DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 44

POLARIMETRY

[2d Edition]

Issued January 30, 1918

PRICE 25 CENTS

Sold only by the Superintendent of Documents, Government Printing Office
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PREFACE TO FIRST EDITION

This circular supersedes Bureau of Standards Circular No. 12, issued July 16, 1906. New material has been added with the object of presenting in condensed form the basic principles of modern polarimetry. In recent years there has been a rapid growth in the applications of polarimetry to the arts and the sciences, with a proportionate increase in the requests made upon the Bureau for information. The preceding circular therefore has been enlarged by a résumé of the work done at the Bureau of Standards and elsewhere, with the object of answering as far as possible inquiries on this subject.

While it is impossible to anticipate all questions that may arise in this field, it is hoped that the present circular will furnish information of a broader character and in greater detail than could be given by letter.

JANUARY 15, 1914.

PREFACE TO SECOND EDITION

This circular has been revised and 43 pages of additional matter added in the appendixes. The new material comprises 10 tables, including the new Bureau of Standards Baumé scale for liquids heavier than water; results of recent researches; a consideration of the polarization of low-grade products; a résumé of the work of the International Commission for Uniform Methods of Sugar Analysis; and amendments to the United States Treasury Department Sugar Regulations.

NOVEMBER 1, 1917.

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TABLES

POLARIMETRY

I. INTRODUCTION

Since the organization of the Bureau of Standards there has been submitted for test a great variety of polariscopic apparatus typifying the designs and methods of construction adopted by American and European manufacturers. The Bureau is equipped with examples of the standard apparatus of the leading polariscope builders, as well as special apparatus for work requiring the highest attainable precision. In the case of most of the apparatus sent to the Bureau for test no intimation is given as to the degree of accuracy desired. In all such cases it is the practice to give such precision as the Bureau's previous experience with the type has shown it to merit. On the other hand, a precision is frequently requested which is greater than the apparatus justifies. In general, two grades of accuracy have been found adequate for polariscopic apparatus, one for the highest commercial accuracy and the other for all scientific work except special research in which the precision of the remaining data entering into the result justifies a still higher accuracy. In such cases the Bureau will be glad to cooperate with investigators, not only in providing for tests of the highest precision, but also, on request, in furnishing any information at its disposal in reference to methods of measurement and the design and construction of special apparatus. It is also the desire of the Bureau to cooperate with manufacturers, scientists, and others in bringing about more satisfactory conditions relative to the weights, measures, measuring instruments, and physical constants used in polariscopic work, and to place at the disposal of those interested such information relative to these subjects as may be in its possession. Persons interested are invited to visit the laboratories of the Bureau, where leading types of polariscopes may be seen in operation.

II. ABSOLUTE MEASUREMENTS IN CIRCULAR DEGREES

1. POLARIZING SYSTEMS

(a) GENERAL

Biot produced in 1840 the first instrument for measuring the rotation of plane polarized light by the so-called optically active substances. It consisted merely of a stand on which were mounted two Nicol prisms and a graduated circle, the analyzing nicol rotating with the circle. Subsequently the simple apparatus of Biot was improved by Mitscherlich and Robiquet, the latter adding the biquartz, which made the setting depend on the transition tint (teinte de passage). Some of these instruments are still in use.

In 1860 Jellett invented the first half-shadow polariscope. The utilization of the half shadow was the first important step in the perfection of the modern instrument. Prior to this both the polarizing and analyzing nicols were simple prisms. Jellett's idea was to introduce into polariscope design the photometric principle of making the setting of the instrument depend on the matching of two unequally illuminated portions of the field, the eye under favorable conditions easily detecting very minute differences in intensity. In order to take advantage of this principle he removed a small wedge-shaped section from one-half of a Nicol prism and then cemented the three pieces just as in making an ordinary nicol. In mounting, the divided half was placed toward the analyzer, and each part of this half gave light vibrating in a plane, which made an angle equal to the removed section, with the plane of vibration of the light coming from the other part. This angle is known as the half-shadow angle. The field of the instrument thus appears divided into two parts, and the setting is made by turning the analyzing nicol until they become of equal intensity. The sensibility of the instrument depends on the magnitude of the angle of the half shadow. As the angle diminishes, the accuracy with which a setting can be made increases. However, the total illumination of the field diminishes with the half-shadow, so that with an angle of about 2.5° the minimum working value is reached.

The advantage of the half-shadow principle was universally recognized, and a number of half-shadow polarizing systems

were introduced by various investigators. Two of these—namely those of Laurent and Lippich—in addition to Jellett's, have been extensively used by polariscope builders.

When plane polarized light of more than one wave length traverses an optically active substance, it emerges with the vibration planes of the individual waves all inclined to each other in a sort of fan-shaped arrangement; the violet waves having been rotated through the greater angle being the most inclined to the original direction of vibration. An analyzing nicol on being rotated will cut out each wave in turn, but it is impossible to darken the field, owing to the fact that some light from each of the remaining waves passes through the analyzer. If the polarizing nicol be of the Jellett type, it will be found impossible to darken either half of the field, and color will always be present. Thus in all polariscopes in which the setting is made by rotating the analyzing nicol it is necessary that the light source be monochromatic, or at least consist of only a few waves of nearly the same length.

(*b*) LAURENT AND JELLETT POLARIZERS

Of the three half-shadow polarizing systems mentioned above the Laurent alone is limited to the use of a single monochromatic source. In this system a thin plate of quartz cut parallel to the optic axis covers one-half the field of the polarizing nicol. In order that the two rays of the doubly refracting quartz may combine to give plane polarized light in the analyzer, they must have an optical difference of path equal to one-half a wave length. Thus the thickness of the quartz must always be such as to bring this condition about, and its use is then limited to a light source giving the particular wave length for which the condition is fulfilled. The angular position of the new plane of polarization is slightly different from that of the polarizing nicol and the conditions for a half shadow are established. The advantage of this system is due to its adjustable sensibility; the half shadow, being twice the angle between the optic axis of the plate and the plane perpendicular to the principal section of the polarizer, can be readily varied by rotating the polarizer. Inasmuch as the Laurent polarizer requires a monochromatic source it is never combined with a quartz compensating system. The Jellett polarizing nicol, described above, has a fixed half shadow, and therefore the sensibility can not be varied. Its advantage lies in the fact that it does not easily get out of adjustment.

(c) LIPPICH SYSTEM

In the Lippich polarizing system the half-shadow angle is formed by two beams of plane polarized light, which come from two separate nicols, one of which covers but one-half the aperture of the other. If these two nicols are turned until the vibration planes of the light which they transmit coincide, they act as a single nicol. If one of them be rotated through any angle, a half shadow is formed equal to that angle. Because of the ease with which the half shadow can be varied, as well as the high degree of perfection attained by the opticians, we have in the Lippich a most adaptable and sensitive polarizing system. The accuracy with which a setting can be made depends upon how nearly the dark dividing line between the halves of the field vanishes, and with a broad source of light this condition is very nearly attained in the Lippich. However, it requires the use of a monochromatic source if the half shadow is to remain adjustable.

(d) SENSITIVE STRIP SYSTEM

In 1903 Brace [1] described the sensitive strip spectropolariscope. In the ordinary Nicol prisms the extraordinary ray is utilized. It occurred to Brace that it was possible to reverse this condition and use the ordinary ray. Thus instead of a film of liquid between two large pieces of Iceland spar he proposed using a thin piece of spar immersed in liquid and placed in a cell with glass ends, the spar plate covering the entire field and being inclined at an angle of 70° to the axis of the system. To obtain a polarizing system similar to the Lippich it would be necessary to place a second cell with a narrow strip covering one-half the field in the position ordinarily occupied by the small nicol of a Lippich system. If such a system could be perfected, it would have many advantages over the Lippich. Among these may be mentioned the saving of Iceland spar and rectilinear passage of the light through the system. In addition great sensibility would be secured owing to the fact that a practically vanishing line would be obtained between the halves of the field, as the small strip of spar need not be over one-tenth of a millimeter thick. The device was perfected and used by Bates, who subsequently succeeded in combining the two cells into one. The Brace sensitive strip spectropolarizing system is the most sensitive yet devised. It is, however, rather fragile and its use is not recommended except in work requiring the highest obtainable precision.

[1] Brace: Phil. Mag., Jan. 1903, pp. 161–170.

(*e*) EQUIPMENT

Polariscopes with circular scales for measuring absolute rotations are now made by most polariscope builders. The Bureau is fortunate in having a large Schmidt and Haensch precision instrument with a silver scale reading to 0°.001. The Lippich polarizing system is unusually good, the larger nicol having an available opening of 15 mm. The instrument is mounted on a cast-iron base 1 m in length. Owing to the necessity of controlling the temperature while measuring rotations a large air thermostat, constant to within 0°.03 C, is mounted between the polarizing and analyzing systems. The variations are noted on a mercury thermometer located in the center of the bath. The case is a wooden box 40 cm by 55 cm by 60 cm covered with asbestos. A small hole in each end of the box permits the passage of the light. Access is had to the interior by means of a small door in the side. The temperature, if necessary, is brought to a few tenths of a degree below the desired temperature by means of a copper coil through which ice water flows. Approximate regulation of the ice water is secured through a long arm stopcock. An electric heater then brings the temperature up to and maintains it at the proper degree. The heater is made of small resistance wire wound around a framework which fits inside the box. The current is controlled by means of a relay operated by a mercury contact, which in turn is operated by toluene contained in a series of glass tubes so constructed and placed as to give a maximum change of volume in a minimum of time when a small temperature change takes place. The air is kept constantly stirred by a small fan.

An additional precision polarimeter is now in course of construction. It has been designed with the object of obtaining the highest possible accuracy in rotation measurement. It combines for the first time a quartz compensation of unusual perfection, with a circular scale, the wedges being so mounted that they can be instantly swung into and out of the path of the light. The Bureau also possesses facilities for the examination of polarizing systems and separate nicols.

A large Weiss electromagnet equipped with a suitable polariscope is available for the study of magnetic rotation. This magnet is cooled by water circulation, thereby permitting continuous use even when heavy currents are employed.

2. POLARISCOPES WITH CIRCULAR SCALES

(See Fee Schedule 41)

Polariscopes with circular scales will be accepted for test. A thorough examination is given all optical parts. The scale will be checked for as many points as desired.

3. LIGHT SOURCES

(*a*) GENERAL

In accordance with the rapidly increasing use of polarimetry in commercial and scientific work there has arisen a demand for greater accuracy. This has resulted in an investigation of the light sources used in order to lessen the largest source of error in precision measurements of this character. The production and utilization of suitable light sources is by far the most difficult problem with which the polariscopist must cope, and it is therefore receiving much careful study at this Bureau. For many years any sodium source was considered suitable for this work. then came the so-called light filters of Lippich [2] and Landolt.[3] These filters, however, are open to two severe criticisms: The efficiency of the purification is a function of the intensity of the source, and the available light is reduced by absorption in the liquids used in the cells.

Subsequently spectrum filtration came into use for precision work. In this method light from an intense source is passed through an optical system containing a dispersing medium and only the desired wave lengths are permitted to enter the polariscope.

(*b*) SODIUM

Until recently the sodium lines have been the one intense source with which a large percentage of the precision work has been done. This source has been used for determining practically all the polarimetric constants as well as for the standardization of quartz control plates. Unfortunately the two sodium lines are difficult to separate from the remainder of the spectrum, and as the flame is intense there is danger of the lines reversing. In 1906 a careful study of spectrum lines as light sources for polarimetric work was made at this Bureau. It was found that the lack of intensity, the high dispersion necessary for purification, the presence of other lines of considerable intensity in the neighborhood of D_1 and D_2, as well as the unstable line structure under certain

[2] Lippich: Zs. für Instrk., 12, p. 340; 1892.

[3] Landolt: Ber. d. chem. Ges., 27, p. 2872; 1894.

conditions, renders this source far from satisfactory. Owing to the great precision required in present-day polariscopic measurements, intensity is of paramount importance. Even in commercial instruments the half-shadow angle is generally not over 10 degrees, which means that the polarization plane of the analyzing nicol is practically at right angles to the planes of the polarizing system. Thus only a very small fraction of the incident light ever reaches the eye of the observer. After an extensive investigation the Bureau has found that for an intense sodium source the best results are obtained by feeding some form of fused Na_2CO_3 into an oxyhydrogen flame. In utilizing this source a rod of this substance is placed in the flame at one of the positions shown in Fig. 1. The line structure of the sodium lines obtained by this method was studied with an echelon spectroscope. The lines were found to be extremely sharp and to differ from the arc spectra by the absence of the characteristic haziness of the edges. If displacements as large as 0.5 mμ had occurred, they would have been readily detected. The broadening was at all times symmetrical. In this respect the observations agree with the more recent work of other observers, but are contradictory to the results obtained by Ebert [4] which have been accepted in polariscopic work.

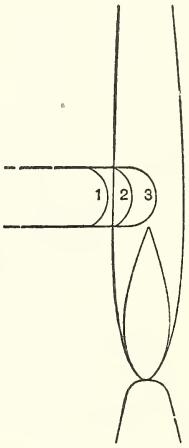

FIG. 1.—*Sodium light source*

By careful manipulation of the flame in position three reversals of the lines took place. D_2 preceded D_1, in this respect.

TABLE 1

Structure of Sodium Lines at Different Intensities

Spectrum line	Relative intensity	Position 1, width mμ	Position 2, width mμ	Position 3, width mμ		
				Na_2CO_3 melting slowly	Na_2CO_3 melting very rapidly	
D_1	1.0	0.008	0.02	0.3–0.4	0.4 Reversed	Reversed 0.6
D_2	1.6	0.008	0.02	0.3–0.4	0.6	Reversed 0.6

[4] Ebert: Wied. Ann., 34, p. 39; 1888.

It is thus evident that so far as their line structure is concerned the sodium lines can be depended upon to give a sufficiently definite optical center of gravity up to the point of reversal in position 3 (Fig. 1). However, very noticeable variations in polariscopic measurements are likely to be observed with sodium sources at different intensities. These variations, it is believed, are not due to changes in the line structure of the source, but to the difficulty of excluding all extraneous light even with a very narrow slit and a dispersion sufficient to separate D_1 and D_2. This extraneous light constitutes a different percentage of the total illumination whenever the intensity of the source varies. It may, therefore, appreciably affect the optical center of gravity when the field appears dim, and inversely when bright. Aside from the color and stability of the sodium lines up to reversal there is nothing in their favor as a polariscopic source. The flame requires the constant attention of an assistant, and even in reversal the intensity is not nearly sufficient to permit of the use of the greatest sensibility of a good polarizing system.

(c) MERCURY

It is proposed to use the green line of incandescent mercury vapor, $\lambda = 546.1 m\mu$,[5] as the standard source for all accurate polariscopic work. Quartz mercury-vapor lamps as now made are reliable in action. If sufficient care is exercised in preparing the mercury and exhausting the lamps, the five characteristic lines only will be obtained in the visible spectrum and with great intensity.

Different observers have found markedly different line structures for the line $\lambda = 546.1 m\mu$, depending upon the method of analysis employed. The map in Fig. 2 was obtained with the echelon with 1.8 amperes passing through the lamp. The fractional values given are the relative intensities as nearly as they could be estimated. It was found impossible to decide whether the satellite -0.024 belongs to the positive or negative side of the primary. When the current was increased to more than 2.1 amperes, the satellite -0.055 increased in intensity until it about equaled the primary. The difference in wave lengths of the extreme satellites is less than $0.04 m\mu$. With a different source Fabry and Perot[6]

[5] For greater clearness and to conform to the system of numeral prefixes in use with metric and cgs units the numeral prefix *micro-*($=10^{-6}$) is abbreviated μ in combination, and *milli-*($=10^{-3}$) is abbreviated m, so that *micro-micron* (10^{-12} meters) would be abbreviated $\mu\mu$ and *milli-micron* (10^{-9} meter) abbreviated $m\mu$, as in this circular.

[6] C. R., p. 409; 1898.

found 0.035mμ and Houstoun[7] 0.0215mμ. The distance between D_1 and D_2 is fifteen times 0.04mμ. As far as it has been possible to determine, the line structure for the quartz lamp under widely varying conditions is such that for polariscopic purposes $\lambda = 546$mμ is a monochromatic source of great intensity and perfect reliability. In measuring a rotation of 250° no differences could be detected due to changes in the emission, and probably none for much larger rotations. The quartz lamp requires little attention and can be operated indefinitely. Since only the lines $\lambda = 579$, 576, 546, 435, and 404 mμ are present the difference in wave length is such as to permit of perfect separation of the line 546mμ by even a relatively small dispersion, and without bringing other lines in close proximity to the edges of the slit. Hence, this source permits the elimination of practically all diffused light.

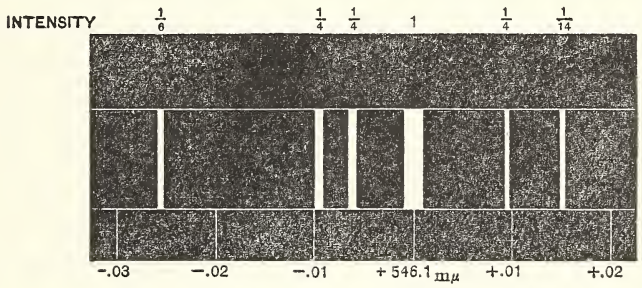

FIG. 2.—*"Yellow green" line of mercury vapor*

Since its adoption as the official source for polarimetric measurements by the Bureau of Standards its universal acceptance has been recommended by a number of investigators. The Bureau urges its general use especially when measuring circular degrees in research and precision work, to the end that reliable comparisons may be made between the results of different investigators.

(*d*) CADMIUM AND LITHIUM

The necessity for a number of suitable line sources for polariscopic work has resulted in numerous investigators giving much time to the subject. So far as possible it is desirable that the lines utilized be uniformly distributed throughout the visible spectrum.

Lowry[8] has suggested the following: Lithium, 670.8, red; cadmium, 643.8, red; sodium, 589.3, yellow; mercury, 546.1, green;

[7] Houstoun: Phil. Mag., 7, p. 456; 1904.

[8] Phil. Mag., 18, pp. 320–327; 1909.

cadmium, 508.6, green; cadmium, 480.0, blue; mercury, 435.9, violet. 670.8 and 589.3 are obtained from flame spectra, and 546.1 and 435.9 from the quartz mercury lamp. The cadmium lines 643.8, 508.6, and 480.0 Lowry suggests be obtained from a rotating arc. The electrodes must rotate in opposite directions at a speed sufficiently high to prevent flickering. As electrodes he uses an alloy of 28 per cent cadmium and 72 per cent silver. The melting point is 860°. This method has been used at the Bureau and is capable of giving excellent results. The rotating arc, is however, rather difficult to manipulate.

4. QUARTZ CONTROL PLATES

(See Fee Schedule 44)

(*a*) METHOD OF TESTING

Inasmuch as precision work of the highest type is frequently called for in meeting the demands for accuracy in standardizing quartz control plates, the mercury line $\lambda = 546.1 m\mu$, for the reasons outlined above, is used entirely. In order to utilize this same source the temperature coefficient, α, of quartz for $\lambda = 546.1 m\mu$ as well as the constant $\frac{\phi_{\lambda=546.1}}{\phi_{\lambda=589.2}}$ (where ϕ is a rotation) were determined. It was thought advisable to measure α, although V. Lang,[9] Sohncke,[10] and Le Chatelier [11] state that it has the same value for all wave lengths. We have

$$\phi_t = \phi_o (1 + \alpha t) \tag{1}$$

where ϕ_t is the rotation at temperature t and ϕ_o at zero. For any other temperature t_1 we have

$$\phi_{t_1} = \phi_o (1 + \alpha t_1) \tag{2}$$

Hence

$$\alpha = \frac{\phi_{t_1} - \phi_t}{\phi_t t_1 - \phi_{t_1} t} \tag{3}$$

The measurements were made with the most improved types of apparatus. $\lambda = 546.1 m\mu$ was separated by means of two dense prisms. The left rotating quartz plate was placed in a water cell closed with glass end plates. The cell could be opened and the quartz removed without disturbing the mounting of these plates. This is of the greatest importance, as it insures constancy of the

[9] V. Lang: Pogg. Annalen, 156; 422 p.; 1875.
[10] Sohncke: Wied. Annalen, 3, 516. [11] Le Chatelier: C. R., 109–244 (1889).

optical path at all times save that caused by the presence and absence of the quartz plate. Water at the desired temperature flowed through the glass cell during all measurements. Twenty consecutive settings were always made—5 on the zero point, 10 with the quartz inserted, and 5 on the zero. By computing α from the value of ϕ at temperatures between 4° C and 50° C the following was obtained:

$$\alpha = 0.000144.$$

Hence
$$\phi_t = \phi_o\,(1 + 0.000144t) \qquad (4)$$
between 4° C and 50° C.

In measuring $\frac{\phi_{\lambda=546.1}}{\phi_{\lambda=589.25}}$ a large number of determinations were made, practically all of which were concordant. However, in order to eliminate the personal equation and avoid as far as possible errors due to the character of the sodium source, the value of ϕ is computed from the measurements of five plates, whose sodium value has recently been determined at the Physikalisch-Technische Reichsanstalt. The mean of this value and that of the Bureau was taken as the rotation for $\lambda = 589.25$. The rotations were measured in part with a sensitive strip polarizing system. The greater number, however, were made with an exceptionally good Lippich system.

The average value obtained was

$$\frac{\phi_{\lambda=589.25}}{\phi_{\lambda=546.1}} = 0.85085 \qquad (5)$$

Thus any quartz rotation for the wave length 589.25 may be obtained by measuring the rotation for the wave length 546.1 and multiplying it by the constant 0.85085. By this method the errors due to the character of the sodium source of light are eliminated and the measurements of one observer may be readily compared with those of another. Certificates show the rotation in circular degrees at 20° C for wave lengths $\lambda = 546.1\text{m}\mu$ and $\lambda = 589.25\text{m}\mu$. The latter is the so-called optical center of gravity of the two sodium lines D_1 and D_2.

(*b*) SPECIAL TESTS

Additional data upon quartz control plates submitted for test may be had by special arrangement. Standardization for wave lengths other than $\lambda = 546.1\text{m}\mu$ and $\lambda = 589.25\text{m}\mu$ will be made provided the order of accuracy desired is consistent with the intensity of the source available.

A test for the so-called "axis error" will also be made. Often, for special purposes, it is desired to know the order of accuracy with which the normal to the plate coincides with the optic axis. In well-cut plates this angle is often less than one minute of arc. The possibility of errors in rotation from this source is relatively small.

(*c*) SPECIFICATIONS

Control plates should be optically homogeneous with the faces plane, parallel, and cut accurately at right angles to the optic axis. They should invariably be mounted loosely in a metal frame, the axis of which forms an angle of 90° with the faces of the plate. The amount of play in every direction between the plate and the surrounding frame should be as small as possible, but the metal should exert no pressure upon the plate. The Bureau does not issue certificates for plates mounted in wax, but plates so mounted will be tested and a statement of the rotation issued. The Bureau reserves the right to reject any plate showing faults which tend to make it unreliable. The sugar value of control plates is discussed below under saccharimeters.

III. SACCHARIMETERS

(See Fee Schedule 43)

1. DEVELOPMENT

In the development of the saccharimeter there are two factors that have of necessity received most consideration. They are, first, sufficient illumination of the field for average work and, second, the highest sensibility obtainable without too great a sacrifice of other desirable features. The application of the photometric principle as realized in the half shadow nominally requires the use of a nearly monochromatic light source such as is used on polariscopes for absolute measurements. Unfortunately a monochromatic source of sufficient intensity and otherwise suitable for all polarimetric work has never been realized. In order to obviate this difficulty, Soleil, a Parisian optician, as early as 1848 invented the first quartz-wedge compensation and applied it to the polariscope of Robiquet. He used negatively rotating quartz, the vibration planes of the different waves being thus returned to the original vibration plane common to all. Since the calibrated wedge is driven across the field until conditions are as they were before the rotating substance was placed in the instrument, rotary dispersion is practically eliminated and white light may be used.

The absence of light sources of sufficient intensity has always been one of the most potent factors in influencing the design of saccharimeters. The higher limit of the sensibility has been almost entirely determined by this factor. Even with the average half shadow of 6 to 8 degrees the polarizing and analyzing nicols are practically crossed, so that only a mere fraction of the incident light ever reaches the eye of the observer; and if the half shadow is decreased in order to increase the accuracy with which observations can be made, the intensity of the light transmitted is rapidly reduced. Thus monochromatic sources are inadequate in intensity when even fairly accurate settings are to be made, unless the active substance whose rotation is to be measured is quite transparent. Unfortunately this is not the case with most of the optically active liquids. This is especially true of the average raw-sugar solution, and hence Soleil, as stated above, invented the quartz-wedge compensation, which permits the use of white light with its relatively great intensity.

The necessity for using white light has resulted in the quartz compensating instrument displacing practically all other saccharimeters, as is evidenced by the similarity in the perfected instruments of Frič, Schmidt and Haensch, Peters, Reichert, and others. This has been brought about despite the fact that the wedge prevents the use of the adjustable half shadow of the Lippich polarizing system. Thus, while the best results in the designing of polariscopes for use with a white-light source have so far been obtained by using the Lippich polarizing system and a quartz-wedge compensation, all makes have had the great weakness of an unadjustable half shadow, and therefore a fixed sensibility. Only one value of the half shadow can be used, and it must necessarily be large enough to give sufficient light to read, for example, the darkest colored raw-sugar solutions. When polarizing substances having a small coefficient of light absorption, as the better grade of sugars, and the observer has more light than he needs, he still has available only the low sensibility which corresponds to that value of the half shadow which gives sufficient light to polarize substances with a relatively large coefficient of absorption, such as very dark raw sugars. If, then, it were possible to retain the quartz compensation and at the same time have the half shadow adjustable, an advance in polariscope construction would be made comparable with the invention of the wedge.

The defect due to the lack of an adjustable sensibility on a white-light instrument has been in evidence not only in ordinary use but especially when the saccharimeter was used for research work. The ordinary quartz compensating polariscope is utilized in practically every chemical laboratory. The highest available precision of the instrument is required to meet the demands of routine use. Yet the investigator has been compelled to depend upon it. The futility of taking a large number of observations on an instrument sensitive to 0.15 per cent, and using the average value as good to 0.015 per cent is too well known to need discussion here. Nevertheless, the chemist has been compelled to do this because the majority of the research problems involving the use of the polariscope require the measuring of rotations to less than 0.1 per cent. There can be no question that the present status of polarimetry would have been immeasurably advanced had there been a saccharimeter capable of being read to 0.01 per cent in the hands of chemists for the past 25 years.

In order to build a white-light polariscope with an adjustable sensibility, the analyzing nicol would have to rotate through a

definite angle as the half shadow was varied. In such an instrument it is not sufficient that the half shadow be merely adjustable, but the far more difficult requirement must be met of having it adjustable without shift of the zero point. This is indispensable for two reasons—first, to permit of making polarizations with the same rapidity as on an ordinary saccharimeter, and, second, to eliminate the danger of the observer not properly setting the analyzing nicol whenever the half shadow is changed. The designing of an instrument to meet these requirements would be comparatively simple if the vibration plane of the analyzing nicol bisected the half shadow when the halves of the field were matched. In general the intensities of the light emerging from the large and small nicols of a Lippich system are unequal. Hence when the analyzer is set for a match its position is different from what it would have been had the beams been of equal intensity. The angular difference, δ, between the two positions of the analyzer was found by Bates [12] to be

$$\delta = \tan^{-1}\left(\tan^3\frac{\alpha}{2}\right) + 0.0103\alpha \qquad (6)$$

It is thus evident that if the vibration plane of the analyzer always bisects the half shadow of the zero of the instrument will be in error by the angle δ, and the amount of the error depends on the half shadow α. The zero error δ is much smaller and much more nearly linear with α than had been suspected, so that in order to have a negligible change in the zero point as the half shadow is varied it should be necessary to make only a slight modification of the ideal gear ratio in which the analyzing nicol always turns through one-half the rotation of the large nicol of the Lippich polarizer.

(*a*) ADJUSTABLE SENSIBILITY

The instrument shown in Fig. 3 was designed at the Bureau of Standards in 1907 to fulfill the theoretical conditions mentioned above, and is one of a number built for the Bureau and the United States Customs Service. It was constructed by the firm of Messrs. Josef & Jan Frič, Prague, and has been brought to a high degree of perfection. It is double quartz-wedge compensating and has a Lippich polarizing system with the highest grade of nicol prisms. The adjustable sensibility is attained by a simple mechanism which acts to maintain the analyzer in the proper position to keep

[12] Bull. B. S., 4, pp. 461–466, and 5, pp. 193–198.

the two halves of the field at equal intensities, no matter how the half shadow may be varied to suit the pleasure of the observer. In order to accomplish this the vibration plane of the analyzer is constantly maintained at the angle δ to a line bisecting the half shadow. A constant match of the field results. Messrs. Frič have succeeded in doing this to such a degree of perfection that there is no observable change in the zero point for a half shadow range of 2°.5 to 15°. The analyzing nicol and the large nicol of the polarizing system are mounted in bearings and driven by gears from the common horizontal connecting rod shown in the figure. The half shadow is varied by turning the milled head on the end of this rod. The angle of the half shadow is indicated on an engraved dial 3 cm in diameter in constant view of the operator.

Another important improvement [13] has been made in the location of the milled heads which move the quartz wedges. Heretofore polariscope builders have mounted these heads on the ends of vertical rods, thereby forcing the hand and arm of the observer into a cramped and unnatural position while making the setting. It will be observed that the milled heads are at right angles to the customary position, thereby overcoming this objection. The wedges can be instantly clamped rigid at any position of the scale.

Both the right and left rotating wedges are of unusual length, reading from $\pm 5°$ sugar to $\mp 105°$ sugar. Their scales are the regulation type ordinarily used on Frič saccharimeters. The scale now used by manufacturers generally is of metal and read by reflected light. Owing to the shortness of the wedge the reading is necessarily made by means of a magnifying telescope. A heavy black line thus separates the vernier and the scale proper. Owing to the fact that the eye must bridge this line and that the edges of the rulings are not sharp, interpolation of the vernier to hundredths is impossible, and in many cases it is very easy to make an error of 0.1° sugar. The Frič scale, which has been in use for some years, is made with the lines etched on ground glass, which permits of very sharp rulings. What is of even greater advantage, it is read by transmitted light, the black dividing line between the vernier and the scale being thus eliminated. Not only is this scale much easier on the eye of the observer, but it also permits of reading accurately to 0.01° sugar. It is illuminated by waste light collected by a 45° mirror, located in front of the polarizing system. Thus it is not necessary to have any

[13] Bates: Bull. B. S., 4, pp. 461–466, and 5, pp. 193–198; Reprints 86 and 98.

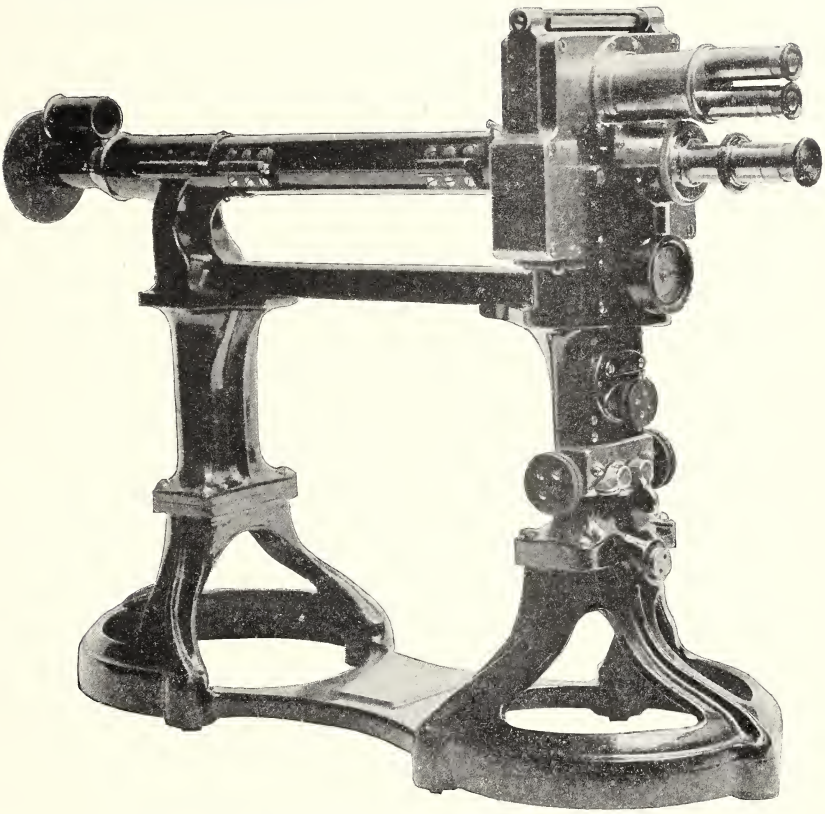

FIG. 3.—*Quartz-wedge polariscope with adjustable sensibility*

extraneous light in the room, as all the light used enters the instrument through the collecting lens in the end of the tube. In investigations utilizing the saccharimeter, where temperature corrections are to be made, it is necessary to know accurately the temperature of the quartz wedges. Polariscope builders do not generally make provision for this. A thermometer (10°–40° C, in one-fifth degrees) with a horizontal scale and with its bulb between the quartz wedges has accordingly been mounted in a brass case on top of the metal box containing the compensator. For all ordinary sugar testing, where the temperature of the room changes slowly, the reading of the thermometer is practically the temperature of the room. The observer is thus able to take the temperature with the same facility that he reads the scale on his wedge, since the thermometer scale is in a similar position and is illuminated by the same light source.

When a tube of liquid is placed in a polariscope, there is always present a certain amount of haziness which seems to overlie the field of view. It is due to depolarized light and interferes with the focusing and the accurate matching of the halves of the field. This has been practically eliminated by proper diaphragming. When a tube is placed in the instrument, the observer sees a clear, sharply defined circular field with no extraneous light. The observing as well as the two reading telescopes for the scale have screw adjustments which permit of accurate and rapid focusing. Another minor improvement has resulted from making the base of the instrument exceptionally heavy and mounting it on rubber tips. The resulting inertia of the instrument and friction on its supporting bench prevent accidental shifting with reference to the light source.

A twofold object has been kept constantly in view in designing this instrument. The first has been to produce a saccharimeter of great flexibility for regular commercial testing and to correct the defects of the ordinary instrument. The second has been to provide the chemist with a white-light instrument suitable for research work. The result has been the production of an instrument of a greater range of adaptability than any polariscope heretofore built. In measuring rotations with the greatest possible accuracy, or when it is desired to make the settings with the least possible strain on the eye, the observer has only to change the half-shadow angle until he has just sufficient light to bring the two halves of the field to the same intensity. He then has for

his eye an instrument so adjusted as to give the maximum sensibility for making the setting, no matter what the character of the substance whose rotation is being measured.

(*b*) BASIS OF CALIBRATION

The specifications defining the 100° point of saccharimeters have been changed many times since Ventzke defined the normal sugar solution in 1842. At the present time there are three sugar scales in common use—the French scale, the German or Ventzke scale, and the scale agreed upon by the international committee for unifying methods of sugar analysis (International Sugar Commission).

(1) **French Scale.**—On the French sugar scale the 100° point is fixed by the rotation, for sodium light, of a control plate of right-handed quartz 1 mm in thickness, with its faces perpendicular to the optic axis. The normal sugar solution is, then, obviously that solution which contains the proper weight of sucrose in 100 cc to give a rotation, in a 200-mm tube, equal to that of the 1-mm quartz plate. Here, as in all polarimetric measurements made at an early date, we find a marked difference in the results of various investigators. The values for the rotation of the quartz plate vary from 20°.98 to 22°.67. In 1895 E. Gumlich,[14] of the Physikalisch-Technischen Reichsanstalt, made a very careful determination of the rotation of the quartz plate with the following result: Pure sodium light is rotated by a quartz plate 1 mm in thickness at a temperature of 20°, 21°.718 ± 0.0005. This value has been generally accepted. Subsequent determinations of this important constant by other investigators seem to indicate a slightly higher value, namely, 21°.723. The grams of sucrose necessary to give the same rotation in 100 cc as the 1-mm quartz plate have also varied.[15] Over 20 different values have been assigned to this quantity, the amounts ranging from 16.0 g (Dubrunfaut) to 16.471 g (Clerget and Biot). The old normal weight established for French instruments was 16.35 g, and this weight is still largely used in technical work with the Soleil-Duboscq saccharimeter. In 1875 the value of Girard and de Luynes, 16.19 g, was adopted as the official weight and remained such for more than 20 years. In 1896 the International Congress of Applied Chemistry at Paris established the value of 16.29 g sucrose dissolved at 20° C in 100 metric cc, and this is the official weight used at present by the French Ministry of Finance.

[14] Zs. für Instrk., 1896, p. 97.

[15] Browne: Handbook of Sugar Analysis, p. 112.

(2) **German or Ventzke Scale.**—Ventzke, in 1842, proposed a method for preparing the normal sugar scale which would make the use of a balance unnecessary. He determined that the normal sugar solution should have a density of 1.100 at 17°.5 C referred to water at 17°.5 C. The 100° point of many saccharimeters was fixed by the use of this solution. However, it was soon found that the standardization effected by this means was unsatisfactory when the instrument was placed in use. Accordingly 26.048 g, the weight of sucrose in 100 cc of Ventzke's solution, was taken as the normal weight and the specific gravity method abandoned. It is thus entirely reasonable to suppose that many of the old instruments were made for use with a weight of 26.048 g in 100 cc. When the Mohr sugar flask came into general use in 1855, polariscope builders began determining the 100° point by the use of this flask and the normal weight 26.048 g. This was an entirely new basis, as 100 Mohr cc = 100.234 cc. Most of the saccharimeters in use to-day have their 100° points determined on this basis, which may be more fully stated as follows:

The 100° point is determined by polarizing, in a 200-mm tube, a solution containing 26.048 g of sucrose, weighed in air with brass weights, in 100 Mohr cc at 17°.5 C, the temperature of the quartz wedges, as well as the polarization temperature, being 17°.5 C. From 1855 to 1900 practically all saccharimeters except those using the French scale had their 100° points determined on the basis given by this last definition of the Ventzke scale.

(3) **International Scale.**—The Ventzke scale, although in general use, has never been fully understood by polariscopists generally. This has led to much confusion and to the use of 100-cc flasks on instruments standardized for use with the Mohr flask. In addition 17°.5 C is well below the temperature of the average laboratory. Because of these and other considerations the International Sugar Commission at the Paris meeting in 1900 recommended the use of a new definition of the 100° point based upon true cc and a standard temperature of 20° C. Owing to the absence of a more suitable term and in order to divorce it as completely as possible from confusion with the Ventzke scale, the new scale will be referred to as the international sugar scale because of its origin. The change to 20° C necessitated a change in the normal weight in order to keep the new scale comparable with the Ventzke. Correcting for the change in the specific rotation (−0.000184), the expansion of a glass tube (+0.000008),

quartz wedge (−0.000130), and metal scale (−0.000018), the new weight becomes 26.000+ g. The international sugar scale was then defined at the Paris meeting as follows: The graduation of the saccharimeter shall be made at 20° C, 26 g of sucrose dissolved in water and the volume made up to 100 metric cc. All weighings are to be made in air with brass weights, the completion of the volume and the polarization are to be made at 20° C. This will determine the 100° point.

The advantages of the new scale were at once appreciated. It has been adopted by the United States Bureau of Standards, the United States Treasury Department, the Physikalish-Technische Reichsanstalt, the Institut für Zucker-Industrie, and also by the makers of saccharimeters. All saccharimeters and quartz control plates sent to this Bureau for test will, unless requested to the contrary, be standardized according to the international sugar scale for a white-light source filtered through a 15-mm layer of a 6 per cent solution of potassium bichromate.

(4) **Conversion Factors.**—In order that comparisons may be made between the readings of different scales it is necessary to know the conversion factors. A number of these have been collected by Browne [16] into a convenient table.

TABLE 2

Saccharimeter-Scale Conversion Factors

Scale	Equivalent
1° International sugar scale	0°.34620 angular rotation D
1° angular rotation D	2°.8885 International sugar scale
1° French sugar scale	0°.21666 angular rotation D
1° angular rotation D	4°.61553 French sugar scale
1° French sugar scale	0°.62516 International sugar scale
1° International sugar scale	1°.59960 French sugar scale
1° Wild sugar scale	0°.13284 angular rotation D
1° angular rotation D	7°.52814 Wild sugar scale
1° Wild sugar scale	0°.38329 International sugar scale
1° International sugar scale	2°.60903 Wild sugar scale
1° Wild sugar scale	0°.61313 French sugar scale
1° French sugar scale	1°.63098 Wild sugar scale

(Normal weight=26.00 g International scale; 16.29 g French scale; 10.00 g Wild scale.)

The international sugar scale is employed upon the Schmidt and Haensch, Peters, and Frič saccharimeters. The French sugar scale is employed upon the Laurent-Jobin and Duboscq-Pellin saccharimeters.

[16] Browne's Handbook of Sugar Analysis, p. 145.

2. LIGHT SOURCES

It has been most unfortunate in the development of saccharimetry that careful consideration has not been given earlier to the question of suitable light sources and particularly to the influence of the source on the saccharimeter reading. Manufacturers have neglected to specify the character of source for which the scales of their instruments were constructed; and it has been common practice among the users of saccharimeters to employ whatever source happened to be most convenient without consideration of its effect on the reading.

(a) BICHROMATE ABSORPTION CELL

Owing to the fact that the rotation dispersion curves of optically active substances are not identical, the quartz wedge does not completely return the polarization planes of all waves to their original positions after they have been rotated by the substance being tested. In the case of a solution of sugar the dispersion is nearly the same as that of quartz, but the divergence is sufficient to cause the halves of the field to appear of different tints. The field must appear uniform in color if the readings by different observers are to agree. Obviously the same instrument will also give different readings with different sources inasmuch as the luminosity curves of the sources are different. In testing sugar the field may be made almost uniform in color for all sources of ordinary intensity by placing a cell of potassium-bichromate solution between the polarizing system and the lamp. This eliminates by absorption most of the shorter waves from the visible spectrum.[17] Some saccharimeters are provided with a cell, fitted in the metal tube which houses the polarizing system, for containing the absorbing solution. Owing to their small diameter this Bureau has not found these cells satisfactory. Better results have been obtained by using a cell with a diameter of 40 or 50 mm placed in front of the saccharimeter. Any thickness may be used. The optical path in the bichromate solution should, however, always be equivalent to a layer of liquid 15 mm thick for a 6 per cent solution. If the cell is not 15 mm in thickness the concentration of the solution must be changed accordingly. A simple rule is always to have the product of the thickness in millimeters and the per cent concentration equal to 90.

[17] See p. 164 for additional matter on this subject.

Owing to the fact that the bichromate absorption cell is indispensable when a white-light source is used and that a suitable and convenient form has not been available, the type[18] shown in Fig. 4 has been designed at this Bureau especially for saccharimetric use. The cell is entirely of glass with an inner separation of the plate-glass walls of 15 mm. It is mounted in a metal frame carried on the stand *F*. The height is adjustable with ample range to fit any saccharimeter. To utilize the filter it is only necessary to fill the cell with a 6 per cent solution of $K_2Cr_2O_7$ and place it between the light source and the polarizer, preferably as close to the latter as possible.

(*b*) INFLUENCE ON READING

In 1904 Schönrock[19] made an investigation of the effect of different sources on the saccharimeter reading. His results are summarized in Table 3.

TABLE 3

Effect of Light Sources on the 100° S Point

Light source	Purification	Optical center of gravity in mμ	Saccharimeter reading
White light	Bichromate solution	About 600	100.00
Sodium	Dispersion by prism	589.3	100.03
Do	Bichromate solution	589.3	100.03
White light	None	About 551	100.12
"Yellow-green" mercury line	Dispersion by prism	546.1	100.15
Electric	Color-glass 436[III]	About 520	100.224

The above data was obtained with uncolored sugar solutions. It will be observed that with a white-light source the presence of the bichromate absorbing solution makes a difference of 0°.12 in the saccharimeter reading. It thus becomes important that the instrument be used under the same conditions as prevailed at the time it was standardized. If, as is usually the case, a quartz control plate is used, the plate should be read in the instrument under the same conditions as prevailed when the plate was standardized.

(*c*) TYPES OF LAMPS

(1) **Monochromatic.**—Many different types of lamps designed for use with the saccharimeter have been brought out. They may be divided into two classes—those giving a monochromatic or

[18] Manufactured by Bausch & Lomb, Rochester, N. Y. [19] Z. Ver. Deut. Zuckerind., pp. 521–558.

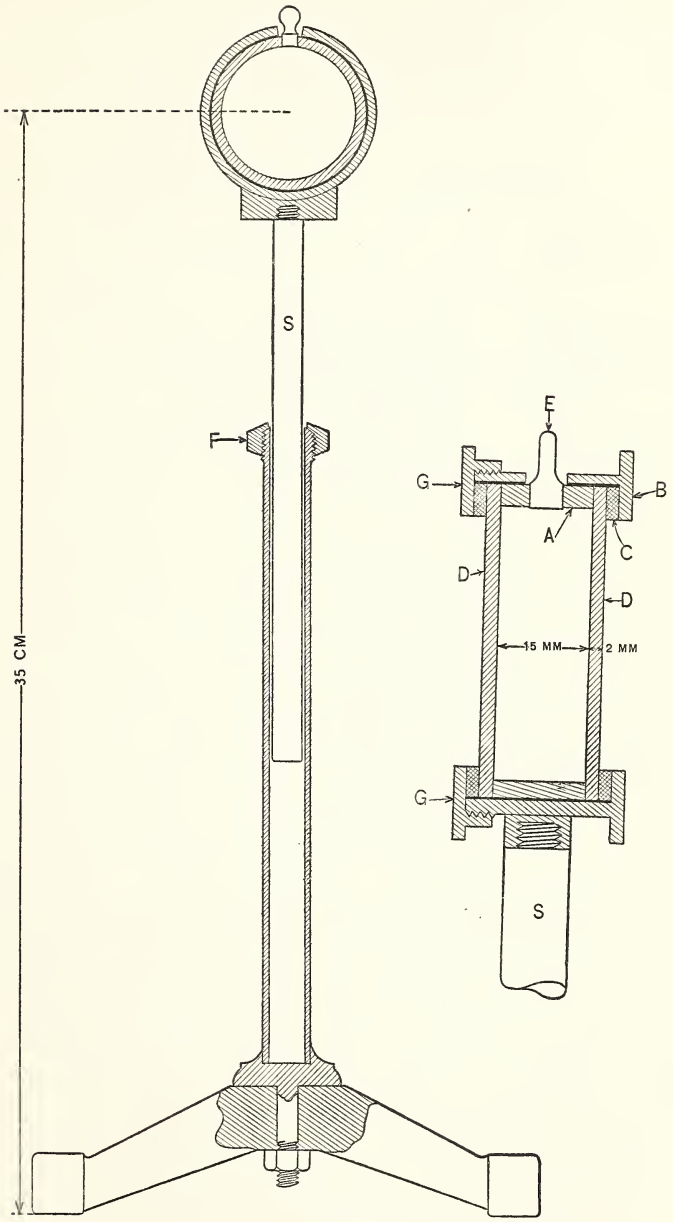

FIG. 4.—*Absorption cell*

nearly monochromatic light and those giving a white light. In the first class only the sodium flame and the yellow-green mercury line ($\lambda = 546.1 m\mu$) have been utilized to any extent.

Sodium.—The sodium sources have been summarized by Landolt in Table 4.

TABLE 4

Optical Center of Gravity of Sodium Light Sources

Source of light	Purification	Effective wave length
		mμ
Bunsen flame with NaBr	10-cm layer of 9 per cent $K_2Cr_2O_7$ in water	592.04
Bunsen flame with NaCl	10-cm layer of 9 per cent $K_2Cr_2O_7$ in water	589.48
Burner with NaCl or NaBr	Lippich filter $K_2Cr_2O_7$ and $U(SO_4)_2$	589.32
Sodium	Prism purifications lines D_1 and D_2 only	589.25
Landolt lamp with NaCl	1.5-cm layer of 6 per cent $K_2Cr_2O_7$ in water	588.94
Bunsen flame with NaCl	10-cm layer of 9 per cent $K_2Cr_2O_7$ in water and 1-cm layer of 13.6 per cent $CuCl_2$ in water	588.91
Landolt lamp with NaCl	Unpurified	588.06

The various types of sodium lamps have been designed to give the greatest possible intensity consistent with a minimum of attention. In the Pribram[20] lamp fused salt in platinum boats is exposed to a Bunsen flame. When the supply in one boat is exhausted, the boat is withdrawn and a second containing a fresh supply is instantly introduced into the flame. Fairly constant illumination is obtained for a long time. In the Schmidt & Haensch lamp fine platinum wires are bent into a spoon, the melted salt being drawn up to the point by capillarity to the hottest portion of the flame. In the Landolt [21] type a Muencke burner (Bunsen lamp with conical wire-gauze top and sufficiently strong air supply to cause the inner dark cone of the flame to disappear) is used. Exposed to the flame are two heavy nickel wires around the middle of which nickel gauze is wrapped. The gauze is charged by immersing in melted salt. An intense flame is obtained. The Zeiss lamp is a simple and convenient type. Pumice stone saturated with salt is exposed to a Bunsen flame. The position of the pumice stone with respect to the flame is important and is easily controlled by means of a thumbscrew. For a very intense sodium flame the method of molded sticks of fused sodium carbonate described earlier in this circular is the best.

[20] Zs. anal. Chem., 34, p. 166; 1895.

[21] Zs. für Instrk., 4, p. 390; 1884.

Mercury.—For the production of the so-called yellow-green line of mercury ($\lambda = 546.1 m\mu$) several types of lamps are available. In all of them advantage is taken of the fact that mercury vapor heated to incandescence by an electric current in a vacuum gives the intense line spectrum previously described. Some type of optical dispersion system must be resorted to in order to separate the desired line. The Arons[22]-Lummer[23] type is perhaps the most well known. The mercury is housed in a water-cooled glass vessel. About 60 volts are necessary for satisfactory operation. At this Bureau the fused silica mercury lamps of Heraeus are used. They may be obtained in almost any desired shape. Owing to the relatively high melting point of fused quartz, they can be safely operated at high intensities without water cooling. When it is desired to work at very high intensities, a copious current of cold air is blown over the lamp. *Great care must be exercised not to permit the radiation from these lamps to enter the eyes without first passing through glass.*

(2) **White Light**—*Gas.*—A considerable variety of lamps suitable for white-light sources is available. They are practically all designed either for gas or for electricity. Most of the gas lamps utilize the Welsbach mantle, which is the source most generally used in saccharimetry. The light is convenient, has considerable intensity, and the radiating surface has a nearly uniform intensity over a sufficiently large area. A ground-glass screen may be used close to the mantle if desired, and is necessary if the lamp can not be so placed as to eliminate a mottled appearance of the field when the telescope is in focus for the analyzer diaphragm.

Electric.—The available electric lamps are of three types—the incandescent lamp for 110 volts, the small straight filament for 6 volts, and the Nernst lamp for 110 or 220 volts. A ground-glass disk, which becomes the new source of radiation, must be used with all three types, and is preferably located as near the radiating surface as the temperature will permit. In Fig. 5 is shown an electric lamp developed at this Bureau.[24] The spiral-filament incandescent stereopticon lamp for 110 volts is used. The candlepower is over 100. The area illuminated is ample for the purpose, and the intensity is sufficient. Convenience has been the chief consideration in the design. The base is

[22] Wied. Ann., 47, p. 767; 1892.
[23] Zs. für Instrk., 15, p. 294; 1895.
[24] Manufactured by Bausch & Lomb, Rochester, N. Y

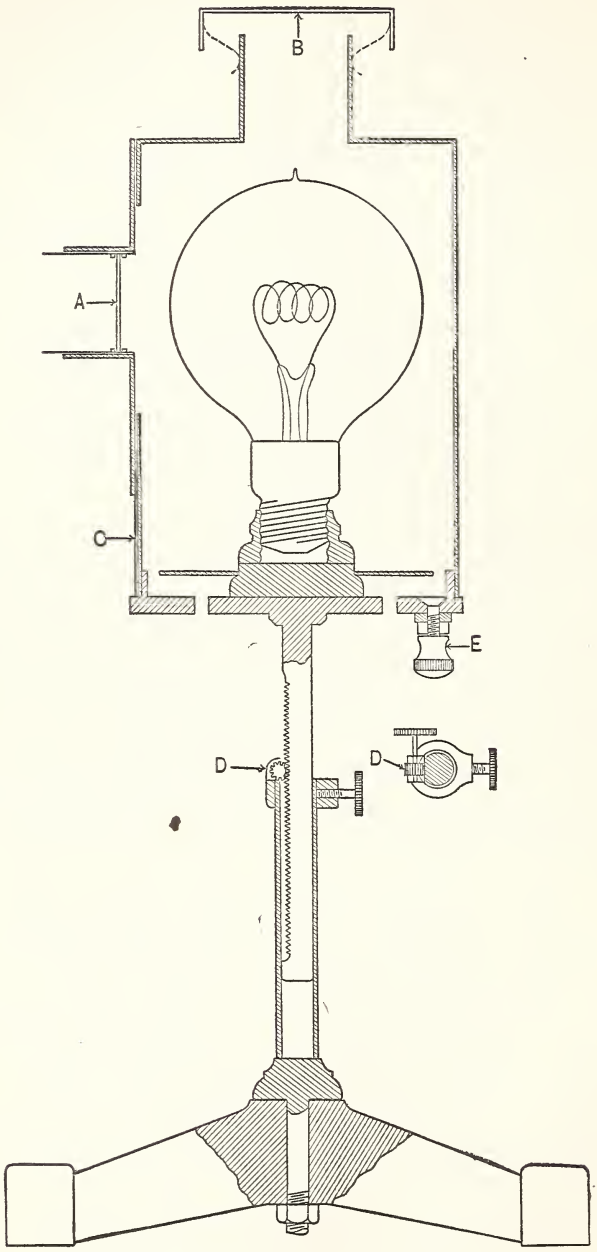

FIG. 5.—*Electric light source for saccharimeters*

heavy. The ground-glass disk, *A*, 38 mm in diameter, is easily removable and is adjustable vertically with respect to the body *C*. Thus the spiral filament and the disk are kept centered, giving uniform illumination of the disk. The cap *B* permits the heat to pass off but no light to escape into the room. The height of the lamp is regulated by the rack and pinion *D*. The center of the disk can thus be accurately set in the axis of the optical system of the saccharimeter. The electrical connection is made at the binding posts *E*. This lamp has proved very satisfactory. The firm of Schmidt & Haensch have taken advantage of the small size of the 6-volt lamp to mount it in an attachment which fits the metal housing containing the polarizing system of their saccharimeter. The heat developed so near the optical parts is objectionable. The illumination is only fairly satisfactory when the lamp is new, and the efficiency in most cases decreases rapidly with use. The best results are secured with a storage battery to supply the current.

The Nernst glower has been utilized at the Bureau of Standards for some years. It is a very intense source, but difficult to handle. Recently an automatic Nernst projection lamp has been brought out abroad and utilized by the Bureau as a saccharimeter source. The burner carries three large Nernst glowers which require 4 amperes. At 110 volts the candlepower is 500 and at 220 volts 1000. This lamp is not recommended except for special work.

3. QUARTZ CONTROL PLATES

(See Fee Schedule 44)

Quartz control plates will be accepted by the Bureau for standardization with reference to the sugar value. The conditions as to character of mounting, purity of the quartz, etc., given on page 20 are equally applicable here. In standardizing the procedure is to measure the absolute rotation in circular degrees at 20° C on a large precision polariscope, monochromatic light ($\lambda = 546.1 m\mu$) being used. This can be done with great accuracy. The value so obtained is divided by a conversion factor, which gives the value of the plate in sugar degrees for the international sugar scale. The checking of a control plate or the scale of a saccharimeter by the use of the standard sugar solution is a difficult measurement. It is never used at this Bureau except in fundamental determinations. The scales of saccharimeters are checked with quartz plates, which are primary standards. Yet

even the values of these plates depend on the conversion factor. For the old German or Ventzke sugar scale the value accepted was:

100° Ventzke = 34.68 circular degrees for sodium light at 17°.5 C (7)

The value at 20° C was 34°.69.

When the international sugar scale was established, Herzfeld and Schönrock [25] redetermined the conversion factor. This factor is not the rotation in circular degrees of the normal sugar solution. It is the rotation in circular degrees of the normal quartz control plate—that is to say, the rotation of a plate which reads 100° on a saccharimeter whose 100° point has been located by the use of a normal sugar solution at 20° C—and a white-light source with a bichromate filter. Herzfeld determined the sugar values of a set of 10 control plates. Schönrock measured the rotation of these plates in circular degrees, from which he found

100° int. sugar scale = 34.657 [26] circular degrees for sodium light at 20° C (8)

This value is used by the Bureau in all standardizations of saccharimeters and plates unless requested to the contrary. Apparatus so tested should be used with a white-light source and the bichromate absorbing solution. In this connection attention is directed to the fact that the importance of maintaining all standardizing bureaus on the same basis of standardization can not be over emphasized.

[25] Zs. Ver. deut. Zuckerind. 54, pp. 521–558.

[26] This value has been superseded by 34°.620. See Appendix, p. 161.

IV. TEMPERATURE CORRECTIONS AND CONTROL

1. QUARTZ-WEDGE SACCHARIMETERS

The question of temperature corrections for polarimetric apparatus, as well as for the optically active substances, is a difficult one. The literature on this subject is extensive, but it has not always been a simple matter to select the proper correction owing to the different results secured by various investigators. For the ordinary polarimeter used for measuring absolute rotations no instrument correction is necessary. It may be used at any temperature if care is taken to allow for any zero-point shift that may occur. However, a correction is unavoidable for saccharimeters in which a quartz wedge is used to neutralize the rotation of the substance being tested.

