(2) the low-ash tendency of the west coast sugars is due to low concentrations of both inorganic and organic salts, and (3) the moderately high ash of the eastern sugars is due to high concentrations of organic salts and in spile of low values for inorganic salts. In addition, from portions of the tables presented earlier, we may say that the differences in the salt components of the sugars are probably rather directly related to the composition of the corresponding beet non-sugars. The high and low ashes in a particular region may, however, be partly due to (1) differences in the amount of raw sugars on percentage of juice solids that are recirculated, (2) sugar-boiling conditions, and (3) effectiveness of washing in removing external surface of the sugar crystals which are high in ash. A more comprehensive study is in progress on white massecuites and molasses in hope that general relations may be found which will indicate whether at each particular factory the quantity of sugar ash is affected more by beet composition or by the thoroughness of refining operations.

The Measurement of Color and Turbidity in Granulated Beet Sugars

R. A. MCGINNIS AND E. E. MORSE[1]

In the early days of beet-sugar manufacturing, the measurement of white-sugar color and turbidity did not present serious problems. As long as the product was one which was white to visual inspection, all requirements were satisfied. The last 20 years, however, have been marked by steady and successful efforts to improve various sugar-quality factors, until today minute differences which are totally invisible excepting to the highly trained eye are regarded of great importance. Unfortunately, in the case of color and turbidity at least, the skill of the research workers and instrument designers has not been adequate to keep pace with the requirements.

The result is that scarcely any two beet-sugar companies use the same method. Turbidity is seldom measured. As far as color is concerned there are innumerable methods in use. The most official method is probably that of Keane and Brice, since this is used by the Carbohydrate Division of the United States Department of Agriculture in their annual survey of the Nation's beet sugars. However, their measurements cannot be duplicated or checked by anyone else.

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[1] Spreckeis Sugar Company. This paper was presented by P. W. Alston, General Chemist.

As stated in a letter by H. S. Paine. Chief of the Agricultural Chemical Research Division:

"We feel that readings on different instruments should show the same comparative values on a series of sugars, but the level of the readings need not necessarily be identical."

This unsatisfactory situation is due chiefly to the very great difficulties inherent in the problem. It appears almost impossible to obtain satisfactory color readings on solid sugars. Turbidity, of course, can only be read on solutions. Any color readings on solutions are tremendously complicated by the fact that it is necessary 1o separate the light absorptions due to color and turbidity. Another difficulty in the problem is the extremely small amount of absorption involved in the coloring matter of white sugars. The authors have reached the conclusion that this field must be a unique one in photometry, as the great majority of the instrument manufacturers do not design instruments to measure such small absorptions.

Measurement of Turbidity

Measurements of turbidity must be made on solutions of the white sugars. As far as can be determined, turbidity measurements in the beet-sugar industry have been seldom made, and when made, have been done in a strictly qualitative manner by visual inspection.

Quantitative turbidity measurement can be divided into at least three types:

Measurement by Visual Clarity. -In this type, an image of some nature, such as a candle flame or a black and white figure, is observed through a column of liquid, and the length of the column at which the image can no longer be seen distinctly serves as a measure of the turbidity. The most common example of this type is the Kopke turbidimeter, which is widely used for measuring the turbidity of thin juices. This type of measurement is little affected by the presence of color, and might be quite suitable if it were not for the minute nature of the turbidity in white sugars. Some preliminary experiments by the authors indicated that a liquid column length of over a meter would frequently be required for our sugars. This type of measurement also suffers from the fact that the results must depend to a certain extent on the visual acuity of the observer, since no way has been suggested of applying photoelectric methods.

Measurement of Absorption by Transmitted Light.—This type of measurement falls into two classes. Tn the first, no mechanical filtration of the solution is used. Thus, unless a correction is made for the coloring matter present, false results will be obtained. Correction may be made by comparison with a solution or other light filter having the same color but without the turbidity of the solution being measured. The Klein turbidimeter, which is generally used for measuring the specific surface of lime, is a good example of this type.

Another instrument, the Lovibond-Schofield apparatus (2) in which the color is compensated for by Lovibond plates, has recently been suggested.[2] Practical difficulties make the use of such an apparatus inadvisable. In addition to the time involved in making up plate combinations to secure a match, the actual coloring matter appears to be altered by the presence of turbidity, making it highly improbable that an accurate compensation for color would ever be made.

