. Furthermore, such raw sugars obtained by the crystallization in motion process have approximately the same coloration and give the same yield as the second syrups of the refinery. This combination seems, therefore, perfectly advisable.

From the ingredients contained in 100 parts of worked raw sugar, namely:

95.6 S 2.64 NS
88.35 S 0.355 NS are recovered in the affined sugar, and

7.25 S 2.285 NS will pass into the syrup and form the IId massecuite. This IId massecuite will give ∼4.57 parts of second sugar of the composition above given, if we consider the IId massecuite as directly separated into molasses of 60 purity and a sugar of the composition stated.

If we suppose the above 9.535 parts of dry substance converted into a massecuite of 90 Ds, there will be produced:

$$\frac{9.535 \times 100}{90} = 10.59 \text{ parts of IId massecuite, 76 P.}$$

According to the equation (17) this massecuite will give the following yield:

$$Y = 100 \frac{90(76-60)}{97(94.33-60)} = 43.20 \text{ per cent. of IId sugar.}$$

of 97° Brix and 94.33 purity.

10.59 parts will give, consequently:

$$\frac{10.59 \times 43.2}{100} = \sim 4.57 \text{ parts.}$$

These 4.57 parts will give:

$$\frac{4.57 \times 91.5}{100} = \sim 4.18 \text{ parts sugar}$$

and

$$\frac{4.57 \times 5.5}{100} = \sim 0.25 \text{ parts non-sugar}$$

that pass into the second syrup. The dry substance of the later will be:

10.6966	sugar from the syrup of the IId product			
4.1800	"	"	"	after-product
14.8766	sugar,			

and

0.805	non-sugar from the syrup of the IId product			
0.250	"	"	"	after-product
1.055	parts non-sugar.			

The purity of the syrup will be 93.4. During the boiling it will, however, retrogradate to ~93, because $\frac{14.8 \times 0.4}{100} = \sim 0.05$ parts of S will be destroyed. If we suppose that the dry substance forming this IId massecuite is separated into crystalline sugar and molasses of 60 purity, we can calculate this last quantity of white marketable product that can be obtained from 100 parts of a raw sugar.

1.055 parts non-sugar need for the formation of the molasses $\frac{1.055 \times 60}{40} = \sim 1.583$ p. sugar.

The IId rf. massecuite will then give

$$14.8766 - 1.583 = 13.2936$$

parts of white sugar.

In order to render complete what has been exposed above, in general lines, it must be remarked that the separation of the green syrup from the sugar, in the refined as well as in the raw products, takes place by itself only partially. The balance of the syrup adhering to the yellowish grains must be separated by the use of perfectly colorless saturated sugar solutions (washing-claires).

For the treatment of 100 parts of raw sugar about 25–30 parts of sugar are needed for the preparation of the claires, etc.

The syrups resulting from the washing of the massecuites are boiled, according to their lighter or deeper coloration, with the syrups of the house.

Generally, it can be observed that by modifications of the methods of working, the amounts of white sugar recovered in the different products are subject to a kind of displacement. However, this does not cause any further substantial alteration of the total, and even the "washing" hardly affects the final results.

SUMMARY

From 100 parts of raw sugar (95.6 polarization, 1.20 ash, 1.44 organic non-sugar, 1.76 water) that entered the refining process, there are hence recovered, calculated as chemically pure sugar:

In the I product.........	∼60.1	per cent.
In the II product.........	∼16.2	"
In the II syrup..........	∼13.3	"
Total...............	∼89.6	"

Besides these, there will be produced ∼9.0–10.0 per cent. molasses of 60 purity. Consequently the loss amounts to ∼0.5–1.5 per cent. of the mass of the raw product.

The extent of this loss depends on the amount of mechanical losses (∼0.5 per cent.) and also on the greater or smaller quantity of water contained in the raw product and in the resulting molasses.

THE SUGAR INVENTORY

The drawing-up of the sugar inventory is one of the most important tasks that befall the technical employee.

The principal conditions that must be kept in view are a comprehensive arrangement and absolute accuracy. Above all, it should be made a rule not to admit too high coefficients for calculating the stock.

Special attention must be bestowed upon the accounts at the close of the year, as any eventual errors will become diagreably evident during the whole next working period.