The rotation for quartz in the neighborhood of 20° C is given by the following:

$$\alpha_t^D = \alpha_{20}^D + \alpha_{20}^D \, 0.000143 \, (t-20) \qquad (9)$$

and since the linear coefficient of expansion of quartz parallel to the optic axis is approximately 0.000007 we have 0.000136 as the specific rotation coefficient. The linear coefficient of expansion perpendicular to the optic axis is 0.000013 and for the so-called nickelin scale on the wedge 0.000018. Thus, the total temperature coefficient [27] for the ordinary quartz-wedge saccharimeter is

$$0.000136 + 0.000007 - 0.000013 + 0.000018 = 0.000148 \qquad (10)$$

If the scales are etched on the wedges the scale coefficient becomes zero, and if the scale be of glass we substitute 0.000008 for 0.000018. Since the effect of the expansion coefficient 0.000148 is to lower the reading of the scale with an increase of temperature, the apparent polarization of any substance is lower than it should be and the reading at 20° (S_{20}) is given by the following:

$$S_{20} = S_t + S_t \, 0.000148 \, (t-20) \qquad (11)$$

When a quartz control plate is read in a saccharimeter this effect is not completely compensated. The temperature coefficient of

[27] Schönrock: Z. Ver. deut. Zuckerind., 54, p. 521.

the plate is obviously $0.000136+0.000007=0.000143$. The reading ($S_{20}$) of the plate is then

$$T_{20}=T_t+T_t\ 0.000005\ (t-20) \tag{12}$$

The correction given by (12) changes sign if the scale be of glass and is so small at all times as to be negligible in ordinary polarizations.

2. SUGARS

(a) SUCROSE

The influence of temperature on the specific rotation of sucrose has been studied by numerous investigators, of whom Dubrunfaut [28] was the first to discover that the constant decreased with increase in temperature. Unfortunately subsequent determinations of this variation have not shown satisfactory agreement.

In 1896 Schönrock at the Reichsanstalt carried out an elaborate investigation and found for the specific rotation

$$[\alpha]_D^t=[\alpha]_D^{20}-[\alpha]_D^{20}\ 0.000217\ (t-20) \tag{13}$$

Later he found that for the normal sugar solution ($p=23.701$) the temperature coefficient was independent of the wave length of the light used, but that it decreased with increase in temperature as follows:

10° C, 0.000242; 20° C, 0.000184; 30° C, 0.000121.

If a proper temperature correction is to be applied to a polarization, it is necessary to add algebraically all the corrections applicable to the conditions under which the polarization is being made. In the ordinary testing of sucrose the solution is made up to volume and read at the same temperature, which in general is not the standardization temperature. It is desirable, therefore, to know the variation in the saccharimeter reading of a near normal sucrose solution per 1° C. The results of different investigators are given in the following table:

TABLE 5

Saccharimeter Temperature Coefficient for Sucrose

Andrews	0.0300	Watts and Tempany	0.0310
U. S. Coast and Geodetic Survey	.0293	Average	.0303
Wiley	.0314		
Geerligs	.0300		

By a summation of the best known values of the separate coefficients which enter into this constant we obtain the value

[28] Ann. Chim. phys. (3), 18, p. 201.

0.0348, which, compared with 0.0303, is reasonably close. The value varies slightly for individual instruments. The polarization in sugar degrees at 20° C $(S)_{20}$ of an approximately normal solution of sucrose made up and polarized at the same temperature (t°C) is given by the following:

$$V_{20} = V_t + V_t \, 0.0003 \, (t - 20) \qquad (14)$$

Equation (14) is sufficiently accurate for all ordinary polarizations irrespective of type of tube or scale.

If the solution be made up to volume at 20°, but is polarized at another temperature, all apparatus being at that temperature, (14) is no longer applicable. Under these conditions the temperature coefficient of the normal sucrose solution alone is given by Schönrock as 0.000469, while that of the saccharimeter, as previously shown, is 0.000148. If a glass tube be used we have as the total temperature correction

$$0.000469 - 0.000008 + 0.000148 = 0.000609 \qquad (15)$$

The polarization in sugar degrees at 20° C (S_{20}) of the near normal solution of sucrose is therefore given by (16).

$$W_{20} = W_t + W_t \, 0.000609 \, (t - 20) \qquad (16)$$

Equation (16) obviously holds only while the number of grams of sugar in 100 g of the solution remains unchanged.

(*b*) MIXTURES

The coefficient 0.0003, in equation (14), having been determined for the normal weight of sucrose should be applied with considerable care. It has, however, long been a widespread practice to apply it to all sorts of saccharine products, with the result that a polarization, supposedly accurate, may contain errors of appreciable magnitude. If the solution does not read approximately 100° *S*, the correction to give the reading at 20° C should not be obtained by multiplying 0.03 by the difference in temperature—a common practice. In general no great error will be introduced by following this procedure provided the polarization is above 85° *S*. Nevertheless, the better and safer practice is to solve equation (14), thereby correcting for the difference in sucrose concentration from the normal solution.

An even more widespread practice has been to apply (14) to sugar polarizations without regard to the associated impurities. This

is particularly true of raw sugars and molasses which contain appreciable quantities of invert sugar. Of the constituents of invert sugar, the dextrose has a negligible temperature coefficient, while the levulose has a very large coefficient, and in such a direction that the positive rotation of the mixture tends to increase upon elevation of temperature.

It is therefore manifestly erroneous to apply a pure sucrose temperature coefficient to a mixture unless all the substances, except sucrose, are present only in such small quantities that the error introduced is negligible.

For the temperature correction of the better grades of raw sugar the temperature formulas (14) and (16) give results which are sufficiently accurate, but if they are applied to low-grade products errors are introduced. Raw sugars may be considered as mixtures of pure sucrose and cane molasses. To correct the whole mixture for the effect of temperature change, it would be necessary to apply the resultant coefficient obtained by combining the two separate values, taking into consideration the relative quantities of the two and the constitution of the particular molasses which contaminates the sample. Dr. C. A. Browne [29] has done this and shows that the temperature coefficient varies in almost direct proportion to the content of molasses. It is in general incorrect to apply this computed correction because of possible individual variation in the constitution of the molasses. Accordingly Browne advises the omission of the temperature correction for low-grade samples. He has computed an average coefficient for large numbers of samples of raw sugar which may be determined according to the polarization. Thus, for cane products the coefficient is 0.0015. It is seen from this that at 80° the coefficient becomes zero and for lower grades it becomes positive instead of negative. If individual variations did not occur this correction would be a useful one, but as it stands it merely serves to show the possible error of applying equation (13) to low-grade sugar. For beet products the coefficient is 0.0006.

3. THERMOSTATS

(*a*) WATER

The satisfactory control of temperature in polarimetric work is an important and troublesome subject. In general two types of thermostats have been found sufficient at this Bureau for

[29] J. Ind. Eng. Chem., 1, p. 567.

saccharimeter work, including most research problems. For accurately making up solutions to volume at a desired temperature a water thermostat is used which gives extremely close regulation. It consists of a cylindrical vessel about 40 cm high and 50 cm in diameter nearly filled with water. A copper coil through which ice water flows is placed in the bottom and serves to cool the bath, if necessary, to a fraction of a degree below the desired temperature. The flow of ice water is regulated closely by means of a long arm stopcock. A coil of fine enameled wire, carrying a small current at low voltage, is immersed in the water near the sides of the vessel and serves to raise the temperature to the proper degree. When this point is reached a mercury contact operated by a toluene coil, also immersed in the water, closes a relay circuit and throws the current off the heater. A small fan near the bottom of the bath keeps the water in constant motion, insuring an even temperature throughout. A perforated metal shelf serves to hold the flasks, the perforations allowing free circulation of the water. The temperature is read from an accurately standardized thermometer immersed in the bath. Electrolysis is minimized by using alternating current. On account of the high specific heat of water and the very narrow limits of temperature for which the heater was designed the inertia of the system is made very small, the maximum variation of the temperature from 20° C being not more than 0.01° C.

(*b*) AIR

For controlling the temperature at which the polarizations are made a thermostat of relatively liberal dimensions and with a wide range of control is utilized. The dimensions of the room are as follows: Height, 2.5 m; width, 2 m; length, 2.5 m. The walls are made double in order to minimize conduction of heat to or from the outer room.

The temperature is controlled by means of a brine coil and an electric heater. The latter consists of iron wires wound upon a porcelain-insulated frame. It is suspended just below a false ceiling, and the flow of current is controlled by means of a mercury contact, actuated by the change in volume, with the temperature, of kerosene contained in a small copper tube. This tube is wound about the room some distance away from the walls. The brine coil is contained in a small closet, which has an opening at the bottom and one at the top. A fan draws the warm air in at the bottom and forces the cold air out above the false ceiling, which

is full of holes. This false ceiling insures an even distribution of the cold air throughout the whole room.

The operation is as follows: The fan is started, which forces air over the brine coil and out through the holes in the false ceiling into the room. As soon as the temperature sinks slightly below that for which the thermostat has been set, the kerosene, contracting, causes the mercury contact to open the circuit through a small relay; this operates a heavy current relay, which throws the current on the heater and the room begins to warm up. When the desired temperature is reached, the mercury contact closes the relay circuit and throws off the current from the heater. By this means the temperature is kept very nearly constant, the maximum variation at the working level being only about two or three tenths of a degree. Thus, if set for 20° C, the temperature of the air in the room would alternately rise and fall to about 20°.15 and 19°.85, respectively. This variation is caused by the inertia of the system, which is necessarily rather large, the system being designed to operate anywhere between 15° C and 35° C. The heater takes about 7 or 8 amperes at 120 volts. This thermostat is found to be very satisfactory, as it operates indefinitely and requires almost no attention after it has once been adjusted.

The saccharimeters are placed upon a table at a convenient height. One instrument is incased in an asbestos-lined box. This so retards any change of temperature of the instrument that, with the room operating to within two or three tenths of a degree, no change whatever can be noted on the thermometer inside the instrument case after equilibrium has once been reached. The illumination for the instruments is secured by placing suitable light sources (Welsbach mantle, electric-glow lamp, etc.) just outside the room, allowing the light to pass through the wall by way of a small glass window just large enough to cover the end of the polarizer. Incandescent lights for reading the scales, thermometers, etc., are operated by suitable switches placed within convenient reach of the observer.

V. POLARISCOPE TUBES

(See Fee Schedule 44)

1. TYPES

(a) ORDINARY

There are at present available a variety of polariscope observation tubes, each designed to give satisfactory results under certain conditions. In making a selection the user must be guided by his own peculiar needs. In general, all tubes must fulfill three requirements that are essential and which, if not fulfilled by the maker, can not be remedied by the user. They are parallel ends, accurate length, and accurate centering of the axis of the tube with all points of support. The type for ordinary polarizations at temperatures not far removed from 20° C is the simplest and, unfortunately, has received least consideration. Its design should have had careful study, even to the slightest detail. This is essential owing to its widespread and constant use both for scientific and commercial purposes.

It has the same diameter of bore for its entire length and small cover glasses closing its ends. It is generally made entirely of brass, although many are in use in which the body is of glass, to which are cemented metal caps for carrying the cover glasses.

Glass tubes are little used except when polarizing acids or other corrosive liquids. Not only are they easily broken by impact, but the metal end pieces, to which the cap screws, must be mounted with wax. If placed in warm water for cleaning, or even on warm days, the wax softens. The metal tubes have always been constructed from tubing with thin walls which a slight blow is sufficient to bend, thereby causing a change in length and permanently ruining the tube. In the United States customs and many other laboratories it is necessary that a tube be available which will stand the most arduous usage. In addition there are important defects in the design of the ordinary tube. Some effort has been made to partially overcome several of these defects, but only in glass, a material which for reasons previously stated can not be satisfactorily used. The diameter of the bore has been too small. The diaphragming in the modern saccharimeter is designed to give the highest possible illumination of the field. To

utilize this, as well as eliminate the undesirable "halo" incidental to the ordinary tube, it is necessary that the bore have a diameter of not less than 9 mm. Considerable time is lost in filling owing to the fact that the tube must be so completely filled that no trace of air remains. Also the weight is carried upon the caps which contain the cover glasses. If the tube be rotated in the trough of the instrument, the caps may be tightened and cause double refraction in the cover glasses, which has the effect of a change in rotation.

(*b*) BATES

In order to overcome the prevalent defects in the theoretical design, as well as to secure a tube suitable for severe usage, this Bureau has brought out the new Bates [30] type of tube shown in Fig. 6. It will be observed that the weight is carried upon two shoulders, which are integral parts of the tube, and not upon the caps, thereby eliminating all danger from turning while in the trough of the instrument. The bore is 9 mm, permitting the utilization of the full aperture of the polarizing system. This also reduces to a minimum the light depolarized by reflection from the walls of the tube. The field of the instrument thus appears for the first time as a bright, sharply defined circle with no overlying haziness, and the reading can be made with increased accuracy. Both ends are enlarged with all the attendant advantages, yet but one size of cover glass and washer is required. The walls are unusually heavy, eliminating all danger from bending.

(*c*) SPECIAL

There are in addition a number of tubes designed for special purposes. The Schmidt and Haensch water-jacketed type permits of holding the solution at a nearly constant temperature. An opening midway between the ends allows a thermometer to be inserted into the solution. Landolt has designed a glass tube with one end enlarged and sliding caps, which fasten with bayonet catches. The Pellet tube has two side openings, permitting of filling and emptying without removing from the saccharimeter. Much time can be saved by this scheme on certain kinds of polarizations where accuracy is not the first consideration. Yoder has produced a so-called volumetric tube. The graduation is marked upon a side connection joined to the middle of the tube. Often when polarizing at temperatures below the dew point the

[30] Manufactured by Bausch & Lomb, Rochester, N. Y.

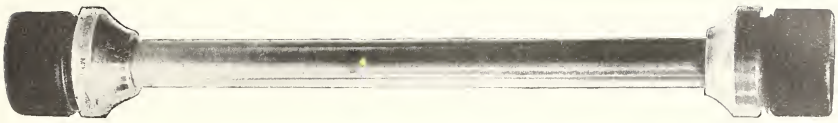

FIG. 6.—*Bates polariscope tube*

FIG. 7.—*Flask for sugar testing*

moisture condenses on the cover glasses. Wiley [31] has overcome this by an ingenious desiccating cap, which carries calcium chloride and screws to the end of the polarization tube.

2. TEMPERATURE CORRECTION

The length of any tube at any temperature is given by the following:

$$L_t = L_{20}[1 + \beta(t° - 20°)] \qquad (17)$$

where L_{20} is the length at 20° C and β is the coefficient of expansion of the material of which the tube is made. For glass $\beta =$ 0.000008, and for brass $\beta = 0.000019$. From (17) for $L_{20} = 200$, $L_{30} = 200.016$ for glass and 200.038 for brass. It is thus evident that the errors resulting from changes in length for tubes from either material are neglible in ordinary use.

3. ACCURACY

All types of tubes are accepted by the Bureau for test. The limit of accuracy, unless by special arrangement, is ± 0.04 mm.

[31] J. Am. Chem. Soc., 18, p. 81.

VI. COVER GLASSES

(See Fee Schedule 44)

Glass which is not free from strain is doubly refractive and on this account can never be used between the polarizing and analyzing systems of a polariscope. It is thus of the greatest importance that cover glasses be thoroughly annealed. A strain in the glass is in effect a rotation. Many baffling differences in polarizations are due to cover-glass strain. There is no infallible method of detecting this trouble after the glass is in use. After a setting has been made, it is a good plan to rotate the tube while in the instrument; if the halves of the field show variations in intensity, strain exists in one or both cover glasses. The only safe procedure is to use tested glasses and as little pressure as possible on the caps. Strains frequently arise from poorly fitting washers. Washers should be made from pure rubber, soft and flexible, and lie flatly and evenly in the cap. Once a glass has been strained it should not be used for two days or longer. All cover glasses must have plane, parallel surfaces, free from scratches and should never be less than 1 mm thick. A thickness of 2 mm is preferable. The Bureau will accept cover glasses for test. The necessity for optically perfect glasses seldom receives the attention its importance demands.

VII. FLASKS[32]

(See Fee Schedule 23)

1. SPECIFICATIONS

(a) MATERIAL AND ANNEALING

The material should be the best quality of glass, transparent, and free from bubbles and striæ. It should have small thermal hysteresis and should adequately resist chemical action. All flasks should be thoroughly annealed before being graduated.

(b) DESIGN

The cross section of the neck must be circular, and the shape of the flask must be such as to admit of complete emptying and drainage from the whole interior surface at the same time. The bottom of the flask should be slightly concave upward, and should be of sufficient size to enable the flask to stand on a surface inclined at an angle of 15 degrees to the horizontal. The neck must be cylindrical for at least 1 cm on each side of every graduation mark, but may be enlarged in the form of a bulb between graduation marks (for example, Giles flasks). At the graduation mark the inside diameters of the neck of the flask must be within the limits given in Table 6.

TABLE 6

Diameters of Necks of Flasks

Capacity of flask (in cc) up to and including	25	50	100	200	250	500	1000	2000	3000	4000	5000	6000
Maximum diameter (in mm)	8	10	12	13	15	18	20	25	30	35	40	45
Minimum diameter (in mm)	6	6	8	9	10	12	14	18	20	22	25	30

(c) GRADUATION MARKS

The graduation marks must be of uniform width, finely but distinctly etched, must be perpendicular to the axis of the flask, and must extend completely around the neck.

On flasks having a capacity of 100 cc or less the graduation mark shall be not less than 3 cm from the upper end nor less than 1 cm from the lower end of the neck, and on flasks having a capacity of more than 100 cc the graduation mark shall be not less than 6 cm from the upper end nor less than 2 cm from the lower end of the neck.

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[32] For further details in regard to volumetric apparatus, see B. S. Circular No. 9.

(*d*) UNIT OF VOLUME

The unit of volume employed is the liter, which is defined as the volume occupied at the temperature of its maximum density (4° C) by a quantity of pure water having a mass of 1 kilogram. The water is under a pressure of 760 mm of mercury, and the weighings are reduced to vacuo. The one-thousandth part of the iter, called the milliliter (ml) or the cubic centimeter (cc), is also employed as the unit of volume.

(*e*) STANDARD TEMPERATURE

Twenty degrees centigrade has been adopted by the Bureau as the standard temperature for volumetric apparatus, and an extra charge is made for testing apparatus graduated for use at other temperatures.

(*f*) INSCRIPTIONS

Each flask must bear, in permanent and legible characters, the capacity in liters or in cubic centimeters, the temperature at which it is to be used, the method of use, i. e., whether to contain or to deliver, and an identification number. In the case of flasks with stoppers the stopper must bear the same number as the flask.

A suitable arrangement of the inscription is as follows:

No. 134
Contains
100 cc
at 20° C

2. TOLERANCES

The tolerances for flasks of various sizes are shown in Table 7.

TABLE 7

Tolerances for Flasks

Capacity less than and including—	Tolerance		Capacity less than and including—	Tolerance	
	If to contain—	If to deliver—		If to contain—	If to deliver—
cc	cc	cc	cc	cc	cc
10	0.01	0.02	1000	0.30	0.50
25	.03	.05	2000	.50	1.00
50	.05	.10	3000	.75	1.50
100	.08	.15	4000	1.0	2.0
200	.10	.20	5000	1.2	2.4
300	.12	.25	6000	1.5	3.0
500	.15	.30			

(*a*) PRECISION STAMPS

Flasks tested by the Bureau of Standards and found to comply with the foregoing specifications will be given the official precision stamp of the Bureau. The stamp consists of the letters "U. S." and the year in which the test is made, surrounded by a circle. Thus, for the year 1914 the stamp will be:

The stamp will be placed on the neck of the flask above the graduation mark.

(*b*) SUGAR TESTING FLASK

The type of flask used in the United States Customs Service is shown in Fig. 7. It is especially designed for sugar polarizations and is described in the Regulations Governing the Weighing, Taring, Sampling, Classification, and Polarization of Imported Sugars and Molasses, 1908, as follows: "The flasks shall have a height of 130 millimeters; the neck shall be 70 millimeters in length and have an internal diameter of not less than 11.5 millimeters and not more than 12.5 millimeters. The upper end of the neck shall be flared, and the graduation marks shall be not less than 30 millimeters from the upper end and 15 millimeters from the lower end of the neck." These flasks are not in accordance with the Bureau of Standards specifications, in that the diameter of the neck allowed is too large. They will not, therefore, be given the precision stamp of the Bureau. But when found to meet the Bureau specifications in other respects they will be stamped with the letters "B. S." and the year in which the test is made. Thus for the year 1914 the stamp will be:

B. S.
1914.

In this type of flask the neck, while smaller than the ordinary 100 cc commercial flask, is made slightly larger than the Bureau requirements for a flask of this size in order that the neck shall not become clogged when the sugar is being introduced into the flask. The upper end is provided with a small lip to facilitate pouring. The height of only 130 mm minimizes the dilution of the solution by drops of water on the upper part of the neck and gives a length which readily permits the flask to be closed with the thumb while the forefinger rests on the bottom, thereby facilitating a thorough mixing by shaking, with no loss by spilling.

(*c*) SPECIAL

Other varieties of flasks designed for special purposes are shown in Fig. 8. Some of these are taken from Browne's Handbook of Sugar Analysis, p. 165.

No. II has low center of gravity insuring greater stability.

Nos. II and III have double graduation marks which are of use for any work where one volume of liquid is diluted to a different volume. This is frequently done in inversion and clarification operations.

No. IV permits the convenient transfer of solid material.

No. V is the diagram of a flask designed at this Bureau for work of high precision. The inside diameter of the graduated neck is 5 or 6 mm. The enlarged portion of the neck has for its purpose the complete mixing of the contents of the flask without the use of

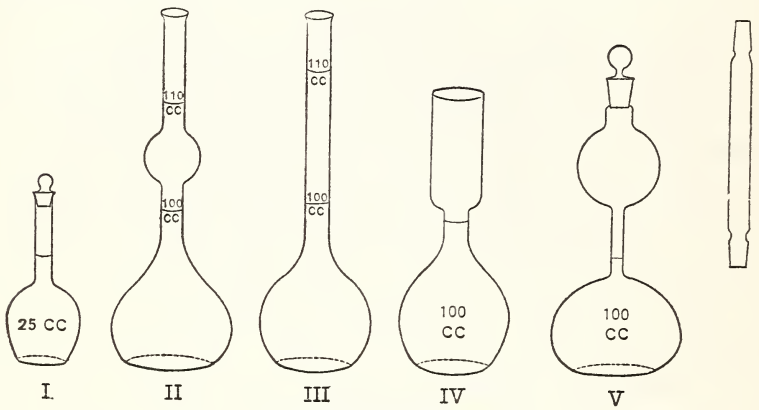

FIG. 8.—*Special flasks*

the thumb or a ground stopper, both of which may prevent small quantities of liquid from mixing with the remainder. Before making to volume this bulb should be dried inside by a current of filtered air. The glass tube fits into the grinding of the flask and enables a transfer from flask to polariscope tube without exposure to the air and a consequent evaporation of the solution. For this purpose the polariscope tube is fitted with a tubulature and grinding. With this apparatus it is possible to calibrate the flask and reproduce the volume of liquid with an accuracy of 0.002 cc.

(*d*) CORRECTION TABLES

Tables 8 and 9, page 127, are given for the convenience of those who wish to verify the graduation of volumetric apparatus. More complete data for this purpose will be found in Bureau Circular No. 19.

VIII. THERMOMETERS[33]

(See Fee Schedule 10)

1. GENERAL

Thermometers should be made of a suitable hard glass having small "zero depression" and small thermal hysteresis. Among the glasses best fulfilling these requirements are 16^{III} Jena normal glass, 59^{III} Jena borosilicate glass, and French hard glass. It is only important that the bulbs of the thermometers be made of a suitable hard glass; for the stem of the thermometers a softer glass with white enamel back may be used. For ordinary laboratory thermometers, when an order of accuracy of 0°.02 or 0°.03 C is sufficient, the stem should be so graduated by the maker that the indications of the thermometer will be in close agreement with the indications of the gas thermometer, which is taken as the standard.

It is highly desirable that the ice point (0° C or 32° F) be found on the scale so that variations in the volume of the bulb can be easily detected and allowed for. The divisions on the stem should be fine and clear, the width of the graduation marks in no case exceeding 0.2 of a scale division, and should be numbered at such frequent intervals and in such a way that identification of any graduation mark is not unnecessarily difficult. Where the thermometers are provided with metal backs which carry a graduation, the stem of the thermometer should nevertheless be graduated. The thermometer should be securely and firmly fastened and should have a fiducial mark on the stem coinciding with a mark on the metal back, so that any relative displacement may be controlled. If the thermometer is of the inclosed-scale (Einschluss) type, such fiducial mark should be found on the outer glass tube inclosing the scale and capillary stem of the thermometer. The bore of the stem and the spacing of the graduation marks should be uniform and free from such irregularities as would produce errors in the indication by amounts exceeding the limits otherwise set by the type of thermometer.

[33] Further details of the construction and precautions in use of mercurial thermometers are given in B. S. Circular No. 8.

2. LABORATORY AND SPECIAL THERMOMETERS

Under this head may be broadly grouped most of the thermometers of the usual types, including secondary, and working standards, whose order of accuracy is 0.01° or 0.02° C, and ordinary thermometers whose order of accuracy is 1 or 2°. Illustrations of special thermometers are maxima and minima thermometers, calorimetric, hypsometric, deep-sea, and other thermometers used for special purposes. For information concerning the testing of high-temperature, industrial, calorimetric, and Beckman thermometers see Bureau of Standards Circular No. 8.

IX. WEIGHTS [34]

1. SUGAR WEIGHTS

It is generally advantageous to have special 26-g or 13-g weights for weighing out sugar samples. For this work the Bureau recommends that the ordinary screw-knob type of weights be avoided in favor of one in which the knob forms an integral part of the weight. Such weights may be strictly one-piece weights or they may have a cavity on the upper side closed by a driven plug or pin of brass or other hard metal. The working standards should conform to the Bureau's requirements for class B. The reference standards (i. e., those used only for checking the working standards) should conform to the requirements for class A. The maximum error allowed in both classes is 2 mg on the 26-g weight and 1.5 mg on the 13-g weight. Class B weights may have the adjusting plug or pin mentioned above, and when tested at this Bureau no corrections will be given, but they will be certified merely as conforming to the requirements of this class. Class A weights must be strictly one-piece weights, and when tested at this Bureau the actual correction will be certified for each weight, and they will be tested for constancy over a period of three months.

2. ANALYTICAL WEIGHTS

A good grade of analytical weights should be accurate enough for this work, but it is not safe to rely on them unless they are tested. For work that requires considerable accuracy in the weighing the weights should conform to the Bureau's requirements for class S. This class includes practically all sets sold as high grade analytical weights, if they are adjusted to the proper degree of accuracy. The maximum errors allowable range from 0.5 mg on the 100-g weight to 0.1 mg on the 1-g weight and 0.02 mg on the 10-mg weight. For less accurate work the weights may have errors from 30 mg on the 100-g weight to 2 mg on the

[34] Full details on classification, requirements, and testing of weights suitable for various purposes are given in Circular No. 3, from which parts of this section are either copied or adapted. This circular may be had on application. In purchasing weights the denominations, the type of weights, and the fact that they must conform to the Bureau's requirements for weights of a certain class are generally the only specifications that are necessary. Manufacturers and dealers are in possession of these requirements or can readily procure them.

1-g weight and 0.15 mg on the 10-mg weight.[35] The list of tolerances is given in Table 10. When weights of either class are tested at this Bureau, the actual correction for each weight will be certified. The use of weights constructed like those recommended for the "sugar weights" would introduce a distinct gain in reliability.

3. REFERENCE STANDARDS

Weights are liable to change. They can not be used without a certain amount of wear, which must ultimately make an appreciable change in their values. Ordinary analytical weights sometimes suffer serious change from the oxidation of adjusting material placed in the cavity under the knob. Weights must therefore be retested from time to time according to the nature of the weights and of the work for which they are used. Reference standards are therefore needed, since it is seldom advisable to send the weights to this Bureau as often as would be needed. There is no gain in the purchase of complete sets for this purpose when this is done at the expense of quality, as must usually be the case. A set of working standards can readily be tested by intercomparison of the weights among themselves if one or two reference standards are available on which to base the calibration. The Bureau will gladly furnish information in regard to series that are much better than the ones generally used and yet involve no great amount of additional labor. Probably the best denominations for reference standards would be one 100-g or 50-g weight, one 1-g weight, one 10-mg weight, one 26-g weight, one 13-g weight. The 1-g weight should be made of platinum, as it is the starting point for the determination of the milligram weights.

For the best reference standards the Bureau recommends one-piece weights. Gold-plated Tobin bronze weights are the most satisfactory ones now available for this purpose for weights above 1 g. Weights having a hard-metal driven plug, as recommended for the working standards for "sugar weights," would rank next. Standards for the analytical sets should conform to the requirements for class S and be tested under that class.[36] Reference standards for the "sugar weights" should come under class A, as stated above.

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[35] See column headed class C.

[36] The same kind of weights, but less accurately adjusted, may be obtained as class A and class B weights. For extreme accuracy (seldom, if ever, needed in weighings for polarimetry), when careful corrections must be made for the buoyant force of the air, only one-piece weights can be relied upon, and the volume of each weight must be determined. This requires that the weights come under class M.

4. CERTIFICATION

Sugar weights and analytical weights are among the weights tested by this Bureau, but the rougher weights are not regularly accepted for test. Corrections will be certified to the degree of precision indicated in Table 10. The corrections for the platinum and aluminum fractions of a gram will be given both on the basis of actual mass and on the basis of their apparent weight in air against brass standards. To assist in the identification of the weights the test number assigned to the weights by the Bureau of Standards will be stamped on the bottom of the box provided for keeping them, thus:

B. S. Test No. 4978

The shipping case or the inner wrappings will always be sealed when tested weights are shipped from the Bureau.

5. PACKING

A great many of the milligram weights that are packed under the glass covers in the regular boxes reach the Bureau bent or otherwise damaged. For this reason greater care should be given to the packing of these weights and sufficient extra packing should be used to hold the glass cover securely in place.

X. OPTICAL ACTIVITY IN ORGANIC COMPOUNDS

The phenomenon of optical activity or the rotation of the plane of polarized light is inherent in many substances. These substances exhibit the property either in the crystalline state with which the cause of the activity is closely connected or while in liquid or dissolved state, in which case the activity is connected with the molecular configuration. This latter class is limited to the carbon compounds.

The advances in stereochemistry show that optical activity occurs when the "asymmetric" carbon atom is present. According to this conception, which was originated by van't Hoff and Le Bel, the four valences of carbon are situated spatially at the four corners of a regular tetrahedron. If these four valences be satisfied by combination with four different radicles or groups of elements, there are found to be two different methods of arrangement which can not be made to coincide with each other. This fact may be very easily demonstrated diagrammatically by drawing a tetrahedron having three apexes in the plane of the paper and attaching four arbitrary but different radicles to the four corners. If now the mirror image of this diagram be drawn it will be evident that the two arrangements can not be made to coincide. This fact would not be true if any two of the four attached radicles were the same. It has been shown experimentally that whenever the asymmetric carbon atom occurs there is usually to be found another modification exactly similar in all its properties except an equal but opposite rotation of polarized light. Such a substance would be represented graphically by the mirror image of the former, and the two are called optical antipodes. If the rotation occurs toward the light it is called a dextro-rotatory substance, designated by *d;* if to the left it is called a laevo-rotatory substance, designated by *l.*

Organic substances such as the sugars which are built up in the cells of organisms, are almost invariably dextro or laevo rotatory, seldom mixtures of the two. Substances which have been synthesized in the laboratory are usually equal mixtures of the two antipodes, and the rotation is thus neutralized. In many cases these mixtures may be separated into their constituent parts. The simpler sugars, pentoses and hexoses, frequently have from three to five asymmetric carbon atoms; the more complex, the bioses and trioses, may have twice or three times this number. It is thus evident that very great diversity in rotatory power is possible.

XI. TESTING OF RAW SUGAR

1. SAMPLING AND MIXING OF SAMPLES

The importance of a correct method of sampling raw sugar can not be overestimated. If this step is carelessly or erroneously carried out, the most careful work on the part of the chemist is vitiated. The details of the process of sampling should be arranged with two requirements kept in view: (1) The sample should be thoroughly representative of the package; (2) after the sample is taken it should undergo no change until used for analysis.

In order to obtain a representative sample, the sampling instrument called the "trier" should be plunged into the middle of the package and drawn out filled with sugar. If the trier has the correct length and the sampling is skillfully done, all the layers of sugar in the package are represented in the sample. Great care should be exercised to avoid taking a surface sample, since the variations caused by drying or absorption of moisture have their maximum effect at the surface. The dimensions of sugar triers are given on page 116 of this circular in the regulations of the United States Treasury Department relative to the sampling of imported sugars.

If the sugar is contained in barrels or other wooden packages, it should be sampled by running the long trier or barrel trier diagonally through the package from chime to chime. In case molasses has drained to the bottom of the package especial care must be taken that the sample be taken symmetrically.

In procuring samples from large shipments of sugar it is advisable to take samples from every package, mix the large quantity of material thoroughly, and resample the mixture for analysis.

In order to prevent a change in the composition of the sample taken, the total contents of each trier should be emptied into a tightly covered receptacle and the trier left clean for the next sample, the whole operation being completed within a few seconds. The subsequent mixing and resampling should be conducted in such manner as to avoid unnecessary exposure to the atmosphere. These precautions are needful because of the great tendency of raw sugar to change its moisture content when exposed to the air.

A large proportion of the impurities in raw sugar are in the form of molasses clinging to the surface of the crystals, and the evaporation or absorption of moisture may be very rapid. The action of an absorbing material during mixing (such as the brown paper which is frequently used) may affect the polarization very markedly by wiping the molasses from the surfaces of the crystals. If samples are to be preserved before analysis or for subsequent reference, they should be placed in tightly sealed containers in order to avoid loss by evaporation.

Further details as to the correct procedure in sampling will be found in the United States Treasury Regulations (arts. 3–22), which are printed as an appendix to this circular.

2. DUTCH COLOR STANDARD

The Dutch color standard consists of a series of crystallized sugar samples of approximately equal gradations of color ranging from No. 7, which is very dark, to No. 25, which is almost white. The color grade of any given sample is determined by a comparison with the standard series, prepared by an establishment in Holland for the sugar trade. The standards are contained in sealed bottles, but are renewed at least once a year because of the tendency of the colors to change.

No. 16 Dutch standard is the technical color distinction in the United States between refined and raw sugar.

3. DIRECT POLARIZATION

(See Fee Schedule 45)

Much of the analytical work on which is based not only the chemical control during extraction and refinement but also the adjustment of commercial transactions consists of the so-called direct polarization. The term "direct polarization" may be defined as the reading in the polariscope of 26.000 g of the sample in 100 true cubic centimeters of solution at 20° C with only such substances removed as impede the passage of light. In distinction to the direct polarization is the Clerget or double polarization method, which indicates the per cent of sucrose. The direct polarization is the resultant optical rotation of all optically active substances present in the sample. In high grades of sugar the Clerget and direct polarizations give results not far apart, but in low grades of sugar and in molasses the difference may become considerable.

The direct polarization is executed in a great variety of ways with respect to the details of manipulation.

The following method is the one most conveniently used in commercial work. It gives a value which is somewhat in error, but if it is carefully carried out the results are sufficiently uniform to adjust trade relations and to control manufacture. The sample is thoroughly mixed, all lumps broken up, and weighed very quickly into the capsule, great care being taken to prevent moisture change during weighing by hastening the process as much as due accuracy will permit. If the polariscope is read to only 0.05 *S* it is useless to weigh more closely than 0.015 g, and it is distinctly advantageous not to exceed this precision because the extra time involved allows increased opportunity for moisture change. The sample is then washed into a 100 true cubic centimeter flask and dissolved. The transference to the flask may be conveniently accomplished by the use of a funnel. This will allow the use of a narrower necked flask without any greater expenditure of time. The sugar is then brought into solution by a few minutes' shaking, a shaking machine being convenient if a large number of samples are to be done. At this point the clarifying agent must be added. The method of clarification depends on the nature and amount of impurities present. The universal principle to be applied is to add the minimum quantity necessary to clarify, whatever the agent added. In a large proportion of samples clarification will consist of the addition of 1 to 3 cc of basic lead acetate solution, followed by 1 or 2 cc of alumina cream. Frequently a foam appears on the surface of the meniscus which renders it impossible to adjust the volume accurately. This may be dispersed by blowing on it a small quantity of alcohol or ether from an atomizer.

To obtain good definition while making up to volume, the bottom of the meniscus should be made to appear dark by reflection of the finger or section of a rubber tube placed a few millimeters below the mark on the neck of the flask. The meniscus shaded in this way should be made tangential to the upper edge of the graduation mark. It is essential that the temperature of the solution during the process be the same as that of polariscopes, tubes, and quartz control plates.

For high grades of sugar the temperature correction of 0.03° *S* for each degree centigrade removed from 20° C has been calculated for conditions where the whole operation is carried out at the same temperature. This correction is not valid if these conditions are not fulfilled.

The solution is then shaken thoroughly and poured on a filter. The first few cubic centimeters of filtrate are rejected, since they are almost invariably made turbid by the passage of a small amount of the lead precipitate through the filter paper. During filtration it should be made an invariable practice to cover the funnels with cover glasses to prevent evaporation of the solution. This important precaution is frequently neglected. The contention that the evaporation is one of the constant errors of this method is not valid, because the evaporation is not constant, but depends on the accidental conditions of temperature, relative humidity of the atmosphere, and movement of air in the room.[36a]

In filling the polariscope tube the tube is rinsed two or three times with the solution to be polarized. During this rinsing the filtration jar should be given a rotary motion to stir its contents. This stirring brings the solution to a uniform density, thereby permitting a sharp focusing of the polariscope eyepiece. Care should be exercised to avoid errors due to the physical condition of the tube.

The accepted reading of the polariscope should be the average of at least three settings of the end point, and it is a great advantage to use both eyes for the determination.

Polarization by this method gives a value which is uniformly reproducible. It does not, however, represent the per cent of sucrose, because it does not take into account the other optically active substances which are usually present, nor does it represent the true direct polarization, because the 26 g of substance are not contained in 100 cc solution.

4. CLERGET POLARIZATION

(See Fee Schedule 45)

Owing to the presence of invert sugar besides other optically active substances occurring in raw sugar the direct polarization does not represent the true per cent of sucrose, but rather a resultant of all optically active substances present. The classic method of Clerget takes advantage of the fact that the molecule of sucrose is hydrolyzed in the presence of acid. By this hydrolysis or "inversion" the sucrose molecule is split into two simpler molecules, the one called dextrose or d-glucose and the other levulose or d-fructose. The mixture of equal quantities of the two is called invert sugar. It is upon the readiness with which this split

[36a] See appendix, p. 165.

takes place that Clerget's method depends. Under the conditions which cause the complete hydrolysis of sucrose the other optically active sugars are relatively stable, and therefore the change in rotation is due to the change in sucrose alone.

(*a*) DETERMINATION OF SUCROSE IN THE ABSENCE OF RAFFINOSE[37]—OFFICIAL METHOD OF THE ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS.

"Dissolve the normal weight of the substance in water, clarify with lead subacetate, and dilute to 100 cc. Filter and polarize the filtrate at 20° C in a 200-mm tube. The reading obtained is the direct reading or polarization before inversion. Free 50 cc of this filtrate from lead by treating with anhydrous sodium carbonate, sodium sulphate, or potassium oxalate, place in a 100 cc flask, and add 25 cc of water. Then add, little by little, while rotating the flask, 5 cc of hydrochloric acid, containing 38.8 per cent of the acid. Heat the flask after mixing in a water bath which is at 70° C. The temperature of the solution in the flask should reach 67° to 69° C in two and one-half to three minutes. Maintain a temperature of as nearly 69° as possible during seven to seven and one-half minutes, making a total time of heating of 10 minutes. Remove the flask and cool the contents rapidly to 20° C and dilute to 100 cc. Polarize this solution in a tube provided with a lateral branch and a water jacket, passing a current of water around the tube to maintain a temperature of 20° C.

"The inversion may also be accomplished as follows: To 50 cc of the clarified solution, freed from lead, add 5 cc of a 38.8 per cent solution of hydrochloric acid and set aside during a period of 24 hours at a temperature not below 20 ° C, or if the temperature be above 25° C set aside for 10 hours. Make up to 100 cc at 20° C and polarize at that temperature. This reading must be multiplied by two, which gives the invert reading. In case it is necessary to work at a temperature other than 20° C, which is allowable within narrow limits, the volumes must be completed, and both direct and invert polarizations must be made at exactly the same temperature. The sucrose is calculated by the following formula:

$$S = \frac{100\,(P - I)}{142.66 - \frac{T}{2}} \qquad (18)$$

S = per cent of sucrose.
P = direct reading.
I = invert reading.
T = temperature at which readings are made."

[37] Bull. Bur. Chem., 107, p. 41.

(*b*) DETERMINATION OF SUCROSE AND RAFFINOSE

[Of value chiefly in the analysis of beet sugars]

"If the direct reading be more than 1° higher than the per cent of sucrose, as calculated by the formula given above, raffinose is probably present, and sucrose and raffinose should be calculated by the following formulæ of Creydt:

$$S=\frac{0.5188\,P-I}{0.8454};\ R=\frac{P-S}{1.85}," \tag{19}$$

5. INVERTASE METHOD

(See Fee Schedule 45)

Occasionally there occur in samples of saccharine products substances besides sucrose whose optical activity is changed by the acid hydrolysis under the same conditions which cause the inversion of sugar. If an estimation of sucrose is desired, any such change introduces an error. For many such cases the inversion by invertase is more suitable in that it confines its action to sucrose. Invertase is a substance of unknown composition belonging to the class of enzymes and is synthesized only in the tissues of living organisms. Its activity in the inversion of sucrose is due to true catalysis, since it is in no way diminished or altered during the course of the reaction. It is destroyed by boiling or by the addition of strong acids or alkalis. Invertase has never yet been obtained in the pure condition, because it does not crystallize from its solutions.

C. S. Hudson [38] gives a method for its preparation and use. From this article the following is taken:

To prepare a stock solution of invertase, break up 5 pounds of pressed yeast, which may be either baker's or brewer's yeast, add 30 cc of chloroform to it in a closed flask, and allow it to stand at room temperature over night. By morning the solid mass will have become fluid, and it should then be filtered through filter paper, allowing several hours for draining. To the filtrate add neutral lead acetate until no further precipitate forms and again filter. Precipitate the excess of lead from the filtrate with potassium oxalate and filter. To this filtrate add 25 cc of toluene and dialyze the mixture in a pig's bladder or collodion membrane for two or three days against running tap water. The dialyzed solution is colorless, perfectly clear after filtration, neutral to litmus, has a solid content about one-half of 1 per cent, an ash content of a few hundredths of 1 per cent, will keep indefinitely in an ice box if a little toluene is kept on its surface to prevent the growth of microorganisms, and is exceedingly active in inverting cane sugar. The invertase solution does not reduce Fehling's solution.

[38] J. Ind. Eng. Chem., 2, p. 143.

The collodion dialyzer may be made by pouring into a clean, dry test tube or other glass vessel of the desired size a collodion solution and immediately pouring the liquid back into the container. The tube is thus left with a layer of liquid clinging to the walls. It is held in an inverted position until the evaporation of the solvent leaves the collodion somewhat sticky. It is then filled with water. After a few moments the membrane may be removed from the tube ready for use. If water is added too early, the collodion becomes white and opaque. If it is allowed to become too dry, it is too impermeable.

Invertase has a slight optical activity, which is negligible for any but the most careful work. Its activity is greatly increased by the addition of a small quantity of acetic acid, but too great an excess causes a diminution of activity. With hydrochloric acid the maximum activity occurs at a concentration of one-thousandth normal.

To perform the analysis, the normal weight of sugar is dissolved and clarified in the usual way and made up to 100 cc. Filter and polarize. From the filtrate remove the lead by addition of potassium oxalate or sodium carbonate and filter. To 50 cc of the filtrate add acetic acid until the solution is acid to litmus, add 5 cc of invertase solution and complete to 100-cc volume. Add enough toluene to prevent growth of microorganisms and allow to stand at room temperature over night. Bring the solution to the temperature at which the first solution was read and polarize in a 400-mm tube. Calculate the per cent sucrose by the formula

$$\frac{S-I}{141.7-\frac{t}{2}}\times 100$$

For a more complete discussion see above reference.

6. CLARIFICATION

All methods of clarification at present available have accompanying disadvantages which necessitate great precautions in order to minimize their effect.

The choice of a clarifying agent depends on the darkness of the sample of sugar to be tested. Those in most frequent use are, 1, alumina cream; 2, basic lead acetate; 3, animal charcoal In less frequent use, but having some advantages in special cases, are, 4, neutral lead acetate; 5, basic lead nitrate; 6, alum solution, 7, sodium hydrosulphite; 8, sodium hypochlorite.

(*a*) ALUMINA CREAM

Alumina cream is a suspension of aluminum hydroxide $Al(OH)_3$ in water. It is prepared by precipitation from alum or aluminum sulphate solution by means of ammonia. The precipitate is washed free from soluble salts or left unwashed according to the use to which it is to be put.

In case the precipitate is to be washed it is advisable to add the ammonia in slight excess. The washing of the precipitate may be conveniently carried out by suspending the mixture in parchment-paper bags in a vessel of water, changing the water in the vessel frequently. Or it may be washed in the usual way on a filter, provided that caution is used to prevent the precipitate from becoming dry. The washing is continued until a portion of the wash water tested with barium chloride shows only traces of dissolved sulphates.

The washed alumina cream may be used either as the sole clarifier for high-grade samples if its action is sufficiently effective or it may be used in conjunction with basic lead acetate. When used together with lead, it increases the clarifying action of the basic lead acetate and permits the use of a smaller quantity than would otherwise be necessary. When the washed alumina cream is used alone, the only error introduced into the analysis by the process of clarification is caused by the volume of the precipitate of aluminum hydroxide. If only a few cubic centimeters are used, the volume of the dry solid is small and for all ordinary purposes negligible.

If the alumina cream contains an excess of alum and other soluble sulphates, its use is recommended by many as an aid to clarification by basic lead acetate in the analysis of very impure products where a large quantity of lead acetate is required. The alumina cream then fulfills several purposes. It precipitates the excess of lead as lead sulphate. It adds its own clarifying effect and tends to furnish a slightly acid solution, which decomposes some of the compounds which lead forms with some varieties of sugar, notably levulose.

Impure saccharine products usually contain large quantities of dissolved inorganic salts, so that the addition of a clarifier containing a relatively small quantity of soluble salts is not seriously detrimental.

The method of preparation described by the Association of Official Agricultural Chemists [39] is as follows: Prepare a cold

[39] Bull. Bu. Chem., 107, p. 40.

saturated solution of alum in water and divide into two unequal portions. Add a slight excess of ammonium hydroxide to the larger portion and then add by degrees the remaining alum solution until a faintly acid reaction is secured.

(*b*) BASIC LEAD ACETATE

(1) **Preparation.**—Basic lead acetate is the clarifier of most extensive application. It is formed by chemical combination of normal lead acetate Pb $(C_2H_3O_2)_2$ with litharge PbO. There are thought to be three well-defined basic acetates varying in the relative quantities of the two constituents. These are 3 $Pb(C_2H_3O_2)_2 . 2$ PbO the basic acetate containing the lowest percentage of combined litharge and the one ordinarily prescribed for clarification; Pb $(C_2H_3O_2)_2 .$ PbO the monobasic acetate; and Pb $(C_2H_3O_2)_2 . 2$ PbO the dibasic acetate. Basic lead acetate of a satisfactory degree of purity is prepared by some commercial firms, and it is in many cases advisable to use the purchased substance for preparing the clarifying solution. The laboratory method of preparation recommended by the Association of Official Agricultural Chemists[40] is as follows: Prepare lead-subacetate solution by boiling 430 g of normal lead acetate, 130 g of litharge, and 1000 cc of water for half an hour. Allow the mixture to cool and settle and dilute the supernatant liquid to 1.25 specific gravity with recently boiled water. Solid lead subacetate may be substituted for the normal salt and litharge in the preparation of the solution.

For some purposes a concentrated solution may be used, which is prepared as follows (Spencer's Handbook for Cane Sugar Manufacturing): Heat nearly to boiling for about half an hour 860 g of neutral lead acetate, 260 g of litharge, and 500 cc of water. Add water to compensate for the loss by evaporation. Cool, settle, and decant the clear solution. This solution may be prepared without heat, provided the mixture is set aside several hours, with frequent shaking.

With the exception of the basic acetate prepared by a few firms, the samples occurring in commerce and also samples prepared in the laboratory even by official methods vary in composition within wide limits. Basic acetates having the highest proportion of PbO have the greatest clarifying power, but also combine to

[40] Bull. Bu. Chem., 107, p. 40.

the greatest extent the errors accompanying clarification with this reagent.

The constitution of basic acetate may be determined chemically by a double analysis of the sample.

(2) **Analysis.**—Weigh out 10 g of the solid or take a known volume of the solution containing approximately this quantity of the solid substance and dissolve in water in a 500-cc flask. In general this will give a milky solution, which is due to the partial hydrolysis of the lead salt. In order to avoid the possibility of the formation of basic lead sulphate subsequently, it is advisable to add a measured volume of normal acetic acid until a clear solution is obtained. Then add the equivalent of 60 cc of normal sulphuric acid, fill to a volume of 501.3 cc, close the flask, shake thoroughly, and allow the precipitate to settle. The extra 1.3 cc are to compensate for the volume of the precipitated lead sulphate. It may be added from a burette to the solution after filling to the 500-cc mark.

After the precipitate has settled determine the excess of sulphuric acid by adding to 100 cc of the clear solution a slight excess of $BaCl_2$. Filter the precipitate, ignite, and weigh as $BaSO_4$. The calculation of the total lead present computed as PbO is as follows:

$$5\left[\text{cc } H_2SO_4 \times \text{normality factor} - \frac{\text{Wt. } BaSO_4}{\frac{1}{2}\text{ Mol. Wt. } BaSO_4}\right]\frac{1}{2}\text{ Mol. Wt. PbO}$$

$$\text{or } 5.578\left[\text{cc } H_2SO_4 \times \text{factor} - \frac{\text{Wt. } BaSO_4}{.1167}\right]$$

To ascertain the quantity of lead present in the form of $Pb(C_2H_3O_2)_2$ and that in the form of PbO add to another 100-cc aliquot portion a few drops of phenolphthalein and tritate with a standard caustic alkali solution, taking the necessary precautions to free the solution from carbonic acid. The calculation of PbO is as follows:

$$5\left[\text{Total cc normal acid added} - \text{cc normal alkali}\right]\frac{1}{2}\text{ Mol. Wt. PbO}$$

The total normal acid is the sum of the acetic and sulphuric. This computation gives the weight of lead present as PbO. If this is subtracted from the total PbO the remainder is the PbO present in the form of neutral acetate, and this weight multiplied by the factor 1.4574 reduces it to the weight of neutral acetate.

The basic lead acetate has the great advantage of efficiency, but has also many disadvantages which require the exercise of great caution in its use. In general the minimum quantity which is necessary to clarify the solution should be used. This quantity is gauged by experienced workers with the requisite accuracy. The needed quantities for particular cases can not be stated, but the following approximate numbers are given as examples: For Java, Peruvian, and Cuban "first" sugars from 1 to 2 cc, molasses sugars 2 to 4 cc, Philippine III 3 to 6 cc. Molasses usually requires 6 to 12 cc. Many analysts follow up the lead by a little alumina cream. The washed alumina cream is used for high-grade samples, the cream with soluble sulphates for low-grade samples.

(3) **Corrections for the Volume of Precipitate.**—The basic lead acetate owes its clarifying action to its ability to precipitate the suspended albuminoids with other organic impurities. Since the total volume of 100 cc is occupied by the solution and precipitate, the solution alone occupies somewhat less than the volume indicated and is thus correspondingly concentrated. The error in the polarization thus caused has occasioned considerable discussion, and a number of methods have been devised either to correct or avoid it.

Method of Sachs.[41]—This is practically a direct measurement of the volume of the precipitate. It is described in Spencer's Handbook, page 83, as follows: Clarify 100 cc of the juice or the dissolved normal weight with the subacetate as usual. Wash the precipitate by decantation first with cold water and finally with hot water until all of the sucrose is removed. Transfer the precipitate to a 100-cc flask and add one-half the normal weight of cane sugar (of known polarization), dissolve the sugar, and dilute the solution to 100 cc; mix, filter, and polarize, using a 400-mm observation tube.

The volume of the precipitate is $\frac{100\,P' - 100\,P}{P}$ in which P is the polarization of the sugar taken and P' the polarization of the sugar the presence of the precipitate.

Method of Scheibler.[42]—To 100 cc of the sugar solution 10 cc of lead solution are added and the saccharimetric reading taken. A second solution is prepared by mixing the same volumes of the saccharine liquid and lead solution, which is then diluted to 200 cc and polarized.

[41] Revue Universelle de la Fabrication de Sucre, 1, p. 451. [42] Zs. f. Zuckerind., 1054; 1875.

Scheibler's method may be expressed by the following equations: $r=\frac{100\ R}{100-A}$, where r is polariscopic reading, R is the true reading if the solution were contained in 100 cc, and A is the volume of the precipitate. Similarly $r_1=\frac{100\ R}{20-A}$. Combining the two equations and eliminating A, we obtain $R=\frac{r\,r_1}{r-r_1}$. A further simplification is due to C. A. Browne, who deduces the expression $R=4\,r_1-r$.

Method of Horne.—The following method gives a more direct determination of this volume and is free from the difficulty of determining small differences between large numbers. A solution of the raw sugar is prepared and precipitated in the usual manner. The precipitate is allowed to settle and is washed by decantation, all the washings being poured through a weighed Gooch crucible. As little of the precipitate as possible is transferred to the filter. When the washing is completed, the precipitate is transferred to a weighed picnometer, which is filled to the mark and weighed. The Gooch crucible is dried at 100° and weighed and the remainder of the precipitate poured on it. It is again dried and weighed. The difference between the first and final weighings gives the total weight of the lead precipitate.

The density of the precipitate is found in the following way:

Let c = Weight of precipitate transferred in decanting.

A = Weight of water in picnometer when filled.

B = Weight of water and precipitate in picnometer.

C = Weight of precipitate in picnometer found by difference between second and third weighing of Gooch crucible.

$C+W$ = total weight of precipitate.

$$\text{Density}=\frac{C}{A-(B-C)} \tag{20}$$

The total volume of the precipitate is then its total weight divided by its density.

$$\text{Volume}=\frac{W}{D}=\frac{C+c}{\frac{C}{A-(B-C)}} \tag{21}$$

If care is taken to avoid any considerable loss of precipitate during the decantation, the determination may be shortened by neglecting the small quantity of precipitate which is lost in this way. The washed precipitate may be transferred directly to the picnometer, which is filled and weighed. The picnometer is then

emptied directly upon a weighed Gooch filter. The volume of the precipitate is then the weight of water displaced in the picnometer by the precipitate or $A-(B-C)$. If the weight of the precipitate lost in the decantation does not exceed a few per cent the shorter method is satisfactory.

(4) **Horne's Dry Method.**—A method intended to avoid rather than correct for the effect of the volume of the lead precipitate has been proposed by Horne.[43] Dissolve the sample in water and make up to 100 cc before adding the clarifier. Add a minimum quantity of dry basic lead acetate until sufficient clarification is obtained. Or, as in careful work with a lead solution, add the solid in successive small amounts until precipitation is almost

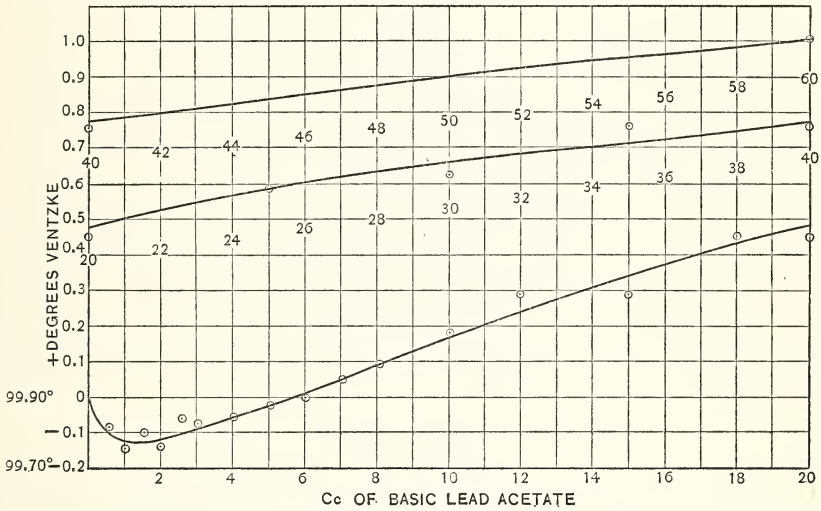


FIG. 9.—*Influence of lead acetate on normal sugar solution*

complete. It is evident that it is necessary to stop short of complete precipitation because an excess of the solid which does not produce a corresponding precipitate serves to swell the volume of solution and a corresponding error is introduced.

Horne has been able to show that by this method the volume of the solution is very approximately that indicated.