The second class of measurement of this type may be considered as the truly fundamental method. The absorption of monochromatic light is measured by a spectrophotometer. The solution is then mechanically filtered to remove the turbidity and the absorption measured again. The difference between the two absorption measurements is obviously an index of the turbidity. This method was proposed by Balch (1) in 1931. The difficulty with this type of measurement lies entirely in the filtration of the solutions. Peters and Phelps (5) have given a procedure for the rigorous filtration required. This is laborious and time consuming, and utterly impractical for even semi-routine work. There is likewise always the possibility that a filtration capable of yielding an optically clear filtrate tends to remove some of the coloring matter. Turbidity, as we have found at Woodland, appears to be of at least two types; one composed of larger particles which may be readily distinguished by the eye or under a microscope, and a milky type resembling colloidal sulfur, which at least borders on the colloidal state and is filtered out only with the greatest difficulty. While this method will always be of value for absolute measurements in which time and labor are not a factor, it cannot be considered for routine work.

Measurement by Tyndall Beam Intensity.—Many methods have been proposed using this principle. Strictly speaking, only colloidal solutions give a Tyndall Beam, but suspensions scatter light in such a manner that the intensity of the scattered light may be used in a similar manner to measure turbidity. Unfortunately, most methods do not allow for correction of alterations in the scattered light caused by coloring matter in the solutions. This method is frequently used in filter-press control, where the turbidities involved are large enough so that the effects of reasonably constant coloring matter are negligible.

During the 1940 campaign, the Woodland factory put into routine use an instrument working on this principle, the Hellige turbidimeter. It was better than having no turbidity control at all, but was never really satisfactory. We feel, however, that it is at present the most accurate independent method of measuring sugar turbidity (barring a method mentioned later in the paper) and that by its use one has a valuable tool with which to improve sugar quality.

[2] Figures in parentheses refer to Literature Cited.

Measurement of Color

Measurement on Solid Sugar.—The measurement of white-sugar color may be divided into two types, that in which measurement is made on the solid sugar, and that in which it is made on a solution of the sugar.

Measurement in the solid state is generally accomplished by measuring the reflectance of the sugar. So many other factors than the sugar color can cause variations in the amount of reflected light that the errors in this method can be very great. In the first place, the amount of reflected light varies, depending on the angle from which it is viewed. This angle must be either rigidly fixed, or an integrated reading of all the light reflected must be made. This is frequently done by the use of integrating spheres. The size of the sugar crystals has a very great influence on the amount of light reflected. For example, even a very highly colored sugar, when powdered, gives a very high reflectance, while Confectioner's A, probably as pure a sugar as is manufactured, gives a very low reflectance. Experiments have shown that in order to eliminate this factor, reflectance measurements must be made on carefully screened samples of identical grain size. The amount of packing in the sample cup is of great importance. The cup must be deep enough so that there is no chance for the cup material to affect the color. This matter is far more critical than might be supposed. The sugar must be packed in the cup to a very constant density. Assuming that the measurements are made at a fixed angle, on samples of identical screen size, packed in a deep cup, to exactly the same density, the measurements will be again found to vary with the amount of moisture in the sugar. Differences resulting from processing methods, such as are noted between Steffen or non-Steffen sugars, will result in subtle differences in surface texture directly affecting reflectance, without any difference in color. The Spreckeis Company, probably in common with many other sugar companies who have investigated the subject, decided long ago that measurements of reflectance were unlikely to lead to satisfactory color measurements.

In many sugar factories a visual examination of the sugar, sometimes in comparison with standard sugars, suffices for control purposes. It must be noted, however, that such measurements are not of color alone, but of a great number of other factors as well. This combination reading may be what is required. This is largely a matter of definition. In the Spreckeis Company, by the color of a sugar is meant the color of a 50-percent aqueous solution of the sugar.