Taking stock is a comparatively easy task in raw sugar houses, where few products have to be considered; on the contrary it proves a decidedly more complex question in refineries where account must be kept of a great number of half finished and floating products that exhibit important variations in their composition. However, as the method is the same, and the raw sugar technician can easily deduce from the examples given the part necessary for his purpose, we shall consider here the more difficult cases that are met with and which must be overcome when taking the inventory at the end of a refining season.

This work can be done in different ways. There are several starting points all leading to the same end. Thus, for instance, we can refer all the masses at the time in course of manufacture (we can call these products "half-finished" if solid, "floating" if liquid), either to raw sugar, to polarization sugar, or to yield sugar. The same relations (= 100 RS : 95.5 PS : 90 YS) will be valid between the respective categories of products. This relation is perfectly true for those products that can be directly transformed into raw sugar or white marketable commodity (= yield sugar), but not for lower products needing an intermediary treatment before they become of equal value to the raw sugar.

The following terms will be used for easier distinction between the different qualities. The marketable white sugar will be called "refined." The sugar existing in forms of half-finished products actually in course of manufacture, but not yet completely purified, is termed "melis." The sugar contained in after products that can be recovered in crystalline form is called "farin."

As to the yields to be expected from the different products, the special chapter can be consulted. Briefly, the following can be said for a rationally conducted work:

When normal raw sugar of 90 per cent. yield (calculated by the ash coefficient) is worked, this yield must also be approximately obtained. From products of higher yield, and for raw sugars in which a relation between ash and organic non-sugar is higher than 1:1.25–1.30, the ash yield cannot serve as an indication.

Of the imported sugar shown by the polarimeter (= polarization sugar), not more than 1.05 per cent., calculated on raw sugar, should be lost.

The mass loss should not exceed 1.5 per cent. of the raw sugar; it is assumed in this case that the molasses produced contains not less than 20 per cent. of water.

More recent methods of working the after-products make it possible to almost totally avoid any mass loss. It then happens that the weight of the final product (refined sugar) plus the weight of the molasses is almost equal to the weight of the imported raw sugar.

Some preparatory work is necessary and very helpful for taking stock:

(*a*) We must have a list of all juice or massecuite receptacles, tanks, filters, etc., giving the dimensions and capacity of each.

(*b*) It is very advisable to annex to the dimensions of each tank a factor or coefficient showing the capacity corresponding to one centimeter of height. It is then sufficient to multiply the empty height of the vessel in centimeters by the factor and to subtract the product from the total capacity in order to obtain the volume * of contents present.

The number of liters corresponding to one centimeter of a receptacle is found by multiplying the area of its horizontal section by 10.

If, for instance, a quadrangular tank has the following dimensions:

Length, 4 m., breadth, 2 m.; height, 2 m.

its volume will be

$$4 \times 2 \times 2 = 16 \text{ m}^3 = 16{,}000 \text{ liters.}$$

One centimeter in height then corresponds to

$$4 \times 2 \times 10 = 80 \text{ liters.}$$

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* Or directly, when practicable the full height in centimeters by the coefficient.—(TRANSLATOR.)

If then, for instance, when taking stock we find 20 cms. empty, this will mean, 20×80 = 1600 liters. So that the vessel contains: 16,000 − 1600 = 14,400 liters or 14.4 m^3.

(*c*) The knowledge of the chemical composition of the product is also necessary in order to deduce the factors for the calculation of their value. These factors, evidently, will vary according to whether the products are referred to the raw, the polarization, or the yield sugar.

The following examples will make clear how these coefficients are calculated.

Washing Clairces. Polarization = 67.5, specific gravity = 1.335, weight of 1 m^3 = 1335 kgs.

$$1 \text{ m}^3 \text{ contains } \frac{1335 \times 67.5}{100} = \sim 900 \text{ kgs. polarization sugar.}$$

Calculated on sugar of 95.5 polarization and 90 yield, this corresponds to ∼940 kgs. of raw sugar, because the sugar of the washing clairces is of at least equal value to the raw sugar, and $95.5 : 900 :: 100 : x = \sim 940$.

It follows that the yield of white sugar contained in 1 m^3 of the clairce is:

$$\frac{940 \times 90}{100} = \sim 840 \text{ kgs.}$$

Clairces for Boiling. Polarization = 59, specific gravity = 1.284.

$$1 \text{ m}^3 \text{ weighs} = 1284 \text{ kgs.}$$

$$1 \text{ m}^3 \text{ contains } \frac{1284 \times 59}{100} = \sim 750 \text{ kgs. pol. S.}$$

This product is certainly of equal value to the raw sugar. 750 kgs. of polarization sugar will correspond consequently to

$$95.5 : 750 :: 100 : x = \sim 780 \text{ kgs. raw sugar,}$$

or

$$\frac{780 \times 90}{100} = \sim 700 \text{ kgs. yield sugar per } 1 \text{ m}^3.$$

Syrups. Polarization 60.0, specific gravity 1.35.