(5) **Effect on Sucrose.**—It is often erroneously stated that basic lead acetate is without effect on the rotation of sucrose. The experiments of Bates and Blake [44] show that errors in rotation caused by excessive amounts of basic lead acetate are of equal importance to the other errors in saccharimetry. These authors have found, Fig. 9, that an excess of ½ cc causes a diminution

[43] J. Am. Chem. Soc., 26, p. 186.

[44] Bull. B. S., 3, p. 105.

of polarization of 0.10° *S;* 1 cc, 0.12° *S;* 2 cc, 0.°11 *S;* 3 cc, 0.°09 *S.* The rotation reaches a minimum value when an excess of 1 cc is present. It returns to its initial value when 6 cc in excess have been added and continues to increase linearly with the amount of lead solution added until as much as 50 cc are present the rotation is increased by a whole degree Ventzke. This source of error is avoided if the minimum quantity of lead solution necessary to clarify is added.

(6) **Effect on Levulose.**—By the action of basic lead acetate on levulose the direct polarization may be considerably disturbed. This effect may occur from two causes. A soluble combination of lead and levulose may be formed which has a lower specific rotation than levulose, or the lead-levulose compound may be actually precipitated from solution. The result in either case is an increase in dextro-rotation or a higher polarization. Prinsen Geerligs has shown that basic acetate of lead precipitates levulose when the same solution contains salts which are capable of producing insoluble compounds with lead.

The combinations between lead and levulose are very easily broken up by a slight acidification. Acetic acid is sufficiently effective, but many other acids have been used for this purpose. Sulphur dioxide, tannic acid, and, as is frequently claimed, a solution of alum is acid enough to decompose this rather loose combination. In any case only a slight excess of acid should be present.

(c) BONE CHAR

In cases where the action of neither alumina cream nor lead subacetate is sufficient to produce a clear solution recourse may be had to bone black. Bone black for analytical purposes may be prepared by treating the granular material used in sugar refining with a slight excess of hydrochloric or nitric acid until all of the mineral matter is dissolved. The treated char is washed with boiling water, dried at 120°, and finely powdered and bottled. The more completely the material is freed from mineral matter the more effective is its action for analytical purposes. Bone black probably owes its clarifying action to the very large surface which is caused by its porosity.

The most serious error accompanying clarification with bone char is caused by its tendency to absorb sugar and thus give abnormally low readings. For this reason most official methods of clarification exclude bone black as an agent. It is difficult to

make a correction for the amount of sugar absorbed, because it varies with the composition and concentration of the sample and the condition of the bone char. In order to avoid the error arising from the absorption of sugar, the absorption coefficient may be determined under the approximate conditions of the analysis or the solution may be made up to volume and filtered through a column of bone black, the first third of the filtrate being rejected.

(*d*) BASIC LEAD NITRATE (Herles's solution)

Herles's [45] solution is prepared by dissolving 100 g of solid caustic soda in 2 liters of water and mixing with a solution of 1 kg of neutral lead nitrate in 2 liters of water. Under these conditions basic lead nitrate is precipitated.

$$2\ Pb(NO_3)_2 + 2\ NaOH = Pb(NO_3)_2.Pb(OH)_2 + 2\ NaNO_3$$

The precipitate is washed free of soluble impurities and mixed to a cream for use in clarification. The clarification may also be performed by forming the basic lead nitrate in the solution to be polarized. This is done by first adding a measured quantity of the lead-nitrate solution, 1 to 10 cc, according to the darkness of the sample, and then an exactly equal quantity of the alkaline solution. The excess of alkali must be avoided. The whole is then shaken and made to volume. The latter procedure gives the better clarification, but introduces a considerable quantity of soluble salts, which may affect the polarization. The defects of the basic nitrate are in general those of the basic acetate. The volume of the precipitate is even greater because of the bulk of the solid clarifier. The precipitation of reducing sugar is even more marked than in the case of the basic acetate.

(*e*) HYPOCHLORITE (ZAMERON'S METHOD)

The hypochlorite solution is prepared by grinding 625 g of dry bleaching powder in a mortar with 1 liter of water. The mass is squeezed out in a sack and the extract filtered through paper. The filtered solution, about 700 to 800 cc of about 18° B, is preserved in a stoppered bottle of dark glass in darkness. To perform the clarification a few cubic centimeters of the hypochlorite solution are added to the sugar solution and then a few cubic centimeters of neutral lead acetate solution. The reagent usually causes a slight rise of temperature, so that the solution should be readjusted to the temperature of the polariscope before making

[45] Herles: Zs. Zuckerind Böhmen, **13**, p. 559; **14**, p. 343, **21**, p. 189.

to volume. This method of clarification is very effective; and if no great excess of the reagent is employed, the reducing sugars are unaffected. The volume of the precipitate which is increased because of insoluble lead chloride is the main fault of this method.

(*f*) HYDROSULPHITE

Sodium hydrosulphite is prepared by the reaction of zinc, sodium bisulphite, and sulphuric acid according to the formula

$$2\ NaHSO_3 + Zn + H_2SO_4 = ZnS_2O_4 + Na_2SO_4 + 2\ H_2O$$

The zinc hydrosulphite is changed to the sodium compound by the reaction

$$ZnS_2O_4 + Na_2CO_3 = Na_2S_2O_4 + ZnCO_3\ .$$

The sodium hydrosulphite is salted out from solution by sodium chloride and dehydrated by warming with strong alcohol. The compound is then dried in a vacuum at 50°–60° C. This substance is produced commercially under the names of "Blankit" or "Redo" and is frequently used in sugar manufacture for bleaching massecuites and in dissolved form as a wash for whitening sugar in the centrifugal machine. To prepare a solution for polarization a quantity of alumina cream is added and then a few crystals of hydrosulphite—0.1 g to 1 g, according to the color of the solution. The solution is made up to volume, shaken thoroughly, and filtered. As the solutions occasionally redarken they should be polarized immediately. The clarifying action according to Weisberg [46] is due to free sulphurous acid and nascent hydrogen. The reduction by the latter leaves compounds which may be reoxidized and cause a redarkening of the solution.

Another hydrosulphite derivative (sodium sulphoxylate-formaldehyde) known as "Rongalite" accomplishes a permanent clarification, but is slower and less effective than "Blankit."

The defects of hydrosulphites as clarifiers are, in addition to the frequent redarkening, their effect on reducing sugars, the possible separation of finely divided sulphur, and their ineffectiveness in discharging the color of caramel bodies. Bryan [47] states that the rotation of dextrose is lowered by hydrosulphites and finds evidence of the formation of a lævo oxysulphonate. No immediate effect is observable upon sucrose or fructose, but sucrose is apparently inverted by a prolonged action. These clarifiers have not come into general use in analytical work, but

[46] Centrbl. Zuckerind, 15, p. 975. [47] Bull. Bur. Chem., 116.

nevertheless they are almost alone in the respect that they produce no volume error.

7. DETERMINATION OF MOISTURE

(*a*) GENERAL

An accurate determination of moisture in sugar products is a matter of great difficulty, and the proper procedure for its estimation has not been definitely established. The water content of moist raw sugar or sugar products frequently exists in the state of a dense sirup and resists drying with great obstinacy. Sometimes also the material is very hygroscopic. At ordinary pressures moisture can only be removed by a prolonged heating at a high temperature. But a high temperature frequently exerts a destructive effect on the solid sugars. The destructive action of a temperature of 100° C is particularly important in the case of levulose and to a less extent in the cases of dextrose and sucrose. The best drying methods are those which combine high temperature and high vacuum. If the substance is in the form of a sirup, the drying is facilitated by mixing thoroughly with dry quartz sand or pumice. The action of the sand is to cause a larger area to be exposed and prevent the formation of a crust. Flaked asbestos, or for fluid substances a roll of filter paper, may be used.

Below are given various methods of determining dry substance which are in common use. The method to be adopted depends somewhat upon the material. If levulose is present in considerable quantity, the temperature should not be raised over 70° C.

(*b*) METHOD OF THE UNITED STATES TREASURY

ARTICLE 1007. For the determination of moisture in sugars dry approximately 4 g in a nickel dish of a diameter of 55 mm and a height of 15 mm. Each sample shall be subjected to a temperature of 98° C for two hours.

For the determination of moisture in molasses, sirups, and massecuites, dry approximately 2 g in a flat dish of not less than 70 mm in diameter. Each sample shall be subjected to a temperature of 98° C for a period of two hours. Care must be taken to run the liquid in a film over the bottom of the dish and to retain in a horizontal position during the entire operation.

Although this method is capable of yielding uniform results, it is doubtful whether the last portions of moisture are removed, especially in the case of sirups.

(c) METHODS OF THE ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS[48]

(1) **By Drying**—*Sugars—Official.*—Dry from 2 to 5 g in a flat dish (nickel, platinum, or aluminum) at the temperature of boiling water for 10 hours; cool in a desiccator and weigh; return to the oven and dry for an hour or until there is only a slight change in weight.

In Massecuites, Molasses, Honeys, and Other Liquid and Semi-liquid Products—Provisional.—Prepare pumice stone in two grades of fineness. One of these should pass through a 1 mm sieve, while the other should be composed of particles too large for a millimeter sieve, but sufficiently small to pass through a sieve having meshes 6 mm in diameter. Make the determination in flat metallic dishes or in shallow, flat-bottom weighing bottles. Place a layer of the fine pumice stone 3 mm in thickness over the bottom of the dish, and upon this place a layer of the coarse pumice stone from 6 to 10 mm in thickness. Dry the dish thus prepared and weigh. Dilute the sample with a weighed portion of water in such manner that the diluted material shall contain from 20 to 30 per cent of dry matter. Weigh into the dish, prepared as described above, such a quantity of the diluted sample as will yield 1 g of dry matter. Use a weighing bottle provided with a cork through which a pipette passes if this weighing can not be made with extreme rapidity. Place the dish in a water oven and dry to constant weight at the temperature of boiling water, making trial weighings at intervals of two hours. In case of materials containing much levulose or other readily decomposable substances conduct the drying in vacuo at about 70° C.

Molasses with Quartz Sand—Provisional.—In a flat-bottom dish place 6 or 7 g of pure quartz sand and a short stirring rod. Dry thoroughly, cool in a desiccator, and weigh. Then add 3 or 4 g of the molasses, mix with the sand, and dry at the temperature of boiling water from 8 to 10 hours. Stir at intervals of an hour, then cool in a desiccator, and weigh. Stir, heat again in the water oven for an hour, cool, and weigh. Repeat heating and weighing until loss of water in one hour is not greater than 3 mg.

Before using, digest the pure quartz sand with strong hydrochloric acid, wash, dry, ignite, and keep in a stoppered bottle.

(2) **Areometric Method**[49]—**Official**—*Specific Gravity, Water, and Total Solids by Means of a Spindle.*—The density of juices,

[48] Bull. Bu. Chem., 107, p. 64.

[49] This method does not apply to low-grade sugar products, since materials high in salts give excessive percentages.

sirups, etc., is most conveniently determined by means of the Baumé or Brix hydrometer, preferably the latter, as the graduation of the scale gives close approximations to the percentages of total solids. The Brix spindle should be graduated to tenths. The range of degrees recorded by each individual spindle should be as limited as possible. The solution should be as nearly as practicable of the same temperature as the air at the time of reading, and if the variation from the temperature of the graduation of the spindle amounts to more than 1° a compensation must be applied according to the table of corrections for temperature, page 128. Before taking the density of a juice it should be allowed to stand in the cylinder until all air bubbles have escaped.

In case the sample is too dense to determine the density directly, dilute a weighed portion with a weighed quantity of water or dissolve a weighed portion and dilute to a known volume with water. In the first instance the per cent of total solids is calculated by the following formula:

$$\text{Per cent of solids in the undiluted material} = \frac{WS}{w}.$$

S = per cent of solids in the diluted material.
W = weight of the diluted material.
w = weight of the sample taken for dilution.

When the dilution is made to a definite volume, the following formula is to be used:

$$\text{Per cent of solids in the undiluted material} = \frac{VDS}{w}.$$

V = volume of the diluted solution.
D = specific gravity of the diluted solution.
S = per cent of solids in the diluted solution.
w = weight of the sample taken for dilution.

A table for the comparison of specific gravities $\frac{20°}{20°}$, degrees Brix (per cent by weight of sucrose), and degrees Baumé, is given in Table 31.

Specific Gravity, Water, and Total Solids by Means of a Picnometer.—When a more accurate determination of the per cent of solids or of water or of the specific gravity is desired, the determination should be made with a specific-gravity bottle or picnometer. When of too high density for a direct determination, the sample may be diluted, as described above.

When the number expressing the specific gravity found by analysis falls between the numbers given in Table 31, the exact equivalent in degrees Brix or Baumé is found by a simple calculation.

Example: The picnometer shows the specific gravity $\frac{20°}{20°}$ of a certain sirup to be 1.20909. The table shows that the corresponding degree Brix is between 45.8 and 45.9. Subtracting the specific gravity of a solution of 45°.8 Brix from the corresponding figure for 45°.9, we have (expressing the specific gravities as whole numbers) $120947 - 120894 = 53$, the difference in specific gravity for 0°.1 Brix at this point in the table. Subtracting the specific gravity corresponding to 45°.8 from the specific gravity found by analysis, we have $120909 - 120894 = 15$; $\frac{15}{53} = 0.03$, the fraction of 0°.1 Brix more than 45°.8. The degree Brix, corresponding to a specific gravity of 1.20909, is therefore 45.83.

Temperature Correction.—If the spindle reading or picnometer determination be made at any other temperature than 20° C., the result should be corrected by the use of Table 11, page 128

Example: A sugar solution shows a reading of 25°.2 Brix at 30° C. To find the necessary correction for the conversion of this reading to the reading which would have been obtained if the observation had been made at 20° C, find the vertical column in the table headed 25° Brix, which is the nearest to the observed reading. Follow down this column until the number is reached which is opposite to the temperature of observation, in this case 30°. The number found, 0.71, is to be added to the observed reading.

8. REFRACTOMETRIC ESTIMATION OF SOLIDS

The refractive index of sugar solutions and of sugar-house products has been found to be a reliable indication of the quantity of total solids present. Tolman and Smith found that solutions of practically all sugars in equal percentage composition by weight gave the same refractive indices. A determination of the index therefore serves as a measure of the dry substance contained in solution, even if it be a mixture of several different sugars. To extend the usefulness of the refractometer Geerligs showed that the refractive index of impure sugar solutions, even when the impurities consisted of mineral salts, was a reliable measure of total solid substance and much superior to the analysis by density measurements.

(*a*) ABBE REFRACTOMETER

The refractometer of Abbe is especially adapted for solutions, sirups, and other saccharine liquids. In this instrument advantage is taken of the law of total reflection when the angle of incidence exceeds a certain value. The essential parts are a compensator and two flint-glass prisms of index $N_D = 1.75$, one of which is cemented to a hinged mounting. The prisms are separated and a few drops of the liquid whose index of refraction is to be measured are placed upon the polished face of the fixed prism. The prisms are then slowly brought together again and the instrument swung into an upright position. The illumination is preferably obtained from an electric lamp or Welsbach gas mantle, although ordinary daylight will answer under certain conditions. The telescope is attached to a sector and the prisms to a movable arm. To set the instrument, the arm is adjusted until the intersection of the reticule in the telescope cuts the dividing line between the bright and dark portions of the field. The refractive index can then be read directly from the scale on the sector. Owing to the fact that the index of the liquid must always be less than that of the prisms in order to secure total reflection, indices may not be determined that are higher than 1.75, the index of the prisms.

In order to eliminate the dispersion produced by the prisms, a compensator consisting of two similar direct-vision prisms is placed in the telescope tube. By rotating one of these with respect to the other the exact compensation necessary to remove all color from the field is secured.

Since the refractive index of sugar solutions varies with the temperature, increasing as the temperature decreases, it is desirable to maintain uniform conditions during the measurement. To accomplish this, the prisms with the solution between them are surrounded by a water jacket.

(*b*) IMMERSION REFRACTOMETER

The immersion refractometer (described in Z. angew. Chem., p. 1168, 1899) consists of a straight telescope tube with a prism of hard glass of index 1.51 attached rigidly to the lower end. This prism dips directly into the liquid whose refractive index is to be measured. The scale upon which the line of total reflection falls directly is divided into 110.0 arbitrary divisions comprising indices of refraction from 1.325 to 1.367. The reference point for calibration is scale division 15.0, which should be the reading for distilled water at 17°5.

V. Stanek [50] describes a method for estimation of water in raw sugar by means of the immersion refractometer.

It is unfortunate that in the construction of his table Stanek has used the Mohr cubic centimeter as the unit of volume. According to his procedure 20 g of the sample are weighed out and transferred to a flask calibrated to contain 100 Mohr cc (the volume at 17°.5 occupied by 100 g of pure water weighed in air with brass weights). The sugar is dissolved and made to volume and thoroughly shaken. It is then placed in a water bath to take up a steady temperature. The refractometer reading is made and simultaneously the temperature observed. The percentage of moisture is then read directly from the tables after the proper temperature correction is applied.

In case a flask calibrated to contain 100 Mohr cc is not at hand, a flask calibrated to contain 100 true cc may be used provided a weight of 19.954 g is taken and dissolved to make 100 true cc. (See Table 12.)

[50] Zs. Zuckerind Böhmen, 35, p. 57; 1910.

XII. POLARIMETRIC ANALYSIS OF OTHER SUGARS

1. SPECIFIC ROTATION

The specific rotation of any substance may be defined as the rotation caused by a length of 1 dm of a solution containing 1 g of substance in 1 cc. This value varies with the wave length of light used, it being greatest for the shortest wave lengths. It is, however, the common practice to express specific rotation in terms of the *D* lines of the sodium spectrum in spite of the doubtful advantage of such a light source. Specific rotation for sodium light is designated by the abbreviation $[\alpha]_D$ and is expressed mathematically in two ways:

$$[\alpha]_D = \frac{\alpha}{l \times c} \tag{22}$$

in which α expresses the observed rotation, l the length of the solution in decimeters, and c the weight of substance in 1 cc.
Or

$$[\alpha]_D = \frac{\alpha}{l \times p \times d} \tag{23}$$

in which p = per cent concentration of substances and d the density of solution. Since $p \times d = c$ these two formulæ reduce to the same expression. $[\alpha]$ varies not only with the wave lengths of the light source, but also slightly with the concentration of substance and with temperature. It is therefore necessary to take these variations into consideration in order to apply the proper value of the specific rotation. Table 26, page 150, gives the values of the specific rotations of the more important sugars at 5 per cent intervals of concentration. From this table the $[\alpha]_D$ for all other concentrations may be found by simple interpolation. Table 25, page 149, gives the formulas for variation of specific rotation from which the above tables were computed.

2. MONOCHROMATIC LIGHT METHOD

The methods described in the foregoing sections make it possible to apply a correct value for the specific rotation of the sugar in question for the particular temperature and concentration. This being known, it is merely necessary to observe the rotation

of the solution and substitute the values in the equations $c=\frac{100\alpha}{l\times[\alpha]_D}$ and $p=\frac{100\alpha}{l\,d[\alpha]_D}$, where c is grams per 100 cc, α is the observed rotation, l is length of tube in decimeters, p is number of grams in 100 g of solution, and d is the density of solution.

3. SACCHARIMETRIC METHOD

Since monochromatic light sources are always difficult to obtain, it is frequently more convenient to use a white-light source and determine the sugar on a quartz-wedge saccharimeter. The saccharimeter is particularly applicable to the sugar group because the rotary dispersions of quartz and the common sugars are very similar. The conditions for accurate observing are improved if the violet end of the spectrum is absorbed by the potassium bichromate cell. It must be remembered that the saccharimetric scale is defined by the rotation of sucrose, its hundred point being the rotation of 26 g in 100 cc of solution. Therefore in order to determine a sugar having a different rotary power we must adjust the weight of the substance to the sucrose scale, i. e., the normal weight of the sugar in question is that weight dissolved in 100 cc of solution which will give a rotation of 100° on the sucrose scale. To compute this weight we should use, whenever the data are available, the results of direct determinations of the values of the rotations on the sucrose scale.

In the case of the first four sugars of the following table we have determinations of the relation between the rotation in sugar degrees and circular degrees of sodium light caused by the same solution. If this relation is known we can compute from the precisely known specific rotation the normal weight for the saccharimeter.

In the case of many sugars no direct determinations of the relative values of the sugar and circular degrees are available, and in these instances the normal weight must be computed from the relative specific rotations of sucrose and of the sugar in question. This necessitates an assumption that the rotation dispersion of all the sugars is the same as that of sucrose, which is not strictly true. These normal weights must therefore be considered only as the nearest approximation at present available. It is the purpose of this Bureau to obtain these data with the requisite precision. The computation depends upon the assumption that the normal weights of the sugars vary inversely as their specific rotations.

TABLE 20

Saccharimetric Normal Weights

Glucose.....(1° S=.3448) hence $C=\frac{100\times34.48}{2\times53.46}=32.248$

Lactose.....(1° S=.3452) hence $C=\frac{100\times34.52}{2\times52.53}=32.857$

Maltose.....(1° S=.3449) hence $C=\frac{100\times34.49}{2\times138.25}=12.474$

Raffinose (5 H_2O).....(1° S=.3450) hence $C=\frac{100\times34.50}{2'\times104.5}=16.507$

Inverse Ratio of Specific Rotations

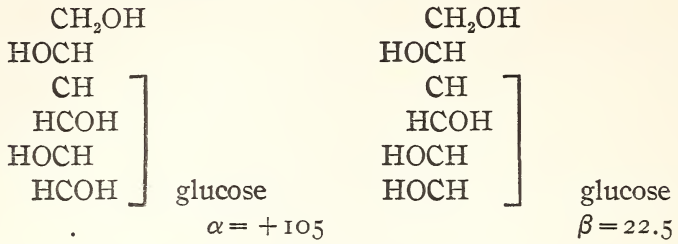
Fructose	18.592
Invert sugar	86.450

Thus in the determination of these sugars it is merely necessary to weigh out the appropriate normal weight of the sugar and proceed exactly as in the analysis of sucrose. The specific rotation in general is not precisely proportional to the concentration of the sugar, and for exact work a correction should be applied for readings which vary much from the hundred-degree point. Many experimenters advise using a variable normal weight according to the concentration of the sugar taken, but this requires a previous knowledge of the quantity of sugar present or a preliminary assay of the material. It is much more convenient to use a uniform normal weight and apply a correction for the various parts of the sugar scale. In Table 27 are given the corrections for dextrose at 10° intervals.

4. MUTAROTATION

In a very large class of sugars a considerable lapse of time is required for the dissolved sugar to exhibit a stable rotary power. The freshly prepared solution in general possesses a relatively high activity, which steadily decreases according to the laws of unimolecular reactions to a steady state, where no further change occurs. This phenomenon is called "mutarotation." The specific rotation of the sugar is expressed in terms of this equilibrium condition. Mutarotation has been satisfactorily explained by the discovery of two modifications of each of the sugars in which the phenomenon exists. These two modifications have been designated the α and β forms. When the sugar crystallizes, but one of these forms separates from solution, usually on account of a considerable difference in solubility, and, consequently, when a fresh solution is prepared the rotary power of this form is exhibited. The most plausible explanation of the isomerism of the α and β forms is connected with the end carbon atom which is capable of changing its relation to the rest of the molecule.

For example, in the case of dextrose the mutarotation reaction is regarded as a balanced reaction between the two forms



The steady state is, under this hypothesis, a state in which the reactions velocities $\alpha \rightarrow \beta$ and $\beta \rightarrow \alpha$ are equal.

In analytical work it is necessary that the solution of the substance reach its equilibrium before the rotation is recorded. This may be accomplished simply by allowing the solution to stand at room temperature until constant rotation is reached. This way is preferable whenever possible.

If it is desired to complete the reading speedily, equilibrium may be reached by heating the solution to a high temperature. It is reached almost instantly at 100°. The addition of 0.1 per cent ammonia or $\frac{N}{200}$ KOH will cause the completion of the reaction in 10 to 15 minutes. Stronger alkali will tend to cause decomposition.

XIII. ESTIMATION OF REDUCING SUBSTANCES

1. PREPARATION OF SOLUTIONS

(a) SOXHLET SOLUTION [61]

A. 34.639 g $CuSO_4.5\ H_2O$ in 500 cc of solution.

B. 173 g of Rochelle salts, 51.6 g NaOH in 500 cc of solution.

For analysis mix equal volumes of A and B just before using.

(b) ALLIHN'S SOLUTION

A. Dissolve 34.639 g $CuSO_4.5\ H_2O$ and dilute to 500 cc.

B. Dissolve 173 g of Rochelle salts and 125 g of KOH and dilute to 500 cc.

2. PREPARATION OF CRUCIBLES

Prepare the asbestos, which should be the amphibole variety, by first digesting with 1:3 hydrochloric acid for two or three days. Wash free from acid and digest for a similar period with soda solution, after which treat for a few hours with hot alkaline copper tartrate solution of the strength employed in sugar determinations. Then wash the asbestos free from alkali, finally digest with nitric acid for several hours, and after washing free from acid shake with water for use. In preparing the Gooch crucible load it with a film of asbestos one-fourth inch thick, wash this thoroughly with water to remove fine particles of asbestos; finally, wash with alcohol and ether, dry for 30 minutes at 100° C, cool in a desiccator, and weigh. It is best to dissolve the copper precipitate with nitric acid each time after weighing and use the same felts over and over again, as they improve with use.

In order to prepare the Gooch-Munroe-Nebauer crucible, a quantity of ammonium chlor-platinate is made by dissolving scrap platinum in aqua regia. Boil off the excess of nitric acid by repeated additions of hydrochloric acid. Evaporate to dryness and dissolve in a small quantity of water. Precipitate the ammonium salt by adding ammonium chloride. The precipitate is collected on a filter and dried. To obtain larger crystals it may be recrystallized from hot water. To make the mat sprinkle a uniform layer of the ammonium chlor-platinate in the bottom of the Gooch crucible, preferably one with small holes. A small platinum foil should

[61] Commonly known as Fehling's solution.

be placed under the crucible to prevent the salt from sifting through. Crucible and cap are then placed in a larger porcelain or platinum dish and heated gradually to decompose the ammonium salt. When decomposition is complete allow the crucible to cool. If on inspection an even unbroken layer of platinum sponge is obtained it should be very carefully pressed down with a glass rod, the end of which has been flattened to a smooth area 5–10 mm in diameter. The spongy platinum is pressed down gently at first, later more and more firmly, and is finally burnished slightly. The operation is by no means an easy one, and is far more difficult in a porcelain crucible than in a platinum one, but after several attempts the necessary experience is obtained. These crucibles have the advantage of greater constancy of weight and in general, if correctly made, permit a more rapid and more perfect filtration. Furthermore, the mat is not deranged by any of the ordinary manipulations.

3. UNIFIED METHOD OF MUNSON AND WALKER[52]

(See Fee Schedule 45)

Transfer 25 cc each of solutions A and B of the Soxhlet reagent to a 400-cc Jena or Non-sol beaker and add 50 cc of reducing sugar solution, or if a smaller volume of sugar solution be used add water to make the final volume 100 cc. Heat the beaker upon an asbestos gauze over a Bunsen burner, so regulate the flame that boiling begins in four minutes, and continue the boiling for exactly two minutes. Keep the beaker covered with a watch glass throughout the entire time of heating. Without diluting, filter the cuprous oxide at once on a Gooch crucible, using suction. Wash the cuprous oxide thoroughly with water at a temperature of about 60° C, then with 10 cc of alcohol and finally with 10 cc of ether. Dry for 30 minutes in a water oven at 100° C, cool in a desiccator, and weigh as cuprous oxide, or determine the copper by one of the methods given on pages 86–90.

The analytical procedure for any one of these sugars may be verified by carrying out the operation upon the standard dextrose sample or upon the invert-sugar solution.

A table by Munson and Walker has been computed for the determination of reducing sugar in the presence of sucrose under conditions where a large quantity of reducing substance is present and where a small quantity is present. If the composition of

[52] J. Amer. Chem. Soc., 28, p. 663; 29, p. 541.

the mixture is known approximately, the weight of substance required can be judged without a previous assay. If less than 10 per cent of reducing sugar is present, a weight of 2 g of total sugar should be taken in 50 cc. If more than 10 per cent, 0.4 g in 50 cc is the required amount. For unknown mixtures it is best to make an analysis with either one of the amounts of total sugar. This will serve either as a preliminary or final assay according to the amount present. The method allows great latitude of procedure.

4. HERZFELD'S METHOD[53] FOR LOW PERCENTAGES OF REDUCING SUGAR

(See Free Schedule 45)

Herzfeld's method is intended for high grades of raw sugar containing less than 1.5 per cent of reducing substances. Clarification is performed with normal lead acetate in order not to precipitate reducing sugar. It is convenient to take 44 g of sugar in a 200-cc flask, dissolve in about 100 cc, add normal lead acetate just sufficient to clarify, complete to 200 cc, and filter. One hundred cubic centimeters of the filtrate is taken in a 100 to 110 cc flask and sufficient sodium carbonate or sulphate added to precipitate the excess of lead. The volume is completed to 110 cc, the solution shaken and filtered; 50 cc of the filtrate contains 10 g of the sugar.

To perform the analysis, take 25 cc each of A and B of Soxhlet's solution, heat to boiling, and add 50 cc of the clarified solution. Bring the mixture to boiling and boil for exactly two minutes. The cuprous oxide is filtered off, washed, and the copper determined. If the sugar contains more than 1.5 per cent of reducing sugar, the method of Munson and Walker must be employed.

5. ALLIHN'S METHOD FOR GLUCOSE[54]

(See Fee Schedule 45)

ALLIHN'S SOLUTIONS

(*a*) **Copper Sulphate Solution.**—Dissolve 34.639 g of $CuSO_4.5H_2O$ in water and dilute to 500 cc.

(*b*) **Alkaline Tartrate Solution.**—Dissolve 173 g of Rochelle salts and 125 g of potassium hydroxide in water and dilute to 500 cc.

Place 30 cc of the copper solution, 30 cc of the alkaline-tartrate solution, and 60 cc of water in a beaker, and heat to boiling.

[53] Zs. Ver. Zuckerind, p. 985, 1885. [54] Bull. Bur. Chem., 107, p. 49.

Add 25 cc of the solution of the material to be examined, which must be so prepared as not to contain more than 0.250 g of glucose, and boil for exactly two minutes, keeping the beaker covered. Filter immediately through asbestos without diluting and obtain the weight of copper by one of the methods, pages 86–90. The corresponding weight of dextrose is found from Table 23, page 148, prepared by Allihn.

6. ESTIMATION OF COPPER IN THE CUPROUS OXIDE PRECIPITATE

The estimation of copper in the cuprous oxide precipitate may be accomplished gravimetrically or volumetrically. The gravimetric methods, which consist of the weighing of this precipitate either directly or after conversion into copper or cupric oxide, may be employed only in case the precipitate is uncontaminated. Contamination may be caused by the precipitation of inorganic or organic impurities during the reduction. Such precipitation is the more likely to occur the cruder the sample to be analyzed. In case a contaminated precipitate is suspected, the copper in the precipitate must be determined analytically.

The electrolytic method is available for impure precipitates. The volumetric determination by use of $KMnO_4$ is reliable if the precipitate is not contaminated by organic substances. Most generally applicable for accurate work are the electrolytic methods and the iodimetric methods of Low and Kendall. It is the intention of this Bureau to study these various methods critically.

Of the following methods sections *a*, *b*, *d*, *e*, and *f* have been adopted by the Association of Official Agricultural Chemists.[55]

(*a*) REDUCTION IN HYDROGEN

"Filter the cuprous oxide immediately through a weighed filtering tube made of hard glass, using suction. Support the asbestos film in the filtering tube with a perforated disk or cone of platinum, and wash free from loose fibers before weighing; moisten previous to the filtration. Provide the tube with a detachable funnel during the filtration, so that none of the precipitate accumulates near the top, where it could be removed by the cork used during the reduction of the cuprous oxide. Transfer all the precipitate to the filter and thoroughly wash with hot water, following the water by alcohol and ether successively. After being dried, connect the tube with an apparatus for supplying a continuous current of dry hydrogen, gently heat until the cuprous oxide is

[55] Bull. Bur. Chem., 107, p. 51.

completely reduced to the metallic state, cool in the current of hydrogen, and weigh. If preferred, a Gooch crucible may be used for the filtration.

(*b*) DIRECT WEIGHING OF CUPROUS OXIDE

"Prepare a Gooch crucible with an asbestos felt one-fourth of an inch thick. First thoroughly wash the asbestos with water to remove small particles, then follow successively with 10 cc of alcohol and 10 cc of ether, and dry the crucible and contents 30 minutes in a water oven at the temperature of boiling water.

"Collect the precipitated cuprous oxide on the felt as usual, thoroughly wash with hot water, then with 10 cc of alcohol, and finally with 10 cc of ether. Dry the precipitate 30 minutes in a water oven at the temperature of boiling water; cool and weigh. The weight of cuprous oxide multiplied by 0.8883 gives the weight of metallic copper."

(*c*) DETERMINATION OF COPPER AS CUPRIC OXIDE

The cuprous oxide is ignited (best in a muffle) at red heat for 15 to 20 minutes in an oxidizing atmosphere. The weighing should be performed rapidly to prevent increase of weight due to absorption of moisture. Multiply by 0.7989 to convert to copper.

(*d*) ELECTROLYTIC DEPOSITION FROM NITRIC-ACID SOLUTION

"Filter and wash as under (*e*). Transfer the asbestos film and adhering oxide to the beaker. Dissolve the oxide still remaining in the crucible by means of 2 cc of nitric acid (specific gravity, 1.42), adding it with a pipette and receiving the solution in the beaker containing the asbestos film. Rinse the crucible with a jet of water, allow the rinsings to flow into the beaker. Heat the contents of the beaker until the copper is all in solution, filter, dilute the filtrate to a volume of 100 cc or more, and electrolyze. When a nitrate solution is electrolyzed, the first washing of the deposit should be made with water acidulated with sulphuric acid, in order that the nitric acid may be all removed before the current is interrupted.

(*e*) VOLUMETRIC PERMANGANATE METHOD

"Filter the cuprous oxide in a Gooch, wash the beaker and precipitate thoroughly with hot water without any effort to transfer the precipitate to the filter. Transfer the asbestos film to the beaker, add about 30 cc of hot water, and heat the precipitate and asbestos thoroughly. Rinse the crucible with 50 cc of a hot saturated solution of ferric sulphate in 20 per cent sulphuric

acid, receiving the rinsings in the beaker containing the precipitate. After the cuprous oxide is dissolved, wash the solution into a large Erlenmeyer flask and immediately titrate with a standard solution of potassium permanganate. One cubic centimeter of the permanganate solution should equal 0.010 g of copper. In order to determine the strength of this solution, make six or more determinations with the same sugar solution, titrating one-half of the precipitate obtained, and determining the copper in the others by electrolysis. The average weight of copper obtained by electrolysis divided by the average number of cubic centimeters of permanganate solution required for the titration is equal to the weight of copper equivalent to 1 cc of the standard permanganate solution. A solution standardized with iron or oxalic acid will give too low results."

(*f*) LOW'S VOLUMETRIC IODIDE METHOD[56]

(1) **Standardization of the Thiosulphate Solution.**—Prepare a solution of sodium thiosulphate containing about 19 g of the pure crystals to the liter. Standardize as follows: Weigh accurately about 0.2 g of pure copper foil and place in flask of about 250 cc capacity. Dissolve by warming with 5 cc of a mixture of equal volumes of strong nitric acid (sp. gr. 1.42) and water and then dilute to about 50 cc. Boil for a few minutes to expel partially the red fumes and then add 5 cc of strong bromine water and boil until the bromine is thoroughly expelled. The bromine is to insure the complete destruction or removal of the red fumes. Remove from the heat and add a slight excess of strong ammonia water. Ordinarily it suffices to add 7 cc of ammonia water of 0.90 sp. gr. Again boil until the excess of ammonia is expelled, as shown by a change of color of the liquid and a partial precipitation of the copper as hydroxide or oxide. Now add strong acetic acid in slight excess, perhaps 3 or 4 cc of the 80 per cent acid in all and again boil for a moment if necessary to redissolve the copper precipitate. Cool to room temperature and add about 3 g of potassium iodide or 6 cc of a solutiou of the salt containing 50 g in 100 cc. Cuprous iodide will be precipitated and iodine liberated according to the reaction.

$$2\ Cu\ (C_2H_3O_2) + 4\ KI = Cu_2I_2 + 4\ (KC_2H_3O_2) + 2\ I$$

The free iodine colors the mixture brown. Titrate at once with the thiosulphate solution until the brown tinge has become weak and then add sufficient starch liquor to produce a marked

[56] J. Amer. Chem. Soc., 24, p. 1082, and Bull. Bur. Chem., 107, p. 241.

blue coloration. Continue the titration cautiously until the color due to free iodine has entirely vanished. The blue color changes toward the end to a faint lilac. If at this point the thiosulphate be added drop by drop and a little time be allowed for complete reaction after each addition, there is no difficulty in determining the end point within a single drop. One cubic centimeter of the thiosulphate solution will be found to correspond to about 0.005 g of copper. The reaction between the thiosulphate and the iodine is:

$$2Na_2S_2O_3 + 2I = 2NaI + Na_2S_4O_6$$

The starch liquor may be made by boiling about 0.5 g of starch with a little water and diluting with hot water to about 250 cc. The liquor should be homogeneous and free from lumps. It should be used cold and must be prepared frequently.

(2) **Analysis.**—After washing the precipitated cuprous oxide, cover the Gooch crucible with a watch glass and dissolve the oxide by means of 5 cc of warm nitric acid (1 : 1) poured under the watch glass with a pipette. Catch the filtrate in a flask of 250 cc capacity and wash watch glass and Gooch crucible free of copper; 50 cc of water will be sufficient. Boil to expel red fumes, add 5 cc of bromine water, boil off the bromine, and proceed as in standardizing the thiosulphate.

(g) KENDALL'S MODIFIED IODIDE METHOD[57]

The cuprous oxide, after filtering and washing upon a Gooch crucible, is dissolved in 10 to 15 cc of 30 per cent nitric acid in a 300 cc Erlenmeyer flask. The volume of the solution should now be 50 to 60 cc and of acidity equivalent to 4 to 5 cc of concentrated nitric acid. A greater volume or acidity should be avoided. The temperature should not be above 25°. Five cubic centimeters of the hypochlorite solution are now added and the flask well shaken. A sufficiency of hypochlorite solution is indicated by a change from blue to greenish tint or by liberation of chlorine. The solution is allowed to stand about two minutes. Ten cubic centimeters of 5 per cent colorless phenol solution are now added as quickly as possible. The chlorine gas above the solution is removed by blowing into the flask and the sides are rinsed down. The solution is now made alkaline with sodium hydroxide until a slight precipitation occurs. Acidify with a few drops of acetic acid. Add 10 cc of 30 per cent potassium iodide solution and titrate with thiosulphate.

[57] J. Amer. Chem. Soc., 33, p. 1947.

The sodium hypochlorite solution is prepared by boiling 112 g of calcium hypochlorite and 100 g of anhydrous sodium carbonate in 1200 cc of water. Five cubic centimeters of the filtered solution are added to 100 cc of water containing 5 cc of 30 per cent KI solution and a few cubic centimeters of dilute HCl solution and a few cubic centimeters of dilute HCl added. The liberated iodine is titrated with 0.1 N sodium thiosulphate. The volume of the solution is now adjusted so that 5 cc of the hypochlorite solution are equivalent to 30 cc of 0.1 N sodium thiosulphate.

Additional methods are the electrolytic methods in which sulphuric acid is present [58] and the thiocyanate method of Volhard and Pflüger.[59]

7. VOLUMETRIC DETERMINATION OF REDUCING SUGAR[60]

(*a*) SOXHLET'S METHOD

"Make a preliminary titration to determine the approximate percentage of reducing sugar in the material under examination. Prepare a solution which contains approximately 1 per cent of reducing sugar. Place in a beaker 100 cc of the mixed copper reagent and approximately the amount of the sugar solution for its complete reduction. Boil for two minutes. Filter through a folded filter and test a portion of the filtrate for copper by use of acetic acid and potassium ferrocyanide. Repeat the test, varying the volume of sugar solution, until two successive amounts are found which differ by 0.1 cc, one giving complete reduction and the other leaving a small amount of copper in solution. The mean of these two readings is taken as the volume of the solution required for the complete precipitation of 100 cc of the copper reagent. Under these conditions 100 cc of the mixed copper reagent require 0.475 g of anhydrous dextrose or 0.494 g of invert sugar for complete reduction. Calculate the percentage by the following formula:

"V = the volume of the sugar solution required for the complete reduction of 100 cc of the copper reagent.

"W = the weight of the sample in 1 cc of the sugar solution.

$$\text{"Then } \frac{100 \times 0.475}{VW} = \text{per cent of dextrose} \tag{24}$$

$$\text{"and } \frac{100 \times 0.494}{VW} = \text{per cent of invert sugar."} \tag{25}$$

[58] Bull. Bur. Chem., 107, p. 52. [59] Pflüger's Archiv., 69, p. 423. [60] Bull. Bur. Chem., 107, p. 42.

(*b*) STANDARD MATERIALS FOR CHECKING

The volumetric determination should be checked frequently against known solutions of pure dextrose or of pure invert sugar as the volume of solution reduced varies with the details of manipulation. The Bureau of Standards offers standard samples of pure sucrose and dextrose for this purpose.[61] The former may be used to prepare invert-sugar solutions or to make up sucrose-invert-sugar mixtures.

8. RATIO OF REDUCING POWERS OF REDUCING SUGARS

The term "reducing power" signifies the weight of copper reduced by a given weight of sugar which may, if desired, be taken as unit weight. The usual method of expressing reducing power is not, however, in terms of copper, but in terms of the relative weights of two sugars required to produce the same weight of copper. One of these sugars, namely, dextrose, is arbitrarily selected to serve as a standard reducing substance and its reducing power is said to be 1. The ratio of the weight of dextrose to that of the sugar in question is said to be the reducing ratio or reducing factor. These ratios have been determined by C. A. Browne[62] and are given in the appended table. In order to reproduce these ratios, quantities of sugar in excess of 50 mg are required and Allihn's solution and method should be employed. If any sugar other than dextrose be analyzed in this way and determined as dextrose, its actual weight is $\frac{1}{\text{factor}}$ times the weight of dextrose as given in Allihn's table. The reducing ratio is of great importance in the analysis of sugar mixtures. Suppose, for example, we have determined a mixture of two sugars and have expressed the result as per cent dextrose $= R$. The respective percentages of the two sugars are given by x and y in the expression

$$ax + by = R \qquad (26)$$

where a and b are the reducing factors. The factors for the various sugars are given in Table 24.

TABLE 24

Reducing Power Factors by Allihn's Method

Dextrose	1.000	Arabinose	1.032
Invert sugar	.958	Xylose	.983
Levulose	.915	Lactose	.66–.71
Galactose	.898	Maltose	.56–.62

[61] See p. 92 of this circular.

[62] J. Amer. Chem. Soc., 28, p. 439.

XIV. PREPARATION OF PURE SUGARS

1. DEXTROSE

(See Fee Schedule 13)

With a view to assisting in the unification of analytical sugar work this Bureau issues as one of its standard samples chemically purified dextrose. In the preparation of this material the purest "anhydrous glucose" of commerce, containing at least 90 per cent dextrose, is submitted to a preliminary treatment similar to that described by Bauer.[63] The crude material is digested in a shaking machine with alcohol in order to wash the mother liquor from the crystals. The mass is then poured into a centrifugal machine and drained at high velocity. The drained crystals are then washed repeatedly with fresh portions of alcohol after each addition, running the machine at 3000 r. p. m. The washed substance is dissolved by heating in 40 per cent of its weight of water and 140 cc of alcohol added for each 100 g of the washed substance. This mixture is then heated on a steam bath and filtered to remove the precipitated impurities. The filtrate is boiled in the vacuum boiling apparatus described on page 95 to about 60 per cent sugar. The supersaturated liquid is then transferred to a shaking machine, a few crystals of dextrose added, and the substance allowed to crystallize in motion. After standing over night the crystal mass is centrifuged and washed four or five times with redistilled alcohol. The crystals obtained are very white and possess already a high purity. They are then dissolved in water, the solution filtered through asbestos into the boiling apparatus, and recrystallized. The second crystals are carefully dried and analyzed for moisture, ash, polarization, and reducing power. If these tests indicate the presence of any remaining impurity, the recrystallization is repeated until a satisfactory product is obtained.

The standard dextrose sample may be used to standardize analytical determinations of reducing substances. Frequently it may replace the usual invert sugar solution and has the advantages of greater convenience in the preparation of the solution and greater certainty of composition. Some uncertainty arises in the prepa-

[63] Orig. Comm. 8 Int. Congress of App. Chem., 13, p. 21.

ration of invert sugar solutions owing to the question of purity of the sucrose and the method of inversion employed. Reversion products may be formed or either levulose or dextrose injured by too long action of the acid. Furthermore, if the solution is preserved, decomposition may occur if either acid or alkali is in excess. The standard dextrose solution may be prepared very readily and conveniently by weighing out the required amount of solid substance and dissolving in the necessary volume of water. In this way a neutral solution of known composition is very rapidly and conveniently prepared.

Instead of the dextrose solution a solution of invert sugar may be used if carefully prepared.

2. STANDARD INVERT SUGAR SOLUTION

[Method of the Association of Official Agricultural Chemists]

"Dissolve 4.75 g of pure sucrose in 75 cc of water, add 5 cc of 38.8 per cent hydrochloric acid, and set aside during a period of 24 hours at a temperature not below 20° C, or if the temperature be above 25° C set aside for 10 hours. Neutralize the acid exactly with dilute sodium hydroxide and make up to 1 liter; 100 cc of this solution contains 500 mg of invert sugar."

The practice of checking frequently the analytical work on reducing substance determination should be observed whether a volumetric or gravimetric method is employed. The amount of reduced copper obtained is dependent in great measure upon the conditions of the particular analysis carried out. Errors may arise from impurities in reagents, time of boiling, or from many other circumstances connected with individual differences of procedure, but these are all eliminated if the analyst standardizes his own procedure by means of a known quantity of reducing substance and subsequently adheres rigidly to that same procedure.

3. SUCROSE

(See Fee Schedule 13)

Most of the methods for the purification of sucrose which have been described depend upon the use of alcohol as a precipitant. Sucrose is almost insoluble in absolute alcohol, and its solubility in alcohol-water mixtures diminishes very rapidly as the concentration of alcohol increases.

(*a*) METHOD OF HERZFELD[64]

Prepare a cold, saturated, filtered, refined sugar solution and with continual stirring add an equal volume of 96 per cent alcohol. Filter after 15 minutes, wash with ether, and dry it in a water bath.

(*b*) METHOD OF HERLES

This method gives particular attention to the elimination of raffinose. To exclude traces of raffinose, precipitate a cold, saturated, filtered solution of refined sugar with alcohol, warm on a water bath to 60°, decant the solution, pour fresh alcohol on the precipitate, warm with stirring, decant again, wash the sugar on a filter with absolute alcohol, and dry in a thin layer on filter paper at 30° to 40°.

On account of the well-known solubility of raffinose in methyl alcohol many operators have used this as a precipitant to insure the removal of this impurity.

(*c*) METHOD OF THE INTERNATIONAL COMMITTEE

To prepare pure sugar, further purify the purest commercial sugar in the following manner: Prepare a hot, saturated, aqueous solution, precipitate the sugar with absolute ethyl alcohol, spin the sugar carefully in a small centrifugal machine, and wash in the latter with absolute alcohol. Redissolve the sugar thus obtained in water, again precipitate the saturated solution with alcohol, and wash as above. Dry the second crop of crystals between blotting paper and preserve in glass vessels for use. Determine the moisture still contained in the sugar and take this into account when weighing the sugar which is to be used.

(*d*) METHOD OF BATES AND JACKSON

A method of purification has been developed at this Bureau in which recrystallization from aqueous solution is utilized. The purest granulated sugar of commerce is dissolved in an equal weight of water. This relatively dilute solution is clarified from albumenoids and suspended material by the addition of alumina cream which has been carefully freed from soluble salts by continued washing and testing the wash water by barium chloride. The solution of sugar is filtered by pouring on large fluted filters of hardened filter paper. The filtered solution which usually has the brilliancy of distilled water is boiled in a vacuum-distilling apparatus at a temperature not exceeding 35° C until the concen-

[64] v. Lippmann, Die Chem. der Zuckerarten, II, 1051.

tration of the solution, which was initially 50 per cent, reaches 76 to 80 per cent.

The requisites for a serviceable concentrator may be briefly summarized as follows: 1, Cleanliness; 2, low boiling point; 3, large capacity; 4, filtration of entering sirup.

The concentrator is shown diagrammatically in Fig. 10. The entire assembly, with the exception of the aluminum vessel *B* and condensing coils *C*, is of glass, and with the exception of the small asbestos filter the sirup never comes in contact with any other substance. The evacuating is done by a power-driven

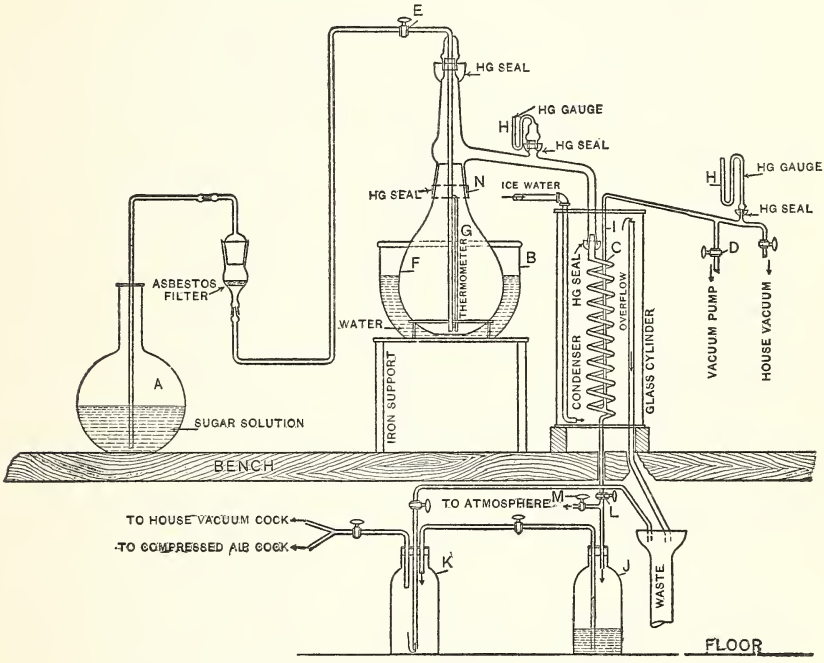


FIG. 10.—*Vacuum apparatus for concentrating sirups*

Duplex and Geryk pump connected at *D*. When it is desired to concentrate a sugar sirup the procedure is as follows: The solution, usually 40 to 50 per cent concentration, is placed in the flask *A*, and the entire system evacuated up to the cock *E*. This cock is then carefully opened and the solution slowly driven through the asbestos filter into the boiling flask *F*, capacity 13 liters. Here it is gently warmed by the water bath, and the temperature of the sirup noted on the thermometer *G*. In order to obtain any desired boiling point it is only necessary to regulate the pressure. The degree of the vacuum is indicated by the mercury gauges

H, *H*. The efficiency of the assembly is such that sirup is rapidly brought to the desired concentration of about 80 per cent at a temperature below 32° C. This is made possible by the high efficiency of the condensing system and by having all joints carefully ground to a fit. The stopcocks are lubricated with water or sugar sirup. The condensing coils *C* are of copper, eight in number, connected in parallel, and immersed in ice water. To prevent vapor reaching the vacuum pump, the pipe *I* is joined to the base of the condenser. As rapidly as the vapors condense they pass into the vessel *J* and subsequently by closing the cock *L* and opening *M* are expelled into *K*, from which the liquid is eventually driven into the waste. By noting the quantity of this liquid, the concentration of the sirup in *F* is known at all times.

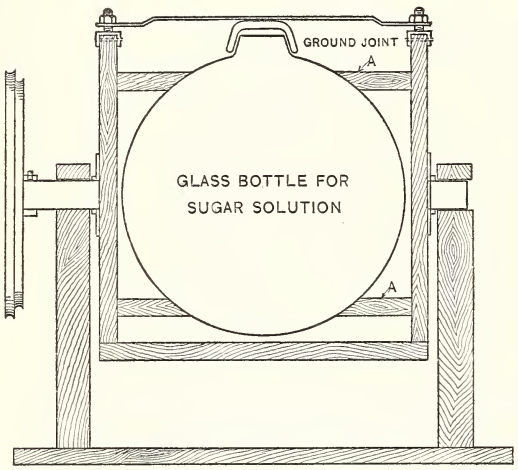


FIG. 11.—*Crystallizer*

The question of size of crystals is of the first importance. In general the smaller the crystals the less the "included solvent" or entrapped mother liquor. When the solution in the boiling flask *F* has reached the desired concentration, the vacuum is broken at *N* and the solution poured out to crystallize. Crystallization in general does not begin in these pure solutions until they are seeded with a few fine crystals of sugar. This is not done until after the solution is removed from the boiling flask. Two methods of crystallization have been tried. In the first the concentrated solution is transferred to a precipitation jar. It is then carefully stirred with a glass rod provided with a glass shield. This procedure gives satisfactory results so far as the control of the crystal growth is concerned, but it is laborious. In the second, the liquid is transferred to a crystallizer, a cross section of which is shown in Fig. 11. By this means it was found practicable to crystallize from a larger quantity of liquid and with no danger of contamination. The device is very simple and consists of a hardwood box mounted on bearings and driven by an electric motor. The supports *A*, *A*,

which carry the container, are adjustable in order to keep the center of gravity on the axis of rotation. The box is rotated at about 35 revolutions per minute, so that the contents are subjected to a gentle and continuous agitation.

The solid is separated from the mother liquor by a motor-driven centrifugal machine. The centrifuge shown in cross section

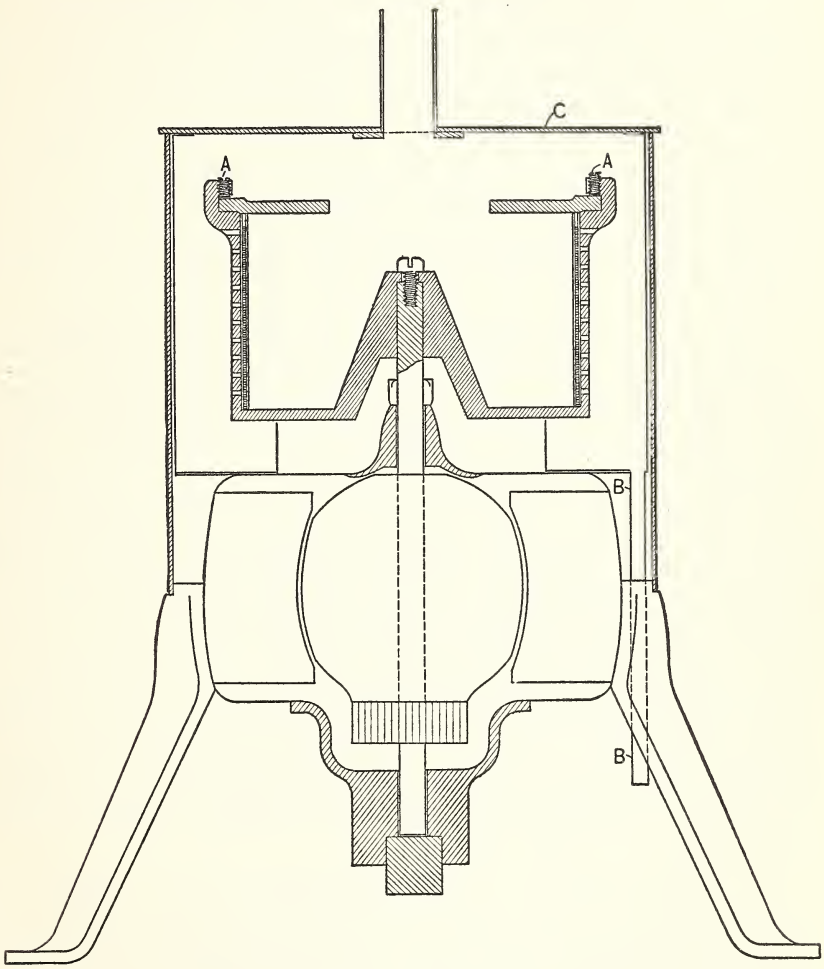


FIG. 12.—*Centrifuge*

in Fig. 12 was built by the International Instrument Co. of Cambridge, Mass., in cooperation with the Bureau, and has met all requirements. Its height over all is 2 feet, and it requires but 4 square feet of floor space. All the inside walls of the metal housing, in fact all surfaces with which either the crystals or the

mother liquor can come in contact, are silver or nickel plated. The basket is carried on the end of the vertical shaft of a three-fourths horsepower motor. It has an inside diameter of 9½ inches, and is capable of carrying 10 pounds of sugar. Its heavy cover is held in place by a number of set screws *A*, *A*, and is readily removable in order to facilitate the removal of the centrifuged material. The problem of a suitable lining has given considerable trouble. To be satisfactory it must retain very small crystals, permit of free drainage of the mother liquor, and be able to stand the severe strains incidental to high speeds. It is obvious that no single lining is available that will meet all three requirements. A built-up lining was accordingly resorted to. It consists of two layers. The outer one is the regular copper centrifuge lining [65] with elongated conical holes. The inner one is of 200-mesh brass gauze. Both linings are silver plated.