Measurements on Sugar Solutions.—Methods of measuring sugar-solution colors may be divided into two classes:

1. Visual measurements.
2. Photoelectric measurements.

Visual Measurements

Up to recent years all measurements were visual, for the very good reason that usable photoelectric cells did not exist. The simplest method is to look at a solution and grade it fair or good. This is still in use in some modern beet-sugar factories. Such a grading generally combines color and turbidity. The method in most general use to date is unquestionably that involving the use of the color comparator. In this general method the color of a column of a solution is observed and compared with a standard. For quantitative measurements a series of fixed standards may be used, a variable standard, or the column of solution is varied to match a fixed standard.

One of the most well-known comparators is the Stammer,

lu this instrument a colored glass is used for a standard, and a match is obtained between the two fields by varying the height of the sugar-solution column with a glass plunger.

In many comparators the standard is itself a solution of some colored material approximating that of the sugar solutions. Among the solutions that have been used are caramel (ulmin), bichromate, and various mixed chemicals.

The Spreckels Company uses platinum chloride (H_2PtCl_6+6H20) which is a well-known reagent for potassium determination. The origin of the method is unknown, but it is believed that it was originated by S. C. Meredith. In any case it has been used for more than 15 years by certain of this company's plants. Spectrographs have shown that the absorption spectrum of platinum chloride very closely approximates that of normal sugar-coloring matter. It has the additional advantage that it is very stable in the absence of reducing agents; however, it deteriorates immediately if any such are present, as for example sugar. This material is dissolved and standardized against Lovibond plates. In practice, a simple comparator of the type shown is used.

A sample of the white sugar is dissolved in an equal weight of boiling water and stirred with an electric stirrer. This procedure results in a solution that is quite free from air bubbles. Experiments have shown that the use of hot water slightly increases the color, but as this increase is roughly constant it is ignored. The solution is poured into a Nessler tube up to a predetermined mark. The observer then varies the height of platinum-chloride solution in a similar tube beside it, until, on looking down through the tubes, the shade of color in the two tubes appears to be equal. The depth of the platinum-chloride solution is then measured, and used as a color index.

The advantages and disadvantages of this type of measurement are common to almost all comparator methods.

Among the advantages are: 1. The effect of turbidity is largely eliminated. Many tests have shown that a skilled observer can match the color successfully with a very considerable amount of turbidity present.

2. The apparatus is low in cost.
3. The method is very rapid.

Among the disadvantages are: 1. The presence of turbidity actually changes the color to a certain extent, since the short-wave lengths of light are more easily scattered than the long-wave lengths.

2. While an absorption standard may be obtained, which, on the average, matches the sugar-coloring matter very closely, deviations from the average are unfortunately very common and frequently large. When the colors are actually different, only very approximate matches can be made.

3. The personal element enters into these methods very seriously. After studying this type of instrument for a long period of time, the Spreckels Sugar Company has come to the conclusion that the deviations from the average of the spectral sensitivity of human eyes are very great.

The following table illustrates this effect very well. A number of sugar solutions of widely different colors were read on the platinum-chloride comparator by a number of trained observers. The table shows how these observers read with respect to the average reading for each solution (the average being 1.00).

Table 1,

	PtCl Reading in Respect to Average (Av.=1.00)						
Observer	Solution No. 1	2	3	4	5	6	7
1	1.44	1.10	1.30	1.23	1.06	1.14	1.10
2	1.05	1.05	1.25	1.05	1.11	0.95	1.21
3	0.88	0.92	1.05	0.90	1.11	1.01	1.04
4	1.01	0.92	1.02	0.90	1.01	0.95	1.02
5	0.88	0.70	0.90	0.90	0.93	0.95	0.92
6	0.93	0.77	0.62	0.93	0.88	0.78	1.03
7	0.85	1.18	0.80	0.87	0.83	0.95	0.96

It will be seen that certain observers fairly consistently read above or below the average.

When the reading is critical, i. e., when it is near the color limit, and the reading is to decide whether or not the strike is to be remelted, the above effect can be a serious matter. Few more pitiful spectacles exist than that of a shift chemist reading a color that is near the limit, in a turbid solution with non-standard color distribution, surrounded by operating men and other chemists ready to contest any reading he makes. It is largely for the above reasons that the Spreckels Company has for years been seeking a method of reading color that would be free from the influence of turbidity, that would be free from the personal element, that would be more precise than the present method, and that would give reproducible results on different instruments.