1 m^3 weighs $= 1350$ kgs.

1 m^3 contains $\dfrac{1350 \times 60}{100} = \sim 800$ kgs. pol. S.

This product is of a lower value than the raw sugar. The estimation can be made by the use of the formula (17).

The dry substance being ~ 70 and the purity ~ 85, the yield that can be expected is 48 per cent. raw sugar, as:

$$x = 100\,\frac{70(85-60)}{98(97-60)} = \sim 48 \text{ per cent.}$$

One m³ corresponds consequently to ~ 650 kgs. raw sugar, because

$$\frac{1350 \times 48}{100} = \sim 650.$$

or

$$\frac{650 \times 90}{100} = \sim 570 \text{ kgs. of yield sugar.}$$

Raw-sugar Massecuite. Polarization $= 80.0$, specific gravity $= 1.487$:

1 m^3 weighs $= 1487$ kgs.

1 m^3 contains $= \dfrac{1487 \times 80}{100} = 1180$ kgs. pol. S.

The raw sugar (according to formula (17)) is

$$x = 100 \frac{90(88 - 60)}{98(97 - 60)} = \sim 70 \text{ per cent.}$$

1 m³ corresponds to

$$\frac{1487 \times 70}{100} = \sim 1040 \text{ kgs. raw sugar,}$$

or

$$\frac{1040 \times 90}{100} = \sim 930 \text{ kgs. white product.}$$

IId Massecuite. Polarization = 70, specific gravity = 1.50:

1 m³ weighs = 1500 kgs.

$$1 \text{ m}^3 \text{ contains} = \frac{1500 \times 70}{100} = 1050 \text{ kgs. pol S}$$

1 m³ corresponds to ~500 kgs. raw sugar, as:

$$x = 100 \frac{(9375 - 60)}{98(97 - 60)} = \sim 37;$$

$$\frac{1500 \times 37}{100} = \sim 550;$$

$$\frac{550 \times 90}{100} = \sim 490 \text{ kgs. yield sugar.}$$

The examples given above will suffice to make clear the methods of calculating the different coefficients. Their practical use consists simply in multiplying the found cubic meters of each product by the corresponding coefficient in order to find the quantity of sugar contained.

Thus, for instance, 50 m^3 of washing claircc correspond to

$50 \times 900 = 45{,}000$ kgs. of polarization sugar;
$50 \times 940 = 47{,}000$ kgs. of raw sugar;
$50 \times 840 = 42{,}000$ kgs. of white sugar.

The inventory of the non-sugar is of less importance for practical purposes than that of the sugar. On the contrary, the former is of great importance for theoretical observations. Consequently, the technical employee should not neglect at the close of the year to also devote his attention to the quantities of imported, exported, and produced non-sugar.

As has been said in another part of this book, the change of the relation between ash and organic non-sugar in the molasses of the refinery, as compared with the relation existing between these ingredients in the introduced raw sugar, enables us to draw conclusions as to the extent of sugar losses by chemical alteration. The details can be found in the special chapter (see p. 26).

The quantity of non-sugar corresponding to a given amount of polarization sugar is found from the purity of the product, as shown in the following example. The above-mentioned IId massecuite contains for a coefficient of 75, ~1050 kgs. polarization sugar. The dry substance contained in 1 m^3 is given by the equation:

$$75 : 100 :: 1050 : x,$$

$$x = \frac{100 \times 1050}{75} = 1400 \text{ kgs.}$$

It follows that 1 m^3 of the mass contains:

$$1400 - 1050 = 350 \text{ kgs. NS.}$$

The coefficient of the mass is again:

$$1400:1050::100:x=75,$$

which proves the accuracy of the calculation.

We can now turn to the sugar inventory. Let us take, as example, a refinery that worked 30,000,000 kgs. raw sugar of 95.5 polarization and 2.5 per cent. NS. The yield can be taken, roundly as =90 per cent.

We see in the reports that at the beginning of the campaign there existed, at that time, in course of refining:

1,450,000 kgs. pol. S, 1,350,000 white S, 50,000 kgs. NS.