In order to hold the flimsy gauze in place it was necessary to fold it over the edge of the heavy copper lining, both above and below, and also around the ends where the vertical edges meet, in every case allowing it to overlap by 1 or 2 centimeters. At the junction of the two edges an extra piece of gauze was fastened to close the crack. Inasmuch as the wear on the gauze lining occurs at the top, it was protected by a piece of thin copper tape which was bent into place. This combination has given excellent results. The mother liquor finds an outlet through the drain *B*. The small space left between the lid and the frame was closed by stretching a rubber band tightly around the whole machine.

It will be observed that when the centrifuge is in operation with the hinged lid *C* closed the contents of the basket as well as the mother liquor are safe from contamination by the air of the room. The speed of rotation of the basket is controlled by a rheostat in series with the motor.

In order to secure a proper distribution of the crystals and insure smooth running of the basket, the crystal mass is introduced while the machine is stationary or running at very low velocity. The speed is gradually increased as the mother liquor runs off until finally the maximum speed of 3000 revolutions per minute is attained.

The substance is then recrystallized in a similar manner, but a second filtration is accomplished through the layer of asbestos in

[65] Manufactured by Fontanie & Co.

a glass filter shown in Fig. 10, connected directly to the boiling apparatus which supplies the necessary vacuum. This asbestos filter effectively removes the shreds of filter paper which are almost invariably in the filtrate after a filtration through paper. After the solution has passed this filter it comes in contact with nothing but clean glass, and all manipulation of the solution or crystals is carried out under glass cabinets, to reduce possible contamination by dust. The air-dried crystals are powdered to dust in an agate mortar, of which the pestle carries a shield to prevent contamination, and are placed in a vacuum desiccator over lime.

(*e*) MODIFICATION OF METHOD OF BATES AND JACKSON

A modification of the method of Bates and Jackson has been tried at this Bureau. A 50 per cent solution is clarified by alumina cream, filtered and boiled below 35° C as described above. The boiling is continued to a concentration of 70 to 73 per cent sugar. It is then poured into a crystallizing jar and precipitated by the addition of an equal volume of pure alcohol. The precipitate is separated centrifugally, washed with alcohol, and air dried. This process is repeated. Before bottling it is dried over lime in a vacuum.

The alcohol used for the precipitation of pure sugar should be highly purified with respect to acids or aldehydes. It is not essential that it be dry or free from other members of the alcohol group. The method of purification described by Dunlap [66] meets these requirements. Dissolve 1.5 g of silver nitrate in 3 cc of water, add to a liter of 95 per cent alcohol in a glass-stoppered cylinder and shake. Dissolve 3 g of caustic potash in 10 cc of warm alcohol and after cooling pour slowly into the alcoholic $AgNO_3$ solution. Do not shake. Allow to stand overnight. Siphon off and distill.

(*f*) ANALYSIS

(See Fee Schedule 45)

If sugar is to be used for the purpose of standardizing instruments, its purity should be ascertained. This is particularly true of samples required for polarimetric standards and for scientific data of all kinds. There are many sorts of impurities whose presence if undetected may lead to false conclusion in the interpretation of data. These impurities may be grouped into classes

[66] J. Am. Chem. Soc., 28, p. 397.

for the sake of convenience: (*a*) Soluble inorganic impurities, (*b*) soluble organic impurities which reduce alkaline copper, (*c*) soluble organic impurities which do not reduce alkaline copper, (*d*) moisture.

Inorganic impurities may readily be recognized by an ash determination. To perform this a quantity of the sugar should be weighed into a very carefully weighed platinum capsule and burned to a char. The char should then be ignited in a muffle furnace at a low red heat, properly below 650° C, until the carbon has been consumed. The ash from a sample of properly purified sugar should not amount to 0.01 per cent. It must be ascertained that the dish itself is of constant weight during a similar period of heating. Samples prepared at this Bureau frequently have an ash content of less than 0.1 mg for a 5 g sample.

The estimation of very small quantities of reducing substances in the presence of the very large quantity of sucrose requires the employment of special methods. The usual methods in which copper sulphate is dissolved in caustic alkali are unsuitable because of the destructive action of the reagent upon the sucrose. The following method used at this Bureau gives reliable results. A solution containing 297 g of $KHCO_3$ and 1 g $CuSO_4.5\ H_2O$ is prepared. The potassium bicarbonate should not contain much K_2CO_3. Fifty cubic centimeters are pipetted into a beaker, boiled for one minute, and a solution of 50 cc containing 10 g of the sugar are added, the whole brought to boiling, and ebullition continued for two minutes. At the end of this period 100 cc of cold boiled water are added and the precipitate collected on a Gooch-Munroe crucible or on a very closely packed asbestos mat. It has been shown at this Bureau that pure sucrose will produce under this procedure a precipitate of 1.1 mg Cu_2O, while each 0.01 per cent impurity of reducing substance (estimated as invert sugar) increases this precipitate by 1.9 mg. Pure sugar causes a precipitate with all alkaline copper solutions due to its own reducing action. The greater the alkalinity of the copper solution the greater the precipitate, and the greater the copper content the more the precipitate is increased.

The impurities of class *c* are not so easily detected, but investigations at this Bureau have shown that recrystallization from aqueous solution or by precipitation with alcohol results, in every case examined, in a purification of the sucrose. This fact can only be shown by a polarimetric study.

In order to dry pure powdered sucrose, care should be exercised not to subject the sample to a prolonged high temperature. Under the influence of an elevated temperature sucrose undergoes a decomposition which is similar to a process of "caramelization." In Table 28 is given the time at each temperature required to form "caramel" equivalent in reducing power to 0.01 per cent of invert sugar. Caramel can be detected by its reducing action on the alkaline copper solution. Finely pulverized sugar can be dried at 70° C in a vacuum in four hours. The moisture remaining will in general amount to less than 0.01 per cent.

XV. ANALYTICAL METHODS FOR SUGAR MIXTURES

(See Fee Schedule 45)

In general in a sugar mixture it is necessary to have as many different analytical processes as there are sugars. These methods should be selected in such a way that the most varied properties of the sugars are represented.

1. TWO SUGARS

(*a*) COMBINATION OF TWO POLARIMETRIC EQUATIONS

In many instances it is possible to polarize a sugar mixture under conditions sufficiently different to emphasize some striking difference in properties of the two sugars. The variation in specific rotation of the two individuals under the varied conditions must be known in order to substitute in the two corresponding equations. If x and y are the respective percentages of each sugar in the mixture, a and a' the known specific rotations of one of the sugars under the two varied conditions, b and b' those of the second sugar,

$$a\,x+b\,y=100[\alpha]_D \tag{27}$$

$$a'\,x+b'\,y=100[\alpha']_D \tag{28}$$

in which $[\alpha]_D$ and $[\alpha']_D$ are determined experimentally.

The variation of conditions may take the form of a change of temperature, change of solvent, change from neutral to acid solution. Frequently the addition of some foreign substance exerts a striking influence upon the specific rotation of one of the sugars. It must be borne in mind that these influences upon the individual sugars must be known with precision before making application to a mixture.

(*b*) COMBINATION OF POLARIMETRIC AND DENSIMETRIC EQUATIONS

If no other solid substance than the two sugars be present in a solution, it is possible to determine the density or degrees Brix of such solution and set up an equation with the known total sugar present, e. g., $x+y=$total sugar, where x and y are the respective per cent of each sugar. This procedure does not give the total sugar with high precision because the densities of the various sugars of equal percentage composition are not exactly

the same, but for ordinary requirements the approximation is satisfactory. If the only impurity besides the two sugars is an inorganic substance, it is a frequent practice to determine the ash and subtract this weight from the total solids as determined by the density or refractive index. This method is, of course, only approximate.

(*c*) COMBINATION OF POLARIMETRIC AND REFRACTOMETRIC EQUATIONS

Total sugar may also be determined by measuring the refractive index of the solution. Reference to tables gives the total solid with considerable exactitude. $x+y=$per cent total solid.

(*d*) COMBINATION OF POLARIMETRIC AND REDUCING POWER EQUATIONS

In case the sample is not a mixture of the two pure sugars it is preferable to combine with the polarimetric equation an equation of combined reducing power in terms of dextrose; that is, the weight of reduced copper converted from the table directly into dextrose. For this purpose reducing sugar is determined in the manner described on page 85. C. A. Browne [67] has shown experimentally that the reducing power of a sugar mixture is very exactly the additive property of the constituents.

Let a be the reducing ratio of the first sugar to dextrose.

Let b be the reducing ratio of the second sugar to dextrose.

Then the combined influence of the two reducing sugars is

$$a\,x+b\,y=R \qquad (29)$$

in which x and y are the respective per cents of the two sugars and R is the per cent of total reducing sugar estimated as dextrose.

(*e*) MIXTURE OF GLUCOSE AND FRUCTOSE

If the two substances are present in the pure state, the first equation may be

$$x+y=\text{per cent total solids} \qquad (30)$$

as found by density or refractometer. If the reduction method is used, the equation is

$$a\,x+b\,y=R \qquad (31)$$

where R is the reducing substance estimated as dextrose.

To find the coefficients for the polarimetric equation, the respective specific rotations for the approximate concentration of each sugar at the temperature of the experiment (see p. 149)

[67] J. Am. Chem. Soc., 28, p. 439.

may be used, if the specific rotation of the mixture is determined. If the saccharimeter is used, the polarizing power should be expressed in terms of sucrose. The coefficient of each sugar is then the ratio of its specific rotation to that of sucrose, bearing in mind the variation of the respective specific rotations with temperature and concentration. If the specific rotation of sucrose is 66.5, the polarizing ratio of fructose (at 20°, 10 per cent solution) is $\frac{90.18}{66.5}=1.356=\alpha$; that of dextrose is $\frac{52.74}{66.5}=0.793=\beta$.

The specific rotation of the sucrose may be considered constant, regardless of the concentration, because 66.5 is the value at the hundred point, and all portions of the scale are marked off in exact proportion of concentration. The specific rotation of the other sugars, however, should be corrected for both temperature and concentration.

Formula for polarimetric equation:

Let α be polarizing power of first sugar.

Let β be polarizing power of second sugar.

Let P be polarizing power of mixture.

then,

$$\alpha x+\beta y=P. \tag{32}$$

The term polarizing power may mean the respective specific rotations, in which case the experimental data P for analyzing the mixture will require a determination of the specific rotation of the mixture; α and β are the respective $[\alpha]_D^t$'s of the pure components. Or polarizing power may be determined on the saccharimeter on the sucrose scale. In this case 26 grams of the mixture are dissolved in 100 cc of solution, or the equivalent calculation made by reference to the density of the solution. The polarization is performed in a 200-mm tube in the saccharimeter. In this case the coefficients α and β are the ratios of polarizing power of the sugar in question to that of sucrose and may be found from the ratios of the respective specific rotations. By combination of equations (27) and (30) we obtain

$$x=\frac{bP-\beta R}{\alpha b-a\beta} \tag{33}$$

$$y=\frac{\alpha R-aP}{\alpha b-a\beta} \tag{34}$$

$$=\frac{R-ax}{b} \tag{35}$$

2. THREE SUGARS[68]

(See Fee Schedule 45, *f*)

For the determination of three sugars three equations are necessary. One of these usually expresses the per cent of total sugar, determined densimetrically, by drying or by refractive index. If inorganic substances are also present, an approximate correction may be made to the per cent of total solids by subtracting the weight of the ash. A second equation represents total reducing power of the mixture in terms of dextrose. A third represents total or resultant polarizing power.

The equations are

$$x+y+z=\text{Total sugar.} \tag{36}$$

$$ax+by+gz=\text{Total reducing sugar estimated as dextrose.} \tag{37}$$

$$\alpha x+\beta y+\gamma z=P \text{ (polarization).} \tag{38}$$

The second equation represents dextrose as determined by Allihn's method. The third equation again may be computed as specific rotation or it may be determined on the sucrose scale, using the factors given on page 149.

A frequently occurring mixture of three sugars is that of sucrose, dextrose, and levulose. The reducing power of sucrose may be taken as zero. The equations then become

$$x+y+z=\text{Total sugar.}$$

$$x+0.915\ y=R.$$

$$0.793\ x-1.356\ y+z=P \text{ (on saccharimeter).}$$

This method gives very good approximation, which may be increased if a small reducing factor is given to sucrose.

In sugar mixtures the approximation may be improved by a direct determination, whenever possible, of any one of the three. Whenever sucrose is present it is always possible to determine it directly by means of the double Clerget polarization. In the presence of the two hexoses the acid method should be used with great caution in order to prevent decomposition. The invertase method is preferable because no decomposition can occur under the conditions of the analysis.

[68] Browne: Handbook of Sugar Analysis, p. 484.

XVI. STANDARD SAMPLES

1. SUCROSE

(See Fee Schedule 13)

This Bureau is prepared to issue standard sucrose samples prepared by recrystallization from aqueous solution or by precipitation with alcohol. In the case of each sample the process of purification has been continued until analysis shows a satisfactory product. A certificate of analysis accompanies the sample. The sugar usually contains but little moisture, and in a moderately dry atmosphere shows very little hygroscopicity. It is advisable to store the sample in a cool dry place. If placed in a desiccator, the drying agent used should be pure. Vapors from impure sulphuric acid or phosphorus pentoxide frequently damage the sugar.

The uses of standard sucrose samples may be briefly stated as follows:

(1) As a primary saccharimetric standard; (2) as a source of pure invert sugar for the standardization of analytical determinations of reducing sugar; (3) as a material for the standardization of bomb calorimeters. It has the advantage of being nonvolatile and nonhygroscopic. It is rather difficult to ignite and sometimes does not burn completely. It has a heat of combustion of about 3,950 calories, or only about half that of the average coal. The more exact value for each sample will be given in the certificate. For details of the standardization of bomb calorimeters, see Circular No. 11.

2. DEXTROSE

(See Fee Schedule 13)

The standard dextrose samples are prepared by purification of the purest glucose of commerce in the manner described on page 92. A certificate of analysis will show the degree of purification of the sample. The standard dextrose sample is intended to assist in research work of a general nature and in particular to serve as a standard reducing sugar for analytical work.

XVII. SPECIAL TESTS

The special requirements of scientific investigators, manufacturers of apparatus, and others for higher precision than is considered in the foregoing schedules will be met as far as the regular work of the Bureau will permit. The application for a special test should state fully the purpose for which the apparatus has been used or is to be used in the future, the need for the test, and the precision desired. The test should be arranged for by correspondence before shipment of the apparatus. The special fee charged will depend chiefly upon the time consumed and the amount of alteration required in the regular Bureau testing set-ups. An estimate will be given when possible.

XVIII. CERTIFICATES AND STATEMENTS

When apparatus submitted fulfills the requirements for certification, it will be tested and given a certificate of corrections. The certificate can only indicate the corrections of the apparatus at the time of the test, and does not guarantee the constancy of the values. When there are defects which exclude an apparatus from certification, a statement will be rendered giving such information as has been found.

XIX. GENERAL INSTRUCTIONS TO APPLICANTS FOR TESTS

1. APPLICATION FOR TEST

The request for test should be made in writing, addressed to "Bureau of Standards, Washington, D. C.," and should enumerate the articles submitted for test, giving the identification marks of each—for example, maker's name and number—and should state the nature of the test desired.

2. NATURE OF TEST

The classification of tests in this circular should be followed, and the schedule numbers above should be used to indicate the test desired. When the desired test is not included under the regular schedules, the applicant must comply with the requirements for special tests. When apparatus is sent simply for test, without definite instructions, the Bureau will, if practicable, decide upon the nature of the test.

3. IDENTIFICATION MARKS

All packages should bear the shipper's name and address and, when convenient, a list of the contents.

Each separate piece of apparatus or sample of material should be provided with an identification mark, which in many cases may be the maker's name and number. The identification mark should be given in the application for the test.

4. SHIPPING DIRECTIONS

Apparatus or test specimens should be securely packed in cases or packages which will not be broken in transportation. The shipment in both directions is at the applicant's risk. To facilitate packing and shipping, the tops of the cases should have the return or forwarding address on the underside and should be put on with screws. Transportation charges are payable by the party desiring the test and must be prepaid. Unless otherwise arranged articles will be returned or forwarded by express "collect."

5. RETURN OF APPARATUS

Regular tests will be made in the order in which the applications are received, except as this practice may be varied by grouping similar tests together. It is suggested, therefore, that

the applicant, if possible, make request for a test from two weeks to a month preceding the shipment of the apparatus. This facilitates the work of the Bureau as well as the prompt return of the apparatus.

6. ADDRESS

Apparatus submitted for test, as well as all correspondence, should be addressed simply "Bureau of Standards, Washington, D. C." Apparatus delivered in person or by messenger should be accompanied by a written request for the test.

7. REMITTANCES

Fees should be sent with the request for test, in accordance with the foregoing schedules, or promptly upon receipt of bill. Certificates are not given nor is apparatus returned until the fees due thereon have been received. Remittances may be made by money order or check drawn to the order of the "Bureau of Standards."

XX. SCHEDULES OF TEST FEES

These schedules will go into effect November 1, 1917, and on and after that date supersede previous schedules.[69] All standardizations at 20° C unless otherwise specified.

SCHEDULE 41.—Polariscopes for Absolute Measurement—Circular Scales

(*a*) Test on five to ten points ±0.01°, with critical examination of optical parts.. $5.00
(*b*) Test on five to ten points ±0.002°, with critical examination of optical parts. 10.00

SCHEDULE 43.—Saccharimeters

(*a*) Single-quartz wedge, five points..... $3.50
(*b*) Double-quartz wedge, five points on positive wedge and three points on negative wedge..... 5.00
(*c*) Double-quartz wedge, five points on each wedge..... 7.00
(*d*) Laurent type, five points..... 5.00
(*e*) Other types, price according to conditions.

SCHEDULE 44.—Quartz Control Plates, Cover Glasses, and Polariscope Tubes

(*a*) Rotation in circular degrees, "yellow-green mercury line" (λ=546.1 mμ) and sodium lines (λ=589.25 mμ) at 20° C..... $1.50
(*b*) Rotation in circular degrees and sugar degrees at 20° C..... 2.00
(*c*) Rotation at other temperatures by special arrangement.
(*d*) Table of sucrose corrections for temperature..... 1.00
(*e*) Absence of double refraction in cover glasses.....each.. .05
(*f*) Determination of the average length of polariscope observation tubes to ±0.02 mm of tubes 100, 200, and 400 mm in length with ends of equal diameter.....each.. .40
(*g*) Same, for five or more tubes of the same length.....each.. .25
(*h*) Determination of the average length to ±0.005 mm of tubes of any length up to 500 mm with ends of equal diameter, provided the construction of the tube justifies the above accuracy.....each.. 1.00
(*i*) Determination of the average length to ±0.22 mm of tubes of any length up to 500 mm with ends of unequal diameters.....each.. .75
(*j*) Same, for five or more tubes of the same length.....each.. .50
(*k*) Tubes of variable length will be tested for a fee dependent upon the character and amount of work desired.

SCHEDULE 45.—Sugars and Other Materials

(*a*) Raw sugars and molasses, direct polarization..... $1.00
(*b*) Clerget polarization by acid inversion..... 1.50
(*c*) Clerget polarization by invertase..... 2.00
(*d*) Polarization at 87°..... 1.50
(*e*) Reducing sugars..... 1.00
(*f*) Other sugars..... 1.00 to 2.00

[69] For schedule of test fees for hydrometers, see B. S. Circular No. 16.

(*g*) Moisture determination	$0.50
(*h*) Ash determination	.50
(*i*) Determination of purity of purified sucrose, dextrose, and other sugars	4.00
(*j*) Optical rotation for any substance by special arrangement.	
(*k*) Specific gravity of molasses	1.50

Extract from Fee SCHEDULE 23.—Flasks

[This schedule is subject to change. See latest edition Circular No. 9]

(*a*) For testing and stamping, each capacity tested	$0.25
(*e*) For testing, stamping, and certifying, each capacity tested	.35
(*g*) For testing apparatus intended for temperatures other than 20° C between 15° C and 30° C, additional charges for each piece	.20
(*h*) For testing apparatus of indicated capacity other than in cubic centimeters, additional charges for each piece	.20
(*i*) For preliminary examination of apparatus disqualified for test, charges for each piece	.10

Extract from Fee SCHEDULE 10.—Thermometers

[This schedule is subject to change. See latest edition of Circular No. 8]

(*a*) Determination of corrections in the interval 0° to 100° C to an order of accuracy of 0°.01 or 0°.02, or as accurately as the construction of the thermometer warrants, for each point tested on a single thermometer	$0.30
For the same points tested on additional similar thermometers, per point	.20
(*b*) Determination of corrections in the interval 0° to 100° C to the nearest 0°.1 or 0°.2, for each point tested on a single thermometer	.20
For the same points tested on additional similar thermometers, per point	.10

Extract from Fee SCHEDULE 11.—Weights

CLASS A

	Per weight
(*a*) Regular test,[70] single weights	$1.00
(*b*) Regular test, equal weights and sets made up in the usual series	.75

CLASS B

(*c*) Regular test, single weights	.60
(*d*) Regular test, equal weights and sets made up in the usual series	.40
(*e*) For constancy test add one-half of the fee for the regular test.	

SCHEDULE 12

CLASS M

(*a*) Determination of volume of weight, single weights	$2.00
(*b*) Determination of volume, two or more weights	1.50
(*c*) Determination of corrections, single weights	.80
(*d*) Determination of corrections, equal weights or sets made up in the usual series	.50
(*e*) For constancy test add one-half of the fee for determining the corrections.	

[70] The regular test under class A includes the test for constancy, which will mean that the weight will have to be held at the Bureau for a period of over three months.

CLASS S

(*f*) Regular test, single weights $0.60
(*g*) Regular test, equal weights and sets made up in the usual series ..... .40
(*h*) For constancy test add one-half of the fee for the regular test.

SCHEDULE 13

STANDARD SUGAR SAMPLES

Sample No.		
17.	Sucrose	60 g., $2.00
41.	Dextrose	70 g., $2.00

S. W STRATTON,
Director.

Approved:
WILLIAM C. REDFIELD,
Secretary.

87143°—17——8

APPENDIXES

APPENDIX 1.—REGULATIONS GOVERNING THE WEIGHING, TARING, SAMPLING, CLASSIFICATION, AND POLARIZATION OF IMPORTED SUGARS AND MOLASSES

The following regulations promulgated by the United States Treasury Department are reproduced here because of their general interest. They were prepared with the cooperation of the Bureau of Standards.

WEIGHING

ART. 1. All imported raw sugars shall be weighed without regard to mark, except as provided in articles 12 and 13. The weigher's return shall show the total weight of the cargo, and shall also show separately for each scale, each half day, the weight of all (*a*) wet sugar, (*b*) damaged sugar not wet, (*c*) ship sweepings, (*d*) dock sweepings, (*e*) other sugar. The weigher will make a daily report, as per form Cat. No. 961, to the examiner or sampler in charge, which shall show separately for each scale, each half day, the total number of packages weighed of (*a*) wet sugar, (*b*) damaged sugar not wet, (*c*) ship sweepings, (*d*) dock sweepings, (*e*) other sugar. All ship and dock sweepings shall be weighed before the weigher completes his half day's work. In no instance shall the weigher make a return by filling in the weight from the invoice. In the event that a cargo be consigned to two or more consignees, any consignee's sugar shall be treated as a separate cargo, provided separate entry be made by such consignee.

TARING

ART. 2. All tare shall be taken by mark. When sugar is in tierces, hogsheads, barrels, boxes, or irregular packages, actual tare shall be taken. When sugar is in bags, baskets, and mats, actual tare shall be taken as follows:

	Per cent
Marks of less than 1,000	4
Marks of 1,000 and less than 4,000 (but in no such mark less than 40 receptacles)	3
Marks of 4,000 and less than 10,000 (but in no such mark less than 120 receptacles)	2.5
Marks of 10,000 and over	1 to 2

However, when sugar is discharged and weighed at points other than refineries, actual tare shall be taken of the largest number of baskets and mats practicable and as nearly as possible the percentage above prescribed. When, in the opinion of the weigher, the condition of the receptacles is such as to make it advisable to tare a larger percentage than that above provided, he shall tare as many receptacles as in his judgment are necessary to secure a proper tare. All such receptacles are to be thoroughly cleaned by scraping and sweeping before the tare is taken.

A schedule tare is hereby adopted of 2.5 pounds per bag for Cuban sugars imported in bags measuring 29 by 48 inches, and such schedule tare shall be verified from time to time by actual tare. When actual tare is taken the percentage of bags to be tared shall be as above prescribed.

The bags shall be first carefully cleaned by sweeping and scraping and then weighed. They shall then be steamed for 2 hours and dried for 24 hours and again weighed. The difference in the two weights thus found will represent the sugar recovered in the steaming process. From the weight of the dry-cleaned bags there shall be deducted such proportionate weight of the material recovered in the steaming process as the ratio between ninety-five one-hundredths of 1 per cent per pound and the rate of duty chargeable against the cargo as shown by the regular polariscopic test. The weight per bag thus ascertained shall be the actual tare to be allowed upon the entire importation. For convenience in arriving at the proper amount of duty accruing on an importation when actual tare is taken the following procedure will be observed:

The weigher will report, in addition to the total weight of the importation, the weights of the dry-cleaned and steam-cleaned bags separately. From the total weight of the importation the liquidating clerk will deduct the weight of the dry-cleaned bags and will assess upon the net weight the proper rate of duty according to the polariscopic test. To the amount thus ascertained he will then add the duty at the rate of ninety-five one-hundredths of 1 cent per pound upon the quantity of sucrose material recovered in the steaming process; that is, the difference between the weights of the dry-cleaned bags and the steam-cleaned bags.

Schedule tare of 2.5 pounds shall be allowed on all importations, except where the importers shall file a written application representing that the particular importation named in the application contains an excessive number of damaged bags and giving the approximate percentage of the damaged and undamaged bags, and also requesting that actual tare be taken, in which case the surveyor may, with the approval of the collector, if satisfied that the importation includes an excessive number of damaged bags, ascertain the actual tare on the importation in the manner above provided. If the actual tare thus found does not vary from the schedule tare hereinbefore established by more than 5 per cent, then schedule tare only shall be allowed on such importation.

SAMPLING

ART. 3. All sampling shall be done at the time of weighing. In sampling imported raw sugars a general sample shall be taken; that is, each cargo shall be sampled without regard to marks, except as provided in articles 12 and 13. In the event that a cargo is consigned to two or more consignees, any consignee's sugar shall be treated as a separate cargo, provided separate entry be made by such consignee. A separate general sample shall also be taken of (*a*) wet sugar, (*b*) damaged sugar not wet, (*c*) ship sweepings, (*d*) dock sweepings. In taking the general sample 100 per cent of the packages shall be sampled.

It shall be the duty of all samplers to secure a thoroughly representative sample.

In the event that bags are stained from lying in storage, or any other cause, but the sugar not damaged, the sampler in charge, as well as all other samplers, shall exercise every precaution to see that the bags come approximately alternately with the clean and stained sides up. When, in the opinion of the sampler in charge, the bags are not being so discharged, he shall direct the attention of the inspector to the fact and it shall be the duty of the inspector to thereupon stop the discharge of the cargo until the instructions of the sampler are complied with. If, from any cause, in any cargo, the condition of the bags from the ground tier or any other tier shall differ markedly from the condition of the cargo as a whole, such bags shall be treated as damaged. In order to prevent any unnecessary labor and inconvenience in obtaining the sample the inspector shall direct that the packages when discharged from the vessel upon the wharf shall be so placed that the sampler can readily obtain a 100 per cent sample. All ship and dock sweepings shall be sampled before the sampler completes his half day's work.

ART. 4. In the treatment of sugars under these regulations great care will be taken by samplers and other appraising officers to prevent the drying out of the samples. All the sugar buckets in the possession of a sampler shall be either entirely filled or entirely empty, with the exception of one bucket for each general sample. The tag on each bucket must indicate the character of the sugar and the particular half day on which its contents were drawn. The covers of the buckets must be kept carefully closed, except when momentarily opened to receive the sample. The buckets shall be made of heavy galvanized iron and have a height of 31.5 centimeters and a diameter of 18.5 centimeters. All buckets, after being duly labeled for identification, shall be locked before leaving the hatch preparatory to being forwarded to the appraiser's stores. Except as provided in article 11, no general sample of raw sugars will be mixed and prepared on the wharves. The name of the sampling officer responsible for the sampling of each hatch or vessel will be placed on the label, and the examiner or sampler in charge will forward the samples to the appraiser's office with a dock list as per form Cat. No. 994. After the discharge of the cargo has been completed the examiner or sampler in charge shall forward a letter of transmittal to the appraiser as per form Cat. No. 985.

ART. 5. The sugar triers used shall have the following dimensions:

	Short trier	Long trier	Barrel trier
	Centimeters	Centimeters	Centimeters
Length over all	40.6	152.4	104.0
Length of spoon	22.9	132.1	91.4
Length of shank	17.8	20.3	12.7
Length of handle	26.7	38.1	30.5
Width of spoon	2.7	2.5	2.5
Depth of spoon	0.8	1.3	1.1
Diameter of handle	3.8	3.8	3.8

ART. 6. Sugar in hogsheads and other wooden packages shall be sampled by putting the long trier diagonally through the package from chime to chime, one trierful to constitute a sample, except in small lots, when an equal number of trierfuls shall be taken from each package to furnish the required amount of sugar necessary to make a sufficient sample. In the sampling of baskets, bags, ceroons, and mats the short trier shall be used, care being exercised to have each sample represent the contents of the package. The greatest precaution shall be taken that the samples from each class of packages shall be kept separate and be uniform in quantity. When the hard condition of the sugar renders the use of the short trier impracticable the sampler in charge shall notify the appraiser immediately and await his instructions. The keys of the sugar buckets shall be in possession of the assistant appraiser or the examiner at the appraiser's office, who shall have sole custody of such keys.

ART. 7. At ports where a number of samplers are employed no one sampler shall be continued in the same sugar district or on the same dock longer than one month. A complete record of the assignment of the examiners and samplers shall be kept and shall be approved by the appraiser.

ART. 8. Sugars conveyed on lighters from the place of original discharge before samples have been taken shall not be removed therefrom until notice has been given by the inspector to the examiner or sampler in charge of the time of their proposed removal.

ART. 9. Inspectors are directed to exercise a personal supervision over the discharging of sugar cargoes. They shall have their permits indorsed by the examiner or sampler in charge after the samples have been obtained in accordance with these regulations. Dock sweepings shall be gathered up and weighed and sampled when discharging has stopped for any cause. The inspector is directed to keep, in every instance, an accurate account of the kind and number of packages of sweepings, which

he shall indorse on the back of the permit or lighter manifest before it is presented to the appraiser's office for indorsement. If no sweepings are found the inspector shall indorse the permit or manifest accordingly.

ART. 10. In cases where vessels discharge in one district and the sugars are lightered to another before sampling, the manifest which accompanied the lighter and is delivered to the inspector in charge of the district where such sugars are to be weighed and sampled shall be presented to the examiner or sampler in charge for his indorsement, the same as in the case of an original permit. The inspector in charge of such district shall be held responsible for the treatment of all such sugars under these regulations, the same as if working under the original permit.

ART. 11. All sugar samples drawn on any given half day shall reach the examining room in the appraiser's stores not later than the close of the first official half day following, except where the place of discharge is more than 15 miles distant from the appraiser's stores. Whenever practicable the samples for each half day will be forwarded to the appraiser's stores as soon as the half day is completed. When sugars are discharged at places where the distance makes it impracticable for the regular conveyance to call for the samples, and where special provision is made by contract for other means of transportation, an official shall be detailed by the appraiser to take charge of such samples until they reach the appraiser's stores. When such transportation, owing to accident or storm, is interfered with, an officer may be detailed by the appraiser to go to such place, mix the samples, and bring a sufficient part of the mixed samples to the appraiser's stores.

ART. 12. All raw sugars from the Philippine Islands shall be weighed and sampled as grades 1, 2, and 3. When in the opinion of the examiner or sampler in charge the markings upon the packages do not correctly represent the grade of the sugar contained therein, the grade designation marked upon the packages shall be ignored and the packages shall thereupon be weighed and sampled according to the grade actually found by the samplers in each package. In every instance as nearly 100 per cent of the packages shall be sampled as is practicable.

ART. 13. When practicable all refined sugars shall be sampled with a trier specially provided for that purpose, and such percentage shall be sampled as in the judgment of the examiner or sampler in charge will afford a fair representation of the mark. When there is doubt whether a package of sugar is raw or refined, or whether a raw sugar is above or below No. 16 Dutch standard in color, such package shall be sampled in not less than two places to fairly represent the contents, and such samples shall aggregate not less than eleven ounces. The package shall be numbered by the weigher and weighed separately, and the weigher's return shall show the number and weight of such package.

ART. 14. The utmost care must be taken to keep all the apparatus used in the process of sampling sugar clean and absolutely dry. Suitable cleaning and polishing materials will be supplied to the samplers, who are hereby instructed to always have their implements in perfect condition. The sampler shall frequently and thoroughly clean his trier with a scraper provided for that purpose. Failure to observe these requirements will be reported at once to the appraiser by the examiner or the sampler in charge, and such failure will be regarded as sufficient cause for suspension.

ART. 15. Of importations of molasses, as near as possible to 100 per cent of the packages shall be sampled. If any package or packages invoiced as molasses shall, in the judgment of the sampling officer, have the appearance of sirup of cane juice, a separate sample from each such package, properly labeled as to mark and character, shall be taken for examination as hereinafter provided.

ART. 16. In drawing samples of molasses care shall be taken to secure a fair representation and an equal amount of the contents from each package. Packages of the same size shall be sampled in groups of not more than 25; samples from all of the packages of each group being put into a bucket. An accurate tally shall be kept and with

each bucket shall be reported the number of packages the samples therein represent. The dock list accompanying the sample buckets shall convey the same information and account for every package of the mark. Packages of different size, although invoiced and permitted under the same mark, shall be separately sampled, tested, and returned for classification. Molasses discharged from tank vessels shall be sampled as it is pumped from the tanks, a sample of uniform quantity being drawn at either regular intervals of approximately fifteen minutes or for every 5,000 gallons discharged.

ART. 17. Inasmuch as the absorption of sea water or moisture reduces the polariscopic test of sugar, there shall be no allowance on account of increased weight of sugar importations due to unusual absorption of sea water or of moisture while on the voyage of importation. That portion of the cargo claimed by the importer to have absorbed sea water or moisture on the voyage of importation shall be sampled, tested, and classified separately. This claim must be made at the time of weighing. Special care must be taken that such sugars are sampled so as to fairly represent the contents of the packages.

ART. 18. Sugar discharged during a rain or snow storm shall be sampled under cover. When this is impracticable, or if in the judgment of the appraiser, the sugar may be damaged by reason of the stress of weather the inspector shall immediately stop the discharge of the cargo.

ART. 19. All sugars and sugar products discharged under night permits shall be sampled when weighed.

ART. 20. Sugar closets in the districts shall be substantially built and secured by locks furnished by the Department. The keys of the district closets and offices shall be in the possession of the sampling officers of the districts, who, with the sworn officers in charge of the conveyances, shall have sole custody of such keys.

ART. 21. All officers of the customs having duties in connection with the treatment for duty of imported sugars are expected to cooperate and to use the utmost care and diligence so that the work of sampling and classification may be facilitated. The examiners and samplers in charge shall be held responsible by the appraiser for the strict and impartial enforcement of these regulations, and to this end they shall be notified relative to the time of discharge and weighing of sugar cargoes in their respective districts by the inspector or weigher in charge of the same.

ART. 22. The appraiser shall notify the collector of the boundaries of sugar districts and the location of the examiner's or sampler's office in each district, and such information will be furnished by the collector to the inspectors and weighing officers. The collector shall furnish each inspector and weigher with a copy of these regulations.

CLASSIFICATION

ART. 23. All samples shall be carefully examined with reference to color by the Dutch standard after they have reached the classification room in the appraiser's stores. Should any portion thereof be found to be close to No. 16 Dutch standard in color, it shall be examined and passed upon by two experts in the appraiser's office, and in case of disagreement between them as to the number of the color according to the Dutch standard, the appraiser shall designate some person who will decide between them.

ART. 24. Samples of raw sugar found to be above No. 16 Dutch standard in color shall be preserved and sealed in glass bottles labeled with the name of the importer, date of importation, place whence imported, name of vessel, classification, number and character of packages, and the names of the examiners who passed the same. The bottles containing such samples shall be retained by the appraiser for at least one month after the return of the invoice to the collector.

ART. 25. Great care shall be exercised to have all samples mixed and forwarded to the laboratory for test at the earliest possible date. Under no circumstances shall the

contents of more than three sugar buckets be mixed together. In mixing the greatest care shall be exercised by the examiners to have the contents of the sugar buckets thoroughly mixed. Too much stress can not be laid upon this exceedingly important point.

ART. 26. From the sample prepared by mixing the contents of not more than three buckets duplicate samples shall be prepared by closely packing two tin cans full of sugar and transmitted forthwith to the laboratories for polariscopic test. A third portion, consisting of about 3 pounds, shall be placed in a glass jar to constitute a reserve sample. In all cases the jars must be firmly packed full of sugar before closing and so sealed as to make them air-tight. Such samples after being properly labeled for identification shall be held in safe custody by the appraiser for use when required.

When preparing samples for the laboratory from the reserve jars the entire contents shall be taken out and remixed in order that the moisture may again be evenly distributed throughout the sample.

ART. 27. The tin cans used in transmitting the samples to the laboratories for polariscopic test shall have a height of 11.5 centimeters and a diameter of 8 centimeters. They shall be practically air-tight, the seamless lid fitting snugly over the rim, which is topped by a seamless band. No cans shall be used for this purpose that have not been made on the dies owned by the department.

ART. 28. In transmitting the samples from the examiner's room to the laboratory they shall be indicated only by serial numbers, the key of which shall be kept in a permanent form under the special direction of the appraiser, and the laboratory officers shall not be informed in any manner as to the identity of such samples.

ART. 29. Not less than two complete tests by different experts shall be made of each sample sent to the laboratory. Should the polarization shown by the two tests be 92° S. (sugar degree) or above, and should they agree within 0.2° S., the average of the two polarizations shall be accepted as the test of the sample. If the polarization should be less than 92° S., and they agree within 0.3° S., the average of the two shall be accepted as the test of the sample.

ART. 30. If the polarizations of the two tests do not correspond within the limits of accuracy prescribed in article 29, a third test of the sample shall be made by a third expert, when practicable, and of the three tests so made the average of the two most closely corresponding shall be accepted as the test of the sample, provided the polarizations of the two last-mentioned tests correspond within the limits of accuracy prescribed in article 29; and provided further, that if one of the three tests so made be the average of the other two tests and correspond with the same within the limits of accuracy prescribed in article 29, then such test shall be accepted as the test of the sample.

ART. 31. When two of the three tests do not correspond within the limits of accuracy prescribed in article 29, all three tests shall be discarded and the sample shall again be tested as provided in articles 29 and 30.

ART. 32. The polarizations returned by the chemist in charge shall be permanently entered in a record of tests, form Cat. No. 987, together with the accepted test of each sample. Should such accepted tests of duplicate samples provided for in article 26 correspond within 0.3° S., the average of the two shall be taken as the true polariscopic test of the sugar. All appraisement sheets, forms Cat. Nos. 990 1/8 and 990 2/8 of each cargo shall be filed separately by the loose-leaf system for a permanent record.

ART. 33. When the accepted tests of the two samples do not agree within three-tenths of 1° S., a third sample, to be known as the reserve sample, shall be made up from the reserve portion, and treated as a regular sample. The tests of the reserve sample having been duly recorded, the accepted tests of the three samples shall be considered together. Of the three separate tests so recorded, the average of the two most closely corresponding shall be taken as the test of the sugar; but if one of the said tests be the average of the other two it shall be taken as the correct test.

ART. 34. When the test of the sugar has been determined the appraiser shall immediately notify the importer of the average test of the cargo and also the quantity and test of each lot from which such average test is obtained. Should the importer, within two official days after such notice has been sent to him by the appraiser, claim an error in the test so reported and request a retest, such retest may be granted, provided, on evidence furnished, such claim shall appear to the appraiser to be well founded. Before granting retest the appraiser shall require of the importer any information he may deem desirable relative to the samples and polarizations used in the settlement tests. Before any sugar invoice is passed the appraiser shall require the importer to furnish the settlement tests, and in no instance shall a retest be granted when the difference between the appraiser's test and the settlement test is shown to be less than four-tenths of 1° S. Samples for retest shall be made up from the reserve sample and shall be treated in all respects as provided for the original tests.

All requests for retests of sugar shall be properly filed and a record thereof shall be kept by the appraiser on form Cat. No. 982.

ART. 35. In case of retest made under the provisions of article 34, the test upon which the sugar shall be classified shall be the average of the test and the retest unless it can be shown to the satisfaction of the appraiser that either the test or the retest is in error, in which event the test not in error shall be taken as the basis of classification.

ART. 36. In all cases where in the judgment of the appraiser an error has been made the reserve sample may be resorted to by the appraiser at any time before he has made his return on the invoice for the purpose of determining and correcting such error.

ART. 37. Molasses having been sampled in groups of 25 packages or less as provided for in article 16, a test shall be found for the can of samples representing each group in the manner prescribed in articles 29 to 33, inclusive, and the test for classification shall be the average of the ascertained tests of the several groups so found based upon the proportion of the entire number of packages of the same size which each of the said lot represents, provided the test of any group is not above 56° S.

The test for classification of molasses imported in tank vessels shall be an average of the tests of all the various cans of samples drawn during the discharge of the vessel, as provided for in article 16.

In the examination of molasses all samples shall be handled as expeditiously as possible, in order that they may not be affected by fermentation. In sending samples to the laboratory, the small 1-pound cans containing the same shall be given a serial number that will insure as early a test as possible.

Importations invoiced and entered as molasses, possessing in any degree the taste or smell or other characteristics of sirup of cane juice, shall be subjected to chemical analysis, and determinations shall be made of the percentage of water and of the cane sugar in the dry substance.

ART. 38. In the event of the polarization of the dry substance being above 75° S, the samples shall be held to be sirup of cane juice within the meaning of the tariff; but should the polarization of the dry substance not exceed 75° S the sample shall be designated as molasses, unless there be other evidence of a conclusive character to warrant its designation as sirup of cane juice.

ART. 39. It may be here stated as the view of the Department that molasses, within the meaning of the tariff, is the liquid residuum drained or purged from raw sugar, and hence is the result of a process of manufacture which has for its object the formation of sugar; while on the other hand, sirup of cane juice is the juice of the cane highly concentrated, but not to the point of crystallization, and hence is the result of a process of manufacture having for its chief object the concentration of the juice to the point of preservation but short of crystallization.

ART. 40. In the laboratory a permanent record shall be kept of all samples received from the examiner's room, which shall be entered therein by their serial numbers the order in which they are received; and the chemist in charge shall report all tests made and recorded of such samples, severally, including the third and fourth tests, when made, to the assistant appraiser or examiner in charge of classifications.

ART. 41. When an invoice of sugar or molasses has been passed, the appraiser shall at once send written notice to the importer, informing him of the test for classification of his importation.

ART. 42. In order that the results of the testing of imported sugars at the several ports may be compared, it is directed that on each alternate day, beginning with Monday, a sample of sugar shall be tested at each of the ports of Boston, New York, Philadelphia, and New Orleans, and at the same time duplicate samples of the same sugars shall be exchanged for tests between the appraisers of the said ports and the Bureau of Standards, Washington. The duplicates shall be sent in the tin can prescribed in article 27, which must be firmly packed full of sugar and sealed air-tight with paraffin. The samples shall be numbered at each port of importation from 1 upward, beginning each year with the first official day in January, and the duplicates shall be marked for identification with the same number, the name of the importing port, and the date of test at such port.

ART. 43. The duplicate samples must be tested as soon as they have been received and shall be sent to the laboratory under regular serial numbers, the identifying marks having been removed, after having been first entered in a special record, together with their respective serial numbers. Samples at the port of importation and those sent for exchange shall be tested in all respects as provided in articles 29 to 31, both inclusive, and the separate tests of such samples, together with the accepted tests, shall be promptly reported from each port to the Department, under their respective identifying marks.

ART. 44. On each alternate day, beginning with Tuesday, a sample of sugar will be tested in the dry substance at each of the ports named in article 42, and duplicate samples of the same sugar shall at the same time be exchanged as directed in article 42. The duplicates shall be prepared, marked for identification, and forwarded in manner as provided in article 42. Such samples shall be sent to the laboratory as soon as received, under their respective identifying marks, and reports of tests shall be promptly forwarded from each port to the Department under such marks. Such reports shall show the direct polarization, the per cent of moisture, and the test in the dry substance. When sugars are imported and tested at any port other than those named in article 42, samples shall be tested in the dry substance at the port of importation and duplicate samples shall be transmitted for like test to the Bureau of Standards. The samples shall be prepared and reports of said tests shall be made in all respects as herein prescribed for samples exchanged and tested at the said first-named ports. Reports of tests prescribed in this and the preceding paragraph shall be made on form Cat. No. 990. All requests by the Secretary of the Treasury for retests of duplicate samples at the ports mentioned in article 42 shall be immediately complied with and the retest completed not later than the close of the first official day after the receipt of such request. When for any reason the retests requested by the Secretary of the Treasury are not completed by the close of the first official day after the receipt of the request, the retests shall not be made, and the appraiser shall furnish the Secretary of the Treasury with a detailed statement why said retests were not made as herein provided.

ART. 45. Paragraph 212 of the tariff act of July 24, 1897, provides in part that sugars after being refined, when tinctured, colored, or in any way adulterated, shall pay special rates of duty. In view of this provision appraising officers will cause all refined sugars to be subjected to expert examination, and will report to the collector whether the same after being refined have been tinctured, colored, or in any way adulterated. At

ports where the Government has no facilities for making such expert examination samples of all refined sugars imported shall be forwarded to the nearest appraiser, at New York, Boston, Philadelphia, New Orleans, or San Francisco, who will cause the necessary expert examination to be made and report the results to the collector of the port of importation.

ART. 46. Sugars which are subject to the additional duty imposed under the provisions of section 5 of the tariff act because of any bounty or grant paid or bestowed on the exportation of the same from the country of production, and the amount of such bounty or grant is made dependent on the polariscopic test of the sugar, must be subjected to such test, and report thereof will be made to the collector on the invoice for use in liquidation; but all hard refined sugars, such as cut-loaf, crystals, crushed or granulated, shall be deemed to have tested at least 99.5° S. when exported from the country of production. In all cases where the classification of imported sugar for the assessment of duty is liable to be contested, either on the question of its polariscopic test, or on one arising under the provision of law referred to in the preceding article, representative samples of such sugars shall be preserved in manner as provided in article 26, and such samples shall be held until the return of the invoice to the collector.

ART. 47. All samples of sugar sent to the laboratory for test must be preserved as nearly as possible in the same condition as when received, and shall be returned therefrom to the examining room in such condition with the reports of the tests. All samples tested for exchange and all exchange samples, as soon as they have been returned from the laboratory, shall be labeled with their identifying mark, securely sealed airtight, and held in safe custody in the examining room 30 days from the date of test for such further test or investigation as may be ordered by the Department. In case any exchange sample has been received at any port not properly filled and sealed as herein prescribed, the appraiser at the port of receipt shall immediately notify the appraiser at the port of transmittal, and shall also report the facts to the Department.

ART. 48. All persons shall be denied admission to the examining rooms of the appraiser's office, except officers and employees whose duties require them to have access thereto. This provision must be strictly enforced.

POLARIZATION

ART. 49. The expression "testing * * * degrees by the polariscope," occurring in Schedule E, paragraph 209 of the tariff act, shall be construed to mean the percentage of pure sucrose contained in the sugar as ascertained by polarimetric estimation.

ART. 50. Plans for laboratories for the testing of sugar must be approved by the Secretary of the Treasury. The room used for the purpose shall be one that is as far removed as possible from the vibration of machinery; it must be well lighted and have some means of artificial heat, so that the temperature may be controlled, and shall not be too near any source of heat which can not be controlled. The polariscopes shall be placed in the darkest portion of the room whenever possible, and the top of the table upon which they are placed shall be surrounded on three sides by blackened partitions or walls not less than 3 feet in height. If necessary suitable curtains may be hung around the polariscope to cut off interfering lights. The surroundings of the polariscope shall be such as always to permit the air from the remainder of the room to circulate around the instruments with the greatest freedom. The separation of the lamp from the instruments will be accomplished by the wall around the top of the table. The opening in the partition between the lamp and the instrument shall be as small as possible and yet allow sufficient light for the proper illumination of the polariscope. The polariscope shall not be near ovens, assay furnaces, hot-water heaters, or any other source of heat, and must not be exposed to the direct rays of the sun.

ART. 51. All thermometers, flasks, weights, polariscope tubes, polariscope tube cover glasses, quartz control plates, and polariscopes, used in the work of testing sugar, shall be standardized at the Bureau of Standards, Department of Commerce, and with the exception of the polariscope tube cover glasses and weights, shall be marked with the initials "U. S. C. S.," and bear the stamp of the Bureau of Standards. No test of sugar will be made with apparatus which is not properly marked unless special authority is given by the Secretary of the Treasury.

ART. 52. All the apparatus used in the work of testing sugar by the polariscope shall be standardized at a temperature of 20° C.

ART. 53. All thermometers shall have the centigrade scale and be graduated to not less than one-tenth of a degree.

ART. 54. The flasks shall have a height of 130 millimeters; the neck shall be 70 millimeters in length and have an internal diameter of not less than 11.5 millimeters and not more than 12.5 millimeters. The upper end of the neck shall be flared, and the graduation marks shall be not less than 30 millimeters from the upper end and 15 millimeters from the lower end of the neck.

All flasks shall be standardized to contain 100 metric cubic centimeters at 20° C. The glass funnels used in filtering shall have a diameter of approximately 90 millimeters. The cylinders shall have a height of approximately 125 millimeters and a diameter of approximately 40 millimeters.

ART. 55. Only brass weights shall be used in testing sugar, and shall be forwarded to the Bureau of Standards for standardizing not less than once a year. A sufficient number of standardized duplicate weights shall be kept in reserve in each laboratory to take the place of those being standardized.

ART. 56. The length of all polariscope tubes shall be either 100 millimeters $\pm$0.01 millimeter or 200 millimeters $\pm$0.01 millimeter, and the diameter of the opening through the tube shall be not less than 9 millimeters. No tube shall be retained in use that has become bent or has had its threads injured sufficiently to make the adjustment of the cap difficult.

ART. 57. All quartz control plates shall be mounted in a brass retaining box which shall exert absolutely no pressure whatever upon the plate and yet allow it mimimum play. Each plate will be accompanied by a table, signed by the Director of the Bureau of Standards, giving its exact value at different temperatures from 10° to 35° C.

ART. 58. All polariscopes shall be so adjusted that when a 200-millimeter tube filled with the standard sugar solution is polarized at 20° C the instrument shall read 100° S. $\pm$0.01° S. All points on the scale shall indicate percentages of the standard solution. The standard sugar solution shall be prepared by dissolving 26 grams of pure sugar in pure water and making up the volume to 100 metric cubic centimeters, all weighings to be made in air with brass weights and the volume to be completed at 20° C. A length of 200 millimeters of the standard sugar solution shall be considered to give a rotation of 40.728°, for light of wave length 5,461 centimeters $\times 10^{-3}$.

ART. 59. All polariscopes used in the testing of imported sugars shall have a double quartz wedge compensation and a polarizing system known as the Lippich half shadow. The field of the polariscope will be divided into halves by a vertical line, and in no instance shall a reading of the scale be made unless in the opinion of the observer the halves are of exactly equal intensity.

If when the polariscope is empty and the field a match the zero of the movable scale shall fail to correspond with the zero of the vernier by more than 0.3 S (sugar degrees), they shall be made to coincide by turning the small nipple on the left-hand side of the instrument.

In testing the instrument by means of the quartz control plate not less than four careful readings shall be made. After the average of these readings has been corrected for the error in the zero point it should equal the value stamped upon the plate

within 0.05° S. If such is not the case the polariscope shall be readjusted until the difference is not greater than 0.05° S.

When taking the reading on the quartz control plate referred to in articles 64, the deviation of the zero point shall be neglected after the instrument has been found to be accurately adjusted. The total correction for the instrument shall then be found by means of the table accompanying the plate and the reading of a thermometer placed close to the polariscope.

The method of determining and applying the total correction shall be as follows: Let a sugar solution polarize 80.5° S. The control plate had polarized 91.4° S. The temperature of the room during both observations was 25° C. From the table the value of the control plate at 25° C is 91.7° S. The reading is therefore 0.3 too low and 0.3 shall be added to the reading of the sugar solution, making the corrected polarization 80.8° S.

The zeros of the upper scale and its vernier shall be kept in exact coincidence and the scale securely clamped in that position.

The source of light may be either an incandescent gas mantle or white light electric lamp. The radiating source shall not be less than 200 millimeters distant from the polarizing end, the best position of the source being determined by carefully adjusting it back and forth until the illumination of the field is absolutely uniform and a maximum.

ART. 60. After the can of sugar referred to in article 27 has reached the laboratory its contents shall be thoroughly mixed while in the can by stirring with a spoon just before the weighing is made. In case the sugar contains hard lumps not readily crushed and mixed by stirring it shall be mixed in a mortar or by other adequate means. After mixing, 26 grams are weighed on the balance in the tared German silver dish furnished for this purpose. Care must be taken that the operations of mixing and weighing are not unduly prolonged, otherwise the sample may easily suffer considerable loss of moisture, especially in a warm room. The weighed portion of sugar is washed by means of a jet of water into a 100 cubic centimeter flask, the dish being well rinsed three or four times and the rinsings added to the contents of the flask. The water used must be either distilled water or clear water which has been found to have no optical activity. After the dish has been thoroughly rinsed enough water is added to bring the contents of the flask to about 80 cubic centimeters, and it is gently rotated until all the sugar is dissolved. The flask shall be held by the neck between the fingers or with the thumb and finger and the bulb not handled during this operation. Care must be taken that no particle of the sugar or solution is lost. To determine whether all the sugar is dissolved the flask is held above the level of the eye, in which position any undissolved crystals can be easily seen at the bottom. The character of the solution is now observed. If it be colorless, or of a very light straw color and not opalescent so that it will give a clear, transparent liquid on filtration through paper, the volume shall be made up directly with water to the 100 cubic centimeter mark on the flask.

ART. 61. If a clear, transparent liquid is not obtained as directed in article 60, a clarifying agent shall be added. In that event, before making up to the mark a solution of subacetate of lead is added, which is prepared by boiling three parts by weight of acetate of lead, one part by weight of oxide of lead, and ten parts by weight of water, until the reaction is complete. The filtered solution should have a density of about 1.25. Solid subacetate of lead may be substituted for the normal salt and oxide in the preparation of the solution.

After adding the solution of subacetate of lead the flask must be gently shaken, so as to mix it with the water solution. If the proper amount has been added, the precipitate will usually subside rapidly; but if not, the operator may judge of the completeness of the precipitation by holding the flask above the level of the eye and allowing an additional drop of subacetate of lead to flow down the side of the flask

into the solution. If this drop leaves a clear track along the glass through the solution, it indicates that the precipitation is complete. If, on the other hand, all trace of the drop is lost on entering the solution, it indicates that an additional small quantity of the subacetate of lead is required. The operator must learn by experience the point where the addition should cease; an excess of subacetate of lead solution should never be used.

ART. 62. The solution shall be made up to the mark by the addition of distilled water in the following manner: The flask, grasped by the neck between the thumb and finger, shall be held before the operator in an upright position, so that the mark is at the level of the eye, and water is added, drop by drop, from a siphon bottle or wash bottle until the lowest point of the curve or meniscus formed by the surface of the liquid just touches the mark. If bubbles hinder the operation, they may be broken up by adding a single drop of ether or a spray from an ether atomizer before making up to the mark. After making up to volume drops of water adhering to the neck above the meniscus shall be removed. The mouth of the flask shall be tightly closed with the thumb and the contents of the flask are thoroughly mixed by turning and shaking. The entire solution shall be poured upon the filter.

The funnel and the vessel used to receive the filtrate must be perfectly dry. The first portion of the filtrate, about 20 to 30 cubic centimeters, should be rejected entirely. It may be necessary to return subsequent portions to the filter until the liquid passes through perfectly clear.

If a satisfactory clarification has not been obtained, the entire operation must be repeated, since only with solutions that are entirely clear and bright can accurate polarimetric observations be made.

ART. 63. If after having proceeded as directed in article 62 the solution be still too dark to polarize, even in the 100-millimeter tube, as in the case of dark-colored molasses, it shall be decolorized by means of boneblack. The use of this clarifying agent shall be avoided if possible, however, on account of its well-known property of absorbing sugar. If its use is found absolutely necessary, a fresh solution is prepared, and before filtration 4 or 5 grams of dry boneblack are placed in the apex of the filter paper. The first 50 or 60 cubic centimeters of the filtrate must be rejected.

When a sufficient quantity of the clear liquid has passed through the filter the 200-millimeter polariscope tube shall be filled with it. The 100-millimeter tube should never be used except in the rare cases when, notwithstanding all the means used to effect the proper decolorization of the solution it is still too dark to polarize in the 200-millimeter tube. In such cases the shorter tube may be used and its reading multiplied by 2 but the zero deviation must then be determined and applied to the product. This will give the reading which would have been obtained if a 200-millimeter tube could have been used, and it only remains to apply the correction determined by the use of the control plate, as directed in article 59.