Photoelectric Method

With the development of the photoelectric cell, particularly the barrier type, many new possibilities have been opened up in the quantitative measurement of color.

It is not within the field of this paper to discuss in detail types of photoelectric comparators. However, mention will be made of the fact that the electric circuits used fall into two different classes, those using a single photocell, and those using two. The single-photocell instruments require constant voltage to the light source and more manipulations in reading, and have been found in general distinctly inferior to the 2-cell circuits.

With the use of photocells to measure absorption, the personal element is eliminated entirely, and a far more accurate reading is obtained. However, the problem of eliminating the effect of turbidity becomes more acute. The photocell cannot distinguish between absorption due to color and turbidity as can the human eye. Two methods for solving this difficulty have been published in the literature; that of Keane and Brice (3) and that of Nees (4).

Mathematical Relationships

The transmittancey of a turbidity-free sugar solution will be represented by T_e and that of a colorless sugar solution by T_t. For a solution containing both color and turbidity, the transmittancey T is given by the fundamental expression

$$T = T_c \times T_t \qquad (1)$$

If the transmittancey measurements are made with light passed by different filters, say a blue-green and a red filter, then

$$T_g = T_{gc} \times T_{gt} \qquad (2)$$

and

$$T_r = T_{rc} \times T_{rt} \qquad (3)$$

The notation is obvious.

Keane and Brice (3) assume that T_{rc} is constant and equal to **1.00** for solutions of white sugars, stating that there is virtually no light absorption in the red part of the spectrum by the small amount of coloring matter present. From this assumption and equation 3, they obtain

$$T_r = T_{rt} \qquad (4)$$

and set the turbidity index equal to the percentage absorbancy of red light, namely

$$I_t = 100\ (1 - T_{rt}) = 100\ (1 - T_r) \qquad (5)$$

They also set the ratio T_{gt}/T_{rt} equal to 1.00, although they state that it is only an approximation. Then from equations 2 and 3, they obtain

$$T_g/T_r = T_{gc}/T_{rc} \times T_{gt}/T_{rt} = T_{gc}/1 \times 1 = T_{gc} \qquad (6)$$

The color index is thus taken as the percentage absorbancy of the blue-green light in a turbidity-free solution and by the assumptions above is expressed as

$$I_c = 100\ (1 - T_{gc}) = 100\ (1 - T_g/T_r) \qquad (7)$$

A. R. Nees (4) was not able to substantiate the assumption of Keane and Brice that both T_{rc} and T_{gt}/T_{rt} equal 1.00. Nees suggested that experimentally determined factors be applied to correct the difficulty and proposed expressing color and turbidity in terms of percentage absorption of blue light. Nees' method is not satisfactory in that the use of an additive relationship of the absorbancies due to color and turbidity cannot be employed if a long cell is used. If A is the absorbancy, from equation 1

$$1 - A = (1 - A_c)\ (1 - A_t) \qquad (8)$$

whence

$$A = A_c + A_t - A_cA_t \qquad (9)$$

If the absorbancies are low, as was the case with the short cell used by Nees, the term A_cA_t can be neglected. However, if a long cell is used and the absorbancies vary from roughly 0.15 to 0.50, the term A_cA_t cannot be neglected. The absorbancies obtained with a cell of the length used by Nees are not large enough to permit adequate photometric accuracy to be obtained (6).

It would seem that the best solution to the problem is to determine experimentally the relationships between T_{rc} and T_{gc} and between T_{rt} and T_{gt}. By means of these relationships and equations 2 and 3, the color and turbidity indices can be calculated and expressed as

$$I_c = 100\ (1 - T_{gc}) \qquad (10)$$

$$I_t = 100\ (1 - T_{rt}) \qquad (11)$$

Thus the indices are expressed by equations of the same form as employed by Keane and Brice,

Description of Apparatus

A Lumetron photoelectric colorimeter made to our design by the Photovolt Corporation of New York City was used for the transmittancy measurements. The instrument is essentially their Model 4G2E, but altered so as to take a 25.0-cm. cell. The light source was replaced by a 6-8 volt, double-contact, automobile headlamp which was lighted by storage batteries.