At the close of the campaign we find an existing stock of half finished and floating products=967,600 kgs. white sugar. The difference:

$$1,350,000-967,600=382,400 \text{ kgs.}$$

white sugar $\left(=\frac{382,400\times 100}{90}=425,000 \text{ kgs. raw sugar}\right)$ must then be added to the imported 30 millions. The production of refined sugar and molasses must be referred to the total working-up of 30,425,000 kgs. raw sugar.

There have been produced:

27,380,000 kgs. refined	=~90.0 per cent.
2,880,000 kgs. molasses	=~ 9.4 "
Total......	=~99.4 per cent.

The mass loss amounts consequently to 100 −99.4=0.6 per cent. raw sugar.

Calculated as polarization sugar there have been taken into work:

$$\frac{30{,}000{,}000 \times 95.5}{100} = 28{,}650{,}000 \text{ kgs.}$$

In addition, 1,460,000 kgs. that were present at the beginning of the campaign:

$$28{,}650{,}000 + 1{,}460{,}000 = 30{,}110{,}000 \text{ kgs. pol. S.}$$

This quantity should have to be found if no mechanical or chemical losses had taken place. In fact, however, we can trace only $= 29{,}868{,}400$ kgs. The loss hence represents:

$$30{,}110{,}000 - 29{,}868{,}400 = 241{,}600 \text{ kgs.}$$

Calculated on raw sugar this is

$$30{,}425{,}000 : 241{,}600 :: 100 : x = 0.8 \text{ per cent.}$$

The yield sugar is found with but a small difference of 2400 kgs.

On the other hand, there are found 980,000 kgs. non-sugar, while only 800,000 were taken into work. Evidently the remarked surplus of 180,000 kgs. has been formed during the refining. This corresponds to ~ 0.6 per cent. raw sugar.

The remaining data can be seen in the following report that has been calculated for polarization sugar, white sugar, and non-sugar. The different quantities can be turned into raw sugar by the use of the coefficients. Another method of calculation would be, as we have seen, by multiplying $\times 100$ the quantity of white sugar contained in the masses and dividing the product by the percentage yield of the raw sugar worked.

SUGAR INVENTORY WITH SIMULTANEOUS CONSIDERATIONS OF THE POLARIZATION SUGAR, WHITE SUGAR, AND NON-SUGAR.

Imported from 1900 to end 1901 30,000,000 kgs. raw sugar of:	Pol. Sugar, Kgs.	White Sugar, Kgs.	Non-sugar, Kgs.
95.5 pol., 90.0%, yield 2.5 NS	28,650,000	27,000,000	750,000
Plus existence at beginning of campaign	1,460,000	1,350,000	50,000
Total imported	30,110,000	28,350,000	800,000
PRODUCED.			
I. Delivered = 27,380,000 kgs. refined, 100 pol., 100 yield, 0 NS	27,380,000	27,380,000	
Delivered = 2,880,000 kgs. molasses, 48.0 pol., 32.0 NS	1,382,400	......	921,600
Total delivered	28,762,400	27,380,000	921,600
II. Existing stock:			
250,000 raw sugar, 95.5 pol., 90 yield, 2.5% NS	238,700	225,000	6,200
15,000 remaining refined, 100 pol., 100 yield, NS	15,000	15,000	
30,000 loafs, each = 16 kgs. pol. sugar, 15 kgs. yield sugar	480,000	450,000	
40 m³ washing clairces: 900 kgs. pol. sug., 840 kgs. raw sugar, per 1 m³	36,000	33,600	
150 m³ clairces for boiling: 750 kgs. pol. sugar, 700 yield sugar per 1 m³	112,500	105,000	
60 m³ syrups: 800 kgs. pol. sugar, 570 kgs. yield sugar, 145 kgs. NS per 1 m³	48,000	34,200	8,700
60 m³ raw sugar massecuite: 1180 kgs. pol. sugar, 930 yield, 160 NS	70,800	55,800	9,600
100 m³ second massecuite: 1050 pol. sug., 490 yield sug., 350 kgs. NS per 1 m³	105,000	49,000	35,000
Total stock	1,106,000	967,600	59,500
Plus deliveries	28,762,400	27,380,000	921,600
Total produced	29,868,400	28,347,600	981,100
Imported	30,110,000	28,350,000	800,000
Produced	29,868,400	28,347,600	981,100
Difference	−241,600	−2,400	+181,100
Calculated on raw sugar	∼ −0.8%	+0	+0.6%

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