Example

Solution reads in 100-millimeter tube	47.0
Multiplied by 2	2.0
Product	94.0
Zero reads plus 0.3	0.3
Solution would read in 200-millimeter tube	93.7
Reading of control plate	90.4
Sugar value of control plate	90.5
Instrument too low by	0.1
Add 0.1 to	93.7
Correct polarization of solution	93.8

Before filling the tube it must either be thoroughly washed and dried or rinsed several times with a portion of the solution itself. The cover glasses must also be clean and dry and without serious defects or scratches. Under no circumstances after sufficient liquid has passed through the filter shall more than 12 minutes elapse before the tube is filled. Unnecessary warming of the tube by the hands during the filling must be avoided. It is closed at one end with the screw cap and cover glass and grasped by the other end with the thumb and finger. The solution is poured in until its curved surface projects slightly above the opening, the air bubbles allowed time to rise, and the cover glass pushed horizontally over the end of the tube in such a manner that the excess of liquid is carried over the side, leaving the cover glass exactly closing the tube, with no air bubbles beneath it and with no portion of the liquid upon its upper surface. If this result is not attained the operation shall be repeated, the cover glass being rubbed clean and dry and the solution again brought up over the end by adding a few more drops. The cover glass being in position, the tube shall be closed by screwing on the cap. The greatest care must be observed in screwing down the caps that they do not press too tightly upon the cover glasses. By such pressure the glasses themselves may become optically active and cause erroneous readings when placed in the instrument. It shall therefore be ascertained that the rubber washers are in position over the cover glasses and the caps shall be screwed on lightly. A cover glass that has once been compressed may part with its acquired optical activity very slowly and not less than seven official days shall be allowed to elapse before it is used again.

ART. 64. Before the polariscopic reading on the polariscope tube shall be taken an observation on the quartz control plate shall be made as directed in article 59. The tube must be read without altering the position of the instrument relative to the light or changing the character of the light in any way. When a series of successive polarization is made under the same conditions as regards temperature, position of the instrument with relation to the light, intensity of the light, etc., the observation on the control plate need not be made before each polarization; one such observation shall be sufficient for the entire series. The control observation must be repeated oftener if the observer has the slightest reason to think that any of the factors just indicated have been altered After the polariscope tube has been placed in the polariscope the observing telescope shall be so adjusted as to bring the dividing line between the two halves of the field into sharp focus and at the same time vanish as nearly as possible. This condition must be carefully fulfilled before any observation is taken. Each polariscopic tube shall be read on two different instruments by the same observer, and not less than three careful readings of the tube shall be made on each instrument. After the average of these three readings has been corrected by means of the quartz control plate, as directed in article 59, it shall be taken as the polarization of the tube on that polariscope. The average of the two averages obtained from the two polariscopes shall be taken as the final polarization of the tube.

ART. 65. For the determination of moisture in sugars dry approximately 4 grams in a nickel dish of a diameter of 55 mm and a height of 15 mm. Each sample shall be subjected to a temperature of 98° C for two hours.

For the determination of moisture in molasses, sirups, and massecuites, dry approximately 2 grams in a flat dish of not less than 70 mm in diameter. Each sample shall be subjected to a temperature of 98° C for a period of two hours. Care must be taken to run the liquid in a film over the bottom of the dish and to retain in a horizontal position during the entire operation.

ART. 66. No regulation relative to weighing, taring, sampling, classification, and polarization of imported sugars shall be so construed as to permit of mixing together centrifugal, beet, molasses, Philippine, or any sugar different in character from those mentioned for the purpose of weighing, taring, sampling, classification, or polarization.

ART. 67. These regulations shall be and remain in full force and effect from and after the date of approval thereof; and all rules, orders, or regulations heretofore issued or promulgated with reference to weighing, taring, sampling, and classification of imported sugars and molasses are hereby revoked and rendered null and void.

APPENDIX 2.—TABLES

TABLE 8

Apparent Weight (in Grams) of Water in Air

[This table gives the apparent weight for temperatures between 15° and 30° C, humidity 50 per cent, unreduced barometer reading 76 cm, of certain volumes of water weighed with brass weights. The table may be conveniently employed to determine definite volumes of water for calibrating instruments. The air is assumed to be at the same temperature as the water]

Temperature, °C	2000 cc	1000 cc	500 cc	400 cc	300 cc	250 cc	150 cc
15	1996.11	998.05	499.03	399.22	299.42	249.51	149.71
16	1995.80	997.90	498.95	399.16	299.37	249.48	149.68
17	1995.48	997.74	498.87	399.10	299.32	249.43	149.66
18	1995.13	997.56	498.78	399.03	299.27	249.39	149.63
19	1994.76	997.38	498.69	398.95	299.21	249.34	149.61
20	1994.36	997.18	498.59	398.87	299.15	249.30	149.58
21	1993.95	996.97	498.49	398.79	299.09	249.24	149.55
22	1993.51	996.76	498.38	398.70	299.03	249.19	149.51
23	1993.06	996.53	498.26	398.61	298.96	249.13	149.48
24	1992.58	996.29	498.15	398.52	298.89	249.07	149.44
25	1992.09	996.04	498.02	398.42	298.81	249.01	149.41
26	1991.57	995.79	497.89	398.31	298.74	248.95	149.37
27	1991.04	995.52	497.76	398.21	298.66	248.88	149.33
28	1990.49	995.24	497.62	398.10	298.57	248.81	149.29
29	1989.92	994.96	497.48	397.98	298.49	248.74	149.24
30	1989.33	994.66	497.33	397.87	298.40	248.67	149.20

TABLE 9

Temperature Correction for Glass Volumetric Apparatus

[This table gives the correction to be added to actual capacity (determined at certain temperatures) to give the capacity at the standard temperature, 20° C. Conversely by subtracting the corrections from the indicated capacity of an instrument standard at 20° C the corresponding capacity at other temperatures is obtained. The table assumes for the cubical coefficient of expansion of glass 0.000025 per degree centigrade. The coefficients of expansion of glasses used for volumetric instruments vary from 0.000023 to 0.000028]

Temperature, °C	2000 cc	1000 cc	500 cc	400 cc	300 cc	250 cc
15	+0.25	+0.12	+0.06	+0.05	+0.04	+0.031
16	+ .20	+ .10	+ .05	+ .04	+ .03	+ .025
17	+ .15	+ .08	+ .04	+ .03	+ .02	+ .019
18	+ .10	+ .05	+ .02	+ .02	+ .02	+ .012
19	+ .05	+ .02	+ .01	+ .01	+ .01	+ .006
21	− .05	− .02	− .01	− .01	− .01	− .006
22	− .10	− .05	− .02	− .02	− .02	− .012
23	− .15	− .08	− .04	− .03	− .02	− .019
24	− .20	− .10	− .05	− .04	− .03	− .025
25	− .25	− .12	− .06	− .05	− .04	− .031
26	− .30	− .15	− .08	− .06	− .04	− .038
27	− .35	− .18	− .09	− .07	− .05	− .044
28	− .40	− .20	− .10	− .08	− .06	− .050
29	− .45	− .22	− .11	− .09	− .07	− .056
30	− .50	− .25	− .12	− .10	− .08	− .062

TABLE 10

Tolerances and Precision of Corrections for Weights

Denomination	Tolerance classes M and S	Precision of corrections, values given to—			Tolerance classes A and B	Tolerance class C[71]
		Class M	Class S	Class A		
Kilogram:	mg	mg	mg	mg	mg	mg
20	100	10	100	.....	.....	600
10	50	10	10	.....	.....	400
5	25	1	10	.....	.....	250
2	10	1	10	.....	.....	150
1	5	1	10	.....	.....	100
Gram:	.....	.....	[72] 1	.....	.....	.....
500	2.5	1	1	.....	.....	70
200	1.0	0.1	1	.....	.....	40
100	.5	.1	1	.....	.....	30
	.....	.....	[72] 0.1	.....	.....	.....
50	.3	.1	.1	.....	.....	20
26	.2	.1	.1	0.1	2.0	10
20	.2	.01	.1	.....	.....	10
13	.15	.01	.1	.1	1.5	7
10	.15	.01	.1	.....	.....	7
5	.15	.01	.1	.....	.....	5
2	.10	.01	.1	.....	.....	3
1	.10	.01	.1	.....	.....	2
Milligram:	.....	.....	[72] .01	.....	.....	.....
500	.05	.001	.01	.....	.....	1.5
200	.05	.001	.01	.....	.....	.7
100	.05	.001	.01	.....	.....	.5
50	.03	.001	.01	.....	.....	.35
20	.03	.001	.01	.....	.....	.20
10	.02	.001	.01	.....	.....	.15
5	.02	.001	.01	.....	.....	.10
2	.01	.001	.01	.....	.....	.05
1	.01	.001	.01	.....	.....	.04
0.5	.01	.001	.01	.....	.....	.....
.2	.01	.001	.01	.....	.....	.....
.1	.01	.001	.01	.....	.....	.....

[71] Weights whose errors are not larger than these tolerances will be accepted for regular test and certification, but analytical weights need not conform to the class C requirements as to material, structure, etc.
[72] Single reference standards of these denominations will be certified to the higher degree of precision.

TABLE 11

Temperature Corrections to Readings of Saccharometers (Standard at 20° C)

[This table is calculated using the data on thermal expansion of sugar solutions by Plato,[73] assuming the instrument to be of Jena 16[III] glass. The table should be used with caution and only for approximate results when the temperature differs much from the standard temperature or from the temperature of the surrounding air.]

Temperature, °C	Observed per cent of sugar													
	0	5	10	15	20	25	30	35	40	45	50	55	60	70
	Subtract from observed per cent													
0	0.30	0.49	0.65	0.77	0.89	0.99	1.08	1.16	1.24	1.31	1.37	1.41	1.44	1.49
5	.36	.47	.56	.65	.73	.80	.86	.91	.97	1.01	1.05	1.08	1.10	1.14
10	.32	.38	.43	.48	.52	.57	.60	.64	.67	.70	.72	.74	.75	.77
11	.31	.35	.40	.44	.48	.51	.55	.58	.60	.63	.65	.66	.68	.70
12	.29	.32	.36	.40	.43	.46	.50	.52	.54	.56	.58	.59	.60	.62
13	.26	.29	.32	.35	.38	.41	.44	.46	.48	.49	.51	.52	.53	.55
14	.24	.26	.29	.31	.34	.36	.38	.40	.41	.42	.44	.45	.46	.47
15	.20	.22	.24	.26	.28	.30	.32	.33	.34	.36	.36	.37	.38	.39
16	.17	.18	.20	.22	.23	.25	.26	.27	.28	.28	.29	.30	.31	.32
17	.13	.14	.15	.16	.18	.19	.20	.20	.21	.21	.22	.23	.23	.24
17.5	.11	.12	.12	.14	.15	.16	.16	.17	.17	.18	.18	.19	.19	.20
18	.09	.10	.10	.11	.12	.13	.13	.14	.14	.14	.15	.15	.15	.16
19	.05	.05	.05	.06	.06	.06	.07	.07	.07	.07	.08	.08	.08	.08

TABLE 11—Continued

Temperature, °C	Observed per cent of sugar													
	0	5	10	15	20	25	30	35	40	45	50	55	60	70
	Add to observed per cent													
21	0.04	0.05	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.09
22	.10	.10	.11	.12	.12	.13	.14	.14	.15	.15	.16	.16	.16	.16
23	.16	.16	.17	.17	.19	.20	.21	.21	.22	.23	.24	.24	.24	.24
24	.21	.22	.23	.24	.26	.27	.28	.29	.30	.31	.32	.32	.32	.32
25	.27	.28	.30	.31	.32	.34	.35	.36	.38	.38	.39	.39	.40	.39
26	.33	.34	.36	.37	.40	.40	.42	.44	.46	.47	.47	.48	.48	.48
27	.40	.41	.42	.44	.46	.48	.50	.52	.54	.54	.55	.56	.56	.56
28	.46	.47	.49	.51	.54	.56	.58	.60	.61	.62	.63	.64	.64	.64
29	.54	.55	.56	.59	.61	.63	.65	.68	.70	.70	.71	.72	.72	.72
30	.61	.62	.63	.66	.68	.71	.73	.76	.78	.78	.79	.80	.80	.81
35	.99	1.01	1.02	1.06	1.10	1.13	1.16	1.18	1.20	1.21	1.22	1.22	1.23	1.22
40	1.42	1.45	1.47	1.51	1.54	1.57	1.60	1.62	1.64	1.65	1.65	1.65	1.66	1.65
45	1.91	1.94	1.96	2.00	2.03	2.05	2.07	2.09	2.10	2.10	2.10	2.10	2.10	2.08
50	2.46	2.48	2.50	2.53	2.56	2.57	2.58	2.59	2.59	2.58	2.58	2.57	2.56	2.52
55	3.05	3.07	3.09	3.12	3.12	3.12	3.12	3.11	3.10	3.08	3.07	3.05	3.03	2.97
60	3.69	3.72	3.73	3.73	3.72	3.70	3.67	3.65	3.62	3.60	3.57	3.54	3.50	3.43
65	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.2	4.2	4.1	4.1	4.0	4.0	3.9
70	5.1	5.1	5.1	5.0	5.0	5.0	4.9	4.8	4.8	4.7	4.7	4.6	4.6	4.4
75	6.1	6.0	6.0	5.9	5.8	5.8	5.7	5.6	5.5	5.4	5.4	5.3	5.2	5.0
80	7.1	7.0	7.0	6.9	6.8	6.7	6.6	6.4	6.3	6.2	6.1	6.0	5.9	5.6

[73] Wiss. Abh. der Kaiserlichen Normal-Eichungs-Kommission 2, p. 140; 1900.

The above table may also be used with instruments that are standard at 17.5° C, as follows: Find the correction for reducing to 20° C in the usual way, and to this add the correction at 17.5° C with the sign changed; i. e., regarded as positive.

For example, if the instrument reads 20.00 per cent at 24° C, the correction to 17.5° C is +0.26+0.15=0.41, and the true per cent sugar is 20.41. If it reads 20.00 per cent at 18° C, the correction to 17.5° C is −0.12+0.15=+0.03, and the true per cent sugar is 20.03. If it reads 20.00 at 15° C, the correction is −0.28+0.15=−0.13, and the true per cent sugar is 19.87.

TABLE 12 [74]

Stanek's Table for Determination of Water Content of Raw Sugars by Readings on the Immersion Refractometer

Refractometer reading	Per cent water	Refractometer reading	Per cent water	Refractometer reading	Per cent water	Refractometer reading	Per cent water	Refractometer reading	Per cent water
88.0	4.900	88.8	3.900	89.6	2.900	90.4	1.900	91.2	0.900
88.1	4.775	88.9	3.775	89.7	2.775	90.5	1.775	91.3	0.775
88.2	4.650	89.0	3.650	89.8	2.650	90.6	1.650	91.4	0.650
88.3	4.525	89.1	3.525	89.9	2.525	90.7	1.525	91.5	0.525
88.4	4.400	89.2	3.400	90.0	2.400	90.8	1.400	91.6	0.400
88.5	4.275	89.3	3.275	90.1	2.275	90.9	1.275	91.7	0.275
88.6	4.150	89.4	3.150	90.2	2.150	91.0	1.150	91.8	0.150
88.7	4.025	89.5	3.025	90.3	2.025	91.1	1.025	91.9	0.025

Correction for Hundredths Estimated on Scale

0.03° estimated on scale=−0.04% water
0.05° estimated on scale=−0.06% water
0.07° estimated on scale=−0.09% water

[74] See p. 78.

TABLE 13

Temperature Corrections for Determination of Water in Raw Sugars to Accompany Table 12

Temperature, °C	Subtracted from refractometer reading	Temperature, °C	Added to refractometer reading	Temperature, °C	Added to refractometer reading	Temperature, °C	Added to refractometer reading
15.0	0.72	17.6	0.03	20.2	0.82	22.8	1.62
15.1	0.70	17.7	0.06	20.3	0.85	22.9	1.65
15.2	0.67	17.8	0.09	20.4	0.88	23.0	1.69
15.3	0.64	17.9	0.12	20.5	0.91	23.1	1.72
15.4	0.61	18.0	0.15	20.6	0.94	23.2	1.75
15.5	0.58	18.1	0.18	20.7	0.97	23.3	1.78
15.6	0.55	18.2	0.21	20.8	1.00	23.4	1.81
15.7	0.52	18.3	0.24	20.9	1.03	23.5	1.85
15.8	0.49	18.4	0.27	21.0	1.06	23.6	1.88
15.9	0.46	18.5	0.30	21.1	1.09	23.7	1.91
16.0	0.44	18.6	0.33	21.2	1.12	23.8	1.96
16.1	0.41	18.7	0.36	21.3	1.15	23.9	1.99
16.2	0.38	18.8	0.39	21.4	1.18	24.0	2.03
16.3	0.35	18.9	0.42	21.5	1.22	24.1	2.06
16.4	0.32	19.0	0.45	21.6	1.25	24.2	2.09
16.5	0.29	19.1	0.48	21.7	1.28	24.3	2.12
16.6	0.26	19.2	0.51	21.8	1.31	24.4	2.15
16.7	0.23	19.3	0.54	21.9	1.34	24.5	2.19
16.8	0.20	19.4	0.57	22.0	1.37	24.6	2.22
16.9	0.17	19.5	0.61	22.1	1.41	24.7	2.25
17.0	0.15	19.6	0.64	22.2	1.44	24.8	2.29
17.1	0.12	19.7	0.67	22.3	1.47	24.9	2.32
17.2	0.09	19.8	0.70	22.4	1.50	25.0	2.35
17.3	0.06	19.9	0.73	22.5	1.53	25.1	2.38
17.4	0.03	20.0	0.76	22.6	1.56	25.2	2.42
17.5	0.00	20.1	0.79	22.7	1.59	25.3	2.45

TABLE 14

Hübener's Table for Determining Percentages by Weight of Sucrose in Sugar Solution from Readings of the Zeiss Immersion Refractometer

Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose
15.0	0.00	17.0	0.53	19.0	1.05	21.0	1.58	23.0	2.11	25.0	2.64	27.0	3.16
.1	.03	.1	.56	.1	.08	.1	.61	.1	.13	.1	.66	.1	.19
.2	.05	.2	.58	.2	.11	.2	.64	.2	.16	.2	.69	.2	.21
.3	.08	.3	.61	.3	.13	.3	.66	.3	.19	.3	.71	.3	.24
.4	.11	.4	.64	.4	.16	.4	.69	.4	.21	.4	.74	.4	.26
.5	.13	.5	.66	.5	.19	.5	.71	.5	.24	.5	.77	.5	.29
.6	.16	.6	.69	.6	.21	.6	.74	.6	.26	.6	.79	.6	.32
.7	.19	.7	.71	.7	.24	.7	.77	.7	.29	.7	.82	.7	.34
.8	.21	.8	.74	.8	.26	.8	.79	.8	.32	.8	.84	.8	.37
.9	.24	.9	.77	.9	.29	.9	.82	.9	.34	.9	.87	.9	.40
16.0	.26	18.0	.79	20.0	.32	22.0	.84	24.0	.37	26.0	.90	28.0	.42
.1	.29	.1	.82	.1	.34	.1	.87	.1	.40	.1	.92	.1	.45
.2	.32	.2	.84	.2	.37	.2	.90	.2	.42	.2	.95	.2	.48
.3	.34	.3	.87	.3	.40	.3	.92	.3	.45	.3	.98	.3	.50
.4	.37	.4	.90	.4	.42	.4	.95	.4	.48	.4	3.00	.4	.53
.5	.40	.5	.92	.5	.45	.5	.98	.5	.50	.5	.03	.5	.56
.6	.42	.6	.95	.6	.48	.6	2.00	.6	.53	.6	.05	.6	.58
.7	.45	.7	.98	.7	.50	.7	.03	.7	.56	.7	.08	.7	.61
.8	.48	.8	1.00	.8	.53	.8	.05	.8	.58	.8	.11	.8	.64
.9	.50	.9	.03	.9	.56	.9	.08	.9	.61	.9	.13	.9	.66

TABLE 14—Continued

Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose
29.0	3.69	35.0	5.26	41.0	6.82	47.0	8.34	53.0	9.8^	59.0	11.27	65.0	12.69
.1	.71	.1	.29	.1	.84	.1	.36	.1	.83	.1	.29	.1	.72
.2	.74	.2	.32	.2	.87	.2	.39	.2	.85	.2	.32	.2	.74
.3	.77	.3	.34	.3	.90	.3	.41	.3	.88	.3	.34	.3	.76
.4	.79	.4	.37	.4	.92	.4	.44	.4	.90	.4	.36	.4	.79
.5	.82	.5	.40	.5	.95	.5	.46	.5	.92	.5	.39	.5	.81
.6	.84	.6	.42	.6	.97	.6	.49	.6	.95	.6	.41	.6	.83
.7	.87	.7	.45	.7	7.00	.7	.51	.7	.97	.7	.44	.7	.86
.8	.90	.8	.48	.8	.03	.8	.53	.8	10.00	.8	.46	.8	.88
.9	.92	.9	.50	.9	.05	.9	.56	.9	.03	.9	.49	.9	.90
30.0	.95	36.0	.53	42.0	.08	48.0	.58	54.0	.05	60.0	.51	66.0	.93
.1	.98	.1	.56	.1	.10	.1	.60	.1	.07	.1	.53	.1	.95
.2	4.00	.2	.58	.2	.13	.2	.63	.2	.10	.2	.56	.2	.97
.3	.03	.3	.61	.3	.15	.3	.66	.3	.12	.3	.58	.3	13.00
.4	.05	.4	.64	.4	.18	.4	.68	.4	.15	.4	.60	.4	.03
.5	.08	.5	.66	.5	.20	.5	.70	.5	.17	.5	.63	.5	.05
.6	.11	.6	.69	.6	.23	.6	.73	.6	.19	.6	.66	.6	.07
.7	.13	.7	.71	.7	.26	.7	.75	.7	.22	.7	.68	.7	.09
.8	.16	.8	.74	.8	.28	.8	.78	.8	.24	.8	.70	.8	.11
.9	.19	.9	.77	.9	.31	.9	.80	.9	.27	.9	.73	.9	.14
31.0	.21	37.0	.79	43.0	.33	49.0	.83	55.0	.29	61.0	.75	67.0	.16
.1	.24	.1	.82	.1	.36	.1	.85	.1	.32	.1	.78	.1	.18
.2	.26	.2	.84	.2	.39	.2	.88	.2	.34	.2	.80	.2	.20
.3	.29	.3	.87	.3	.41	.3	.90	.3	.36	.3	.83	.3	.23
.4	.32	.4	.90	.4	.43	.4	.92	.4	.39	.4	.85	.4	.25
.5	.34	.5	.92	.5	.46	.5	.95	.5	.41	.5	.88	.5	.27
.6	.37	.6	.95	.6	.49	.6	.97	.6	.44	.6	.90	.6	.29
.7	.39	.7	.98	.7	.51	.7	9.00	.7	.46	.7	.92	.7	.32
.8	.42	.8	6.00	.8	.54	.8	.03	.8	.49	.8	.95	.8	.34
.9	.45	.9	.03	.9	.56	.9	.05	.9	.51	.9	.97	.9	.36
32.0	.48	38.0	.05	44.0	.59	50.0	.07	56.0	.53	62.0	12.00	68.0	.38
.1	.50	.1	.08	.1	.61	.1	.10	.1	.56	.1	.03	.1	.40
.2	.53	.2	.10	.2	.64	.2	.12	.2	.58	.2	.05	.2	.43
.3	.56	.3	.13	.3	.66	.3	.15	.3	.60	.3	.07	.3	.45
.4	.58	.4	.15	.4	.69	.4	.17	.4	.63	.4	.09	.4	.48
.5	.61	.5	.17	.5	.72	.5	.19	.5	.66	.5	.12	.5	.50
.6	.64	.6	.20	.6	.74	.6	.22	.6	.68	.6	.14	.6	.52
.7	.66	.7	.23	.7	.77	.7	.24	.7	.70	.7	.16	.7	.54
.8	.69	.8	.26	.8	.79	.8	.27	.8	.73	.8	.18	.8	.57
.9	.71	.9	.28	.9	.82	.9	.29	.9	.75	.9	.21	.9	.59
33.0	.74	39.0	.31	45.0	.84	51.0	.32	57.0	.78	63.0	.23	69.0	.61
.1	.77	.1	.33	.1	.87	.1	.34	.1	.80	.1	.25	.1	.63
.2	.79	.2	.36	.2	.90	.2	.36	.2	.83	.2	.28	.2	.66
.3	.82	.3	.39	.3	.92	.3	.39	.3	.85	.3	.30	.3	.68
.4	.84	.4	.41	.4	.95	.4	.41	.4	.88	.4	.32	.4	.70
.5	.87	.5	.43	.5	.97	.5	.44	.5	.90	.5	.35	.5	.73
.6	.90	.6	.46	.6	8.00	.6	.46	.6	.92	.6	.37	.6	.75
.7	.92	.7	.49	.7	.03	.7	.49	.7	.95	.7	.39	.7	.77
.8	.95	.8	.51	.8	.05	.8	.51	.8	.97	.8	.42	.8	.79
.9	.98	.9	.54	.9	.07	.9	.53	.9	11.00	.9	.44	.9	.82
34.0	5.00	40.0	.56	46.0	.10	52.0	.56	58.0	.03	64.0	.46	70.0	.84
.1	.03	.1	.59	.1	.12	.1	.58	.1	.05	.1	.49	.1	.87
.2	.05	.2	.61	.2	.15	.2	.60	.2	.07	.2	.51	.2	.89
.3	.08	.3	.64	.3	.17	.3	.63	.3	.10	.3	.53	.3	.92
.4	.11	.4	.66	.4	.19	.4	.66	.4	.12	.4	.56	.4	.94
.5	.13	.5	.69	.5	.22	.5	.68	.5	.15	.5	.58	.5	.96
.6	.16	.6	.72	.6	.24	.6	.70	.6	.17	.6	.60	.6	.98
.7	.19	.7	.74	.7	.27	.7	.73	.7	.19	.7	.63	.7	14.00
.8	.21	.8	.77	.8	.29	.8	.75	.8	.22	.8	.65	.8	.03
.9	.24	.9	.79	.9	.32	.9	.78	.9	.24	.9	.67	.9	.05

TABLE 14—Continued

Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose
71.0	14.07	76.0	15.20	81.0	16.31	86.0	17.44	91.0	18.53	96.0	19.59	101.0	20.66
.1	.09	.1	.22	.1	.33	.1	.47	.1	.55	.1	.61	.1	.68
.2	.11	.2	.24	.2	.35	.2	.49	.2	.57	.2	.63	.2	.70
.3	.14	.3	.26	.3	.38	.3	.51	.3	.59	.3	.66	.3	.72
.4	.16	.4	.28	.4	.40	.4	.53	.4	.61	.4	.68	.4	.74
.5	.18	.5	.30	.5	.42	.5	.55	.5	.63	.5	.70	.5	.76
.6	.20	.6	.32	.6	.44	.6	.58	.6	.66	.6	.72	.6	.78
.7	.23	.7	.34	.7	.47	.7	.60	.7	.68	.7	.74	.7	.80
.8	.25	.8	.36	.8	.49	.8	.62	.8	.70	.8	.76	.8	.82
.9	.27	.9	.38	.9	.51	.9	.64	.9	.72	.9	.78	.9	.85
72.0	.29	77.0	.40	82.0	.54	87.0	.66	92.0	.74	97.0	.80	102.0	.87
.1	.32	.1	.42	.1	.56	.1	.68	.1	.76	.1	.82	.1	.89
.2	.34	.2	.44	.2	.59	.2	.71	.2	.78	.2	.85	.2	.91
.3	.36	.3	.47	.3	.61	.3	.73	.3	.80	.3	.87	.3	.93
.4	.38	.4	.49	.4	.63	.4	.75	.4	.82	.4	.89	.4	.95
.5	.40	.5	.51	.5	.65	.5	.77	.5	.85	.5	.91	.5	.97
.6	.43	.6	.54	.6	.68	.6	.79	.6	.87	.6	.93	.6	21.00
.7	.45	.7	.56	.7	.70	.7	.82	.7	.89	.7	.95	.7	.02
.8	.48	.8	.59	.8	.72	.8	.84	.8	.91	.8	.97	.8	.04
.9	.50	.9	.61	.9	.74	.9	.86	.9	.93	.9	20.00	.9	.06
73.0	.52	78.0	.63	83.0	.76	88.0	.89	93.0	.95	98.0	.02	103.0	.08
.1	.54	.1	.65	.1	.79	.1	.91	.1	.97	.1	.04	.1	.10
.2	.57	.2	.68	.2	.81	.2	.93	.2	19.00	.2	.05	.2	.13
.3	.59	.3	.70	.3	.83	.3	.95	.3	.02	.3	.08	.3	.15
.4	.61	.4	.72	.4	.85	.4	.98	.4	.04	.4	.10	.4	.17
.5	.63	.5	.74	.5	.88	.5	18.00	.5	.06	.5	.13	.5	.19
.6	.66	.6	.76	.6	.90	.6	.02	.6	.08	.6	.15	.6	.21
.7	.68	.7	.79	.7	.92	.7	.04	.7	.10	.7	.17	.7	.23
.8	.70	.8	.81	.8	.95	.8	.06	.8	.13	.8	.19	.8	.25
.9	.73	.9	.83	.9	.97	.9	.08	.9	.15	.9	.21	.9	.27
74.0	.75	79.0	.85	84.0	17.00	89.0	.10	94.0	.17	99.0	.23	104.0	.29
.1	.77	.1	.88	.1	.02	.1	.13	.1	.19	.1	.25	.1	.31
.2	.79	.2	.90	.2	.04	.2	.15	.2	.21	.2	.27	.2	.34
.3	.82	.3	.92	.3	.07	.3	.17	.3	.23	.3	.29	.3	.36
.4	.84	.4	.95	.4	.09	.4	.19	.4	.25	.4	.31	.4	.38
.5	.87	.5	.97	.5	.11	.5	.21	.5	.27	.5	.34	.5	.40
.6	.89	.6	16.00	.6	.13	.6	.23	.6	.29	.6	.36	.6	.42
.7	.92	.7	.03	.7	.15	.7	.25	.7	.31	.7	.38	.7	.44
.8	.94	.8	.05	.8	.18	.8	.27	.8	.34	.8	.40	.8	.47
.9	.96	.9	.07	.9	.20	.9	.29	.9	.36	.9	.42	.9	.49
75.0	.98	80.0	.09	85.0	.22	90.0	.31	95.0	.38	100.0	.44	105.0	.51
.1	15.00	.1	.11	.1	.24	.1	.34	.1	.40	.1	.47	.1	.53
.2	.03	.2	.13	.2	.27	.2	.36	.2	.42	.2	.49	.2	.55
.3	.05	.3	.16	.3	.29	.3	.38	.3	.44	.3	.51	.3	.57
.4	.07	.4	.18	.4	.31	.4	.40	.4	.47	.4	.53	.4	.59
.5	.09	.5	.20	.5	.33	.5	.42	.5	.49	.5	.55	.5	.61
.6	.11	.6	.22	.6	.35	.6	.44	.6	.51	.6	.57	.6	.63
.7	.13	.7	.24	.7	.38	.7	.47	.7	.53	.7	.59	.7	.66
.8	.16	.8	.27	.8	.40	.8	.49	.8	.55	.8	.61	.8	.68
.9	.18	.9	.29	.9	.42	.9	.51	.9	.57	.9	.63	.9	.70
												106.0	21.71

TABLE 15

Geerligs' Table for Dry Substance in Sugar-House Products by Abbe Refractometer, at 28° C

[Intern. Sugar J., 10. p. 69.]

Index refraction	Per cent dry substance	Decimals		Index refraction	Per cent dry substance	Decimals	
1.3335	1	0.0001=0.05	0.0010=0.75	1.4104	46	0.0005=0.25	0.0016=0.8
1.3349	2	0.0002=0.1	0.0011=0.8	1.4124	47	0.0006=0.3	0.0017=0.85
1.3364	3	0.0003=0.2	0.0012=0.8	1.4145	48	0.0007=0.35	0.0018=0.9
1.3379	4	0.0004=0.25	0.0013=0.85	1.4166	49	0.0008=0.4	0.0019=0.95
1.3394	5	0.0005=0.3	0.0014=0.9	1.4186	50	0.0009=0.45	0.0020=1.0
1.3409	6	0.0006=0.4	0.0015=1.0	1.4207	51	0.0010=0.5	0.0021=1.0
1.3424	7	0.0007=0.5		1.4228	52	0.0011=0.55	
1.3439	8	0.0008=0.6		1.4249	53		
1.3454	9	0.0009=0.7		1.4270	54		
1.3469	10						
				1.4292	55	0.0001=0.05	0.0013=0.55
1.3484	11	0.0001=0.05		1.4314	56	0.0002=0.1	0.0014=0.6
1.3500	12	0.0002=0.1		1.4337	57	0.0003=0.1	0.0015=0.65
1.3516	13	0.0003=0.2		1.4359	58	0.0004=0.15	0.0016=0.7
1.3530	14	0.0004=0.25		1.4382	59	0.0005=0.2	0.0017=0.75
1.3546	15	0.0005=0.3		1.4405	60	0.0006=0.25	0.0018=0.8
1.3562	16	0.0006=0.4		1.4428	61	0.0007=0.3	0.0019=0.85
1.3578	17	0.0007=0.45		1.4451	62	0.0008=0.35	0.0020=0.9
1.3594	18	0.0008=0.5		1.4474	63	0.0009=0.4	0.0021=0.9
1.3611	19	0.0009=0.6		1.4497	64	0.0010=0.45	0.0022=0.95
1.3627	20	0.0010=0.65		1.4520	65	0.0011=0.5	0.0023=1.0
1.3644	21	0.0011=0.7		1.4543	66	0.0012=0.5	0.0024=1.0
1.3661	22	0.0012=0.75		1.4567	67		
1.3678	23	0.0013=0.8		1.4591	68		
1.3695	24	0.0014=0.85		1.4615	69		
1.3712	25	0.0015=0.9		1.4639	70		
1.3729	26	0.0016=0.95		1.4663	71		
				1.4687	72		
1.3746	27	0.0001=0.05	0.0012=0.6				
1.3764	28	0.0002=0.1	0.0013=0.65	1.4711	73	0.0001=0.0	0.0015=0.55
1.3782	29	0.0003=0.15	0.0014=0.7	1.4736	74	0.0002=0.05	0.0016=0.6
1.3800	30	0.0004=0.2	0.0015=0.75	1.4761	75	0.0003=0.1	0.0017=0.65
1.3818	31	0.0005=0.25	0.0016=0.8	1.4786	76	0.0004=0.15	0.0018=0.65
1.3836	32	0.0006=0.3	0.0017=0.85	1.4811	77	0.0005=0.2	0.0019=0.7
1.3854	33	0.0007=0.35	0.0018=0.9	1.4836	78	0.0006=0.2	0.0020=0.75
1.3872	34	0.0008=0.4	0.0019=0.95	1.4862	79	0.0007=0.25	0.0021=0.8
1.3890	35	0.0009=0.45	0.0020=1.0	1.4888	80	0.0008=0.3	0.0022=0.8
1.3909	36	0.0010=0.5	0.0021=1.0	1.4914	81	0.0009=0.35	0.0023=0.85
1.3928	37	0.0011=0.55		1.4940	82	0.0010=0.35	0.0024=0.9
1.3947	38			1.4966	83	0.0011=0.4	0.0025=0.9
1.3966	39			1.4992	84	0.0012=0.45	0.0026=0.95
1.3984	40			1.5019	85	0.0013=0.5	0.0027=1.0
1.4003	41			1.5046	86	0.0014=0.5	0.0028=1.0
				1.5073	87		
				1.5100	88		
1.4023	42	0.0001=0.05	0.0012=0.6	1.5127	89		
1.4043	43	0.0002=0.1	0.0013=0.65	1.5155	90		
1.4063	44	0.0003=0.15	0.0014=0.7				
1.4083	45	0.0004=0.2	0.0015=0.75				

TABLE 16

Corrections for the Temperature to Accompany Table 15

Temperature of the prisms in °C	Dry substance												
	0	5	10	15	20	25	30	40	50	60	70	80	90
	Subtract—												
20	0.53	0.54	0.55	0.56	0.57	0.58	0.60	0.62	0.64	0.62	0.61	0.60	0.58
21	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.54	0.56	0.54	0.53	0.52	0.50
22	0.40	0.41	0.42	0.42	0.43	0.44	0.45	0.47	0.48	0.47	0.46	0.45	0.44
23	0.33	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.39	0.38	0.38	0.38
24	0.26	0.26	0.27	0.28	0.28	0.29	0.30	0.31	0.32	0.31	0.31	0.30	0.30
25	0.20	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.24	0.23	0.23	0.23	0.22
26	0.12	0.12	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.16	0.16	0.15	0.14
27	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.07
	Add—												
29	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.07
30	0.12	0.12	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.16	0.16	0.15	0.14
31	0.20	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.24	0.23	0.23	0.23	0.22
32	0.26	0.26	0.27	0.28	0.28	0.29	0.30	0.31	0.32	0.31	0.31	0.30	0.30
33	0.33	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.39	0.38	0.38	0.38
34	0.40	0.41	0.42	0.42	0.43	0.44	0.45	0.47	0.48	0.47	0.46	0.45	0.44
35	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.54	0.56	0.54	0.53	0.52	0.50

TABLE 17

Schönrock's Table for Determining Water in Sugar Solutions by Means of the Abbe Refractometer

$N_D^{20°}$	W	$N_D^{20°}$	W	$N_D^{20°}$	W	$N_D^{20°}$	W	$N_D^{20°}$	W
1.3330	100.0	1.3381	96.5	1.3433	93.0	1.3487	89.5	1.3541	86.0
1.3331	99.9	1.3382	96.4	1.3435	92.9	1.3488	89.4	1.3543	85.9
1.3333	99.8	1.3384	96.3	1.3436	92.8	1.3489	89.3	1.3544	85.8
1.3334	99.7	1.3385	96.2	1.3437	92.7	1.3491	89.2	1.3546	85.7
1.3336	99.6	1.3387	96.1	1.3439	92.6	1.3493	89.1	1.3547	85.6
1.3337	99.5	1.3388	96.0	1.3441	92.5	1.3494	89.0	1.3549	85.5
1.3338	99.4	1.3389	95.9	1.3442	92.4	1.3496	88.9	1.3551	85.4
1.3340	99.3	1.3391	95.8	1.3443	92.3	1.3497	88.8	1.3552	85.3
1.3341	99.2	1.3393	95.7	1.3445	92.2	1.3499	88.7	1.3554	85.2
1.3342	99.1	1.3394	95.6	1.3447	92.1	1.3500	88.6	1.3555	85.1
1.3344	99.0	1.3395	95.5	1.3448	92.0	1.3502	88.5	1.3557	85.0
1.3345	98.9	1.3397	95.4	1.3450	91.9	1.3504	88.4	1.3559	84.9
1.3347	98.8	1.3399	95.3	1.3451	91.8	1.3505	88.3	1.3560	84.8
1.3348	98.7	1.3400	95.2	1.3453	91.7	1.3507	88.2	1.3562	84.7
1.3350	98.6	1.3401	95.1	1.3454	91.6	1.3508	88.1	1.3563	84.6
1.3351	98.5	1.3403	95.0	1.3456	91.5	1.3510	88.0	1.3565	84.5
1.3353	98.4	1.3405	94.9	1.3458	91.4	1.3512	87.9	1.3567	84.4
1.3355	98.3	1.3406	94.8	1.3459	91.3	1.3513	87.8	1.3568	84.3
1.3356	98.2	1.3407	94.7	1.3461	91.2	1.3515	87.7	1.3570	84.2
1.3357	98.1	1.3409	94.6	1.3462	91.1	1.3516	87.6	1.3571	84.1
1.3359	98.0	1.3411	94.5	1.3464	91.0	1.3518	87.5	1.3573	84.0
1.3361	97.9	1.3412	94.4	1.3465	90.0	1.3520	87.4	1.3575	83.9
1.3362	97.8	1.3413	94.3	1.3467	90.8	1.3521	87.3	1.3576	83.8
1.3363	97.7	1.3415	94.2	1.3469	90.7	1.3523	87.2	1.3578	83.7
1.3365	97.6	1.3417	94.1	1.3470	90.6	1.3524	87.1	1.3580	83.6
1.3367	97.5	1.3418	94.0	1.3471	90.5	1.3526	87.0	1.3582	83.5
1.3368	97.4	1.3419	93.9	1.3473	90.4	1.3527	86.9	1.3583	83.4
1.3369	97.3	1.3421	93.8	1.3475	90.3	1.3529	86.8	1.3585	83.3
1.3371	97.2	1.3423	93.7	1.3476	90.2	1.3531	86.7	1.3587	83.2
1.3373	97.1	1.3424	93.6	1.3477	90.1	1.3532	86.6	1.3588	83.1
1.3374	97.0	1.3425	93.5	1.3479	90.0	1.3533	86.5	1.3590	83.0
1.3375	96.9	1.3427	93.4	1.3481	89.9	1.3535	86.4	1.3592	82.9
1.3377	96.8	1.3429	93.3	1.3482	89.9	1.3537	86.3	1.3593	82.8
1.3378	96.7	1.3430	93.2	1.3483	89.7	1.3538	86.2	1.3595	82.7
1.3380	96.6	1.3431	93.1	1.3485	89.6	1.3539	86.1	1.3596	82.6

TABLE 17—Continued

$N_D^{20°}$	W	$N_D^{20°}$	W	$N_D^{20°}$	W	$N_D^{20°}$	W	$N_D^{20°}$	W
1.3598	82.5	1.3715	75.5	1.3838	68.5	1.3968	61.5	1.4107	54.5
1.3600	82.4	1.3716	75.4	1.3840	68.4	1.3970	61.4	1.4109	54.4
1.3601	82.3	1.3718	75.3	1.3842	68.3	1.3972	61.3	1.4111	54.3
1.3603	82.2	1.3720	75.2	1.3843	68.2	1.3974	61.2	1.4113	54.2
1.3604	82.1	1.3721	75.1	1.3845	68.1	1.3976	61.1	1.4115	54.1
1.3606	82.0	1.3723	75.0	1.3847	68.0	1.3978	61.0	1.4117	54.0
1.3608	81.9	1.3725	74.9	1.3849	67.9	1.3980	60.9	1.4119	53.9
1.3609	81.8	1.3726	74.8	1.3851	67.8	1.3982	60.8	1.4121	53.8
1.3611	81.7	1.3728	74.7	1.3852	67.7	1.3984	60.7	1.4123	53.7
1.3612	81.6	1.3730	74.6	1.3854	67.6	1.3986	60.6	1.4125	53.6
1.3614	81.5	1.3731	74.5	1.3856	67.5	1.3987	60.5	1.4127	53.5
1.3616	81.4	1.3733	74.4	1.3858	67.4	1.3989	60.4	1.4129	53.4
1.3617	81.3	1.3735	74.3	1.3860	67.3	1.3991	60.3	1.4131	53.3
1.3619	81.2	1.3737	74.2	1.3861	67.2	1.3993	60.2	1.4133	53.2
1.3620	81.1	1.3738	74.1	1.3863	67.1	1.3995	60.1	1.4135	53.1
1.3622	81.0	1.3740	74.0	1.3865	67.0	1.3997	60.0	1.4137	53.0
1.3624	80.9	1.3742	73.9	1.3867	66.9	1.3999	59.9	1.4139	52.9
1.3625	80.8	1.3744	73.8	1.3869	66.8	1.4001	59.8	1.4141	52.8
1.3627	80.7	1.3745	73.7	1.3870	66.7	1.4003	59.7	1.4143	52.7
1.3629	80.6	1.3747	73.6	1.3872	66.6	1.4005	59.6	1.4145	52.6
1.3631	80.5	1.3749	73.5	1.3874	66.5	1.4007	59.5	1.4147	52.5
1.3632	80.4	1.3751	73.4	1.3876	66.4	1.4008	59.4	1.4150	52.4
1.3634	80.3	1.3753	73.3	1.3878	66.3	1.4010	59.3	1.4152	52.3
1.3636	80.2	1.3754	73.2	1.3879	66.2	1.4012	59.2	1.4154	52.2
1.3637	80.1	1.3756	73.1	1.3881	66.1	1.4014	59.1	1.4156	52.1
1.3639	80.0	1.3758	73.0	1.3883	66.0	1.4016	59.0	1.4158	52.0
1.3641	79.9	1.3760	72.9	1.3885	65.9	1.4018	58.9	1.4160	51.9
1.3642	79.8	1.3761	72.8	1.3887	65.8	1.4020	58.8	1.4162	51.8
1.3644	79.7	1.3763	72.7	1.3889	65.7	1.4022	58.7	1.4164	51.7
1.3645	79.6	1.3765	72.6	1.3891	65.6	1.4024	58.6	1.4166	51.6
1.3647	79.5	1.3767	72.5	1.3893	65.5	1.4026	58.5	1.4169	51.5
1.3649	79.4	1.3768	72.4	1.3894	65.4	1.4028	58.4	1.4171	51.4
1.3650	79.3	1.3770	72.3	1.3896	65.3	1.4030	58.3	1.4173	51.3
1.3652	79.2	1.3772	72.2	1.3898	65.2	1.4032	58.2	1.4175	51.2
1.5653	79.1	1.3773	72.1	1.3900	65.1	1.4034	58.1	1.4177	51.1
1.3655	79.0	1.3775	72.0	1.3902	65.0	1.4036	58.0	1.4179	51.0
1.3657	78.9	1.3777	71.9	1.3904	64.9	1.4038	57.9	1.4181	50.9
1.3658	78.8	1.3779	71.8	1.3906	64.8	1.4040	57.8	1.4183	50.8
1.3660	78.7	1.3780	71.7	1.3907	64.7	1.4042	57.7	1.4185	50.7
1.3662	78.6	1.3782	71.6	1.3909	64.6	1.4044	57.6	1.4187	50.6
1.3663	78.5	1.3784	71.5	1.3911	64.5	1.4046	57.5	1.4189	50.5
1.3665	78.4	1.3786	71.4	1.3913	64.4	1.4048	57.4	1.4192	50.4
1.3667	78.3	1.3788	71.3	1.3915	64.3	1.4050	57.3	1.4194	50.3
1.3669	78.2	1.3789	71.2	1.3916	64.2	1.4052	57.2	1.4196	50.2
1.3670	78.1	1.3791	71.1	1.3918	64.1	1.4054	57.1	1.4198	50.1
1.3672	78.0	1.3793	71.0	1.3920	64.0	1.4056	57.0	1.4200	50.0
1.3674	77.9	1.3795	70.9	1.3922	63.9	1.4058	56.9	1.4202	49.9
1.3675	77.8	1.3797	70.8	1.3924	63.8	1.4060	56.8	1.4204	49.8
1.3677	77.7	1.3798	70.7	1.3926	63.7	1.4062	56.7	1.4206	49.7
1.3679	77.6	1.3800	70.6	1.3928	63.6	1.4064	56.6	1.4208	49.6
1.3681	77.5	1.3802	70.5	1.3929	63.5	1.4066	56.5	1.4211	49.5
1.3682	77.4	1.3804	70.4	1.3931	63.4	1.4068	56.4	1.4213	49.4
1.3684	77.3	1.3806	70.3	1.3933	63.3	1.4070	56.3	1.4215	49.3
1.3686	77.2	1.3807	70.2	1.3935	63.2	1.4072	56.2	1.4217	49.2
1.3687	77.1	1.3809	70.1	1.3937	63.1	1.4074	56.1	1.4219	49.1
1.3689	77.0	1.3811	70.0	1.3939	63.0	1.4076	56.0	1.4221	49.0
1.3691	76.9	1.3813	69.9	1.3941	62.9	1.4078	55.9	1.4223	48.9
1.3692	76.8	1.3815	69.8	1.3943	62.8	1.4080	55.8	1.4225	48.8
1.3694	76.7	1.3816	69.7	1.3945	62.7	1.4082	55.7	1.4227	48.7
1.3696	76.6	1.3818	69.6	1.3947	62.6	1.4084	55.6	1.4229	48.6
1.3698	76.5	1.3820	69.5	1.3949	62.5	1.4086	55.5	1.4231	48.5
1.3699	76.4	1.3822	69.4	1.3950	62.4	1.4088	55.4	1.4234	48.4
1.3701	76.3	1.3824	69.3	1.3952	62.3	1.4090	55.3	1.4236	48.3
1.3703	76.2	1.3825	69.2	1.3954	62.2	1.4092	55.2	1.4238	48.2
1.3704	76.1	1.3827	69.1	1.3956	62.1	1.4094	55.1	1.4240	48.1
1.3706	76.0	1.3829	69.0	1.3958	62.0	1.4096	55.0	1.4242	48.0
1.3708	75.9	1.3831	68.9	1.3960	61.9	1.4098	54.9	1.4244	47.9
1.3709	75.8	1.3833	68.8	1.3962	61.8	1.4100	54.8	1.4246	47.8
1.3711	75.7	1.3834	68.7	1.3964	61.7	1.4102	54.7	1.4249	47.7
1.3713	75.6	1.3836	68.6	1.3966	61.6	1.4104	54.6	1.4251	47.6

TABLE 17—Continued

$N_D^{20°}$	W	$N_D^{20°}$	W	$N_D^{20°}$	W	$N_D^{20°}$	W	$N_D^{20°}$	W
1.4253	47.5	1.4396	41.0	1.4544	34.5	1.4698	28.1	1.4860	21.6
1.4255	47.4	1.4398	40.9	1.4546	34.4	1.4700	28.0	1.4863	21.5
1.4257	47.3	1.4400	40.8	1.4548	34.3	1.4703	27.9	1.4865	21.4
1.4260	47.2	1.4403	40.7	1.4550	34.2	1.4705	27.8	1.4868	21.3
1.4262	47.1	1.4405	40.6	1.4553	34.1	1.4708	27.7	1.4871	21.2
1.4264	47.0	1.4407	40.5	1.4555	[75] 34.0	1.4710	27.6	1.4873	21.1
1.4266	46.9	1.4409	40.4	1.4558	34.0	1.4713	27.5	1.4876	21.0
1.4268	46.8	1.4411	40.3	1.4561	33.9	1.4715	27.4	1.4878	20.9
1.4270	46.7	1.4414	40.2	1.4563	33.8	1.4717	27.3	1.4881	20.8
1.4272	46.6	1.4416	40.1	1.4565	33.7	1.4720	27.2	1.4883	20.7
1.4275	46.5	1.4418	40.0	1.4567	33.6	1.4722	27.1	1.4886	20.6
1.4277	46.4	1.4420	39.9	1.4570	33.5	1.4725	27.0	1.4888	20.5
1.4279	46.3	1.4423	39.8	1.4572	33.4	1.4727	26.9	1.4891	20.4
1.4281	46.2	1.4425	39.7	1.4574	33.3	1.4730	26.8	1.4893	20.3
1.4283	46.1	1.4427	39.6	1.4577	33.2	1.4732	26.7	1.4896	20.2
1.4285	46.0	1.4429	39.5	1.4579	33.1	1.4735	26.6	1.4898	20.1
1.4287	45.9	1.4432	39.4	1.4581	33.0	1.4737	26.5	1.4901	20.0
1.4289	45.8	1.4434	39.3	1.4584	32.9	1.4740	26.4	1.4904	19.9
1.4292	45.7	1.4436	39.2	1.4586	32.8	1.4742	26.3	1.4906	19.8
1.4294	45.6	1.4439	39.1	1.4588	32.7	1.4744	26.2	1.4909	19.7
1.4296	45.5	1.4441	39.0	1.4591	32.6	1.4747	26.1	1.4912	19.6
1.4298	45.4	1.4443	38.9	1.4593	32.5	1.4749	26.0	1.4914	19.5
1.4300	45.3	1.4446	38.8	1.4595	32.4	1.4752	25.9	1.4917	19.4
1.4303	45.2	1.4448	38.7	1.4598	32.3	1.4754	25.8	1.4919	19.3
1.4305	45.1	1.4450	38.6	1.4600	32.2	1.4757	25.7	1.4922	19.2
1.4307	45.0	1.4453	38.5	1.4602	32.1	1.4759	25.6	1.4925	19.1
1.4309	44.9	1.4455	38.4	1.4605	32.0	1.4762	25.5	1.4927	19.0
1.4311	44.8	1.4457	38.3	1.4607	31.9	1.4764	25.4	1.4930	18.9
1.4313	44.7	1.4459	38.2	1.4609	31.8	1.4767	25.3	1.4933	18.8
1.4316	44.6	1.4462	38.1	1.4612	31.7	1.4769	25.3	1.4935	18.7
1.4318	44.5	1.4464	38.0	1.4614	31.6	1.4772	25.1	1.4938	18.6
1.4320	44.4	1.4466	37.9	1.4616	31.5	1.4774	25.0	1.4941	18.5
1.4322	44.3	1.4468	37.8	1.4619	31.4	1.4777	24.9	1.4943	18.4
1.4325	44.2	1.4471	37.7	1.4621	31.3	1.4779	24.8	1.4946	18.3
1.4327	44.1	1.4473	37.6	1.4623	31.2	1.4782	24.7	1.4949	18.2
1.4329	44.0	1.4475	37.5	1.4625	31.1	1.4784	24.6	1.4951	18.1
1.4331	43.9	1.4477	37.4	1.4628	31.0	1.4787	24.5	1.4954	18.0
1.4333	43.8	1.4479	37.3	1.4630	30.9	1.4789	24.4	1.4956	17.9
1.4336	43.7	1.4482	37.2	1.4632	30.8	1.4792	24.3	1.4959	17.8
1.4338	43.6	1.4484	37.1	1.4635	30.7	1.4794	24.2	1.4962	17.7
1.4340	43.5	1.4486	37.0	1.4637	30.6	1.4797	24.1	1.4964	17.6
1.4342	43.4	1.4488	36.9	1.4639	30.5	1.4799	24.0	1.4967	17.5
1.4344	43.3	1.4491	36.8	1.4642	30.4	1.4802	23.9	1.4970	17.4
1.4347	43.2	1.4493	36.7	1.4644	30.3	1.4804	23.8	1.4972	17.3
1.4349	43.1	1.4495	36.6	1.4646	30.2	1.4807	23.7	1.4975	17.2
1.4351	43.0	1.4497	36.5	1.4649	30.1	1.4810	23.6	1.4978	17.1
1.4353	42.9	1.4500	36.4	1.4651	30.0	1.4812	23.5	1.4980	17.0
1.4355	42.8	1.4502	36.3	1.4653	29.9	1.4815	23.4	1.4983	16.9
1.4358	42.7	1.4504	36.2	1.4656	29.8	1.4817	23.3	1.4985	16.8
1.4360	42.6	1.4507	36.1	1.4658	29.7	1.4820	23.2	1.4988	16.7
1.4362	42.5	1.4509	36.0	1.4661	29.6	1.4822	23.1	1.4991	16.6
1.4364	42.4	1.4511	35.9	1.4663	29.5	1.4825	23.0	1.4993	16.5
1.4366	42.3	1.4514	35.8	1.4666	29.4	1.4827	22.9	1.4996	16.4
1.4369	42.2	1.4516	35.7	1.4668	29.3	1.4830	22.8	1.4999	16.3
1.4371	42.1	1.4518	35.6	1.4671	29.2	1.4832	22.7	1.5001	16.2
1.4373	42.0	1.4521	35.5	1.4673	29.1	1.4835	22.6	1.5004	16.1
1.4375	41.9	1.4523	35.4	1.4676	29.0	1.4838	22.5	1.5007	16.0
1.4378	41.8	1.4525	35.3	1.4678	28.9	1.4840	22.4	1.5009	15.9
1.4380	41.7	1.4527	35.2	1.4681	28.8	1.4843	22.3	1.5012	15.8
1.4382	41.6	1.4530	35.1	1.4683	28.7	1.4845	22.2	1.5015	15.7
1.4385	41.5	1.4532	35.0	1.4685	28.6	1.4848	22.1	1.5017	15.6
1.4387	41.4	1.4534	34.9	1.4688	28.5	1.4850	22.0	1.5020	15.5
1.4389	41.3	1.4537	34.8	1.4690	28.4	1.4853	21.9	1.5022	15.4
1.4391	41.2	1.4539	34.7	1.4693	28.3	1.4855	21.8	1.5025	15.3
1.4394	41.1	1.4541	34.6	1.4695	28.2	1.4858	21.7	1.5028	15.2
								1.5030	15.1
								1.5033	15.0

[75] The values of the refractive index from 34 per cent to 15 per cent are taken from Main's table (Int. Sugar Jour., 9, p. 481).