The two filters used were the same as employed by Keane and Brice (Corning light shade blue-green, No. 428, 3.4 mm. thick and Corning traffic red, No. 245, 3.05 mm. thick. The No. 428 filter used in this work was from melt 194.) Data supplied by the manufacturer indicate that the transmission curves for the No. 428 filter are practically indentical for different melts of glass. The No. 245 filter covers a narrower spectral range and should be readily reproducible. If necessary, slight adjustments in filter thickness can be made to correct for any difference in the melts.

The color temperature of the light source was arbitrarily set at 2485° Kelvin. It was measured with an Eastman color temperature meter. For convenience in routine work, the lamp temperature adjustment is made by noting the galvanometer deflection with the No. 428 filter in position. This was checked from time to time against the Eastman meter. Experiments showed that the measured transmittancies were not dependent to any marked extent on the color temperature of the lamp. A change of 160° in the temperature did not change the measured transmittancy with the red filter a measurable amount and changed the blue filter reading 1.9 percent. The color temperature can probably be adjusted to within 15°, which is equivalent to a transmittancy variation of 0.2 percent.

Experimental Procedure

The primary transmission standard used in this work was a colorless, turbidity-free, 50 R.D.S. sugar solution. It was prepared from confectioners sanding sugar by adding Darco decolorizing carbon to the hot solution, allowing it to cool, filtering on a Buchner funnel through No. 40 Whatman paper, and filtering through asbestos, according to the recommendations of Peters and Phelps (5). In this work the word turbidity-free is applied to any solution which was filtered through the specially prepared asbestos. There has been much discussion in the literature regarding color adsorption of asbestos and other filtering media (1, 5, 7). However, experiments made by the Spreckels Sugar Company indicate that any adsorption of coloring matter from solutions of granulated sugar by asbestos is slight and can be neglected without introducing serious error.

For convenience, a secondary transmission standard was prepared and standardized against the primary standard. Two 5-cm. squares of thin glass from photographic plates *were* bound together with the inner surfaces separated by a border mask of thin cardboard. The transmittancies of this absorber for red light and blue-green light were determined, taking the transmittancy of the standard sugar solution In the 25.0-cm. absorption cell as 1.000 in each case. The secondary standard was checked in this manner several times during the course of the work. In routine runs, the circuit of the Lumetron was readily balanced by using the secondary standard without the necessity of having standard sugar solutions always on hand.

Fifty R.D.S. solutions of granulated sugar were prepared by mixing equal weights of sugar and boiling double distilled water. After cooling to room temperature, the transmittancies of the solutions were measured in the 25.0-cm. cell, using first the blue-green and then the red filter. The solutions were next filtered through asbestos and the transmittancies again determined.

Duplicate and triplicate runs made with several sugar samples show that the transmittancies of the asbestos-filtered solutions are quite reproducible. The deviations from the average transmittancy for two or three runs on each of five samples of sugar were only a few tenths of a percent.

A considerable number of colorless but turbid 50 R.D.S. sugar solutions were also run in the colorimeter. The turbidizing agent was prepared by adding a little Fuller's earth to a colorless sugar solution, stirring well and allowing to settle overnight. The supernatant liquid was decanted and used to turbidize other colorless sugar solutions. A few measurements were carried out on solutions made turbid with finely divided amorphous sulfur.

Transmittancy Measurements

A large number of samples of beet sugar from the three factories-ples from the Western Sugar Refinery were used in the work. All the beet-sugar samples were of white granulated sugar.

The ratio T_{rt}/T_{gt} was calculated from the relationship

$$T_{rt}/T_{gt} = \frac{T_r}{T_g} \times \frac{T_{gc}}{T_{rc}}$$

Relationships Between T_{rt} and T_{gt}.—The transmittancy measurements showed plainly that T_{rt}/T_{gt} cannot be set equal to 1.00 if accuracy is desired.

In a number of cases the ratio departs markedly from 1.00. Thus in three cases the ratio was found to be as high as 1.2. It is therefore necessary to establish from the experimental data the relationship between T_{rt} and T_{gt}. In this connection it is advantageous to use the data which were obtained from artificial turbidities. In the first place, the use of artificial turbidity allows one to cover a greater range of turbidity and with greater uniformity. Secondly, it permits the use of a more nearly true turbidity rather than having to depend upon chance in using natural sugar turbidity. Often the low transmittancies observed with sugar solutions are due to fibers, large dust particles and the like, especially if the samples have been stored in cloth bags. Even what might be called true turbidity is not constant in nature or particle size, but depends on its source and other factors.