TABLE 18

Stanek's Correction Table for Determining Water in Sugar Solutions by Means of the Abbé Refractometer when Readings are Made at Other Temperatures than 20° C

Water, per cent	95	90	85	80	70	60	50	40	30	25	Water, per cent
Temperature, °C	To be added to the per cent of water										Temperature, °C
15	0.25	0.27	0.31	0.31	0.34	0.35	0.36	0.37	0.36	0.36	15
16	0.21	0.23	0.26	0.27	0.29	0.31	0.31	0.32	0.31	0.29	16
17	0.16	0.18	0.20	0.20	0.22	0.23	0.23	0.23	0.20	0.17	17
18	0.11	0.12	0.14	0.14	0.15	0.16	0.16	0.15	0.12	0.09	18
19	0.06	0.07	0.08	0.08	0.08	0.09	0.09	0.08	0.07	0.05	19
Temperature, °C	To be subtracted from the per cent of water										Temperature, °C
21	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	21
22	0.12	0.14	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.14	22
23	0.18	0.20	0.20	0.21	0.21	0.21	0.23	0.21	0.22	0.22	23
24	0.24	0.26	0.26	0.27	0.28	0.28	0.30	0.28	0.29	0.29	24
25	0.30	0.32	0.32	0.34	0.36	0.36	0.38	0.36	0.36	0.37	25
26	0.36	0.39	0.39	0.41	0.43	0.43	0.46	0.44	0.43	0.44	26
27	0.43	0.46	0.46	0.48	0.50	0.51	0.55	0.62	0.50	0.51	27
28	0.50	0.53	0.53	0.55	0.58	0.59	0.63	0.70	0.57	0.59	28
29	0.57	0.60	0.61	0.62	0.66	0.67	0.71	0.78	0.65	0.67	29
30	0.64	0.67	0.70	0.71	0.74	0.75	0.80	0.86	0.73	0.75	30
Water, per cent	95	90	85	80	70	60	50	40	30	25	Water, per cent

TABLE 19

Density[76] of Solutions of Cane Sugar at 20° C

[This table is the basis for standardizing hydrometers indicating per cent of sugar at 20° C]

Per cent sugar	Tenths of per cent									
	0	1	2	3	4	5	6	7	8	9
0	0.998234	0.998622	0.999010	0.999398	0.999786	1.000174	1.000563	1.000952	1.001342	1.001731
1	1.002120	1.002509	1.002897	1.003286	1.003675	1.004064	1.004453	1.004844	1.005234	1.005624
2	1.006015	1.006405	1.006796	1.007188	1.007580	1.007972	1.008363	1.008755	1.009148	1.009541
3	1.009934	1.010327	1.010721	1.011115	1.011510	1.011904	1.012298	1.012694	1.013089	1.013485
4	1.013881	1.014277	1.014673	1.015070	1.015467	1.015864	1.016261	1.016659	1.017058	1.017456
5	1.017854	1.018253	1.018652	1.019052	1.019451	1.019851	1.020251	1.020651	1.021053	1.021454
6	1.021855	1.022257	1.022659	1.023061	1.023463	1.023867	1.024270	1.024673	1.025077	1.025481
7	1.025885	1.026289	1.026694	1.027099	1.027504	1.027910	1.028316	1.028722	1.029128	1.029535
8	1.029942	1.030349	1.030757	1.031165	1.031573	1.031982	1.032391	1.032800	1.033209	1.033619
9	1.034029	1.034439	1.034850	1.035260	1.035671	1.036082	1.036494	1.036906	1.037318	1.037730
10	1.038143	1.038556	1.038970	1.039383	1.039797	1.040212	1.040626	1.041041	1.041456	1.041872
11	1.042288	1.042704	1.043121	1.043537	1.043954	1.044370	1.044788	1.045205	1.045625	1.046043
12	1.046462	1.046881	1.047300	1.047720	1.048140	1.048559	1.048980	1.049401	1.049822	1.050243
13	1.050665	1.051087	1.051510	1.051933	1.052356	1.052778	1.053202	1.053626	1.054050	1.054475
14	1.054900	1.055325	1.055751	1.056176	1.056602	1.057029	1.057455	1.057882	1.058310	1.058737
15	1.059165	1.059593	1.060022	1.060451	1.060880	1.061308	1.061738	1.062168	1.062598	1.063029
16	1.063460	1.063892	1.064324	1.064756	1.065188	1.065621	1.066054	1.066487	1.066921	1.067355
17	1.067789	1.068223	1.068658	1.069093	1.069529	1.069964	1.070400	1.070836	1.071273	1.071710
18	1.072147	1.072585	1.073023	1.073461	1.073900	1.074338	1.074777	1.075217	1.075657	1.076097
19	1.076537	1.076978	1.077419	1.077860	1.078302	1.078744	1.079187	1.079629	1.080072	1.080515
20	1.080959	1.081403	1.081848	1.082292	1.082737	1.083182	1.083628	1.084074	1.084520	1.084967
21	1.085414	1.085861	1.086309	1.086757	1.087205	1.087652	1.088101	1.088550	1.089000	1.089450
22	1.089900	1.090351	1.090802	1.091253	1.091704	1.092155	1.092607	1.093060	1.093513	1.093966
23	1.094420	1.094874	1.095328	1.095782	1.096236	1.096691	1.097147	1.097603	1.098058	1.098514
24	1.098971	1.099428	1.099886	1.100344	1.100802	1.101259	1.101718	1.102177	1.102637	1.103097

[76] According to Dr. F. Plato (Kaiserlichen Normal-Eichungs-Kommission, Wiss. Abh., 2, p. 153; 1900)

TABLE 19—Continued

Per cent sugar	Tenths of per cent									
	0	1	2	3	4	5	6	7	8	9
25	1.103557	1.104017	1.104478	1.104938	1.105400	1.105862	1.106324	1.106786	1.107248	1.107711
26	1.108175	1.108639	1.109103	1.109568	1.110033	1.110497	1.110963	1.111429	1.111895	1.112361
27	1.112828	1.113295	1.113763	1.114229	1.114697	1.115166	1.115635	1.116104	1.116572	1.117042
28	1.117512	1.117982	1.118453	1.118923	1.119395	1.119867	1.120339	1.120812	1.121284	1.121757
29	1.122231	1.122705	1.123179	1.123653	1.124128	1.124603	1.125079	1.125555	1.126030	1.126507
30	1.126984	1.127461	1.127939	1.128417	1.128896	1.129374	1.129853	1.130332	1.130812	1.131292
31	1.131773	1.132254	1.132735	1.133216	1.133698	1.134180	1.134663	1.135146	1.135628	1.136112
32	1.136596	1.137080	1.137565	1.138049	1.138534	1.139020	1.139506	1.139993	1.140479	1.140966
33	1.141453	1.141941	1.142429	1.142916	1.143405	1.143894	1.144384	1.144874	1.145363	1.145854
34	1.146345	1.146836	1.147328	1.147820	1.148313	1.148805	1.149298	1.149792	1.150286	1.150780
35	1.151275	1.151770	1.152265	1.152760	1.153256	1.153752	1.154249	1.154746	1.155242	1.155740
36	1.156238	1.156736	1.157235	1.157733	1.158233	1.158733	1.159233	1.159733	1.160233	1.160734
37	1.161236	1.161738	1.162240	1.162742	1.163245	1.163748	1.164252	1.164756	1.165259	1.165764
38	1.166269	1.166775	1.167281	1.167786	1.168293	1.168800	1.169307	1.169815	1.170322	1.170831
39	1.171340	1.171849	1.172359	1.172869	1.173379	1.173889	1.174400	1.174911	1.175423	1.175935
40	1.176447	1.176960	1.177473	1.177987	1.178501	1.179014	1.179527	1.180044	1.180560	1.181076
41	1.181592	1.182108	1.182625	1.183142	1.183660	1.184178	1.184696	1.185215	1.185734	1.186253
42	1.186773	1.187293	1.187814	1.188335	1.188856	1.189379	1.189901	1.190423	1.190946	1.191469
43	1.191993	1.192517	1.193041	1.193565	1.194090	1.194616	1.195141	1.195667	1.196193	1.196720
44	1.197247	1.197775	1.198303	1.198832	1.199360	1.199890	1.200420	1.200950	1.201480	1.202010
45	1.202540	1.203071	1.203603	1.204136	1.204668	1.205200	1.205733	1.206266	1.206801	1.207335
46	1.207870	1.208405	1.208940	1.209477	1.210013	1.210549	1.211086	1.211623	1.212162	1.212700
47	1.213238	1.213777	1.214317	1.214856	1.215395	1.215936	1.216476	1.217017	1.217559	1.218101
48	1.218643	1.219185	1.219729	1.220272	1.220815	1.221360	1.221904	1.222449	1.222995	1.223540
49	1.224086	1.224632	1.225180	1.225727	1.226274	1.226823	1.227371	1.227919	1.228469	1.229018
50	1.229567	1.230117	1.230668	1.231219	1.231770	1.232322	1.232874	1.233426	1.233979	1.234532
51	1.235085	1.235639	1.236194	1.236748	1.237303	1.237859	1.238414	1.238970	1.239527	1.240084
52	1.240641	1.241198	1.241757	1.242315	1.242873	1.243433	1.243992	1.244552	1.245113	1.245673
53	1.246234	1.246795	1.247358	1.247920	1.248482	1.249046	1.249609	1.250172	1.250737	1.251301
54	1.251866	1.252431	1.252997	1.253563	1.254129	1.254697	1.255264	1.255831	1.256400	1.256967
55	1.257535	1.258104	1.258674	1.259244	1.259815	1.260385	1.260955	1.261527	1.262099	1.262671
56	1.263243	1.263816	1.264390	1.264963	1.265537	1.266112	1.266686	1.267261	1.267837	1.268413
57	1.268989	1.269565	1.270143	1.270720	1.271299	1.271877	1.272455	1.273035	1.273614	1.274194
58	1.274774	1.275354	1.275936	1.276517	1.277098	1.277680	1.278262	1.278844	1.279428	1.280011
59	1.280595	1.281179	1.281764	1.282349	1.282935	1.283521	1.284107	1.284694	1.285281	1.285869
60	1.286456	1.287044	1.287633	1.288222	1.288811	1.289401	1.289991	1.290581	1.291172	1.291763
61	1.292354	1.292946	1.293539	1.294131	1.294725	1.295318	1.295911	1.296506	1.297100	1.297696
62	1.298291	1.298886	1.299483	1.300079	1.300677	1.301274	1.301871	1.302470	1.303068	1.303668
63	1.304267	1.304867	1.305467	1.306068	1.306669	1.307271	1.307872	1.308475	1.309077	1.309680
64	1.310282	1.310885	1.311489	1.312093	1.312699	1.313304	1.313909	1.314515	1.315121	1.315728
65	1.316334	1.316941	1.317549	1.318157	1.318766	1.319374	1.319983	1.320593	1.321203	1.321814
66	1.322425	1.323036	1.323648	1.324259	1.324872	1.325484	1.326097	1.326711	1.327325	1.327940
67	1.328554	1.329170	1.329785	1.330401	1.331017	1.331633	1.332250	1.332868	1.333485	1.334103
68	1.334722	1.335342	1.335961	1.336581	1.337200	1.337821	1.338441	1.339063	1.339684	1.340306
69	1.340928	1.341551	1.342174	1.342798	1.343421	1.344046	1.344671	1.345296	1.345922	1.346547
70	1.347174	1.347801	1.348427	1.349055	1.349682	1.350311	1.350939	1.351568	1.352197	1.352827
71	1.353456	1.354087	1.354717	1.355349	1.355980	1.356612	1.357245	1.357877	1.358511	1.359144
72	1.359778	1.360413	1.361047	1.361682	1.362317	1.362953	1.363590	1.364226	1.364864	1.365501
73	1.366139	1.366777	1.367415	1.368054	1.368693	1.369333	1.369973	1.370613	1.371254	1.371894
74	1.372536	1.373178	1.373820	1.374463	1.375105	1.375749	1.376392	1.377036	1.377680	1.378326
75	1.378971	1.379617	1.380262	1.380909	1.381555	1.382203	1.382851	1.383499	1.384148	1.384796
76	1.385446	1.386096	1.386745	1.387396	1.388045	1.388696	1.389347	1.389999	1.390651	1.391303
77	1.391956	1.392610	1.393263	1.393917	1.394571	1.395226	1.395881	1.396536	1.397192	1.397848
78	1.398505	1.399162	1.399819	1.400477	1.401134	1.401793	1.403452	1.403111	1.403771	1.404430
79	1.405091	1.405752	1.406412	1.407074	1.407735	1.408398	1.409061	1.409723	1.410387	1.411051
80	1.411715	1.412380	1.413044	1.413709	1.414374	1.415040	1.415706	1.416373	1.417039	1.417707
81	1.418374	1.419043	1.419711	1.420380	1.421049	1.421719	1.422390	1.423059	1.423730	1.424400
82	1.425072	1.425744	1.426416	1.427089	1.427761	1.428435	1.429109	1.429782	1.430457	1.431131
83	1.431807	1.432483	1.433158	1.433835	1.434511	1.435188	1.435866	1.436543	1.437222	1.437900
84	1.438579	1.439259	1.439938	1.440619	1.441299	1.441980	1.442661	1.443342	1.444024	1.444705
85	1.445388	1.446071	1.446754	1.447438	1.448121	1.448806	1.449491	1.450175	1.450860	1.451545
86	1.452232	1.452919	1.453605	1.454292	1.454980	1.455668	1.456357	1.457045	1.457735	1.458424
87	1.459114	1.459805	1.460495	1.461186	1.461877	1.462568	1.463260	1.463953	1.464645	1.465338
88	1.466032	1.466726	1.467420	1.468115	1.468810	1.469504	1.470200	1.470896	1.471592	1.472289
89	1.472986	1.473684	1.474381	1.475080	1.475779	1.476477	1.477176	1.477876	1.478575	1.479275

TABLE 19—Continued

Per cent sugar	Tenths of per cent									
	0	1	2	3	4	5	6	7	8	9
90	1.479976	1.480677	1.481378	1.482080	1.482782	1.483484	1.484187	1.484890	1.485593	1.486297
91	1.487002	1.487707	1.488411	1.489117	1.489823	1.490528	1.491234	1.491941	1.492647	1.493355
92	1.494063	1.494771	1.495479	1.496188	1.496897	1.497606	1.498316	1.499026	1.499736	1.500447
93	1.501158	1.501870	1.502582	1.503293	1.504006	1.504719	1.505432	1.506146	1.506859	1.507574
94	1.508289	1.509004	1.509720	1.510435	1.511151	1.511868	1.512585	1.513302	1.514019	1.514737
95	1.515455	1.516174	1.516893	1.517612	1.518332	1.519051	1.519771	1.520492	1.521212	1.521934
96	1.522656	1.523378	1.524100	1.524823	1.525546	1.526269	1.526993	1.527717	1.528441	1.529166
97	1.529891	1.530616	1.531342	1.532068	1.532794	1.533521	1.534248	1.534976	1.535704	1.536432
98	1.537161	1.537889	1.538618	1.539347	1.540076	1.540806	1.541536	1.542267	1.542998	1.543730
99	1.544462	1.545194	1.545926	1.546659	1.547392	1.548127	1.548861	1.549595	1.550329	1.551064
100	1.551800									

TABLE 21

Munson and Walker's Table for Calculating Dextrose, Invert Sugar Alone, Invert Sugar in the Presence of Sucrose (0.4 Gram and 2 Grams Total Sugar), Lactose, Lactose and Sucrose (2 Mixtures) and Maltose (Crystallized)

[Expressed in milligrams]

Cuprous oxid (Cu_2O)	Copper (Cu)	Dextrose (*d*-glucose)	Invert sugar	Invert sugar and sucrose		Lactose	Lactose and sucrose		Maltose	Cuprous oxid (Cu_2O)
				0.4 gram total sugar	2 grams total sugar	$C_{12}H_{22}O_{11}+H_2O$	1 lactose, 4 sucrose	1 lactose, 12 sucrose	$C_{12}H_{22}O_{11}+H_2O$	
10	8.9	4.0	4.5	1.6	.....	6.3	6.1	.....	6.2	10
11	9.8	4.5	5.0	2.1	.....	6.9	6.7	.....	7.0	11
12	10.7	4.9	5.4	2.5	.....	7.5	7.3	.....	7.9	12
13	11.5	5.3	5.8	3.0	.....	8.2	7.9	.....	8.7	13
14	12.4	5.7	6.3	3.4	.....	8.8	8.5	.....	9.5	14
15	13.3	6.2	6.7	3.9	.....	9.4	9.1	.....	10.4	15
16	14.2	6.6	7.2	4.3	.....	10.0	9.7	.....	11.2	16
17	15.1	7.0	7.6	4.8	.....	10.7	10.3	.....	12.0	17
18	16.0	7.5	8.1	5.2	.....	11.3	10.9	.....	12.9	18
19	16.9	7.9	8.5	5.7	.....	11.9	11.5	.....	13.7	19
20	17.8	8.3	8.9	6.1	.....	12.5	12.1	.....	14.6	20
21	18.7	8.7	9.4	6.6	.....	13.2	12.7	.....	15.4	21
22	19.5	9.2	9.8	7.0	.....	13.8	13.3	.....	16.2	22
23	20.4	9.6	10.3	7.5	.....	14.4	13.9	.....	17.1	23
24	21.3	10.0	10.7	7.9	.....	15.0	14.5	.....	17.9	24
25	22.2	10.5	11.2	8.4	.....	15.7	15.2	.....	18.7	25
26	23.1	10.9	11.6	8.8	.....	16.3	15.8	.....	19.6	26
27	24.0	11.3	12.0	9.3	.....	16.9	16.4	.....	20.4	27
28	24.9	11.8	12.5	9.7	.....	17.6	17.0	.....	21.2	28
29	25.8	12.2	12.9	10.2	.....	18.2	17.6	.....	22.1	29
30	26.6	12.6	13.4	10.7	4.3	18.8	18.2	.....	22.9	30
31	27.5	13.1	13.8	11.1	4.7	19.4	18.8	.....	23.7	31
32	28.4	13.5	14.3	11.6	5.2	20.1	19.4	.....	24.6	32
33	29.3	13.9	14.7	12.0	5.6	20.7	20.0	.....	25.4	33
34	30.2	14.3	15.2	12.5	6.1	21.4	20.7	.....	26.2	34
35	31.1	14.8	15.6	12.9	6.5	22.1	21.3	.....	27.1	35
36	32.0	15.2	16.1	13.4	7.0	22.8	22.0	.....	27.9	36
37	32.9	15.6	16.5	13.8	7.4	23.5	22.7	.....	28.7	37
38	33.8	16.1	16.9	14.3	7.9	24.2	23.3	.....	29.6	38
39	34.6	16.5	17.4	14.7	8.4	24.8	24.0	.....	30.4	39
40	35.5	16.9	17.8	15.2	8.8	25.5	24.7	.....	31.3	40
41	36.4	17.4	18.3	15.6	9.3	26.2	25.3	.....	32.1	41
42	37.3	17.8	18.7	16.1	9.7	29.6	26.0	.....	32.9	42
43	38.2	18.2	19.2	16.6	10.2	27.6	26.6	.....	33.8	43
44	39.1	18.7	19.6	17.0	10.7	28.3	27.3	.....	34.6	44

TABLE 21—Continued

Cuprous oxid (Cu_2O)	Copper (Cu)	Dextrose (*d*-glucose)	Invert sugar	Invert sugar and sucrose		Lactose	Lactose and sucrose		Maltose	Cuprous oxid (Cu_2O)
				0.4 gram total sugar	2 grams total sugar	$C_{12}H_{22}O_{11}+H_2O$	1 lactose, 4 sucrose	1 lactose, 12 sucrose	$C_{12}H_{22}O_{11}+H_2O$	
45	40.0	19.1	20.1	17.5	11.1	28.9	28.0	.....	35.4	45
46	40.9	19.6	20.5	17.9	11.6	29.6	28.6	.....	36.3	46
47	41.7	20.0	21.0	18.4	12.0	30.3	29.3	.....	37.1	47
48	42.6	20.4	21.4	18.8	12.5	31.0	30.0	.....	37.9	48
49	43.5	20.9	21.9	19.3	12.9	31.7	30.6	.....	38.8	49
50	44.4	21.3	22.3	19.7	13.4	32.3	31.3	.....	39.6	50
51	45.3	21.7	22.8	20.2	13.9	33.0	32.0	.....	40.4	51
52	46.2	22.2	23.2	20.7	14.3	33.7	32.6	.....	41.3	52
53	47.1	22.6	23.7	21.1	14.8	34.4	33.3	.....	42.1	53
54	48.0	23.0	24.1	21.6	15.2	35.1	34.0	.....	42.9	54
55	48.9	23.5	24.6	22.0	15.7	35.8	34.6	.....	43.8	55
56	49.7	23.9	25.0	22.5	16.2	36.4	35.3	.....	44.6	56
57	50.6	24.3	25.5	22.9	16.6	37.1	35.9	.....	45.4	57
58	51.5	24.8	25.9	23.4	17.1	37.8	36.6	.....	46.3	58
59	52.4	25.2	26.4	23.9	17.5	38.5	37.3	.....	47.1	59
60	53.3	25.6	26.8	24.3	18.0	39.2	37.9	.....	48.0	60
61	54.2	26.1	27.3	24.8	18.5	39.9	38.6	.....	48.8	61
62	55.1	26.5	27.7	25.2	18.9	40.5	39.3	.....	49.6	62
63	56.0	27.0	28.2	25.7	19.4	41.2	39.9	.....	50.5	63
64	56.8	27.4	28.6	26.2	19.8	41.9	40.6	.....	51.3	64
65	57.7	27.8	29.1	26.6	20.3	42.6	41.3	.....	52.1	65
66	58.6	28.3	29.5	27.1	20.8	43.3	41.9	.....	53.0	66
67	59.5	28.7	30.0	27.5	21.2	44.0	42.6	40.1	53.8	67
68	60.4	29.2	30.4	28.0	21.7	44.7	43.3	40.7	54.6	68
69	61.3	29.6	30.9	28.5	22.2	45.3	43.9	41.3	55.5	69
70	62.2	30.0	31.3	28.9	22.6	46.0	44.6	41.9	56.3	70
71	63.1	30.5	31.8	29.4	23.1	46.7	45.3	42.5	57.1	71
72	64.0	30.9	32.3	29.8	23.5	47.4	45.9	43.1	58.0	72
73	64.8	31.4	32.7	30.3	24.0	48.1	46.6	43.7	58.8	73
74	65.7	31.8	33.2	30.8	24.5	48.8	47.3	44.2	59.6	74
75	66.6	32.2	33.6	31.2	24.9	49.4	47.9	44.8	60.5	75
76	67.5	32.7	34.1	31.7	25.4	50.1	48.6	45.4	61.3	76
77	68.4	33.1	34.5	32.1	25.9	50.8	49.3	46.0	62.1	77
78	69.3	33.6	35.0	32.6	26.3	51.5	49.9	46.6	63.0	78
79	70.2	34.0	35.4	33.1	26.8	52.2	50.6	47.2	63.8	79
80	71.1	34.4	35.9	33.5	27.3	52.9	51.3	47.8	64.6	80
81	71.9	34.9	36.3	34.0	27.7	53.6	51.9	48.4	65.5	81
82	72.8	35.3	36.8	34.5	28.2	54.2	52.6	49.0	66.3	82
83	73.7	35.8	37.3	34.9	28.6	54.9	53.3	49.6	67.1	83
84	74.6	36.2	37.7	35.4	29.1	55.6	53.9	50.1	68.0	84
85	75.5	36.7	38.2	35.8	29.6	56.3	54.6	50.7	68.8	85
86	76.4	37.1	38.6	36.3	30.0	57.0	55.3	51.3	69.7	86
87	77.3	37.5	39.1	36.8	30.5	57.7	55.9	51.9	70.5	87
88	78.2	38.0	39.5	37.2	31.0	58.4	56.6	52.5	71.3	88
89	79.1	38.4	40.0	37.7	31.4	59.0	57.3	53.1	72.2	89
90	79.9	38.9	40.4	38.2	31.9	59.7	57.9	53.7	73.0	90
91	80.8	39.3	40.9	38.6	32.4	60.4	58.6	54.3	73.8	91
92	81.7	39.8	41.4	39.1	32.8	61.1	59.3	54.9	74.7	92
93	82.6	40.2	41.8	39.6	33.3	61.8	59.9	55.5	75.5	93
94	83.5	40.6	42.3	40.0	33.8	62.5	60.6	56.0	76.3	94
95	84.4	41.1	42.7	40.5	34.2	63.2	61.3	56.6	77.2	95
96	85.3	41.5	43.2	41.0	34.7	63.8	61.9	57.2	78.0	96
97	86.2	42.0	43.7	41.4	35.2	64.5	62.6	57.8	78.8	97
98	87.1	42.4	44.1	41.9	35.6	65.2	63.3	58.4	79.7	98
99	87.9	42.9	44.6	42.4	36.1	65.9	63.9	59.0	80.5	99
100	88.8	43.3	45.0	42.8	36.6	66.6	64.6	59.6	81.3	100
101	89.7	43.8	45.5	43.3	37.0	67.3	65.3	60.2	82.2	101
102	90.6	44.2	46.0	43.8	37.5	68.0	66.0	60.8	83.0	102
103	91.5	44.7	46.4	44.2	38.0	68.7	66.6	61.4	83.8	103
104	92.4	45.1	46.9	44.7	38.5	69.3	67.3	62.0	84.7	104
105	93.3	45.5	47.3	45.2	38.9	70.0	68.0	62.6	85.5	105
106	94.2	46.0	47.8	45.6	39.4	70.7	68.6	63.2	86.3	106
107	95.0	46.4	48.3	46.1	39.9	71.4	63.3	63.8	87.2	107
108	95.9	46.9	48.7	46.6	40.3	72.1	70.0	64.4	88.0	108
109	96.8	47.3	49.2	47.0	40.8	72.8	70.6	65.0	88.8	109

TABLE 21—Continued

Cuprous oxid (Cu_2O)	Copper (Cu)	Dextrose (*d*-glucose)	Invert sugar	Invert sugar and sucrose		Lactose	Lactose and sucrose		Maltose	Cuprous oxid (Cu_2O)
				0.4 gram total sugar	2 grams total sugar	$C_{12}H_{22}O_{11}+H_2O$	1 lactose, 4 sucrose	1 lactose, 12 sucrose	$C_{12}H_{22}O_{11}+H_2O$	
110	97.7	47.8	49.6	47.5	41.3	73.5	71.3	65.6	89.7	110
111	98.6	48.2	50.1	48.0	41.7	74.2	72.0	66.1	90.5	111
112	99.5	48.7	50.6	48.4	42.2	74.8	72.6	66.7	91.3	112
113	100.4	49.1	51.0	48.9	42.7	75.5	73.3	67.3	92.2	113
114	101.3	49.6	51.5	49.4	43.2	76.2	74.0	67.9	93.0	114
115	102.2	50.0	51.9	49.8	43.6	76.9	74.6	68.5	93.9	115
116	103.0	50.5	52.4	50.3	44.1	77.6	75.3	69.1	94.7	116
117	103.9	50.9	52.9	50.8	44.6	78.3	76.0	69.7	95.5	117
118	104.8	51.4	53.3	51.2	45.0	79.0	76.7	70.3	96.4	118
119	105.7	51.8	53.8	51.7	45.5	79.6	77.3	70.9	97.2	119
120	106.6	52.3	54.3	52.2	46.0	80.3	78.0	71.5	98.0	120
121	107.5	52.7	54.7	52.7	46.5	81.0	78.7	72.1	98.9	121
122	108.4	53.2	55.2	53.1	46.9	81.7	79.3	72.7	99.7	122
123	109.3	53.6	55.7	53.6	47.4	82.4	80.0	73.3	100.5	123
124	110.1	54.1	56.1	54.1	47.9	83.1	80.7	73.9	101.4	124
125	111.0	54.5	56.6	54.5	48.3	83.8	81.3	74.5	102.2	125
126	111.9	55.0	57.0	55.0	48.8	84.5	82.0	75.1	103.0	126
127	112.8	55.4	57.5	55.5	49.3	85.1	82.7	75.7	103.9	127
128	113.7	55.9	58.0	55.9	49.8	85.8	83.4	76.3	104.7	128
129	114.6	56.3	58.4	56.4	50.2	86.5	84.0	76.9	105.5	129
130	115.5	56.8	58.9	56.9	50.7	87.2	84.7	77.5	106.4	130
131	116.4	57.2	59.4	57.4	51.2	87.9	85.4	78.1	107.2	131
132	117.3	57.7	59.8	57.8	51.7	88.6	86.0	78.7	108.0	132
133	118.1	58.1	60.3	58.3	52.1	89.3	86.7	79.3	108.9	133
134	119.0	58.6	60.8	58.8	52.6	90.0	87.4	79.7	109.7	134
135	119.9	59.0	61.2	59.3	53.1	90.6	88.1	80.5	110.5	135
136	120.8	59.5	61.7	59.7	53.6	91.3	88.7	81.1	111.4	136
137	121.7	60.0	62.2	60.2	54.0	92.0	89.4	81.7	112.2	137
138	122.6	60.4	62.6	60.7	54.5	92.7	90.1	82.3	113.0	138
139	123.5	60.9	63.1	61.2	55.0	93.4	90.7	82.9	113.9	139
140	124.4	61.3	63.6	61.6	55.5	94.1	91.4	83.5	114.7	140
141	125.2	61.8	64.0	62.1	55.9	94.8	92.1	84.1	115.5	141
142	126.1	62.2	64.5	62.6	56.4	95.5	92.8	84.7	116.4	142
143	127.0	62.7	65.0	63.1	56.9	96.1	93.4	85.3	117.2	143
144	127.9	63.1	65.4	63.5	57.4	96.8	94.1	85.9	118.0	144
145	128.8	63.6	65.9	64.0	57.8	97.5	94.8	86.5	118.9	145
146	129.7	64.0	66.4	64.5	58.3	98.2	95.4	87.1	119.7	146
147	130.6	64.5	66.9	65.0	58.8	98.9	96.1	87.7	120.5	147
148	131.5	65.0	67.3	65.4	59.3	99.6	96.8	88.3	121.4	148
149	132.4	65.4	67.8	65.9	59.7	100.3	97.5	88.9	122.2	149
150	133.2	65.9	68.3	66.4	60.2	101.0	98.1	89.5	123.0	150
151	134.1	66.3	68.7	66.9	60.7	101.6	98.8	90.2	123.9	151
152	135.0	66.8	69.2	67.3	61.2	102.3	99.5	90.8	124.7	152
153	135.9	67.2	69.7	67.8	61.7	103.0	100.1	91.4	125.5	153
154	136.8	67.7	70.1	68.3	62.1	103.7	100.8	92.0	126.4	154
155	137.7	68.2	70.6	68.8	62.6	104.4	101.5	92.6	127.2	155
156	138.6	68.6	71.1	69.2	63.1	105.1	102.2	93.2	128.0	156
157	139.5	69.1	71.6	69.7	63.6	105.8	102.8	93.8	128.9	157
158	140.3	69.5	72.0	70.2	64.1	106.5	103.5	94.4	129.7	158
159	141.2	70.0	72.5	70.7	64.5	107.2	104.2	95.0	130.5	159
160	142.1	70.4	73.0	71.2	65.0	107.9	104.8	95.6	131.4	160
161	143.0	70.9	73.4	71.6	65.5	108.5	105.5	96.2	132.2	161
162	143.9	71.4	73.9	72.1	66.0	109.2	106.2	96.8	133.0	162
163	144.8	71.8	74.4	72.6	66.5	109.9	106.9	97.4	133.9	163
164	145.7	72.3	74.9	73.1	66.9	110.6	107.5	98.0	134.7	164
165	146.6	72.8	75.3	73.6	67.4	111.3	108.2	98.6	135.5	165
166	147.5	73.2	75.8	74.0	67.9	112.0	108.9	99.2	136.4	166
167	148.3	73.7	76.3	74.5	68.4	112.7	109.6	99.8	137.2	167
168	149.2	74.1	76.8	75.0	68.9	113.4	110.2	100.4	138.0	168
169	150.1	74.6	77.2	75.5	69.3	114.1	110.9	101.0	138.9	169
170	151.0	75.1	77.7	76.0	69.8	114.8	111.6	101.6	139.7	170
171	151.9	75.5	78.2	76.4	70.3	115.4	112.3	102.2	140.5	171
172	152.8	76.0	78.7	76.9	70.8	116.1	112.9	102.8	141.4	172
173	153.7	76.4	79.1	77.4	71.3	116.8	113.6	103.5	142.2	173
174	154.6	76.9	79.6	77.9	71.7	117.5	114.3	104.1	143.0	174

TABLE 21—Continued

Cuprous oxid (Cu_2O)	Copper (Cu)	Dextrose (*d*-glucose)	Invert sugar	Invert sugar and sucrose		Lactose	Lactose and sucrose		Maltose	Cuprous oxid (Cu_2O)
				0.4 gram total sugar	2 grams total sugar	$C_{12}H_{22}O_{11}+H_2O$	1 lactose, 4 sucrose	1 lactose, 12 sucrose	$C_{12}H_{22}O_{11}+H_2O$	
175	155.5	77.4	80.1	78.4	72.2	118.2	114.9	104.7	143.9	175
176	156.3	77.8	80.6	78.8	72.7	118.9	115.6	105.3	144.7	176
177	157.2	78.3	81.0	79.3	73.2	119.6	116.3	105.9	145.5	177
178	158.1	78.8	81.5	79.8	73.7	120.3	117.0	106.5	146.4	178
179	159.0	79.2	82.0	80.3	74.2	121.0	117.6	107.1	147.2	179
180	159.9	79.7	82.5	80.8	74.6	121.6	118.3	107.7	148.0	180
181	160.8	80.1	82.9	81.3	75.1	122.3	119.0	108.3	148.9	181
182	161.7	80.6	83.4	81.7	75.6	123.1	119.7	108.9	149.7	182
183	162.6	81.1	83.9	82.2	76.1	123.7	120.3	109.5	150.5	183
184	163.4	81.5	84.4	82.7	76.6	124.3	121.0	110.1	151.4	184
185	164.3	82.0	84.9	83.2	77.1	125.1	121.7	110.7	152.2	185
186	165.2	82.5	85.3	83.7	77.6	125.8	122.4	111.3	153.0	186
187	166.1	82.9	85.8	84.2	78.0	126.5	123.1	111.9	153.9	187
188	167.0	83.4	86.3	84.6	78.5	127.2	123.7	112.5	154.7	188
189	167.9	83.9	86.8	85.1	79.0	127.9	124.4	113.1	155.5	189
190	168.8	84.3	87.2	85.6	79.5	128.5	125.1	113.8	156.4	190
191	169.7	84.8	87.7	86.1	80.0	129.2	125.8	114.4	157.2	191
192	170.5	85.3	88.2	86.6	80.5	129.9	126.4	115.0	158.0	192
193	171.4	85.7	88.7	87.1	81.0	130.6	127.1	115.6	158.9	193
194	172.3	86.2	89.2	87.6	81.4	131.3	127.8	116.2	159.7	194
195	173.2	86.7	89.6	88.0	81.9	132.0	128.5	116.8	160.5	195
196	174.1	87.1	90.1	88.5	82.4	132.7	129.2	117.4	161.4	196
197	175.0	87.6	90.6	89.0	82.9	133.4	129.8	118.0	162.2	197
198	175.9	88.1	91.1	89.5	83.4	134.1	130.5	118.6	163.0	198
199	176.8	88.5	91.6	90.0	83.9	134.8	131.2	119.2	163.9	199
200	177.7	89.0	92.0	90.5	84.4	135.4	131.9	119.8	164.7	200
201	178.5	89.5	92.5	91.0	84.8	136.1	132.5	120.4	165.5	201
202	179.4	89.9	93.0	91.4	85.3	136.8	133.2	121.0	166.4	202
203	180.3	90.4	93.5	91.9	85.8	137.5	133.9	121.7	167.2	203
204	181.2	90.9	94.0	92.4	86.3	138.2	134.6	122.3	168.0	204
205	182.1	91.4	94.5	92.9	86.8	138.9	135.3	122.9	168.9	205
206	183.0	91.8	94.9	93.4	87.3	139.6	135.9	123.5	169.7	206
207	183.9	92.3	95.4	93.9	87.8	140.3	136.6	124.1	170.5	207
208	184.8	92.8	95.9	94.4	88.3	141.0	137.3	124.7	177.4	208
209	185.6	93.2	96.4	94.9	88.8	141.7	138.0	125.3	172.2	209
210	186.5	93.7	96.9	95.4	89.2	142.3	138.6	126.0	173.0	210
211	187.4	94.2	97.4	95.8	89.7	143.0	139.3	126.6	173.8	211
212	188.3	94.6	97.8	96.3	90.2	143.7	140.0	127.2	174.7	212
213	189.2	95.1	98.3	96.8	90.7	144.4	140.7	127.8	175.5	213
214	190.1	95.6	98.8	97.3	91.2	145.1	141.4	128.4	176.4	214
215	191.0	96.1	99.3	97.8	91.7	145.8	142.0	129.0	177.2	215
216	191.9	96.5	99.8	98.3	92.2	146.5	142.7	129.6	178.0	216
217	192.8	97.0	100.3	98.8	92.7	147.2	143.4	130.2	178.9	217
218	193.6	97.5	100.8	99.3	93.2	147.9	144.1	130.9	179.7	218
219	194.5	98.0	101.2	99.8	93.7	148.6	144.7	131.5	180.5	219
220	195.4	98.4	101.7	100.3	94.2	149.3	145.4	132.1	181.4	220
221	196.3	98.9	102.2	100.8	94.7	150.0	146.1	132.7	182.2	221
222	197.2	99.4	102.7	101.2	95.1	150.7	146.8	133.3	183.0	222
223	198.1	99.9	103.2	101.7	95.6	151.3	147.5	133.9	183.9	223
224	199.0	100.3	103.7	102.2	96.1	152.0	148.1	134.5	184.7	224
225	199.9	100.8	104.2	102.7	96.6	152.7	148.8	135.2	185.5	225
226	200.7	101.3	104.6	103.2	97.1	153.4	149.5	135.8	186.4	226
227	201.6	101.8	105.1	103.7	97.6	154.1	150.2	136.4	187.2	227
228	202.5	102.2	105.6	104.2	98.1	154.8	150.8	137.0	188.0	228
229	203.4	102.7	106.1	104.7	98.6	155.5	151.5	137.6	188.8	229
230	204.3	103.2	106.6	105.2	99.1	156.2	152.2	138.2	189.7	230
231	205.2	103.7	107.1	105.7	99.6	156.9	152.9	138.8	190.5	231
232	206.1	104.1	107.6	106.2	100.1	157.6	153.6	139.4	191.3	232
233	207.0	104.6	108.1	106.7	100.6	158.3	154.2	140.1	192.2	233
234	207.9	105.1	108.6	107.2	101.1	159.0	154.9	140.7	193.0	234
235	208.7	105.6	109.1	107.7	101.6	159.6	155.6	141.3	193.8	235
236	209.6	106.0	109.5	108.2	102.1	160.3	156.3	141.9	194.7	236
237	210.5	106.5	110.0	108.7	102.6	161.0	156.9	142.5	195.5	237
238	211.4	107.0	110.5	109.2	103.1	161.7	157.6	143.2	196.3	238
239	212.3	107.5	111.0	109.6	103.5	162.4	158.3	143.8	197.2	239

TABLE 21—Continued

Cuprous oxid (Cu_2O)	Copper (Cu)	Dextrose (*d*-glucose)	Invert sugar	Invert sugar and sucrose		Lactose	Lactose and sucrose		Maltose	Cuprous oxid (Cu_2O)
				0.4 gram total sugar	2 grams total sugar	$C_{12}H_{22}O_{11}+H_2O$	1 lactose, 4 sucrose	1 lactose, 12 sucrose	$C_{12}H_{22}O_{11}+H_2O$	
240	213.2	108.0	111.5	110.1	104.0	163.1	159.0	144.4	198.0	240
241	214.1	108.4	112.0	110.6	104.5	163.8	159.7	145.0	198.8	241
242	215.0	108.9	112.5	111.1	105.0	164.5	160.3	145.6	199.7	242
243	215.8	109.4	113.0	111.6	105.5	165.2	161.0	146.3	200.5	243
244	216.7	109.9	113.5	112.1	106.0	165.9	161.7	146.9	201.3	244
245	217.6	110.4	114.0	112.6	106.5	166.6	162.4	147.5	202.2	245
246	218.5	110.8	114.5	113.1	107.0	167.3	163.1	148.1	203.0	246
247	219.4	111.3	115.0	113.6	107.5	168.0	163.7	148.7	203.8	247
248	220.3	111.8	115.4	114.1	108.0	168.7	164.4	149.3	204.7	248
249	221.2	112.3	115.9	114.6	108.5	169.4	165.1	150.0	205.5	249
250	222.1	112.8	116.4	115.1	109.0	170.1	165.8	150.6	206.3	250
251	223.0	113.2	116.9	115.6	109.5	170.8	166.5	151.2	207.2	251
252	223.8	113.7	117.4	116.1	110.0	171.5	167.2	151.8	208.0	252
253	224.7	114.2	117.9	116.6	110.5	172.1	167.8	152.4	208.8	253
254	225.6	114.7	118.4	117.1	111.0	172.8	168.5	153.1	209.7	254
255	226.5	115.2	118.9	117.6	111.5	173.5	169.2	153.7	210.5	255
256	227.4	115.7	119.4	118.1	112.0	174.2	169.9	154.3	211.3	256
257	228.3	116.1	119.9	118.6	112.5	174.9	170.6	154.9	212.2	257
258	229.2	116.6	120.4	119.1	113.0	175.6	171.3	155.5	213.0	258
259	230.1	117.1	120.9	119.6	113.5	176.3	171.9	156.2	213.8	259
260	231.0	117.6	121.4	120.1	114.0	177.0	172.6	156.8	214.7	260
261	231.8	118.1	121.9	120.6	114.5	177.7	173.3	157.4	215.5	261
262	232.7	118.6	122.4	121.1	115.0	178.4	174.0	158.0	216.3	262
263	233.6	119.0	122.9	121.6	115.5	179.1	174.7	158.6	217.2	263
264	234.5	119.5	123.4	122.1	116.0	179.8	175.3	159.3	218.0	264
265	235.4	120.0	123.9	122.6	116.5	180.5	176.0	159.9	218.8	265
266	236.3	120.5	124.4	123.1	117.0	181.2	176.7	160.5	219.7	266
267	237.2	121.0	124.9	123.6	117.5	181.9	177.4	161.1	220.5	267
268	238.1	121.5	125.4	124.1	118.0	182.6	178.1	161.8	221.3	268
269	238.9	122.0	125.9	124.6	118.5	183.3	178.8	162.4	222.1	269
270	239.8	122.5	126.4	125.1	119.0	184.0	179.4	163.0	223.0	270
271	240.7	122.9	126.9	125.6	119.5	184.6	180.1	163.6	223.8	271
272	241.6	123.4	127.4	126.2	120.0	185.3	180.8	164.3	224.6	272
273	242.5	123.9	127.9	126.7	120.6	186.0	181.5	164.9	225.5	273
274	243.4	124.4	128.4	127.2	121.1	186.7	182.2	165.5	226.3	274
275	244.3	124.9	128.9	127.7	121.6	187.4	182.9	166.1	227.1	275
276	245.2	125.4	129.4	128.2	122.1	188.1	183.5	166.8	228.0	276
277	246.1	125.9	129.9	128.7	122.6	188.8	184.2	167.4	228.8	277
278	246.9	126.4	130.4	129.2	123.1	189.5	184.9	168.0	229.6	278
279	247.8	126.9	130.9	129.7	123.6	190.2	185.6	168.7	230.5	279
280	248.7	127.3	131.4	130.2	124.1	190.9	186.3	169.3	231.3	280
281	249.6	127.8	131.9	130.7	124.6	191.6	187.0	169.9	232.1	281
282	250.5	128.3	132.4	131.2	125.1	192.3	187.6	170.5	233.0	282
283	251.4	128.8	132.9	131.7	125.6	193.0	188.3	171.2	233.8	283
284	252.3	129.3	133.4	132.2	126.1	193.7	189.0	171.8	234.6	284
285	253.2	129.8	133.9	132.7	126.6	194.4	189.7	172.4	235.5	285
286	254.0	130.3	134.4	133.2	127.1	195.1	190.4	173.0	236.3	286
287	254.9	130.8	134.9	133.7	127.6	195.8	191.0	173.7	237.1	287
288	255.8	131.3	135.4	134.3	128.1	196.5	191.7	174.3	238.0	288
289	256.7	131.8	135.9	134.8	128.6	197.1	192.4	174.9	238.8	289
290	257.6	132.3	136.4	135.3	129.2	197.8	193.1	175.5	239.6	290
291	258.5	132.7	136.9	135.8	129.7	198.5	193.8	176.2	240.5	291
292	259.4	133.2	137.4	136.3	130.2	199.2	194.4	176.8	241.3	292
293	260.3	133.7	137.9	136.8	130.7	199.9	195.1	177.4	242.1	293
294	261.2	134.2	138.4	137.3	131.2	200.6	195.8	178.1	242.9	294
295	262.0	134.7	138.9	137.8	131.7	201.3	196.5	178.7	243.8	295
296	262.9	135.2	139.4	138.3	132.2	202.0	197.2	179.3	244.6	296
297	263.8	135.7	140.0	138.8	132.7	202.7	197.9	179.9	245.4	297
298	264.7	136.2	140.5	139.4	133.2	203.4	198.6	180.6	246.3	298
299	265.6	136.7	141.0	139.9	133.7	204.1	199.2	181.2	247.1	299
300	266.5	137.2	141.5	140.4	134.2	204.8	199.9	181.8	247.9	300
301	267.4	137.7	142.0	140.9	134.8	205.5	200.6	182.5	248.8	301
302	268.3	138.2	142.5	141.4	135.3	206.2	201.3	183.1	249.6	302
303	269.1	138.7	143.0	141.9	135.8	206.9	202.0	183.7	250.4	303
304	270.0	139.2	143.5	142.4	136.3	207.6	202.7	184.4	251.3	304

TABLE 21—Continued

Cuprous oxid (Cu_2O)	Copper (Cu)	Dextrose (*d*-glucose)	Invert sugar	Invert sugar and sucrose		Lactose	Lactose and sucrose		Maltose	Cuprous oxid (Cu_2O)
				0.4 gram total sugar	2 grams total sugar	$C_{12}H_{22}O_{11}+H_2O$	1 lactose, 4 sucrose	1 lactose, 12 sucrose	$C_{12}H_{22}O_{11}+H_2O$	
305	270.9	139.7	144.0	142.9	136.8	208.3	203.3	185.0	252.1	305
306	271.8	140.2	144.5	143.4	137.3	209.0	204.0	185.6	252.9	306
307	272.7	140.7	145.0	144.0	137.8	209.7	204.7	186.2	253.8	307
308	273.6	141.2	145.5	144.5	138.3	210.4	205.4	186.9	254.6	308
309	274.5	141.7	146.1	145.0	138.8	211.1	206.1	187.5	255.4	309
310	275.4	142.2	146.6	145.5	139.4	211.8	206.8	188.1	256.3	310
311	276.3	142.7	147.1	146.0	139.9	212.5	207.5	188.8	257.1	311
312	277.1	143.2	147.6	146.5	140.4	213.2	208.1	189.4	257.9	312
313	278.0	143.7	148.1	147.0	140.9	213.9	208.8	190.0	258.8	313
314	278.9	144.2	148.6	147.6	141.4	214.6	209.5	190.7	259.6	314
315	279.8	144.7	149.1	148.1	141.9	215.3	210.2	191.3	260.4	315
316	280.7	145.2	149.6	148.6	142.4	216.0	210.9	191.9	261.2	316
317	281.6	145.7	150.1	149.1	143.0	216.6	211.6	192.6	262.1	317
318	282.5	146.2	150.7	149.6	143.5	217.3	212.2	193.2	262.9	318
319	283.4	146.7	151.2	150.1	144.0	218.0	212.9	193.8	263.7	319
320	284.2	147.2	151.7	150.7	144.5	218.7	213.6	194.4	264.6	320
321	285.1	147.7	152.2	151.2	145.0	219.4	214.3	195.1	265.4	321
322	286.0	148.2	152.7	151.7	145.5	220.1	215.5	195.7	266.2	322
323	286.9	148.7	153.2	152.2	146.0	220.8	215.7	196.3	267.1	323
324	287.8	149.2	153.7	152.7	146.6	221.5	216.4	197.0	267.9	324
325	288.7	149.7	154.3	153.2	147.1	222.2	217.0	197.6	268.7	325
326	289.6	150.2	154.8	153.8	147.6	222.9	217.7	198.2	269.6	326
327	290.5	150.7	155.3	154.3	148.1	223.6	218.4	198.9	270.4	327
328	291.4	151.2	155.8	154.8	148.6	224.3	219.1	199.5	271.2	328
329	292.2	151.7	156.3	155.3	149.1	225.0	219.8	200.1	272.1	329
330	293.1	152.2	156.8	155.8	149.7	225.7	220.5	200.8	272.9	330
331	294.0	152.7	157.3	156.4	150.2	226.4	221.2	201.4	273.7	331
332	294.9	153.2	157.9	156.9	150.7	227.1	221.8	202.0	274.6	332
333	295.8	153.7	158.4	157.4	151.2	227.8	222.5	202.7	275.4	333
334	296.7	154.2	158.9	157.9	151.7	228.5	223.2	203.3	276.2	334
335	297.6	154.7	159.4	158.4	152.3	229.2	223.9	204.0	277.0	335
336	298.5	155.2	159.9	159.0	152.8	229.9	224.6	204.6	277.9	336
337	299.3	155.8	160.5	159.5	153.3	230.6	225.3	205.2	278.7	337
338	300.2	156.3	161.0	160.0	153.8	231.3	226.0	205.9	279.5	338
339	301.1	156.8	161.5	160.5	154.3	232.0	226.7	206.5	280.4	339
340	302.0	157.3	162.0	161.0	154.8	232.7	227.4	207.1	281.2	340
341	302.9	157.8	162.5	161.6	155.4	233.4	228.1	207.8	282.0	341
342	303.8	158.3	163.1	162.1	155.9	234.1	228.7	208.4	282.9	342
343	304.7	158.8	163.6	162.6	156.4	234.8	229.4	209.0	283.7	343
344	305.6	159.3	164.1	163.1	156.9	235.5	230.1	209.7	284.5	344
345	306.5	159.8	164.6	163.7	157.5	236.2	230.8	210.3	285.4	345
346	307.3	160.3	165.1	164.2	158.0	236.9	231.5	211.0	286.2	346
347	308.2	160.8	165.7	164.7	158.5	237.6	232.2	211.6	287.0	347
348	309.1	161.4	166.2	165.2	159.0	238.3	232.9	212.2	287.9	348
349	310.0	161.9	166.7	165.7	159.5	239.0	233.6	212.9	288.7	349
350	310.9	162.4	167.2	166.3	160.1	239.7	234.3	213.5	289.5	350
351	311.8	162.9	167.7	166.8	160.6	240.4	235.0	214.1	290.4	351
352	312.7	163.4	168.3	167.3	161.1	241.1	235.6	214.8	291.2	352
353	313.6	163.9	168.8	167.8	161.6	241.8	236.3	215.4	292.0	353
354	314.4	164.4	169.3	168.4	162.2	242.5	237.0	216.1	292.8	354
355	315.3	164.9	169.8	168.9	162.7	243.2	237.7	216.7	293.7	355
356	316.2	165.4	170.4	169.4	163.2	243.9	238.4	217.3	294.5	356
357	317.1	166.0	170.9	170.0	163.7	244.6	239.1	218.0	295.3	357
358	318.0	166.5	171.4	170.5	164.3	245.3	239.8	218.6	296.2	358
359	318.9	167.0	171.9	171.0	164.8	246.0	240.5	219.2	297.0	359
360	319.8	167.5	172.5	171.5	165.3	246.7	241.2	219.9	297.8	360
361	320.7	168.0	173.0	172.1	165.8	247.4	241.9	220.5	298.7	361
362	321.6	168.5	173.5	172.6	166.4	248.1	242.5	221.2	299.5	362
363	322.4	169.0	174.0	173.1	166.9	248.8	243.2	221.8	300.3	363
364	323.3	169.6	174.6	173.7	167.4	249.5	243.9	222.5	301.2	364
365	324.2	170.1	175.1	174.2	167.9	250.2	244.6	223.1	302.0	365
366	325.1	170.6	175.6	174.7	168.5	250.9	245.3	223.7	302.8	366
367	326.0	171.1	176.1	175.2	169.0	251.6	246.0	224.4	303.6	367
368	326.9	171.6	176.7	175.8	169.5	252.3	246.7	225.0	304.5	368
369	327.8	172.1	177.2	176.3	170.0	253.0	247.4	225.7	305.3	369

TABLE 21—Continued

Cuprous oxid (Cu_2O)	Copper (Cu)	Dextrose (*d*-glucose)	Invert sugar	Invert sugar and sucrose		Lactose	Lactose and sucrose		Maltose	Cuprous oxid (Cu_2O)
				0.4 gram total sugar	2 grams total sugar	$C_{12}H_{22}O_{11}+H_2O$	1 lactose, 4 sucrose	1 lactose, 12 sucrose	$C_{12}H_{22}O_{11}+H_2O$	
370	328.7	172.7	177.7	176.8	170.6	253.7	248.1	226.3	306.1	370
371	329.5	173.2	178.3	177.4	171.1	254.4	248.8	227.0	307.0	371
372	330.4	173.7	178.8	177.9	171.6	255.1	249.5	227.6	307.8	372
373	331.3	174.2	179.3	178.4	172.2	255.8	250.3	228.3	308.6	373
374	332.2	174.7	179.8	179.0	172.7	256.5	250.9	228.9	309.5	374
375	333.1	175.3	180.4	179.5	173.2	257.2	251.5	229.6	310.3	375
376	334.0	175.8	180.9	180.0	173.7	257.9	252.2	230.2	311.1	376
377	334.9	176.3	181.4	180.6	174.3	258.6	252.9	230.8	312.0	377
378	335.8	176.8	182.0	181.1	174.8	259.3	253.6	231.5	312.8	378
379	336.7	177.3	182.5	181.6	175.3	260.0	254.3	232.1	313.6	379
380	337.5	177.9	183.0	182.1	175.9	260.7	255.0	232.8	314.5	380
381	338.4	178.4	183.6	182.7	176.4	261.4	255.7	233.4	315.3	381
382	339.3	178.9	184.1	183.2	176.9	262.1	256.4	234.1	316.1	382
383	340.2	179.4	184.6	183.6	177.5	262.8	257.1	234.7	316.9	383
384	341.1	180.0	185.2	184.3	178.0	263.5	257.8	235.4	317.8	384
385	342.0	180.5	185.7	184.8	178.5	264.2	258.5	236.0	318.6	385
386	342.9	181.0	186.2	185.4	179.1	264.9	259.2	236.6	319.4	386
387	343.8	181.5	186.8	185.9	179.6	265.6	259.8	237.3	320.3	387
388	344.6	182.0	187.3	186.4	180.1	266.3	260.5	237.9	321.1	388
389	345.5	182.6	187.8	187.0	180.6	267.0	261.2	238.6	321.9	389
390	346.4	183.1	188.4	187.5	181.2	267.7	261.9	239.2	322.8	390
391	347.3	183.6	188.9	188.0	181.7	268.4	262.6	239.9	323.6	391
392	348.2	184.1	189.4	188.6	182.3	269.1	263.3	240.5	324.4	392
393	349.1	184.7	190.0	189.1	182.8	269.8	264.0	241.2	325.2	393
394	350.0	185.2	190.5	189.7	183.3	270.5	264.7	241.8	326.1	394
395	350.9	185.7	191.0	190.2	183.9	271.2	265.4	242.5	326.9	395
396	351.8	186.2	191.6	190.7	184.4	271.9	266.1	243.1	327.7	396
397	352.6	186.8	192.1	191.3	184.9	272.6	266.8	243.8	328.6	397
398	353.5	187.3	192.7	191.8	185.5	273.3	267.5	244.4	329.4	398
399	354.4	187.8	193.2	192.3	186.0	274.0	268.2	245.1	330.2	399
400	355.3	188.4	193.7	192.9	186.5	274.7	268.9	245.7	331.1	400
401	356.2	188.9	194.3	193.4	187.1	275.4	269.6	246.4	331.9	401
402	357.1	189.4	194.8	194.0	187.6	276.1	270.3	247.0	332.7	402
403	358.0	189.9	195.4	194.5	188.1	276.8	271.0	247.7	333.6	403
404	358.9	190.5	195.9	195.0	188.7	277.5	271.7	248.3	334.4	404
405	359.7	191.0	196.4	195.6	189.2	278.2	272.3	249.0	335.2	405
406	360.6	191.5	197.0	196.1	189.8	278.9	273.0	249.6	336.0	406
407	361.5	192.1	197.5	196.7	190.3	279.6	273.7	250.3	336.9	407
408	362.4	192.6	198.1	197.2	190.8	280.3	274.4	251.0	337.7	408
409	363.3	193.1	198.6	197.7	191.4	281.0	275.1	251.6	338.5	409
410	364.2	193.7	199.1	198.3	191.9	281.7	275.8	252.3	339.4	410
411	365.1	194.2	199.7	198.8	192.5	282.4	276.5	252.9	340.2	411
412	366.0	194.7	200.2	199.4	193.0	283.2	277.2	253.6	341.0	412
413	366.9	195.2	200.8	199.9	193.5	283.9	277.9	254.2	341.9	413
414	367.7	195.8	201.3	200.5	194.1	284.6	278.6	254.9	342.7	414
415	368.6	196.3	201.8	201.0	194.6	285.3	279.3	255.5	343.5	415
416	369.5	196.8	202.4	201.6	195.2	286.0	280.0	256.2	344.4	416
417	370.4	197.4	202.9	202.1	195.7	286.7	280.7	256.8	345.2	417
418	371.3	197.9	203.5	202.6	196.2	287.4	281.4	257.5	346.0	418
419	372.2	198.4	204.0	203.2	196.8	288.1	282.1	258.1	346.8	419
420	373.1	199.0	204.6	203.7	197.3	288.8	282.8	258.8	347.7	420
421	374.0	199.5	205.1	204.3	197.9	289.5	283.5	259.4	348.5	421
422	374.8	200.1	205.7	204.8	198.4	290.2	284.2	260.1	349.3	422
423	375.7	200.6	206.2	205.4	198.9	290.9	284.9	260.7	350.2	423
424	376.6	201.1	206.7	205.9	199.5	291.6	285.6	261.4	351.0	424
425	377.5	201.7	207.3	206.5	200.0	292.3	286.3	262.1	351.8	425
426	378.4	202.2	207.8	207.0	200.6	293.0	287.0	262.7	352.7	426
427	379.3	202.8	208.4	207.6	201.1	293.7	287.7	263.4	353.5	427
428	380.2	203.3	208.9	208.1	201.7	294.4	288.4	264.0	354.3	428
429	381.1	203.8	209.5	208.7	202.2	295.1	289.1	264.7	355.1	429
430	382.0	204.4	210.0	209.2	202.7	295.8	289.8	265.4	356.0	430
431	382.8	204.9	210.6	209.8	203.3	296.5	290.5	266.0	356.8	431
432	383.7	205.5	211.1	210.3	203.8	297.2	291.2	266.6	357.6	432
433	384.6	206.0	211.7	210.9	204.4	297.9	291.9	267.3	358.5	433
434	385.5	206.5	212.2	211.4	204.9	298.6	292.6	268.0	359.3	434