It was found empirically that the relationship between T_{rt} and T_{gt} is best expressed by an equation of the form $T_{rt}/T_{gt} = k_1 + k_2 T_{rt}$. The data were treated by the method of least squares and the equation obtained was

$$T_{rt}/T_{gt} = 1.224 - 0.220\ T_{rt} \tag{12}$$

The average difference between the observed and calculated values of T_{rt}/T_{gt} is 0.008.

Relationship Between T_{rc} and T_{gc}.—Early in this work it was realized that colored but turbidity-free solutions did not transmit all of the light passed by the red (Corning No. 245) filter. It was at first thought that possibly some constant value of T_{rc} could be employed, but such did not prove to be the case. An analysis of the data showed that the relationship between T_{gc} and T_{rc} could be well expressed by an equation of the same type as was used for the turbidity ratio, namely $T_{gc}/T_{rc}=k_3+k_4T_{gc}$. This relationship was obtained using only the data for the beet-sugar samples inasmuch as it was found that no significant difference was obtained between the equations for the individual beet plants, but that they did differ considerably from the equation obtained for the cane-sugar samples. Thus it seems advisable to use one set of coefficients for beet sugar and one set for cane sugar. Most of the samples investigated in this work were beet-sugar samples (107 beet, 16 cane) and the equation presented applies to beet sugar. Many more cane samples should be run to obtain a truly representative equation for cane sugar. The final equation obtained for beet sugar was

$$T_{gc}/T_{rc} = 0.310 + 0.673 T_{gc}. \qquad (13)$$

and the average difference between the observed and calculated values of the ratio is 0.007.

Derivation of Equations for Color and Turbidity Indices

If the color of a sugar solution is to be expressed as the percentage absorbancy of blue-green light by the turbidity-free solution, it is necessary to calculate T_{gc} from the measured values of T_g and T_r employing equations 2, 3, 12 and 13. Similarly, the turbidity index can be calculated by finding T_{rt}.

After performing the algebra the following equations for T_{gc} and for T_{rt} are obtained:

$$T_{gc}^2 + T_{gc} [0.461 + T_g (0.220 - 1.819/T_r)] + 0.101 T_g = 0 \qquad (14)$$
$$T_{rt}^2 + T_{rt} [-5.564 - T_r (0.673 - 1.409/T_g)] + 3.744 T_r = 0 \qquad (15)$$

Only one root in each equation is significant. T_{gc} must be greater than or equal to T_g, but less than 1.00. Also T_{rt} must be greater than or equal to T_r, but less than 1.00.

A table was prepared by substituting various values of T_g and T_r in equations 14 and 15 to obtain the transmittancies and then these were converted readily to percentage absorbancies, the units of the color and turbidity indices.

Comparison of Observed and Calculated Color and Turbidity Indices

A practical test of the method can be made by comparing the observed and calculated color and turbidity indices. The color index is given as $100\ (1-T_{gc})$ and the turbidity index is $100\ (1-T_r/T_{rc})$. In the following table these, indices are compared with the indices calculated from equations 14 and 15, using the observed values of T_g and T_r.

The average difference between the calculated and observed color indices is 1.9 units; for the turbidity indices, it is 1.4 units. The agreement is especially gratifying in the cases of high turbidity.

Practical Application

The method has been applied for practical control work at the Woodland factory, and has functioned in a very satisfactory manner. It has the full approval both of the laboratory force and the operating men. Just before the close of the campaign, in fact, two more instruments were installed in the other two factories of the Spreckels Sugar Company. About 7 minutes are required for each complete analysis. In a brief form, the procedure is as follows:

1. One hundred and fifty grams of sugar are dissolved in an equal weight of hot, distilled water, and stirred into solution.
2. The hot solution is poured through a heat exchanger from which it emerges at approximately room temperature.
3. The cooled solution is poured into the absorption cell.
4. The color temperature of the light source is checked.
5. The blue-green filter and secondary standard are inserted and the Lumetron balanced to the required value.
6. The secondary standard is removed, the absorption cell inserted, and a reading made of the transmission.
7. The same procedure is carried out with the red filter.
8. From the two readings, the color and turbidity indices are obtained from tables.