TABLE 21—Continued

Cuprous oxid (Cu_2O)	Copper (Cu)	Dextrose (*d*-glucose)	Invert sugar	Invert sugar and sucrose		Lactose	Lactose and sucrose		Maltose	Cuprous oxid (Cu_2O)
				0.4 gram total sugar	2 grams total sugar	$C_{12}H_{22}O_{11}+H_2O$	1 lactose, 4 sucrose	1 lactose, 12 sucrose	$C_{12}H_{22}O_{11}+H_2O$	
435	386.4	207.1	212.8	212.0	205.5	299.3	293.3	268.7	360.1	435
436	387.3	207.6	213.3	212.5	206.0	300.0	294.0	269.3	361.0	436
437	388.2	208.2	213.9	213.1	206.6	300.7	294.7	270.0	361.8	437
438	389.1	208.7	214.4	213.6	207.1	301.4	295.4	270.6	362.6	438
439	390.0	209.2	215.0	214.2	207.7	302.1	296.1	271.3	363.4	439
440	390.8	209.8	215.5	214.7	208.2	302.8	296.8	272.0	364.3	440
441	391.7	210.3	216.1	215.3	208.8	303.5	297.5	272.6	365.1	441
442	392.6	210.9	216.6	215.8	209.3	304.2	298.2	273.3	365.9	442
443	393.5	211.4	217.2	216.4	209.9	304.9	298.9	273.9	366.8	443
444	394.4	212.0	217.8	216.9	210.4	305.6	299.6	274.6	367.6	444
445	395.3	212.5	218.3	217.5	211.0	306.3	300.3	275.3	368.4	445
446	396.2	213.1	218.9	218.0	211.5	307.0	301.0	275.9	369.3	446
447	397.1	231.6	219.4	218.6	212.1	307.7	301.7	276.6	370.1	447
448	397.9	214.1	220.0	219.1	212.6	308.4	302.4	277.2	370.9	448
449	398.8	214.7	220.5	219.7	213.2	309.1	303.1	277.9	371.7	449
450	399.7	215.2	221.1	220.2	213.7	309.9	303.8	278.6	372.6	450
451	400.6	215.8	221.6	220.8	214.3	310.6	304.5	279.2	373.4	451
452	401.5	216.3	222.2	221.4	214.8	311.3	305.2	279.9	374.2	452
453	402.4	216.9	222.8	221.9	215.4	312.0	305.9	280.5	375.1	453
454	403.3	217.4	223.3	222.5	215.9	312.7	306.6	281.2	375.9	454
455	404.2	218.0	223.9	223.0	216.5	313.4	307.3	281.9	376.7	455
456	405.1	218.5	224.4	223.6	217.0	314.1	308.0	282.5	377.6	456
457	405.9	219.1	225.0	224.1	217.6	314.8	308.7	283.2	378.4	457
458	406.8	219.6	225.5	224.7	218.1	315.5	309.4	283.9	379.2	458
459	407.7	220.2	226.1	225.3	218.7	316.2	310.1	284.5	380.0	459
460	408.6	220.7	226.7	225.8	219.2	316.9	310.8	285.2	380.9	460
461	409.5	221.3	227.3	226.4	219.8	317.6	311.5	285.9	381.7	461
462	410.4	221.8	227.8	226.9	220.3	318.3	312.2	286.5	382.5	462
463	411.3	222.4	228.3	227.5	220.9	319.0	312.9	287.2	383.4	463
464	412.2	222.9	228.9	228.1	221.4	319.7	313.6	287.8	384.2	464
465	413.0	223.5	229.5	228.6	222.0	320.4	314.3	288.5	385.0	465
466	413.9	224.0	230.0	229.2	222.5	321.1	315.0	289.2	385.9	466
467	414.8	224.6	230.6	229.7	223.1	321.8	315.7	289.8	386.7	467
468	415.7	225.1	231.2	230.3	223.7	322.5	316.4	290.5	387.5	468
469	416.6	225.7	231.7	230.9	224.2	323.2	317.0	291.2	388.3	469
470	417.5	226.2	232.3	231.4	224.8	323.9	317.7	291.8	389.2	470
471	418.4	226.8	232.8	232.0	225.3	324.6	318.4	292.5	390.0	471
472	419.3	227.4	233.4	232.5	225.9	325.3	319.1	293.2	390.8	472
473	420.2	227.9	234.0	233.1	226.4	326.0	319.8	293.8	391.7	473
474	421.0	228.3	234.5	233.7	227.0	326.8	320.5	294.5	392.5	474
475	421.9	229.0	235.1	234.2	227.6	327.5	321.2	295.2	393.3	475
476	422.8	229.6	235.7	234.8	228.1	328.2	321.9	295.8	394.2	476
477	423.7	230.1	236.2	235.4	228.7	328.9	322.6	296.5	395.0	477
478	424.6	230.7	236.8	235.9	229.2	329.6	323.3	297.1	395.8	478
479	425.5	231.3	237.4	236.5	229.8	330.3	324.0	297.8	396.6	479
480	426.4	231.8	237.9	237.1	230.3	331.0	324.7	298.5	397.5	480
481	427.3	232.4	238.5	237.6	230.9	331.7	325.4	299.1	398.3	481
482	428.1	232.9	239.1	238.2	231.5	332.4	326.1	299.8	399.1	482
483	429.0	233.5	239.6	238.8	232.0	333.1	326.8	300.5	400.0	483
484	429.9	234.1	240.2	239.3	232.6	333.8	327.5	301.1	400.8	484
485	430.8	234.6	240.8	239.9	233.2	334.5	328.2	301.8	401.6	485
486	431.7	235.2	241.4	240.5	233.7	335.2	328.9	302.5	402.4	486
487	432.6	235.7	241.9	241.0	234.3	335.9	329.6	303.1	403.3	487
488	433.5	236.3	242.5	241.6	234.8	336.6	330.3	303.8	404.1	488
489	434.4	236.9	243.1	242.2	235.4	337.3	331.0	304.5	404.9	489
490	435.3	237.4	243.6	242.7	236.0	338.0	331.7	305.1	405.8	490

TABLE 22

Herzfeld's Table for Determining Invert Sugar in Raw Sugars (Invert Sugar not to Exceed 1.5 Per Cent)

Copper (Cu)	Invert sugar	Copper (Cu)	Invert sugar	Copper (Cu)	Invert sugar	Copper (Cu)	Invert sugar	Copper (Cu)	Invert sugar
Mgs	Per cent	Mgs	Per cent	Mgs	Per cent	Mgs	Per cent	Mgs	Per cent
50	0.050	105	0.325	160	0.621	215	0.929	270	1.242
51	0.054	106	0.330	161	0.627	216	0.935	271	1.248
52	0.058	107	0.335	162	0.633	217	0.940	272	1.253
53	0.062	108	0.340	163	0.639	218	0.946	273	1.259
54	0.066	109	0.346	164	0.645	219	0.951	274	1.265
55	0.070	110	0.351	165	0.651	220	0.957	275	1.271
56	0.074	111	0.356	166	0.657	221	0.962	276	1.276
57	0.078	112	0.361	167	0.663	222	0.968	277	1.282
58	0.082	113	0.366	168	0.669	223	0.973	278	1.288
59	0.086	114	0.371	169	0.675	224	0.979	279	1.294
60	0.090	115	0.376	170	0.680	225	0.984	280	1.299
61	0.094	116	0.381	171	0.686	226	0.990	281	1.305
62	0.098	117	0.386	172	0.692	227	0.996	282	1.311
63	0.103	118	0.392	173	0.698	228	1.001	283	1.317
64	0.108	119	0.397	174	0.704	229	1.007	284	1.322
65	0.113	120	0.402	175	0.709	230	1.013	285	1.328
66	0.118	121	0.407	176	0.715	231	1.018	286	1.334
67	0.123	122	0.412	177	0.720	232	1.024	287	1.339
68	0.128	123	0.417	178	0.726	233	1.030	288	1.345
69	0.133	124	0.423	179	0.731	234	1.036	289	1.351
70	0.138	125	0.428	180	0.737	235	1.041	290	1.357
71	0.143	126	0.433	181	0.742	236	1.047	291	1.362
72	0.148	127	0.438	182	0.748	237	1.053	292	1.368
73	0.152	128	0.443	183	0.753	238	1.058	293	1.374
74	0.157	129	0.448	184	0.759	239	1.064	294	1.380
75	0.162	130	0.453	185	0.764	240	1.070	295	1.385
76	0.167	131	0.458	186	0.770	241	1.076	296	1.391
77	0.172	132	0.463	187	0.775	242	1.081	297	1.397
78	0.177	133	0.468	188	0.781	243	1.087	298	1.403
79	0.182	134	0.473	189	0.786	244	1.093	299	1.408
80	0.187	135	0.478	190	0.792	245	1.099	300	1.414
81	0.192	136	0.483	191	0.797	246	1.104	301	1.420
82	0.197	137	0.488	192	0.803	247	1.110	302	1.425
83	0.202	138	0.493	193	0.808	248	1.116	303	1.431
84	0.208	139	0.498	194	0.814	249	1.122	304	1.437
85	0.213	140	0.503	195	0.819	250	1.127	305	1.443
86	0.219	141	0.509	196	0.825	251	1.133	306	1.448
87	0.225	142	0.515	197	0.830	252	1.139	307	1.454
88	0.231	143	0.521	198	0.836	253	1.144	308	1.460
89	0.236	144	0.527	199	0.841	254	1.150	309	1.466
90	0.242	145	0.533	200	0.847	255	1.156	310	1.471
91	0.248	146	0.538	201	0.852	256	1.162	311	1.477
92	0.254	147	0.544	202	0.858	257	1.167	312	1.483
93	0.260	148	0.550	203	0.863	258	1.173	313	1.489
94	0.265	149	0.556	204	0.869	259	1.179	314	1.494
								315	1.500
95	0.271	150	0.562	205	0.874	260	1.185		
96	0.277	151	0.568	206	0.880	261	1.190		
97	0.283	152	0.574	207	0.885	262	1.196		
98	0.288	153	0.580	208	0.891	263	1.202		
99	0.294	154	0.586	209	0.896	264	1.207		
100	0.300	155	0.592	210	0.902	265	1.213		
101	0.305	156	0.598	211	0.907	266	1.219		
102	0.310	157	0.604	212	0.913	267	1.225		
103	0.315	158	0.609	213	0.918	268	1.231		
104	0.320	159	0.615	214	0.924	269	1.236		

TABLE 23

Allihn's Table for the Determination of Dextrose

Milligrams of copper	Milligrams of cuprous oxid	Milligrams of dextrose	Milligrams of copper	Milligrams of cuprous oxid	Milligrams of dextrose	Milligrams of copper	Milligrams of cuprous oxid	Milligrams of dextrose	Milligrams of copper	Milligrams of cuprous oxid	Milligrams of dextrose
11	12.4	6.6	76	85.6	38.8	141	158.7	71.8	206	231.9	105.8
12	13.5	7.1	77	86.7	39.3	142	159.9	72.3	207	233.0	106.3
13	14.6	7.6	78	87.8	39.8	143	161.0	72.9	208	234.2	106.8
14	15.8	8.1	79	88.9	40.3	144	162.1	73.4	209	235.3	107.4
15	16.9	8.6	80	90.1	40.8	145	163.2	73.9	210	236.4	107.9
16	18.0	9.0	81	91.2	41.3	146	164.4	74.4	211	237.6	108.4
17	19.1	9.5	82	92.3	41.8	147	165.5	74.9	212	238.7	109.0
18	20.3	10.0	83	93.4	42.3	148	166.6	75.5	213	239.8	109.5
19	21.4	10.5	84	94.6	42.8	149	167.7	76.0	214	240.9	110.0
20	22.5	11.0	85	95.7	43.4	150	168.9	76.5	215	242.1	110.6
21	23.6	11.5	86	96.8	43.9	151	170.0	77.0	216	243.2	111.1
22	24.8	12.0	87	97.9	44.4	152	171.1	77.5	217	244.3	111.6
23	25.9	12.5	88	99.1	44.9	153	172.3	78.1	218	245.4	112.1
24	27.0	13.0	89	100.2	45.4	154	173.4	78.6	219	246.6	112.7
25	28.1	13.5	90	101.3	45.9	155	174.5	79.1	220	247.7	113.2
26	29.3	14.0	91	102.4	46.4	156	175.6	79.6	221	248.7	113.7
27	30.4	14.5	92	103.6	46.9	157	176.8	80.1	222	249.9	114.3
28	31.5	15.0	93	104.7	47.4	158	177.9	80.7	223	251.0	114.8
29	32.7	15.5	94	105.8	47.9	159	179.0	81.2	224	252.4	115.3
30	33.8	16.0	95	107.0	48.4	160	180.1	81.7	225	253.3	115.9
31	34.9	16.5	96	108.1	48.9	161	181.3	82.2	226	254.4	116.4
32	36.0	17.0	97	109.2	49.4	162	182.4	82.7	227	255.6	116.9
33	37.2	17.5	98	110.3	49.9	163	183.5	83.3	228	256.7	117.4
34	38.3	18.0	99	111.5	50.4	164	184.6	83.8	229	257.8	118.0
35	39.4	18.5	100	112.6	50.9	165	185.8	84.3	230	258.9	118.5
36	40.5	18.9	101	113.7	51.4	166	186.9	84.8	231	260.1	119.0
37	41.7	19.4	102	114.8	51.9	167	188.0	85.3	232	261.2	119.6
38	42.8	19.9	103	116.0	52.4	168	189.1	85.9	233	262.3	120.1
39	43.9	20.4	104	117.1	52.9	169	190.3	86.4	234	263.4	120.7
40	45.0	20.9	105	118.2	53.5	170	191.4	86.9	235	264.6	121.2
41	46.2	21.4	106	119.3	54.0	171	192.5	87.4	236	265.7	121.7
42	47.3	21.9	107	120.5	54.5	172	193.6	87.9	237	266.8	122.3
43	48.4	22.4	108	121.6	55.0	173	194.8	88.5	238	268.0	122.8
44	49.5	22.9	109	122.7	55.5	174	195.9	89.0	239	269.1	123.4
45	50.7	23.4	110	123.8	56.0	175	197.0	89.5	240	270.2	123.9
46	51.8	23.9	111	125.0	56.5	176	198.1	90.0	241	271.3	124.4
47	52.9	24.4	112	126.1	57.0	177	199.3	90.5	242	272.5	125.0
48	54.0	24.9	113	127.2	57.5	178	200.4	91.1	243	273.6	125.5
49	55.2	25.4	114	128.3	58.0	179	201.5	91.6	244	274.7	126.0
50	56.3	25.9	115	129.6	58.6	180	202.6	92.1	245	275.8	126.6
51	57.4	26.4	116	130.6	59.1	181	203.8	92.6	246	277.0	127.1
52	58.5	26.9	117	131.7	59.6	182	204.9	93.1	247	278.1	127.6
53	59.7	27.4	118	132.8	60.1	183	206.0	93.7	248	279.2	128.1
54	60.8	27.9	119	134.0	60.6	184	207.1	94.2	249	280.3	128.7
55	61.9	28.4	120	135.1	61.1	185	208.3	94.7	250	281.5	129.2
56	63.0	28.8	121	136.2	61.6	186	209.4	95.2	251	282.6	129.7
57	64.2	29.3	122	137.4	62.1	187	210.5	95.7	252	283.7	130.3
58	65.3	29.8	123	138.5	62.6	188	211.7	96.3	253	284.8	130.8
59	66.4	30.3	124	139.6	63.1	189	212.8	96.8	254	286.0	131.4
60	67.6	30.8	125	140.7	63.7	190	213.9	97.3	255	287.1	131.9
61	68.7	31.3	126	141.9	64.2	191	215.0	97.8	256	288.2	132.4
62	69.8	31.8	127	143.0	64.7	192	216.2	98.4	257	289.3	133.0
63	70.9	32.3	128	144.1	65.2	193	217.3	98.9	258	290.5	133.5
64	72.1	32.8	129	145.2	65.7	194	218.4	99.4	259	291.6	134.1
65	73.2	33.3	130	146.4	66.2	195	219.5	100.0	260	292.7	134.6
66	74.3	33.8	131	147.5	66.7	196	220.7	100.5	261	293.8	135.1
67	75.4	34.3	132	148.6	67.2	197	221.8	101.0	262	295.0	135.7
68	76.6	34.8	133	149.7	67.7	198	222.9	101.5	263	296.1	136.2
69	77.7	35.3	134	150.9	68.2	199	224.0	102.0	264	297.2	136.8
70	78.8	35.8	135	152.0	68.8	200	225.2	102.6	265	298.3	137.3
71	79.9	36.3	136	153.1	69.3	201	226.3	103.1	266	299.5	137.8
72	81.1	36.8	137	154.2	69.8	202	227.4	103.7	267	300.6	138.4
73	82.2	37.3	138	155.4	70.3	203	228.5	104.2	268	301.7	138.9
74	83.3	37.8	139	156.5	70.8	204	229.7	104.7	269	302.8	139.5
75	84.4	38.3	140	157.6	71.3	205	230.8	105.3	270	304.0	140.0

TABLE 23—Continued

Milligrams of copper	Milligrams of cuprous oxid	Milligrams of dextrose	Milligrams of copper	Milligrams of cuprous oxid	Milligrams of dextrose	Milligrams of copper	Milligrams of cuprous oxid	Milligrams of dextrose	Milligrams of copper	Milligrams of cuprous oxid	Milligrams of dextrose
271	305.1	140.6	320	360.3	167.5	369	415.4	195.1	418	470.6	223.3
272	306.2	141.1	321	361.4	168.1	370	416.6	195.7	419	471.8	223.9
273	307.3	141.7	322	362.5	168.6	371	417.7	196.3	420	472.9	224.5
274	308.5	142.2	323	363.7	169.2	372	418.8	196.8	421	474.0	225.1
275	309.6	142.8	324	364.8	169.7	373	420.0	197.4	422	475.6	225.7
276	310.7	143.3	325	365.9	170.3	374	421.1	198.0	423	476.2	226.3
277	311.9	143.9	326	367.0	170.9	375	422.2	198.6	424	477.4	226.9
278	313.0	144.4	327	368.2	171.4	376	423.3	199.1	425	478.5	227.5
279	314.1	145.0	328	369.3	172.0	377	424.5	199.7	426	479.6	228.0
280	315.2	145.5	329	370.4	172.5	378	425.6	200.3	427	480.7	228.6
281	316.4	146.1	330	371.5	173.1	379	426.7	200.8	428	481.9	229.2
282	317.5	146.6	331	372.7	173.7	380	427.8	201.4	429	483.0	229.8
283	318.6	147.2	332	373.8	174.2	381	429.0	202.0	430	484.1	230.4
284	319.7	147.7	333	374.9	174.8	382	430.1	202.5	431	485.3	231.0
285	320.9	148.3	334	376.0	175.3	383	431.2	203.1	432	486.4	231.6
286	322.0	148.8	335	377.2	175.9	384	432.3	203.7	433	487.5	232.2
287	323.1	149.4	336	378.3	176.5	385	433.5	204.3	434	488.6	232.8
288	324.2	149.9	337	379.4	177.0	386	434.6	204.8	435	489.7	233.4
289	325.4	150.5	338	380.5	177.6	387	435.7	205.4	436	490.9	233.9
290	326.5	151.0	339	381.7	178.1	388	436.8	206.0	437	492.0	234.5
291	327.4	151.6	340	382.8	178.7	389	438.0	206.5	438	493.1	235.1
292	328.7	152.1	341	383.9	179.3	390	439.1	207.1	439	494.3	235.7
293	329.9	152.7	342	385.0	179.8	391	440.2	207.7	440	495.4	236.3
294	331.0	153.2	343	386.2	180.4	392	441.3	208.3	441	496.5	236.9
295	332.1	153.8	344	387.3	180.9	393	442.4	208.8	442	497.6	237.5
296	333.3	154.3	345	388.4	181.5	394	443.6	209.4	443	498.8	238.1
297	334.4	154.9	346	389.6	182.1	395	444.7	210.0	444	499.9	238.7
298	335.5	155.4	347	390.7	182.6	396	445.9	210.6	445	501.0	239.3
299	336.6	156.0	348	391.8	183.2	397	447.0	211.2	446	502.1	239.8
300	337.8	156.5	349	392.9	183.7	398	448.1	211.7	447	503.2	240.4
301	338.9	157.1	350	394.0	184.3	399	449.2	212.3	448	504.4	241.0
302	340.0	157.6	351	395.2	184.9	400	450.3	212.9	449	505.5	241.6
303	341.1	158.2	352	396.3	185.4	401	451.5	213.5	450	506.6	242.2
304	342.3	158.7	353	397.4	186.0	402	452.6	214.1	451	507.8	242.8
			354	398.6	186.6	403	453.7	214.6	452	508.9	243.4
305	343.4	159.3									
306	344.5	159.8	355	399.7	187.2	404	454.8	215.2	453	510.0	244.0
307	345.6	160.4	356	400.8	187.7	405	456.0	215.8	454	511.1	244.6
308	346.8	160.9	357	401.9	188.3	406	457.1	216.4	455	512.3	245.2
309	347.9	161.5	358	403.1	188.9	407	458.2	217.0	456	513.4	245.7
						408	459.4	217.5	457	514.5	246.3
310	349.0	162.0	359	404.2	189.4						
311	350.1	162.6	360	405.3	190.0	409	460.5	218.1	458	515.6	246.9
312	351.3	163.1	361	406.4	190.6	410	461.6	218.7	459	516.8	247.5
313	352.4	163.7	362	407.6	191.1	411	462.7	219.3	460	517.9	248.1
314	353.5	164.2	363	408.7	191.7	412	463.8	219.9	461	519.0	248.7
									462	520.1	249.3
315	354.6	164.8	364	409.8	192.3	413	465.0	220.4			
316	355.8	165.3	365	410.9	192.9	414	466.1	221.0	463	521.3	249.9
317	356.9	165.9	366	412.1	193.4	415	467.2	221.6			
318	358.0	166.4	367	413.2	194.0	416	468.4	222.2			
319	359.1	167.0	368	414.3	194.6	417	469.5	222.8			

TABLE 25

Interpolation Formulas for Specific Rotation

Sucrose $[\alpha]_D^{20} = 66.412 + 0.012673p - 0.0003766p^2$

Dextrose $[\alpha]_D^{20} = 52.50 + 0.0188p + 0.000517p^2$

Fructose $[\alpha]_D^{20} = -113.96 + 0.258q$ (q = % water)

Maltose $[\alpha]_D^{20} = 138.475 - 0.01837p$

Lactose $[\alpha]_D^{20} = 52.53$

Invert sugar $[\alpha]_D^{20} = -19.447 - 0.06068p + 0.000221p^2$

TABLE 26

Interpolation Table of Specific Rotations at Varying Concentrations

Percentage	Sucrose	Dextrose	Fructose	Maltose	Lactose hydrate
5	66.466	52.607	−89.42	138.38	52.53
10	66.501	52.740	−90.72	138.29	
15	66.517	52.898	−92.01	138.20	
20	66.515	53.083	−93.30	138.11	Remains unchanged at all concentrations
25	66.493	53.293	−94.59	138.02	
30	66.453	53.529	−95.88	137.92	
35	66.394	53.791	−97.18	137.82	
40	66.316	54.079	−98.47	.....	
45	66.220	54.393	.....	.....	
50	66.104	54.732	.....	.....	

TABLE 27

Corrections[77] for Saccharimetric Readings of Dextrose Solutions

Scale reading	Correction to be added	Scale reading	Correction to be added	Scale reading	Correction to be added	Scale reading	Correction to be added
100	0	70	0.46	45	0.54	20	0.35
95	0.10	65	0.50	40	0.53	15	0.28
90	0.20	60	0.52$_5$	35	0.50	10	0.20
85	0.28	55	0.54	30	0.46	5	0.10
80	0.35	50	0.55	25	0.41	2	0.05
75	0.41						

[77] See p. 171.

TABLE 28

Time Required at Each Temperature to Form Caramel Equivalent to 0.01 Per Cent of Invert Sugar

Temperature	79.5	66.6	50.0	39.0
Time in hours	.57	10.9	107.0	476.0

TABLE 29[78]

Thickness of the Normal Quartz Plate

Wave length of light source	Rotation of normal plate	Rotation of 1 mm of quartz at 20° C; light parallel to optic axis	Thickness of normal plate
1	2	3	4
			mm
5892.5A	34°.620 (Bates & Jackson)	21°.7182 (Gumlich)	1.5940
5892.5A	34°.620 (Bates & Jackson)	21°.7283 (Lowry)	1.5934
5461. A	40°.690 (Bates & Jackson)	25°.5371 (Lowry)	1.5934

[78] See p. 163

TABLE 30

Clerget Constant[79] at Different Concentrations of Sucrose

Grams sucrose in 100 cc	Constant	Grams sucrose in 100 cc	Constant	Grams sucrose in 100 cc	Constant	Grams sucrose in 100 cc	Constant
1	141.85	8	142.32	15	142.79	21	143.20
2	141.91	9	142.39	16	142.86	22	143.27
3	141.98	10	142.46	17	142.93	23	143.33
4	142.05	11	142.52	18	143.00	24	143.40
5	142.12	12	142.59	19	143.07	25	143.47
6	142.18	13	142.66	20	143.13	26	143.54
7	142.25	14	142.73				

[79] See p. 179.

TABLE 31

Degrees Brix, Specific Gravity, and Degrees Baumé of Sugar Solutions

Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)	Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)
0.0	0.99823	1.00000	0.00	4.5	1.01586	1.01766	2.52
0.1	0.99862	1.00039	0.06	4.6	1.01626	1.01806	2.57
0.2	0.99901	1.00078	0.11	4.7	1.01666	1.01846	2.63
0.3	0.99940	1.00117	0.17	4.8	1.01706	1.01886	2.68
0.4	0.99979	1.00155	0.22	4.9	1.01746	1.01926	2.74
0.5	1.00017	1.00194	0.28	5.0	1.01785	1.01965	2.79
0.6	1.00056	1.00233	0.34	5.1	1.01825	1.02005	2.85
0.7	1.00095	1.00272	0.39	5.2	1.01865	1.02045	2.91
0.8	1.00134	1.00311	0.45	5.3	1.01905	1.02085	2.96
0.9	1.00173	1.00350	0.51	5.4	1.01945	1.02125	3.02
1.0	1.00212	1.00389	0.56	5.5	1.01985	1.02165	3.07
1.1	1.00251	1.00428	0.62	5.6	1.02025	1.02206	3.13
1.2	1.00290	1.00467	0.67	5.7	1.02065	1.02246	3.18
1.3	1.00329	1.00506	0.73	5.8	1.02105	1.02286	3.24
1.4	1.00368	1.00545	0.79	5.9	1.02145	1.02321	3.30
1.5	1.00406	1.00584	0.84	6.0	1.02186	1.02366	3.35
1.6	1.00445	1.00623	0.90	6.1	1.02226	1.02407	3.41
1.7	1.00484	1.00662	0.95	6.2	1.02266	1.02447	3.46
1.8	1.00523	1.00701	1.01	6.3	1.02306	1.02487	3.52
1.9	1.00562	1.00740	1.07	6.4	1.02346	1.02527	3.57
2.0	1.00602	1.00779	1.12	6.5	1.02387	1.02568	3.63
2.1	1.00641	1.00818	1.18	6.6	1.02427	1.02608	3.69
2.2	1.00680	1.00858	1.23	6.7	1.02467	1.02648	3.74
2.3	1.00719	1.00897	1.29	6.8	1.02508	1.02689	3.80
2.4	1.00758	1.00936	1.34	6.9	1.02548	1.02729	3.85
2.5	1.00797	1.00976	1.40	7.0	1.02588	1.02770	3.91
2.6	1.00836	1.01015	1.46	7.1	1.02629	1.02810	3.96
2.7	1.00876	1.01054	1.51	7.2	1.02669	1.02851	4.02
2.8	1.00915	1.01093	1.57	7.3	1.02710	1.02892	4.08
2.9	1.00954	1.01133	1.62	7.4	1.02750	1.02932	4.13
3.0	1.00993	1.01172	1.68	7.5	1.02791	1.02973	4.19
3.1	1.01033	1.01211	1.74	7.6	1.02832	1.03013	4.24
3.2	1.01072	1.01251	1.79	7.7	1.02872	1.03054	4.30
3.3	1.01112	1.01290	1.85	7.8	1.02913	1.03095	4.35
3.4	1.01151	1.01330	1.90	7.9	1.02954	1.03136	4.41
3.5	1.01190	1.01369	1.96	8.0	1.02994	1.03176	4.46
3.6	1.01230	1.01409	2.02	8.1	1.03035	1.03217	4.52
3.7	1.01269	1.01448	2.07	8.2	1.03076	1.03258	4.58
3.8	1.01309	1.01488	2.13	8.3	1.03116	1.03299	4.63
3.9	1.01348	1.01528	2.18	8.4	1.03157	1.03340	4.69
4.0	1.01388	1.01567	2.24	8.5	1.03198	1.03381	4.74
4.1	1.01428	1.01607	2.29	8.6	1.03239	1.03422	4.80
4.2	1.01467	1.01647	2.35	8.7	1.03280	1.03463	4.85
4.3	1.01507	1.01687	2.40	8.8	1.03321	1.03504	4.91
4.4	1.01547	1.01726	2.46	8.9	1.03362	1.03545	4.96

TABLE 31—Continued

Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)	Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)
9.0	1.03403	1.03586	5.02	15.5	1.06131	1.06319	8.62
9.1	1.03444	1.03627	5.07	15.6	1.06174	1.06362	8.67
9.2	1.03485	1.03668	5.13	15.7	1.06217	1.06405	8.73
9.3	1.03526	1.03709	5.19	15.8	1.06260	1.06448	8.78
9.4	1.03567	1.03750	5.24	15.9	1.06303	1.06491	8.84
9.5	1.03608	1.03792	5.30	16.0	1.06346	1.06534	8.89
9.6	1.03649	1.03833	5.35	16.1	1.06389	1.06577	8.95
9.7	1.03691	1.03874	5.41	16.2	1.06432	1.06621	9.00
9.8	1.03732	1.03915	5.46	16.3	1.06476	1.06664	9.06
9.9	1.03773	1.03957	5.52	16.4	1.06519	1.06707	9.11
10.0	1.03814	1.03998	5.57	16.5	1.06562	1.06751	9.17
10.1	1.03856	1.04039	5.63	16.6	1.06605	1.06794	9.22
10.2	1.03897	1.04081	5.68	16.7	1.06649	1.06837	9.28
10.3	1.03938	1.04122	5.74	16.8	1.06692	1.06881	9.33
10.4	1.03980	1.04164	5.80	16.9	1.06736	1.06924	9.39
10.5	1.04021	1.04205	5.85	17.0	1.06779	1.06968	9.45
10.6	1.04063	1.04247	5.91	17.1	1.06822	1.07011	9.50
10.7	1.04104	1.04288	5.96	17.2	1.06866	1.07055	9.56
10.8	1.04146	1.04330	6.02	17.3	1.06909	1.07098	9.61
10.9	1.04187	1.04371	6.07	17.4	1.06953	1.07142	9.67
11.0	1.04229	1.04413	6.13	17.5	1.06996	1.07186	9.72
11.1	1.04270	1.04455	6.18	17.6	1.07040	1.07229	9.78
11.2	1.04312	1.04497	6.24	17.7	1.07084	1.07273	9.83
11.3	1.04354	1.04538	6.30	17.8	1.07127	1.07317	9.89
11.4	1.04395	1.04580	6.35	17.9	1.07171	1.07361	9.94
11.5	1.04437	1.04622	6.41	18.0	1.07215	1.07404	10.00
11.6	1.04479	1.04664	6.46	18.1	1.07258	1.07448	10.05
11.7	1.04521	1.04706	6.52	18.2	1.07302	1.07492	10.11
11.8	1.04562	1.04747	6.57	18.3	1.07346	1.07536	10.16
11.9	1.04604	1.04789	6.63	18.4	1.07390	1.07580	10.22
12.0	1.04646	1.04831	6.68	18.5	1.07434	1.07624	10.27
12.1	1.04688	1.04873	6.74	18.6	1.07478	1.07668	10.33
12.2	1.04730	1.04915	6.79	18.7	1.07522	1.07712	10.38
12.3	1.04772	1.04957	6.85	18.8	1.07566	1.07756	10.44
12.4	1.04814	1.04999	6.90	18.9	1.07610	1.07800	10.49
12.5	1.04856	1.05041	6.96	19.0	1.07654	1.07844	10.55
12.6	1.04898	1.05084	7.02	19.1	1.07698	1.07888	10.60
12.7	1.04940	1.05126	7.07	19.2	1.07742	1.07932	10.66
12.8	1.04982	1.05168	7.13	19.3	1.07786	1.07977	10.71
12.9	1.05024	1.05210	7.18	19.4	1.07830	1.08021	10.77
13.0	1.05066	1.05252	7.24	19.5	1.07874	1.08065	10.82
13.1	1.05109	1.05295	7.29	19.6	1.07919	1.08110	10.88
13.2	1.05151	1.05337	7.35	19.7	1.07963	1.08154	10.93
13.3	1.05193	1.05379	7.40	19.8	1.08007	1.08198	10.99
13.4	1.05236	1.05422	7.46	19.9	1.08052	1.08243	11.04
13.5	1.05278	1.05464	7.51	20.0	1.08096	1.08287	11.10
13.6	1.05320	1.05506	7.57	20.1	1.08140	1.08332	11.15
13.7	1.05363	1.05549	7.62	20.2	1.08185	1.08376	11.21
13.8	1.05405	1.05591	7.68	20.3	1.08229	1.08421	11.26
13.9	1.05448	1.05634	7.73	20.4	1.08274	1.08465	11.32
14.0	1.05490	1.05677	7.79	20.5	1.08318	1.08510	11.37
14.1	1.05532	1.05719	7.84	20.6	1.08363	1.08554	11.43
14.2	1.05575	1.05762	7.90	20.7	1.08407	1.08599	11.48
14.3	1.05618	1.05804	7.96	20.8	1.08452	1.08644	11.54
14.4	1.05660	1.05847	8.01	20.9	1.08497	1.08689	11.59
14.5	1.05703	1.05890	8.07	21.0	1.08541	1.08733	11.65
14.6	1.05746	1.05933	8.12	21.1	1.08586	1.08778	11.70
14.7	1.05788	1.05975	8.18	21.2	1.08631	1.08823	11.76
14.8	1.05831	1.06018	8.23	21.3	1.08676	1.08868	11.81
14.9	1.05874	1.06061	8.29	21.4	1.08720	1.08913	11.87
15.0	1.05916	1.06104	8.34	21.5	1.08765	1.08958	11.92
15.1	1.05959	1.06147	8.40	21.6	1.08810	1.09003	11.98
15.2	1.06002	1.06190	8.45	21.7	1.08855	1.09048	12.03
15.3	1.06045	1.06233	8.51	21.8	1.08900	1.09093	12.09
15.4	1.06088	1.06276	8.56	21.9	1.08945	1.09138	12.14

TABLE 31—Continued

Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)	Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)
22.0	1.08990	1.09183	12.20	28.5	1.11987	1.12185	15.75
22.1	1.09035	1.09228	12.25	28.6	1.12034	1.12232	15.80
22.2	1.09080	1.09273	12.31	28.7	1.12081	1.12280	15.86
22.3	1.09125	1.09318	12.36	28.8	1.12128	1.12327	15.91
22.4	1.09170	1.09364	12.42	28.9	1.12176	1.12374	15.97
22.5	1.09216	1.09409	12.47	29.0	1.12223	1.12422	16.02
22.6	1.09261	1.09454	12.52	29.1	1.12270	1.12469	16.08
22.7	1.09306	1.09499	12.58	29.2	1.12318	1.12517	16.13
22.8	1.09351	1.09545	12.63	29.3	1.12365	1.12564	16.18
22.9	1.09397	1.09590	12.69	29.4	1.12413	1.12612	16.24
23.0	1.09442	1.09636	12.74	29.5	1.12460	1.12659	16.29
23.1	1.09487	1.09681	12.80	29.6	1.12508	1.12707	16.35
23.2	1.09533	1.09727	12.85	29.7	1.12556	1.12755	16.40
23.3	1.09578	1.09772	12.91	29.8	1.12603	1.12802	16.46
23.4	1.09624	1.09818	12.96	29.9	1.12651	1.12850	16.51
23.5	1.09669	1.09863	13.02	30.0	1.12698	1.12898	16.57
23.6	1.09715	1.09909	13.07	30.1	1.12746	1.12946	16.62
23.7	1.09760	1.09954	13.13	30.2	1.12794	1.12993	16.67
23.8	1.09806	1.10000	13.18	30.3	1.12842	1.13041	16.73
23.9	1.09851	1.10046	13.24	30.4	1.12890	1.13089	16.78
24.0	1.09897	1.10092	13.29	30.5	1.12937	1.13137	16.84
24.1	1.09943	1.10137	13.35	30.6	1.12985	1.13185	16.89
24.2	1.09989	1.10183	13.40	30.7	1.13033	1.13233	16.95
24.3	1.10034	1.10229	13.46	30.8	1.13081	1.13281	17.00
24.4	1.10080	1.10275	13.51	30.9	1.13129	1.13329	17.05
24.5	1.10126	1.10321	13.57	31.0	1.13177	1.13378	17.11
24.6	1.10172	1.10367	13.62	31.1	1.13225	1.13426	17.16
24.7	1.10218	1.10413	13.67	31.2	1.13274	1.13474	17.22
24.8	1.10264	1.10459	13.73	31.3	1.13322	1.13522	17.27
24.9	1.10310	1.10505	13.78	31.4	1.13370	1.13570	17.33
25.0	1.10356	1.10551	13.84	31.5	1.13418	1.13619	17.38
25.1	1.10402	1.10597	13.89	31.6	1.13466	1.13667	17.43
25.2	1.10448	1.10643	13.95	31.7	1.13515	1.13715	17.49
25.3	1.10494	1.10689	14.00	31.8	1.13563	1.13764	17.54
25.4	1.10540	1.10736	14.06	31.9	1.13611	1.13812	17.60
25.5	1.10586	1.10782	14.11	32.0	1.13660	1.13861	17.65
25.6	1.10632	1.10828	14.17	32.1	1.13708	1.13909	17.70
25.7	1.10679	1.10874	14.22	32.2	1.13756	1.13958	17.76
25.8	1.10725	1.10921	14.28	32.3	1.13805	1.14006	17.81
25.9	1.10771	1.10967	14.33	32.4	1.13853	1.14055	17.87
26.0	1.10818	1.11014	14.39	32.5	1.13902	1.14103	17.92
26.1	1.10864	1.11060	14.44	32.6	1.13951	1.14152	17.98
26.2	1.10910	1.11106	14.49	32.7	1.13999	1.14201	18.03
26.3	1.10957	1.11153	14.55	32.8	1.14048	1.14250	18.08
26.4	1.11003	1.11200	14.60	32.9	1.14097	1.14298	18.14
26.5	1.11050	1.11246	14.66	33.0	1.14145	1.14347	18.19
26.6	1.11096	1.11293	14.71	33.1	1.14194	1.14396	18.25
26.7	1.11143	1.11339	14.77	33.2	1.14243	1.14445	18.30
26.8	1.11190	1.11386	14.82	33.3	1.14292	1.14494	18.36
26.9	1.11236	1.11433	14.88	33.4	1.14340	1.14543	18.41
27.0	1.11283	1.11480	14.93	33.5	1.14389	1.14592	18.46
27.1	1.11330	1.11526	14.99	33.6	1.14438	1.14641	18.52
27.2	1.11376	1.11573	15.04	33.7	1.14487	1.14690	18.57
27.3	1.11423	1.11620	15.09	33.8	1.14536	1.14739	18.63
27.4	1.11470	1.11667	15.15	33.9	1.14585	1.14788	18.68
27.5	1.11517	1.11714	15.20	34.0	1.14634	1.14837	18.73
27.6	1.11564	1.11761	15.26	34.1	1.14684	1.14886	18.79
27.7	1.11610	1.11808	15.31	34.2	1.14733	1.14936	18.84
27.8	1.11657	1.11855	15.37	34.3	1.14782	1.14985	18.90
27.9	1.11704	1.11902	15.42	34.4	1.14831	1.15034	18.95
28.0	1.11751	1.11949	15.48	34.5	1.14880	1.15084	19.00
28.1	1.11798	1.11996	15.53	34.6	1.14930	1.15133	19.06
28.2	1.11845	1.12043	15.59	34.7	1.14979	1.15183	19.11
28.3	1.11892	1.12090	15.64	34.8	1.15029	1.15232	19.17
28.4	1.11940	1.12138	15.69	34.9	1.15078	1.15282	19.22

TABLE 31—Continued

Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)	Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)
35.0	1.15128	1.15331	19.28	41.5	1.18418	1.18627	22.77
35.1	1.15177	1.15381	19.33	41.6	1.18470	1.18679	22.82
35.2	1.15226	1.15430	19.38	41.7	1.18522	1.18731	22.88
35.3	1.15276	1.15480	19.44	41.8	1.18573	1.18783	22.93
35.4	1.15326	1.15530	19.49	41.9	1.18625	1.18835	22.98
35.5	1.15375	1.15579	19.55	42.0	1.18677	1.18887	23.04
35.6	1.15425	1.15629	19.60	42.1	1.18729	1.18939	23.09
35.7	1.15475	1.15679	19.65	42.2	1.18781	1.18992	23.14
35.8	1.15524	1.15729	19.71	42.3	1.18834	1.19044	23.20
35.9	1.15574	1.15778	19.76	42.4	1.18886	1.19096	23.25
36.0	1.15624	1.15828	19.81	42.5	1.18938	1.19148	23.30
36.1	1.15674	1.15878	19.87	42.6	1.18990	1.19201	23.36
36.2	1.15724	1.15928	19.92	42.7	1.19042	1.19253	23.41
36.3	1.15773	1.15978	19.98	42.8	1.19095	1.19305	23.46
36.4	1.15823	1.16028	20.03	42.9	1.19147	1.19358	23.52
36.5	1.15873	1.16078	20.08	43.0	1.19199	1.19410	23.57
36.6	1.15923	1.16128	20.14	43.1	1.19252	1.19463	23.62
36.7	1.15973	1.16178	20.19	43.2	1.19304	1.19515	23.68
36.8	1.16023	1.16228	20.25	43.3	1.19356	1.19568	23.73
36.9	1.16073	1.16279	20.30	43.4	1.19409	1.19620	23.78
37.0	1.16124	1.16329	20.35	43.5	1.19462	1.19673	23.84
37.1	1.16174	1.16379	20.41	43.6	1.19514	1.19726	23.89
37.2	1.16224	1.16430	20.46	43.7	1.19567	1.19778	23.94
37.3	1.16274	1.16480	20.52	43.8	1.19619	1.19831	24.00
37.4	1.16324	1.16530	20.57	43.9	1.19672	1.19884	24.05
37.5	1.16375	1.16581	20.62	44.0	1.19725	1.19936	24.10
37.6	1.16425	1.16631	20.68	44.1	1.19778	1.19989	24.16
37.7	1.16476	1.16682	20.73	44.2	1.19830	1.20042	24.21
37.8	1.16526	1.16732	20.78	44.3	1.19883	1.20095	24.26
37.9	1.16576	1.16783	20.84	44.4	1.19936	1.20148	24.32
38.0	1.16627	1.16833	20.89	44.5	1.19989	1.20201	24.37
38.1	1.16678	1.16884	20.94	44.6	1.20042	1.20254	24.42
38.2	1.16728	1.16934	21.00	44.7	1.20095	1.20307	24.48
38.3	1.16779	1.16985	21.05	44.8	1.20148	1.20360	24.53
38.4	1.16829	1.17036	21.11	44.9	1.20201	1.20414	24.58
38.5	1.16880	1.17087	21.16	45.0	1.20254	1.20467	24.63
38.6	1.16931	1.17138	21.21	45.1	1.20307	1.20520	24.69
38.7	1.16982	1.17188	21.27	45.2	1.20360	1.20573	24.74
38.8	1.17032	1.17239	21.32	45.3	1.20414	1.20627	24.79
38.9	1.17083	1.17290	21.38	45.4	1.20467	1.20680	24.85
39.0	1.17134	1.17341	21.43	45.5	1.20520	1.20733	24.90
39.1	1.17185	1.17392	21.48	45.6	1.20573	1.20787	24.95
39.2	1.17236	1.17443	21.54	45.7	1.20627	1.20840	25.01
39.3	1.17287	1.17494	21.59	45.8	1.20680	1.20894	25.06
39.4	1.17338	1.17545	21.64	45.9	1.20734	1.20947	25.11
39.5	1.17389	1.17596	21.70	46.0	1.20787	1.21001	25.17
39.6	1.17440	1.17648	21.75	46.1	1.20840	1.21054	25.22
39.7	1.17491	1.17699	21.80	46.2	1.20894	1.21108	25.27
39.8	1.17542	1.17750	21.86	46.3	1.20948	1.21162	25.32
39.9	1.17594	1.17802	21.91	46.4	1.21001	1.21215	25.38
40.0	1.17645	1.17853	21.97	46.5	1.21055	1.21269	25.43
40.1	1.17696	1.17904	22.02	46.6	1.21109	1.21323	25.48
40.2	1.17747	1.17956	22.07	46.7	1.21162	1.21377	25.54
40.3	1.17799	1.18007	22.13	46.8	1.21216	1.21431	25.59
40.4	1.17850	1.18058	22.18	46.9	1.21270	1.21484	25.64
40.5	1.17901	1.18110	22.23	47.0	1.21324	1.21538	25.70
40.6	1.17953	1.18162	22.29	47.1	1.21378	1.21592	25.75
40.7	1.18004	1.18213	22.34	47.2	1.21432	1.21646	25.80
40.8	1.18056	1.18265	22.39	47.3	1.21486	1.21700	25.86
40.9	1.18108	1.18316	22.45	47.4	1.21540	1.21755	25.91
41.0	1.18159	1.18368	22.50	47.5	1.21594	1.21809	25.96
41.1	1.18211	1.18420	22.55	47.6	1.21648	1.21863	26.01
41.2	1.18262	1.1°472	22.61	47.7	1.21702	1.21917	26.07
41.3	1.18314	1.18524	22.66	47.8	1.21756	1.21971	26.12
41.4	1.18366	1.18575	22.72	47.9	1.21810	1.22026	26.17

TABLE 31—Continued

Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)	Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)
48.0	1.21864	1.22080	26.23	54.5	1.25470	1.25692	29.64
48.1	1.21918	1.22134	26.28	54.6	1.25526	1.25748	29.69
48.2	1.21973	1.22189	26.33	54.7	1.25583	1.25805	29.74
48.3	1.22027	1.22243	26.38	54.8	1.25640	1.25862	29.80
48.4	1.22082	1.22298	26.44	54.9	1.25697	1.25919	29.85
48.5	1.22136	1.22352	26.49	55.0	1.25754	1.25976	29.90
48.6	1.22190	1.22406	26.54	55.1	1.25810	1.26033	29.95
48.7	1.22245	1.22461	26.59	55.2	1.25867	1.26090	30.00
48.8	1.22300	1.22516	26.65	55.3	1.25924	1.26147	30.06
48.9	1.22354	1.22570	26.70	55.4	1.25982	1.26204	30.11
49.0	1.22409	1.22625	26.75	55.5	1.26039	1.26261	30.16
49.1	1.22463	1.22680	26.81	55.6	1.26096	1.26319	30.21
49.2	1.22518	1.22735	26.86	55.7	1.26153	1.26376	30.26
49.3	1.22573	1.22789	26.91	55.8	1.26210	1.26433	30.32
49.4	1.22627	1.22844	26.96	55.9	1.26267	1.26490	30.37
49.5	1.22682	1.22899	27.02	56.0	1.26324	1.26548	30.42
49.6	1.22737	1.22954	27.07	56.1	1.26382	1.26605	30.47
49.7	1.22792	1.23009	27.12	56.2	1.26439	1.26663	30.52
49.8	1.22847	1.23064	27.18	56.3	1.26496	1.26720	30.57
49.9	1.22902	1.23119	27.23	56.4	1.26554	1.26778	30.63
50.0	1.22957	1.23174	27.28	56.5	1.26611	1.26835	30.68
50.1	1.23012	1.23229	27.33	56.6	1.26669	1.26893	30.73
50.2	1.23067	1.23284	27.39	56.7	1.26726	1.26950	30.78
50.3	1.23122	1.23340	27.44	56.8	1.26784	1.27008	30.83
50.4	1.23177	1.23395	27.49	56.9	1.26841	1.27066	30.89
50.5	1.23232	1.23450	27.54	57.0	1.26899	1.27123	30.94
50.6	1.23287	1.23506	27.60	57.1	1.26956	1.27181	30.99
50.7	1.23343	1.23561	27.65	57.2	1.27014	1.27239	31.04
50.8	1.23398	1.23616	27.70	57.3	1.27072	1.27297	31.09
50.9	1.23453	1.23672	27.75	57.4	1.27130	1.27355	31.15
51.0	1.23508	1.23727	27.81	57.5	1.27188	1.27413	31.20
51.1	1.23564	1.23782	27.86	57.6	1.27246	1.27471	31.25
51.2	1.23619	1.23838	27.91	57.7	1.27304	1.27529	31.30
51.3	1.23675	1.23894	27.96	57.8	1.27361	1.27587	31.35
51.4	1.23730	1.23949	28.02	57.9	1.27419	1.27645	31.40
51.5	1.23786	1.24005	28.07	58.0	1.27477	1.27703	31.46
51.6	1.23841	1.24060	28.12	58.1	1.27535	1.27761	31.51
51.7	1.23897	1.24116	28.17	58.2	1.27594	1.27819	31.56
51.8	1.23953	1.24172	28.23	58.3	1.27652	1.27878	31.61
51.9	1.24008	1.24228	28.28	58.4	1.27710	1.27936	31.66
52.0	1.24064	1.24284	28.33	58.5	1.27768	1.27994	31.71
52.1	1.24120	1.24339	28.38	58.6	1.27826	1.28052	31.76
52.2	1.24176	1.24395	28.44	58.7	1.27884	1.28111	31.82
52.3	1.24232	1.24451	28.49	58.8	1.27943	1.28169	31.87
52.4	1.24287	1.34507	28.54	58.9	1.28001	1.28228	31.92
52.5	1.24343	1.24563	28.59	59.0	1.28060	1.28286	31.97
52.6	1.24399	1.24619	28.65	59.1	1.28118	1.28345	32.02
52.7	1.24455	1.24675	28.70	59.2	1.28176	1.28404	32.07
52.8	1.24511	1.24731	28.75	59.3	1.28235	1.28462	32.13
52.9	1.24567	1.24788	28.80	59.4	1.28294	1.28520	32.18
53.0	1.24623	1.24844	28.86	59.5	1.28352	1.28579	32.23
53.1	1.24680	1.24900	28.91	59.6	1.28411	1.28638	32.28
53.2	1.24736	1.24956	28.96	59.7	1.28469	1.28697	32.33
53.3	1.24792	1.25013	29.01	59.8	1.28528	1.28755	32.38
53.4	1.24848	1.25069	29.06	59.9	1.28587	1.28814	32.43
53.5	1.24905	1.25126	29.12	60.0	1.28646	1.28873	32.49
53.6	1.24961	1.25182	29.17	60.1	1.28704	1.28932	32.54
53.7	1.25017	1.25238	29.22	60.2	1.28763	1.28991	32.59
53.8	1.25074	1.25295	29.27	60.3	1.28822	1.29050	32.64
53.9	1.25130	1.25351	29.32	60.4	1.28881	1.29109	32.69
54.0	1.25187	1.25408	29.38	60.5	1.28940	1.29168	32.74
54.1	1.25243	1.25465	29.43	60.6	1.28999	1.29227	32.79
54.2	1.25300	1.25521	29.48	60.7	1.29058	1.29286	32.85
54.3	1.25356	1.25578	29.53	60.8	1.29117	1.29346	32.90
54.4	1.25413	1.25635	29.59	60.9	1.29176	1.29405	32.95

TABLE 31—Continued

Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)	Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)
61.0	1.29235	1.29464	33.00	67.5	1.33163	1.33399	36.30
61.1	1.29295	1.29523	33.05	67.6	1.33225	1.33460	36.35
61.2	1.29354	1.29583	33.10	67.7	1.33287	1.33523	36.40
61.3	1.29413	1.29642	33.15	67.8	1.33348	1.33584	36.45
61.4	1.29472	1.29701	33.20	67.9	1.33410	1.33646	36.50
61.5	1.29532	1.29761	33.26	68.0	1.33472	1.33708	36.55
61.6	1.29591	1.29820	33.31	68.1	1.33534	1.33770	36.61
61.7	1.29651	1.29880	33.36	68.2	1.33596	1.33832	36.66
61.8	1.29710	1.29940	33.41	68.3	1.33658	1.33894	36.71
61.9	1.29770	1.29999	33.46	68.4	1.33720	1.33957	36.76
62.0	1.29829	1.30059	33.51	68.5	1.33782	1.34019	36.81
62.1	1.29889	1.30118	33.56	68.6	1.33844	1.34081	36.86
62.2	1.29948	1.30178	33.61	68.7	1.33906	1.34143	36.91
62.3	1.30008	1.30238	33.67	68.8	1.33968	1.34205	36.96
62.4	1.30068	1.30298	33.72	68.9	1.34031	1.34268	37.01
62.5	1.30127	1.30358	33.77	69.0	1.34093	1.34330	37.06
62.6	1.30187	1.30418	33.82	69.1	1.34155	1.34392	37.11
62.7	1.30247	1.30477	33.87	69.2	1.34217	1.34455	37.16
62.8	1.30307	1.30537	33.92	69.3	1.34280	1.34517	37.21
62.9	1.30367	1.30597	33.97	69.4	1.34342	1.34580	37.26
63.0	1.30427	1.30657	34.02	69.5	1.34405	1.34642	37.31
63.1	1.30487	1.30718	34.07	69.6	1.34467	1.34705	37.36
63.2	1.30547	1.30778	34.12	69.7	1.34530	1.34768	37.41
63.3	1.30607	1.30838	34.18	69.8	1.34592	1.34830	37.46
63.4	1.30667	1.30898	34.23	69.9	1.34655	1.34893	37.51
63.5	1.30727	1.30958	34.28	70.0	1.34717	1.34956	37.56
63.6	1.30787	1.31019	34.33	70.1	1.34780	1.35019	37.61
63.7	1.30848	1.31079	34.38	70.2	1.34843	1.35081	37.66
63.8	1.30908	1.31139	34.43	70.3	1.34906	1.35144	37.71
63.9	1.30968	1.31200	34.48	70.4	1.34968	1.35207	37.76
64.0	1.31028	1.31260	34.53	70.5	1.35031	1.35270	37.81
64.1	1.31088	1.31320	34.58	70.6	1.35094	1.35333	37.86
64.2	1.31149	1.31381	34.63	70.7	1.35157	1.35396	37.91
64.3	1.31209	1.31441	34.68	70.8	1.35220	1.35459	37.96
64.4	1.31270	1.31502	34.74	70.9	1.35283	1.35522	38.01
64.5	1.31330	1.31563	34.79	71.0	1.35346	1.35585	38.06
64.6	1.31391	1.31623	34.84	71.1	1.35409	1.35648	38.11
64.7	1.31452	1.31684	34.89	71.2	1.35472	1.35711	38.16
64.8	1.31512	1.31745	34.94	71.3	1.35535	1.35775	38.21
64.9	1.31573	1.31806	34.99	71.4	1.35598	1.35838	38.26
65.0	1.31633	1.31866	35.04	71.5	1.35661	1.35901	38.30
65.1	1.31694	1.31927	35.09	71.6	1.35724	1.35964	38.35
65.2	1.31755	1.31988	35.14	71.7	1.35788	1.36028	38.40
65.3	1.31816	1.32049	35.19	71.8	1.35851	1.36091	38.45
65.4	1.31877	1.32110	35.24	71.9	1.35914	1.36155	38.50
65.5	1.31937	1.32171	35.29	72.0	1.35978	1.36218	38.55
65.6	1.31998	1.32232	35.34	72.1	1.36041	1.36282	38.60
65.7	1.32059	1.32293	35.39	72.2	1.36105	1.36346	38.65
65.8	1.32120	1.32354	35.45	72.3	1.36168	1.36409	38.70
65.9	1.32181	1.32415	35.50	72.4	1.36232	1.36473	38.75
66.0	1.32242	1.32476	35.55	72.5	1.36295	1.36536	38.80
66.1	1.32304	1.32538	35.60	72.6	1.36359	1.36600	38.85
66.2	1.32365	1.32599	35.65	72.7	1.36423	1.36664	38.90
66.3	1.32426	1.32660	35.70	72.8	1.36486	1.36728	38.95
66.4	1.32487	1.32722	35.75	72.9	1.36550	1.36792	39.00
66.5	1.32548	1.32783	35.80	73.0	1.36614	1.36856	39.05
66.6	1.32610	1.32844	35.85	73.1	1.36678	1.36919	39.10
66.7	1.32671	1.32906	35.90	73.2	1.36742	1.36983	39.15
66.8	1.32732	1.32967	35.95	73.3	1.36805	1.37047	39.20
66.9	1.32794	1.33029	36.00	73.4	1.36869	1.37111	39.25
67.0	1.32855	1.33090	36.05	73.5	1.36933	1.37176	39.30
67.1	1.32917	1.33152	36.10	73.6	1.36997	1.37240	39.35
67.2	1.32978	1.33214	36.15	73.7	1.37061	1.37304	39.39
67.3	1.33040	1.33275	36.20	73.8	1.37125	1.37368	39.44
67.4	1.33102	1.33337	36.25	73.9	1.37189	1.37432	39.49