Discussion

The color and turbidity indices in this method are given as percentage absorbancies due to color or turbidity for an absorption cell 25.0 cm. in length. Naturally the values will differ for another cell length. It has been found, however, that a cell of this length is necessary for optimum absorption (6).

With control of color temperature of the illuminant, and some care in duplication of light filters, there should be little difficulty in obtaining substantially the same results with different instruments.

In order to save time, the sugar samples are dissolved in hot water. Tests have shown that this causes a slight increase in color, but as it is roughly constant, it is ignored.

There is no definite assurance that the exact relationships given in this paper will hold for coloring matter and turbidity present in beet sugars from other districts. In the case that they do not, the correct relationships may readily be established by the methods described. The problem is one of unusual complexity, and unfortunately no simple solution seems possible, barring the perfection of **a** method for rapid, optical filtration of sugar solutions.

Table 2.—Comparison of observed and calculated color and turbidity indices.

Sugar sample	Color index		Turbidity index	
	Observed	Calculated	Observed	Calculated
1	24	27	13	12
2	33	38	25	19
3	25	25	13	12
4	27	31	26	24
5	31	32	20	19
6	33	36	28	27
7	26	27	20	20
8	30	34	11	8
9	29	32	10	10
10	28	28	15	14
11	32	36	30	28
12	28	31	17	17
13	28	33	17	14
14	27	25	10	11
15	31	36	23	21
16	35	36	22	22
17	25	29	7.7	5.4
18	30	32	19	19
19	28	32	12	10
20	27	32	13	11
21	24	23	8.8	8.7
22	23	23	7.6	7.6
23	24	25	9.2	9.0
24	23	23	7.7	6.6
25	21	25	12	10
26	21	19	9.2	9.9
27	21	21	9.2	8.1
28	21	22	7.2	5.7
29	23	24	7.0	5.4
30	24	25	9.5	8.7
31	24	21	8.3	10
32	23	22	5.2	5.5
33	27	27	5.9	6.2
34	27	29	7.2	5.8
35	27	29	6.8	4.7
36	26	28	5.0	4.0
37	29	31	8.0	5.8
38	31	37	27	25
39	30	29	10	9.7
40	26	27	6.1	5.5
41	24	23	7.6	7.6
42	25	23	7.5	7.2
43	20	21	7.6	7.4
44	21	21	5.9	6.0
45	20	21	4.6	4,3
46	24	25	6.4	5.7
47	23	22	4.8	4.0
48	24	27	5.4	4.2
49	24	26	3.3	1.6
50	26	25	6.6	6.7
51	24	22	4.5	5.5
52	21	22	5.1	3.6
53	22	21	8.6	9.3
54	25	26	4.6	3.7
55	23	25	8.9	6.9
56	25	25	8.8	9.0
57	30	29	28	28
S8	31	29	58	54
59	30	31	8.2	6.7

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Safety Problems in the Sugar Industry

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General Discussion of Safety and Accidents in Industry

It is felt that this is an appropriate time to discuss safety problems in the beet-sugar industry in view of the fact that accidents and injuries to workmen have been taking such a large toll in American industry. The safety problem is definitely an operating and management problem and is a cost burden to operations that can be reduced. The accident experience in the beet-sugar industry is certainly no better than average when compared with other American industries, and published figures of accident ratios indicate that we have much to accomplish.

As no accident figures for the beet-sugar industry as a whole are available, the scope of the problem can best be brought out by a few figures quoted in current literature on the subject. In 1940 accidents in American factories cost 11/2 billion man hours of production. There were 17,000 deaths and permanent disabilities were quoted from 60,000 to **93,000.** In addition to this, there were over 1,250,000 temporary disabilities or an average accident toll of one day per worker.

In 1939, according to the National Safety Council, accidents cost this country $600,000,000, and of this amount almost $32,000,000 was paid out to cover the cost of eye injuries alone. Each year 75

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