TABLE 31—Continued

Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)	Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)
74.0	1.37254	1.37496	39.54	80.5	1.41504	1.41754	42.71
74.1	1.37318	1.37561	39.59	80.6	1.41571	1.41821	42.76
74.2	1.37382	1.37625	39.64	80.7	1.41637	1.41888	42.81
74.3	1.37446	1.37689	39.69	80.8	1.41704	1.41955	42.85
74.4	1.37510	1.37754	39.74	80.9	1.41771	1.42022	42.90
74.5	1.37575	1.37818	39.79	81.0	1.41837	1.42088	42.95
74.6	1.37639	1.37883	39.84	81.1	1.41904	1.42155	43.00
74.7	1.37704	1.37947	39.89	81.2	1.41971	1.42222	43.05
74.8	1.37768	1.38012	39.94	81.3	1.42038	1.42289	43.10
74.9	1.37833	1.38076	39.99	81.4	1.42105	1.42356	43.14
75.0	1.37897	1.38141	40.03	81.5	1.42172	1.42423	43.19
75.1	1.37962	1.38206	40.08	81.6	1.42239	1.42490	43.24
75.2	1.38026	1.38270	40.13	81.7	1.42306	1.42558	43.29
75.3	1.38091	1.38335	40.18	81.8	1.42373	1.42625	43.33
75.4	1.38156	1.38400	40.23	81.9	1.42440	1.42692	43.38
75.5	1.38220	1.38465	40.28	82.0	1.42507	1.42759	43.43
75.6	1.38285	1.38530	40.33	82.1	1.42574	1.42827	43.48
75.7	1.38350	1.38595	40.38	82.2	1.42642	1.42894	43.53
75.8	1.38415	1.38660	40.43	82.3	1.42709	1.42961	43.57
75.9	1.38480	1.38725	40.48	82.4	1.42776	1.43029	43.62
76.0	1.38545	1.38790	40.53	82.5	1.42844	1.43096	43.67
76.1	1.38610	1.38855	40.57	82.6	1.42911	1.43164	43.72
76.2	1.38675	1.38920	40.62	82.7	1.42978	1.43231	43.77
76.3	1.38740	1.38985	40.67	82.8	1.43046	1.43298	43.81
76.4	1.38805	1.39050	40.72	82.9	1.43113	1.43366	43.86
76.5	1.38870	1.39115	40.77	83.0	1.43181	1.43434	43.91
76.6	1.38935	1.39180	40.82	83.1	1.43248	1.43502	43.96
76.7	1.39000	1.39246	40.87	83.2	1.43316	1.43569	44.00
76.8	1.39065	1.39311	40.92	83.3	1.43384	1.43637	44.05
76.9	1.39130	1.39376	40.97	83.4	1.43451	1.43705	44.10
77.0	1.39196	1.39442	41.01	83.5	1.43519	1.43773	44.15
77.1	1.39261	1.39507	41.06	83.6	1.43587	1.43841	44.19
77.2	1.39326	1.39573	41.11	83.7	1.43654	1.43908	44.24
77.3	1.39392	1.39638	41.16	83.8	1.43722	1.43976	44.29
77.4	1.39457	1.39704	41.21	83.9	1.43790	1.44044	44.34
77.5	1.39523	1.39769	41.26	84.0	1.43858	1.44112	44.38
77.6	1.39588	1.39835	41.31	84.1	1.43926	1.44180	44.43
77.7	1.39654	1.39901	41.36	84.2	1.43994	1.44249	44.48
77.8	1.39719	1.39966	41.40	84.3	1.44062	1.44317	44.53
77.9	1.39785	1.40032	41.45	84.4	1.44130	1.44385	44.57
78.0	1.39850	1.40098	41.50	84.5	1.44198	1.44453	44.62
78.1	1.39916	1.40164	41.55	84.6	1.44266	1.44521	44.67
78.2	1.39982	1.40230	41.60	84.7	1.44334	1.44590	44.72
78.3	1.40048	1.40295	41.65	84.8	1.44402	1.44658	44.76
78.4	1.40113	1.40361	41.70	84.9	1.44470	1.44726	44.81
78.5	1.40179	1.40427	41.74	85.0	1.44539	1.44794	44.86
78.6	1.40245	1.40493	41.79	85.1	1.44607	1.44863	44.91
78.7	1.40311	1.40559	41.84	85.2	1.44675	1.44931	44.95
78.8	1.40377	1.40625	41.89	85.3	1.44744	1.45000	45.00
78.9	1.40443	1.40691	41.94	85.4	1.44812	1.45068	45.05
79.0	1.40509	1.40758	41.99	85.5	1.44881	1.45137	45.09
79.1	1.40575	1.40824	42.03	85.6	1.44949	1.45205	45.14
79.2	1.40641	1.40890	42.08	85.7	1.45018	1.45274	45.19
79.3	1.40707	1.40956	42.13	85.8	1.45086	1.45343	45.24
79.4	1.40774	1.41023	42.18	85.9	1.45154	1.45411	45.28
79.5	1.40840	1.41089	42.23	86.0	1.45223	1.45480	45.33
79.6	1.40906	1.41155	42.28	86.1	1.45292	1.45549	45.38
79.7	1.40972	1.41222	42.32	86.2	1.45360	1.45618	45.42
79.8	1.41039	1.41288	42.37	86.3	1.45429	1.45686	45.47
79.9	1.41105	1.41355	42.42	86.4	1.45498	1.45755	45.52
80.0	1.41172	1.41421	42.47	86.5	1.45567	1.45824	45.57
80.1	1.41238	1.41488	42.52	86.6	1.45636	1.45893	45.61
80.2	1.41304	1.41554	42.57	86.7	1.45704	1.45962	45.66
80.3	1.41371	1.41621	42.61	86.8	1.45773	1.46031	45.71
80.4	1.41437	1.41688	42.66	86.9	1.45842	1.46100	45.75

TABLE 31—Continued

Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)	Degrees Brix or per cent sucrose by weight	Specific gravity at 20°/4° C	Specific gravity at 20°/20° C	Degrees Baumé (modulus 145)
87.0	1.45911	1.46170	45.80	93.5	1.50472	1.50738	48.81
87.1	1.45980	1.46239	45.85	93.6	1.50543	1.50810	48.85
87.2	1.46050	1.46308	45.89	93.7	1.50615	1.50881	48.90
87.3	1.46119	1.46377	45.94	93.8	1.50686	1.50952	48.94
87.4	1.46188	1.46446	45.99	93.9	1.50757	1.51024	48.99
87.5	1.46257	1.46516	46.03	94.0	1.50829	1.51096	49.03
87.6	1.46326	1.46585	46.08	94.1	1.50900	1.51167	49.08
87.7	1.46395	1.46654	46.13	94.2	1.50972	1.51239	49.12
87.8	1.46464	1.46724	46.17	94.3	1.51044	1.51311	49.17
87.9	1.46534	1.46793	46.22	94.4	1.51115	1.51382	49.22
88.0	1.46603	1.46862	46.27	94.5	1.51187	1.51454	49.26
88.1	1.46673	1.46932	46.31	94.6	1.51258	1.51526	49.31
88.2	1.46742	1.47002	46.36	94.7	1.51330	1.51598	49.35
88.3	1.46812	1.47071	46.41	94.8	1.51402	1.51670	49.40
88.4	1.46881	1.47141	46.45	94.9	1.51474	1.51742	49.44
88.5	1.46950	1.47210	46.50	95.0	1.51546	1.51814	49.49
88.6	1.47020	1.47280	46.55	95.1	1.51617	1.51886	49.53
88.7	1.47090	1.47350	46.59	95.2	1.51689	1.51958	49.58
88.8	1.47159	1.47420	46.64	95.3	1.51761	1.52030	49.62
88.9	1.47229	1.47489	46.69	95.4	1.51833	1.52102	49.67
89.0	1.47299	1.47559	46.73	95.5	1.51905	1.52174	49.71
89.1	1.47368	1.47629	46.78	95.6	1.51977	1.52246	49.76
89.2	1.47438	1.47699	46.83	95.7	1.52049	1.52318	49.80
89.3	1.47508	1.47769	46.87	95.8	1.52121	1.52390	49.85
89.4	1.47578	1.47839	46.92	95.9	1.52193	1.52463	49.90
89.5	1.47648	1.47909	46.97	96.0	1.52266	1.52535	49.94
89.6	1.47718	1.47979	47.01	96.1	1.52338	1.52607	49.98
89.7	1.47788	1.48049	47.06	96.2	1.52410	1.52680	50.03
89.8	1.47858	1.48119	47.11	96.3	1.52482	1.52752	50.08
89.9	1.47928	1.48189	47.15	96.4	1.52555	1.52824	50.12
90.0	1.47998	1.48259	47.20	96.5	1.52627	1.52897	50.16
90.1	1.48068	1.48330	47.24	96.6	1.52699	1.52969	50.21
90.2	1.48138	1.48400	47.29	96.7	1.52772	1.53042	50.25
90.3	1.48208	1.48470	47.34	96.8	1.52844	1.53114	50.30
90.4	1.48278	1.48540	47.38	96.9	1.52917	1.53187	50.34
90.5	1.48348	1.48611	47.43	97.0	1.52989	1.53260	50.39
90.6	1.48419	1.48681	47.48	97.1	1.53062	1.53332	50.43
90.7	1.48489	1.48752	47.52	97.2	1.53134	1.53405	50.48
90.8	1.48559	1.48822	47.57	97.3	1.53207	1.53478	50.52
90.9	1.48630	1.48893	47.61	97.4	1.53279	1.53551	50.57
91.0	1.48700	1.48963	47.66	97.5	1.53352	1.53623	50.61
91.1	1.48771	1.49034	47.71	97.6	1.53425	1.53696	50.66
91.2	1.48841	1.49104	47.75	97.7	1.53498	1.53769	50.70
91.3	1.48912	1.49175	47.80	97.8	1.53570	1.53842	50.75
91.4	1.48982	1.49246	47.84	97.9	1.53643	1.53915	50.79
91.5	1.49053	1.49316	47.89	98.0	1.53716	1.53988	50.84
91.6	1.49123	1.49387	47.94	98.1	1.53789	1.54061	50.88
91.7	1.49194	1.49458	47.98	98.2	1.53862	1.54134	50.93
91.8	1.49265	1.49529	48.03	98.3	1.53935	1.54207	50.97
91.9	1.49336	1.49600	48.08	98.4	1.54008	1.54280	51.02
92.0	1.49406	1.49671	48.12	98.5	1.54081	1.54353	51.06
92.1	1.49477	1.49741	48.17	98.6	1.54154	1.54426	51.10
92.2	1.49548	1.49812	48.21	98.7	1.54227	1.54499	51.15
92.3	1.49619	1.49883	48.26	98.8	1.54300	1.54573	51.19
92.4	1.49690	1.49954	48.30	98.9	1.54373	1.54646	51.24
92.5	1.49761	1.50026	48.35	99.0	1.54446	1.54719	51.28
92.6	1.49832	1.50097	48.40	99.1	1.54519	1.54793	51.33
92.7	1.49903	1.50168	48.44	99.2	1.54593	1.54866	51.37
92.8	1.49974	1.50239	48.49	99.3	1.54666	1.54939	51.42
92.9	1.50045	1.50310	48.53	99.4	1.54739	1.55013	51.46
93.0	1.50116	1.50381	48.58	99.5	1.54813	1.55087	51.50
93.1	1.50187	1.50453	48.62	99.6	1.54886	1.55160	51.55
93.2	1.50258	1.50524	48.67	99.7	1.54960	1.55234	51.59
93.3	1.50329	1.50595	48.72	99.8	1.55033	1.55307	51.64
93.4	1.50401	1.50667	48.76	99.9	1.55106	1.55381	51.68
				100.0	1.55180	1.55454	51.73

APPENDIX 3.—RESULTS FROM RECENT RESEARCHES

1. BUREAU OF STANDARDS BAUMÉ SCALE FOR SUGAR SOLUTIONS

In laboratory and refinery measurements on sugar solutions it is customary to determine the percentage of sugar either by means of a picnometer or a hydrometer. In case the picnometer is used it is customary to obtain the specific gravity at some specified temperature in terms of water at the same temperature as unity, and then by means of a conversion table to find the corresponding percentage of sugar. In case the hydrometer is used it is customary either to read the percentage of sugar direct or to read the degrees Baumé and then, by an appropriate conversion table, to determine the corresponding percentage of sugar. In certain cases the Baumé degrees are used without reference to any other scale, but in general a definite relation between degrees Baumé and degrees Brix or specific gravity must be agreed upon before the Baumé readings are of any great value. This relation is arrived at by determining experimentally the specific gravity corresponding to various known percentages of sugar and then calculating the degrees Baumé corresponding to these specific gravities by assuming a constant multiplier or "modulus" on which the Baumé scale is based. Having chosen the modulus, the working out of the table relating specific gravity and degrees Baumé is purely arithmetical, the degrees Baumé corresponding to a series of specific gravities being calculated by means of the equation

$$d=m-\frac{m}{s}, \tag{39}$$

in which d=degrees Baumé, m=modulus, and s=specific gravity. The specific gravities must all be reduced to the same temperature, and it is desirable also that they be expressed in terms of water at the same temperature, in order that zero per cent sugar may have a specific gravity of unity. This will give also a value of zero degrees Baumé corresponding to zero per cent sugar, or zero degrees Brix.

Many different Baumé scales[80] have been proposed and used in the past, and at the present time there are still in use in the United States three different scales for liquids heavier than water. One of these, the American standard Baumé scale, is based on the modulus 145 and on the temperature 60° F and is extensively used in the acid industry and in other similar lines with the exception of the sugar industry. The other two scales, the "old" or "Holland" scale and the "new" or "Gerlach" scale, are used in sugar work. The Gerlach scale, with the modulus 146.78 and the temperature 17°.5 C seems to be most often employed. In the "Methods of Analysis" of the Association of Official Agricultural Chemists both tables are given, the more extensive of the two being the "old" or "Holland" scale based on the modulus 144.

The new table (see Table 31) proposed by the Bureau lies between the so-called "old" and "new" tables, being in almost perfect agreement with the "old" up to 25 per cent sugar and from that point on about 0°.1 Baumé higher than the "old." A brief comparison between the three tables is given in Table 32.

[80] See Circular No. 59, Bureau of Standards.

TABLE 32

Comparison of Baumé Scales

Per cent sucrose or degrees Brix	Corresponding degrees Baumé		
	"New" scale (modulus 146.78)	"Old" scale (modulus 144)	B. S. scale (modulus 145)
0	0.0	0.0	0.00
5	2.8	2.8	2.79
10	5.7	5.6	5.57
15	8.5	8.3	8.34
20	11.3	11.1	11.10
25	14.1	13.8	13.84
30	16.8	16.5	16.57
35	19.6	19.2	19.28
40	22.3	21.9	21.97
45	25.0	24.6	24.63
50	27.7	27.2	27.28
55	30.4	29.8	29.90
60	33.0	32.4	32.49
65	35.6	34.9	35.04
70	38.1	37.4	37.56
75	40.6	39.9	40.03
80	43.1	42.3	42.47
85	45.5	44.7	44.86
90	47.9	47.0	47.20
95	50.3	49.3	49.49
100	.....	.....	51.73

The Bureau of Standards has always held[81] that the relation between specific gravity and degrees Baumé, for liquids heavier than water, should be that based on the modulus 145. This modulus is now in universal use in the United States except in the sugar industry. It has been adopted by the Manufacturing Chemists Association, by the Bureau of Standards, and by all American manufacturers of Baumé hydrometers.

The American Standard Baumé scale, as heretofore used, is based on specific gravities at 60°/60° F instead of specific gravities at 20°/20° C, but this change should not be considered serious, since the same numerical relation between specific gravity and degrees Baumé will still hold. That is, the degrees Baumé corresponding to a given specific gravity will still be the same as before. The only difference is that the specific gravity at 20°/20° C corresponding to any given percentage of sugar is slightly different from what it would be at 60°/60° F.

The relation between specific gravity and degrees Baumé is as follows:

$$\text{Degrees Baumé} = 145 - \frac{145}{\text{Specific gravity}}. \qquad (40)$$

The Baumé scale here presented has three features which should commend it to those who feel that a Baumé scale is necessary or desirable for use in sugar work:

1. It is based upon the specific gravity values of Plato,[82] which are considered the most reliable of any available.

2. It is based on 20° C, the most convenient and widely accepted temperature for sugar work.

3. It is based on the modulus 145, which has already been adopted by the Manufacturing Chemists Association of the United States, by the Bureau of Standards, and by all American manufacturers of hydrometers.

[81] See Circulars 16, 19, and 59.

[82] Dr. F. Plato, Wiss. Abh. der Kaiserlichen Normal-Eichungs-Kommission, 2, p. 153; 1900.

2. CONSTANTS OF THE QUARTZ-WEDGE SACCHARIMETER

(*a*) THE NUMERICAL VALUE OF THE CONVERSION FACTOR

The present basis of standardization of the quartz-wedge saccharimeter is the result of the work of Herzfeld and Schönrock and is expressed by the following relation (see p. 36 this circular):

$$100^\circ\ S \text{ (international sugar commission scale)} = 34.657 \text{ circular degrees for sodium light at } 20^\circ \text{ C} \qquad (41)$$

An extensive investigation by Bates and Jackson [83] fails to confirm the value 34°.657. The sucrose used by them was prepared with great care by recrystallization from aqueous solution, the maximum temperature during the preparation not exceeding 35° C. The apparatus, methods of preparation, and analysis are described above, pages 94 to 101. The precipitate of 1.1 mg Cu_2O, referred to on page 100, which was obtained with the best sucrose which could be prepared, is shown to be due to a slight reducing action of the sucrose itself. The sucrose used in making the measurements is consequently concluded to be free from reducing sugars. The absence of impurities which could not be detected by direct test was established by fractional crystallization, the five fractions finally obtained showing identical rotations of the plane of polarization. A study of the elimination of moisture was made, and it was found that a few hours heating at 50° C to 60° C in a vacuum of 0.001 mm of mercury and in the presence of quicklime eliminates all but negligible quantities of moisture.

The solution used for polarization was never of exactly normal concentration. For preparing it the approximate normal weight was transferred to a weighed volumetric flask. Flask and sugar were then subjected to the drying operations before the final weighing.

The volume of the total solution was found either by filling to the graduation mark of calibrated flasks or was calculated from the weight and density. Density was taken from published tables in which it was coupled with percentage of composition of solutions. These two methods of determining the volume of solution checked satisfactorily.

The measurements of the absolute rotations of the solutions were made on a large polarimeter with a silver scale reading to thousandths of a degree. The temperature of the solutions was controlled by an air bath placed between the polarizing and analyzing systems of the instrument. It was cooled below 20° C by ice water and then heated electrically to 20° C. Regulation was secured more closely than 0°.05 C. The light source was the so-called yellow-green line $\lambda = 5461A$ from a quartz-mercury vapor lamp.

Three different makes of saccharimeters were used in order to eliminate the possibility of some peculiarity of instrument construction affecting the measurements. They were a Bates type Frič, a Schmidt & Haensch, and a Julius Peters. Two instruments were used in each experiment, one in a wooden thermostat with automatic temperature control to within a few hundredths of a degree. The saccharimeter readings were made in a large thermostated room with a content of about 15 cubic meters. With two observers in the large thermostat the maximum variations were about 0°.3 C.

The polarization tubes were of glass. Careful measurements established the fact that the tubes filled with distilled water gave a negligible rotation.

The polariscopic measurements included a long preliminary series and a final series of 10 experiments. The latter are given in Tables 33 and 34.

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[83] The constants of the quartz-wedge saccharimeter and the specific rotation of sucrose, Bull. Bur. Standards, 13, p. 67; 1916; Sci. Paper 268.

TABLE 33

Data on the Preparation of the Solutions

Experiment	Designation	Weight of sugar (air, brass weights)	Weight of solution (air, brass weights)	Sugar by weight in vacuo	Density, K. N. E. K. tables	Volume of solution	
						Computed from weights and density	By flask mark
1	2	3	4	5	6	7	8
		g	g	Per cent		cc	cc
25	Fraction 27..	24.370$_3$	101.570	23.986$_6$	1.09891	92.514	92.518
26	Fraction 27..	26.207$_2$	109.497	23.926$_1$	1.09863	99.761	99.750
27	Fraction 27..	34.052$_3$	142.665	23.861$_0$	1.09834	130.010	130.012
28	Sample C...	24.029$_2$	101.546	23.655$_7$	1.09741	.....	.....
29	Fraction 30..	23.856$_3$	101.381	23.523$_3$	1.09680	92.518	92.520
30	Fraction 32..	34.018$_3$	142.636	23.841$_9$	1.09825	130.000	129.997
31	Fraction 31..	24.181$_1$	101.496	23.817$_0$	1.09814	.....	.....
32	Fraction 31..	26.003$_3$	109.533	23.732$_4$	1.09775	.....	.....
33	Sample A...	34.326$_1$	143.045	23.988$_7$	1.09892	.....	.....
34	Sample B...	25.881$_3$	109.610	23.604$_5$	1.09717	.....	.....

TABLE 34

Reading of the Normal Solution on the Saccharimeter

Experiment	Average rotation of solution for two saccharimeters, degrees sugar	Rotation of normal solution on the saccharimeter, degrees sugar			
		Bates-Fric	Schmidt & Haensch	Peters	Average
1	9	10	11	12	13
25	101.19$_2$	99.90$_0$	99.90$_3$	.....	99.90$_2$
26	100.89$_8$	99.90$_9$	99.85$_2$	.....	99.88$_0$
27	100.61$_4$	99.87$_5$	99.88$_9$	.....	99.88$_2$
28	99.68$_7$	99.88$_1$	99.90$_5$	.....	99.89$_3$
29	99.04$_4$	99.88$_5$	.....	99.85$_3$	99.87$_0$
30	100.56$_0$	99.93$_0$	.....	99.91$_1$	99.92$_1$
31	100.41$_3$	99.87$_6$	.....	99.89$_9$	99.88$_8$
32	100.05$_1$	99.90$_2$	.....	99.92$_7$	99.91$_4$
33	101.23$_2$	99.90$_4$	.....	99.90$_3$	99.90$_4$
34	99.43$_8$	99.90$_3$	.....	99.89$_1$	99.89$_7$
Average.	.....	99°89$_7$S	99°88$_7$S	99°89$_2$S	99°89$_5$S

It will be observed from the values given in column 13 that the normal sugar solution gave a rotation of but 99°.89$_5$ *S* on a saccharimeter calibrated according to the Herzfeld-Schönrock standard. This calibration was obtained by the use of two quartz plates whose absolute rotations and sugar values had been determined by the Reichsanstalt, the Institut für Zuckerindustrie, and also by the Bureau of Standards. It was concluded, therefore, that the Herzfeld-Schönrock standard was in error by over 0.1° *S*.

The data were then recalculated on the basis of the reading of the normal solution, which must be 100°.00 *S* on the true scale. The sugar values of the two quartz plates were thus compared directly with the normal solution and their sugar values calculated. Since the values of the plates were known in terms of monochromatic light, the new conversion factors followed by direct calculation.

$$\text{Normal quartz plate}=100^\circ \text{ sugar}=34^\circ.620\ (\lambda=5892.5\ A) \text{ at } 20^\circ \text{ C} \tag{42}$$

$$1^\circ\ (\lambda=5892.5\ A)=2^\circ.8885\ S \tag{43}$$

$$\text{Normal quartz plate}=100^\circ \text{ sugar}=40^\circ.690\ (\lambda=5461\ A) \text{ at } 20^\circ \text{ C} \tag{44}$$

$$1^\circ\ (\lambda=5461\ A)=2^\circ.4576\ S \tag{45}$$

The agreement between the accepted value, 66°.502, for the specific rotation and the value 66°.529, as given below, in contrast to the disagreement between 66°.502 and the specific rotation 66°.627 from the Herzfeld-Schönrock conversion factor, is shown to corroborate the new value, 34°.620 (λ=5892.5 *A*) for the conversion factor.

(*b*) ROTATION RATIOS FOR QUARTZ AND SUGAR SOLUTIONS

The ratios of the rotations in circular degrees of quartz and of sugar solutions for two wave lengths were determined as follows:

$$\text{For quartz } \frac{\phi^{20}\lambda=5892.5A}{\phi^{20}\lambda=5461A}=0.85085 \tag{46}$$

$$\text{and for sugar } \frac{\phi^{20}\lambda=5892.5A}{\phi^{20}\lambda=5461A}=0.84922 \tag{47}$$

(*c*) ABSOLUTE ROTATION OF NORMAL SUGAR SOLUTION

The rotation of the normal sugar solution for λ=5461 *A* was found by direct measurement.

$$\text{Normal sugar solution}=100^\circ \text{ sugar}=40^\circ.763 \tag{48}$$

Since the rotation ratio for the normal solution for λ=5892.5 *A* and λ=5461 *A* is shown by (47) to be 0.84922 the rotation of the normal solution for λ=5892.5 *A* is

$$\text{Normal sugar solution}=100^\circ \text{ sugar}=34^\circ.617 \tag{49}$$

(*d*) ROTARY DISPERSION CURVES OF QUARTZ AND SUGAR SOLUTION

The difference between the rotations of the normal quartz plate and the normal solution for λ=5892.5 *A* is shown to be 0°.003 and for λ=5461 *A* 0°.073. The values indicate that the rotary dispersion curves of plate and solution cross at about λ=0.585μ. The reading of the normal solution on the true saccharimeter scale with the source λ=5892.5 *A* has been calculated to be 99°.99 *S*.

(*e*) ROTATION DIFFERENCE, IN SUGAR DEGREES, FOR NORMAL SOLUTION, BETWEEN λ=5461 A AND λ=5892.5 A

The difference in rotation in sugar degrees, for the normal solution on the saccharimeter, for the sources λ=5461 *A* and λ=5892.5 *A*, was calculated from the absolute rotations, with the following result:

$$\text{Saccharimeter reading } (\lambda=5461\ A)-\text{saccharimeter reading } (\lambda=5892.5\ A)=0^\circ.19_2\ S. \tag{50}$$

An independent experimental determination was made of this difference and the value 0°.18$_5$ obtained.

3. THICKNESS OF THE NORMAL QUARTZ PLATE

Inasmuch as the value of the conversion factor, in the rotation of the normal quartz plate, is found to be 34°.620 for λ=5892.5 *A* and 40°.690 for λ=5461 *A*, the old value of 1.5958 mm for the thickness of the normal plate is no longer applicable. Gumlich,[84] as the result of a painstaking investigation, found the rotation of 1 mm of quartz for λ=5892.5 *A* (the light traveling parallel to the optic axis) to be 21°.7182±0.0005 at 20° C. Recently Lowry [85] has made a number of measurements on the rotation of quartz and finds at 20° C 21°.7283 per mm for (λ=5892.5 *A*) and 25°.5371 per mm for

[84] E. Gumlich: Wiss. Abh. der Physikalisch-Technischen Reichsanstalt, 2, p. 201 (1895); Zs. für Instrk., p. 97 (1896).

[85] Lowry, Phil. Trans., 212, p. 288 (1912-13).

$\lambda=5461$ *A*. The values of the thickness of the normal plate calculated from the above data are given in Table 29. The agreement between the second and third values in column 4 is very satisfactory in view of the fact that two independent values of the rotation per mm are used. The agreement between Gumlich's and Lowry's values for sodium light is not satisfactory.

4. THE SPECIFIC ROTATION OF SUCROSE

Of all the polarimetric constants relating to the sugars, none have received the thorough study by numerous investigators that has been given to the specific rotation of sucrose. The formulas of Tollens[86] and of Nasini and Villavecchia[87] giving the value at different concentrations have been generally accepted as the most accurate. The former gives

$$[\alpha]^{20}_{5892.5A}=66.386+0.015035p-0.0003986p^2 \tag{51}$$

and the latter gives

$$[\alpha]^{20}_{5892.5A}=66.438+0.010312p-0.0003545p^2 \tag{52}$$

where p is grams of sugar in 100 grams of solution.

Landolt [88] has combined the two giving

$$[\alpha]^{20}_{5892.5A}=66.435+0.00870\,C-0.000235\,C^2\ (C=0\text{ to }65) \tag{53}$$

where C is the number of grams per 100 cc of solution.

Taking $C=26.016$ we obtain from (53)

$$[\alpha]^{20}_{5892.5A}=66.502. \tag{54}$$

Bates and Jackson [89] in their investigation on the constants of the quartz-wedge saccharimeter have made a new determination of the specific rotation for two wave lengths. They have found that the rotation of the normal solution for $\lambda=5892.5$ *A* is 34°.617, and for $\lambda=5461$ *A* is 40°.763. Since this solution contains 26.016 grams of sugar weighed in vacuo, in 100 cc, at 20° C.

$$\left[\alpha\right]^{20}_{5892.5A}=\frac{100\times 34.617}{2\times 26.016}=66°.529 \tag{55}$$

and

$$\left[\alpha\right]^{20}_{5461A}=\frac{100\times 40.763}{2\times 26.016}=78°.342. \tag{56}$$

5. LIGHT TRANSMISSION BY ABSORPTION CELL

Owing to the fact that the rotation dispersion curves of quartz and sugar are not similar for the shorter wave lengths in the visible spectrum, it is impossible to secure satisfactory neutralization of the rotation of a sugar solution without the use of an absorption cell. This subject is discussed on pages 29 and 30.

The transmission curves for two potassium bichromate filters are given in Fig. 13. The curves show the percentage of the light of each wave length that is transmitted. Curve 1 is for the filter ordinarily used in connection with saccharimeters as pre-

[86] Ber., **10**, 1403 (1877).
[87] Public de Lab. chim. delle gabelle Rome, 1891, p. 47.
[88] "Das optische Drehungsvermögen," p. 420 (1898).
[89] Loc. cit.

scribed by the International Sugar Commission, i. e. 1.5 cm of a 6 per cent solution. Curve 2 is for 2 cm of a 9 per cent solution. Both curves are uncorrected for the reflection by the glass of the cell.

6. INFLUENCE OF ATMOSPHERIC CONDITIONS IN THE TESTING OF SUGARS

The question of the influence of atmospheric conditions in the testing of sugars has been thoroughly studied [90] by Bates and Phelps. Marvin's Evaporation equation has been shown to reduce to

$$\frac{Q}{T}=CA\,(P_s-P_a) \qquad (57)$$

for the conditions under which sugars are ordinarily tested, where Q is the amount of water evaporated during the time of filtration T, (P_s-P_a) is the potential head, or

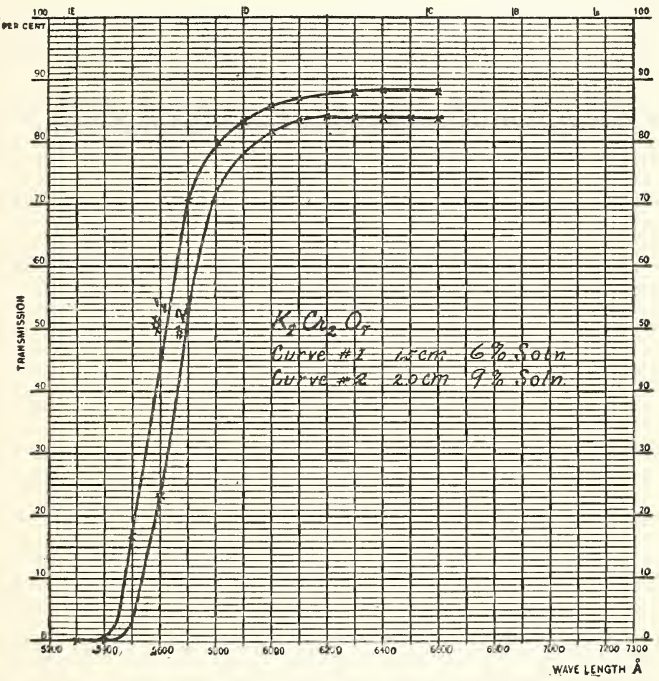

FIG. 13

difference between the vapor pressure of the solution and the pressure of water vapor already in the air, A the area exposed, and C a constant to be determined.

The area of the liquid from which evaporation can occur is constantly changing during the filtration. The total exposure is, however, the same for similar filtrations, and the area A may consequently be taken as unity. If, then, we determine the constant C experimentally, we can calculate the evaporation for any potential head. Obviously, C may vary with the time of filtration, the rate of diffusion, the nature of the exposed surface, etc. It is, nevertheless, a constant for any particular set of similar filtrations.

[90] Bull. Bureau of Standards., **10**, p. 537.

Two methods have been utilized for determining the change in concentration. The first tried was that of weighing the solution during filtration; the second, that of noting the change in the polarization. Since the polarization is directly proportional to the concentration, the change in polarization is proportional to the amount evaporated. $\frac{Q}{T}$ thus has proportionate numerical values in both methods, provided the loss by evaporation is small as compared with the total quantity of solution. The loss in grams by weighing is equal to the increase in degrees sugar in the polarization.

In determining the potential head, P_a was calculated from the vapor-pressure tables for water, the necessary data being secured by means of an Assmann psychrometer. P_s is taken as the vapor pressure of water at the observed temperature of the solution. The lowering of the vapor pressure of the solution due to the presence of the sugar is negligible. At 30° C it amounts to 0.6 mm, which is equivalent to a change in the polarization of 0.°0006 sugar per minute. In all the experiments the normal solution—26 grams in 100 cc—was used.

In carrying out the experimental work it was found desirable to have control, during the filtration, of the atmospheric conditions over a wider range than would ordinarily occur in the average laboratory during a cycle of 12 consecutive months. This was made possible by the use of a constant-temperature room in which any relative humidity between 17 per cent and 92 per cent could be attained at any temperature between 18° C and 39° C. Any desired potential head ($P_s - P_a$) could thus be obtained between 4 mm and 41 mm of mercury.

The weighing experiments were made upon a large balance. The funnel and cylinder were placed directly upon the scale pan.

For making the polarization measurements the Bates type of saccharimeter with adjustable sensibility was available. It was inclosed in a small thermostat, thus insuring a constant temperature during measurements.

C as determined by the weighing experiments is 0.0013, so that equation (57) becomes

$$\frac{Q}{T}=0.0013\ (P_s-P_a) \tag{58}$$

By the polarization method equation (57) becomes

$$\frac{Q}{T}=0.00066\ (P_s-P_a) \tag{59}$$

for refined sugar for a single filtration requiring about 12 minutes, and

$$\frac{Q}{T}=0.00108\ (P_s-P_a) \tag{60}$$

when the solution is poured back on the filter and allowed to run through a second time. These data are shown graphically in Fig. 14.

Since equations (58), (59), and (60) show such large increases in the polarization, the experiments were repeated with the funnels covered with ordinary cover glasses, in order to determine how completely the evaporation could be prevented by this simple expedient. It was found that for a filtration of about 15 minutes under the most adverse conditions ordinarily met in practice the increase in the polarization due to evaporation is not more than 0.02 S.

The experiments on refined sugar indicated the importance of making exhaustive tests on different grades of raw sugars to determine how far the preceding results could be applied to sugars requiring clarification. Three grades were used: Java, testing 97° S; Cuban, testing 94° to 95° S; and a very soft sugar, testing about 80° S. No appreciable differences in the evaporation were observed due to the grade of sugar.

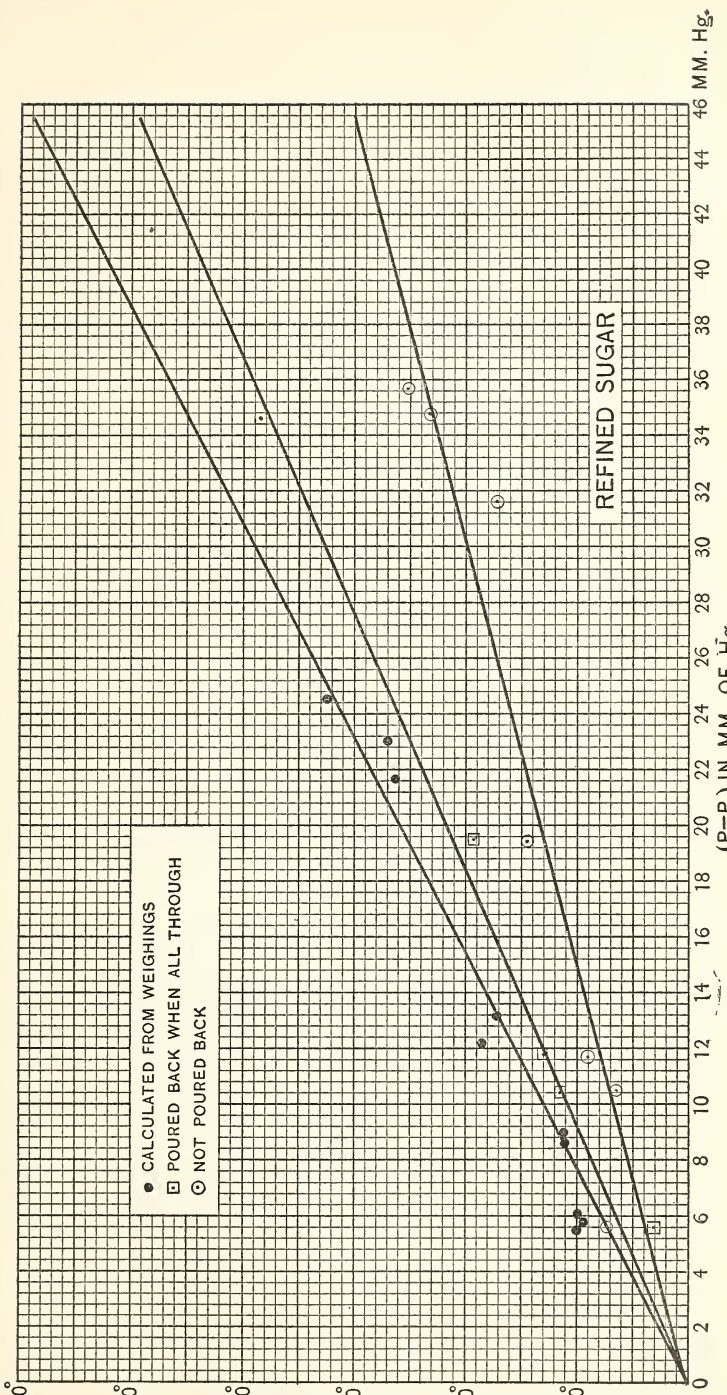
REFINED SUGAR
● CALCULATED FROM WEIGHINGS
⊡ POURED BACK WHEN ALL THROUGH
⊙ NOT POURED BACK
CHANGE IN POLARIZATION PER MINUTE = $\frac{\Delta^\circ}{t}$
DEGREES SUGAR
.060° .050° .040° .030° .020° .010°
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 MM. Hg.
$(P_s - P_a)$ IN MM. OF Hg.

FIG. 14

In every case 260 g was dissolved in water and the volume made up to 1,000 cc at the temperature of the experiment. From 15 cc to 50 cc of basic lead acetate was added for clarification, the quantity used varying with the grade of sugar; 100-cc portions of the liquid were then used for the tests. The flask was thoroughly shaken before pouring off each portion, thus insuring a homogeneous sample. To obtain a point of reference one filtration was always made with the funnel covered. The change by evaporation from this sample was not greater than 0.02° *S*. Other portions of the solution were filtered without being covered and were compared to the reference tube. Since no difference in $\frac{Q}{T}$ was observed, due to the grade of the sugar, the values obtained for the three different grades have been incorporated into a single equation.

The results are shown in the following equations and, graphically, in Fig. 15.

For raw sugar, funnel not covered, filtered once, determinations by polarizations, equation (57) becomes:

$$\frac{Q}{T}=0.00017\ (P_s-P_a) \tag{61}$$

If the solution be poured back on the filter after about one-half has run through, the equation becomes:

$$\frac{Q}{T}=0.00049\ (P_s-P_a) \tag{62}$$

while if the solution be allowed to run entirely through and is then poured back and allowed to run through a second time, we get:

$$\frac{Q}{T}=0.00070\ (P_s-P_a) \tag{63}$$

Table 35 shows the magnitude of the quantities observed. Equation (63) was calculated from this table.

TABLE 35

Raw Sugar, Funnel Not Covered, Determination by Polarization, Filtered Twice

$$\frac{Q}{T}=0.00070\ (P_s-P_a)$$

1	2	3	4	5	6	7	8
Temperature of body of solution	Dry-bulb temperature	Wet-bulb temperature	Relative humidity	P_s-P_a mm of Hg	Total change, degrees sugar	Observed $\frac{Q}{T}$, degrees sugar	Calculated $\frac{Q}{T}$, degrees sugar
°C	°C	°C	Per cent				
27.8	28.0	25.3	80.0	4.21	0.17	0.005	0.003
27.5	27.6	24.8	79.8	5.42	0.20	0.005	0.004
24.1	24.1	14.0	30.9	15.42	0.45	0.011	0.011
28.4	27.3	15.8	28.2	21.18	0.55	0.016	0.015
30.4	27.3	15.8	28.2	24.70	0.84	0.018	0.017
34.0	36.9	19.2	16.5	31.92	1.16	0.023	0.022
37.4	39.0	20.7	17.2	38.79	0.78	0.026	0.027
38.4	39.1	20.9	17.8	41.16	0.78	0.029	0.029
38.4	39.1	20.9	17.8	41.16	0.68	0.023	0.029

In the experiments $\frac{Q}{T}$ was measured for potential heads as high as 41 mm of mercury. During the summer months, when it is most likely to be a maximum, the potential head rarely exceeds 22 mm and is usually much lower; 22 mm corresponds roughly to a temperature of 30° and a relative humidity of 30 per cent. $\frac{Q}{T}$ for the

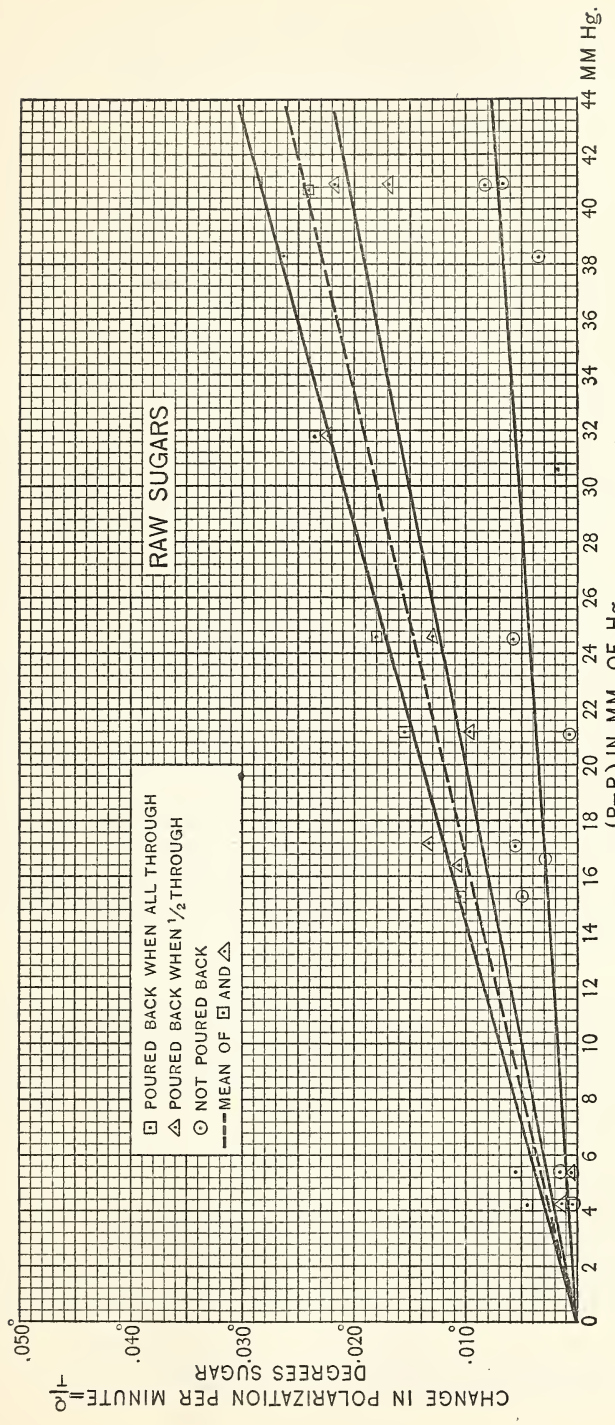
RAW SUGARS
⊡ POURED BACK WHEN ALL THROUGH
△ POURED BACK WHEN ½ THROUGH
⊙ NOT POURED BACK
— — MEAN OF ⊡ AND △
CHANGE IN POLARIZATION PER MINUTE = t/o
DEGREES SUGAR
.050°
.040°
.030°
.020°
.010°
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 MM Hg.
(Ps−Pa) IN MM. OF Hg.

FIG. 15

curve obtained by weighing is much larger than the corresponding value obtained by the polarization method. (See Fig. 14.) This probably is caused by the evaporation from the solution that remains on the filter and which produces no increase in the concentration of the solution which passes the filter. The method of weighing determines the total evaporation, whereas not all the evaporation is instrumental in raising the polarization when that method is utilized.

The curves in Fig. 15 show how inapplicable the corrections for refined sugar are to raw sugars. The value of the correct $\frac{Q}{T}$ for the once-filtered solution is surprisingly small when compared with the similar curve in Fig. 14.

When the solution is filtered but once, the increase in the polarization (see Fig. 15) for a potential head of 22 mm and a filtration of 10 minutes duration is less than 0°.04 *S*. The conclusion, therefore, is reached that it is unnecessary, in the ordinary testing of raw sugars, to use any precautions to prevent or to correct for evaporation, provided that it is not necessary to pour any portion of the filtrate back on the filter. All the more unexpected, then, is the large increase in $\frac{Q}{T}$, as shown by the curves in Fig. 15, when a part or all of the solution is filtered a second time. It is concluded that this is caused largely by the solution which is returned to the filter taking up the solution already adhering to the filter and which has become concentrated by evaporation after the level of the solution in the funnel has fallen. It thus becomes imperative in this case either to prevent evaporation or to apply a correction to the polarization. The correction may most conveniently be taken from the broken curve $\frac{Q}{T}=0.00060\ (P_s-P_a)$, which is the mean of the curve for solutions poured back when one-half has filtered, and the curve for solutions twice filtered. (See Fig. 15.)

Since the practice of returning at least a part of the first filtrate to an uncovered filter is quite general, the conclusion is unavoidable that in many laboratories tests are frequently in error by several tenths of a sugar degree. The important influence of atmospheric conditions on sugar tests has remained so long undetermined, probably because polarizations made on the same sugar and compared with one another are usually made at the same time and hence under similar potential heads. The results, herefore, agree among themselves, although relatively large errors may be present. The importance of either eliminating or correcting for the evaporation when tests made in different laboratories are to be compared can not be overestimated. The following is suggested for the guidance of those who desire to secure the true polarizations of raw sugars:

RAW SUGAR, FILTERED ONCE

1. The increase in the polarization due to evaporation is neglible in ordinary testing for all potential heads up to 22 mm, and it is therefore unnecessary to use any precautions to prevent or to correct for evaporation for ordinary atmospheric conditions, provided the duration of the filtration does not exceed 10 or 12 minutes.

2. If the correction for the increase in polarization is desired, it may be obtained from

$$Q=0.00017\ (P_s-P_a)\ T \qquad (64)$$

where Q=increase in polarization in degrees sugar.

P_s=saturation vapor pressure at the temperature of the solution.

P_a=saturation vapor pressure at the temperature of the dew point in the air.

T=time of filtration, in minutes.

Q should be subtracted from the observed polarization to obtain the true polarization.

3. Practically all increase in polarization, regardless of atmospheric conditions, may be prevented by covering the funnel with a watch glass.

RAW SUGAR, NOT LESS THAN ONE-FOURTH OF SOLUTION FILTERED TWICE

4. The increase in the polarization due to evaporation is not neglible in ordinary testing, but may amount to several tenths of a sugar degree. It is, therefore, necessary to prevent or to correct for evaporation for ordinary atmospheric conditions.

5. The correction for the increase in the polarization may be calculated from

$$Q=0.00060\ (P_s-P_a)\ T \tag{65}$$

where Q, P_s, P_a, and T have the definitions given in 2. Q should be subtracted from the observed polarization to obtain the true polarization.

6. Practically all increase in polarization, regardless of atmospheric conditions, may be prevented by covering the funnel with a watch glass.

7. NORMAL WEIGHT OF DEXTROSE

It has been shown on pages 80 and 81 that dextrose may be analyzed on the direct-reading saccharimeter, provided the correct weight of substance is dissolved in 100 cc. The normal weights of the various sugars given in Table 20 are all the result of computation. Recently Jackson [91] has determined experimentally the value of the normal weight of dextrose. He prepared the pure material in the manner described on page 92 and measured its rotation on two saccharimeters controlled by the standard quartz plates of this Bureau. The value of the normal weight, which is the mean of 12 independent measurements, is conditioned by the values which define the 100° point of the saccharimeter. If the saccharimeter is calibrated according to the Herzfeld-Schönrock conversion factor (34°657), the normal weight of dextrose is 32.264. It should be noted that the Herzfeld-Schönrock scale is the one in general use at the present time, and if the saccharimeter is controlled by quartz plates which have been standardized at this Bureau or at the Physikalisch-Technische Reichsanstalt the conversion factor 34°657 has been used. If, however the saccharimeter has been standardized by careful observations of 26 g of pure sucrose in 100 cc or if the conversion factor 34°620 as determined by Bates and Jackson has been used, the normal weight becomes 32.231, weighed in air with brass weights.

For concentrations less than normal the rotations deviate from proportionality. It is therefore necessary to correct for this deviation. Table 27 gives the corrections to be applied to the scale reading in order to obtain the true per cent of dextrose. These corrections apply only to the readings taken in a 200-mm tube. If taken in a 400-mm tube, the scale reading must be halved in order to obtain the correction. The latter is then multiplied by two and applied to the original reading.

8. ROTATION OF DEXTROSE FOR WAVE LENGTH 5641A

Jackson found for the rotation of the normal dextrose solution for $\lambda=5461A$ 40°897. The normal quartz plate rotates 40°690. There is thus a considerable divergence between the rotary dispersion curves of dextrose and of quartz. This difference, of course, persists when the field of the quartz-wedge saccharimeter is set for a photometric match, and a slight difference in color between the two halves of the field results. This necessarily causes a lower degree of reproducibility for dextrose than for sucrose solutions where the dispersion curves are closer to coincidence. The difficulty is partially overcome by an increased number of settings or by increased experience on the part of the observer.

The specific rotation of dextrose solutions varies with the concentration according to the formula

$$[\alpha]^{20.0}_{5461A}=62.032+0.04257c \tag{66}$$

[91] Bull. Bur. Standards, 13, p. 633; 1916 (Scientific Paper No. 293).

where c is grams of anhydrous dextrose weighed in vacuo and contained in 100 cc of solution, or the formula

$$[\alpha]^{20.0}_{5461A} = 62.032 + 0.042202p + 0.0001897p^2 \quad (67)$$

where p is per cent dextrose by weight in vacuo.

The densities of dextrose solutions are indicated by the formula

$$D\frac{20^\circ}{4^\circ} = 0.99840 + 0.003788p + 0.00001412p^2 \quad (68)$$

9. BASIC LEAD ACETATE

The work of Jackson [92] is a study from the standpoint of the phase rule of the possible combinations of lead oxide and lead acetate in the presence of water. He finds that

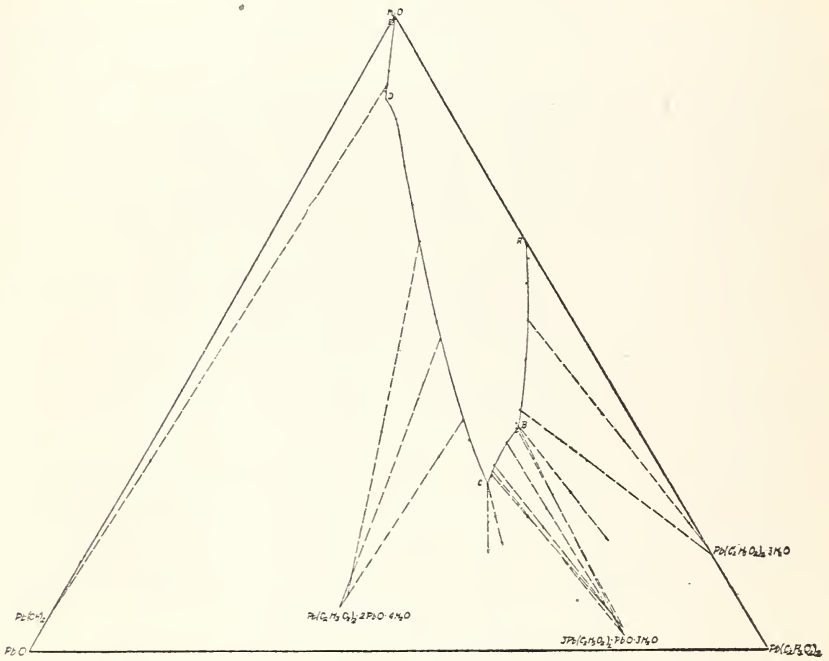

FIG. 16.—*Isothermal equilibrium between lead acetate, lead oxide, and water at 25° C*

there are four solid substances at 25° C which are capable of existence in contact with basic lead-acetate solutions.

The behavior of these four solid phases is shown diagramatically in Fig. 16. Each apex of the triangle represents one of the pure components. Each point on the sides represents a mixture of two components, and each within the triangle a mixture of three components. The apex of each of the fan-shaped figures represents the composition of a pure solid phase. Thus, at the point designated $Pb(C_2H_3O_2)_2 \cdot 3H_2O$, water and lead acetate combine to form the crystals known as "sugar of lead." This the ordinary neutral lead acetate dissolves to the extent of 35.5 per cent in neutral solution, as is indicated by the point A. If, however, the solution is basic, that is, contains dissolved lead oxide, the solubility of the neutral acetate increases very

[92] Bull. Bur. Standards, **11**, p. 331; 1914 (Scientific Paper No. 232).

markedly, and the more basic the solubility the greater the solubility becomes. The solubility curve *AB* shows this relation quantitatively.

If an amount of basic lead is present equivalent to 15.9 per cent PbO (as at the point *B*), a new solid phase appears, namely, the basic acetate of lowest basicity. Its formula is $3Pb(C_2H_3O_2)_2 \cdot PbO\ 3H_2O$. It crystallizes in thin plates and is so soluble in water that its saturated solution possesses a density varying from 1.93 to 2.28 according to the basicity. The basic salt, however, can not be dissolved directly in water. In order to exist at all in contact with a solution, the latter must contain an excess of dissolved basic lead. Thus in the solid phase the ratio of lead oxide to lead acetate is 0.186, while in the solution of the lowest basicity with which the solid phase can exist the ratio of these components is 0.325.

If as much as 24.7 per cent PbO (as at point *C*) is in the solution, the solid phase again changes and the basic acetate of greatest basicity becomes stable. This compound is $Pb(C_2H_3O_2)_2 \cdot 2PbO \cdot 4H_2O$. It usually appears as an amorphous solid, but is capable of crystallizing in the form of needles. *CD* represents the solubility curve.

Lead hydroxide has but slight solubility in water, but dissolves considerably in solutions containing lead acetate. This solubility is shown by the curve *DE*.

It does not follow that the solid basic lead acetates of commerce are accurately represented by one of the above formulas, but it is in most instances probable that the solid is a mixture of the two basic salts with frequently an admixture of the neutral acetate or lead hydroxide.

The aqueous solution of basic lead acetate, moreover, is not confined to any definite proportion of oxide to acetate, but may vary quite continuously from a neutral to a strongly basic solution. The basicity of the solution is limited only by the solubility of the basic acetate. In the special case where the solution has the density 1.25 at 25° C the most basic solution capable of existence contains 11.2 per cent PbO and 14.6 per cent $Pb(C_2H_3O_2)_2$. With respect to its content of lead oxide the solution may vary quite continuously from 11.2 per cent to zero PbO. The neutral solution of density 1.25 contains about 28.9 per cent lead acetate.

The laboratory methods of preparation of the basic lead acetates are described on page 65 of this circular. They can not be relied upon to yield solutions of definite composition, as the quantity of litharge dissolved depends in great measure upon its physical condition as well as upon the agitation of the mixture.

The constitution of the basic acetate may be determined chemically by a double analysis of the sample as described on page 66.

Analysis as oxalate.—In case many samples are to be analyzed a convenient volumetric process in which the lead is precipitated as oxalate may be employed. To the weighed sample in a 500-cc volumetric flask a slight excess of normal acetic acid is added from a pipette or burette. An excess of one-third normal sodium oxalate is added and the solution made to volume, mixed, and allowed to settle. Portions of the supernatant liquid taken with a 100-cc pipette are titrated for free acetic acid with normal alkali and for excess of oxalate with potassium permanganate. The true volume of the total solution may be found by subtracting from the known content of the flask the computed volume of the precipitate, the density of lead oxalate being 5.28.

10. PREPARATION OF INVERTASE

Hudson [93] has shown that the yield and activity of invertase may be greatly improved if the autolysis of the yeast is carried out in the presence of toluene instead of chloroform, as previously described on pages 62 and 63. The enzyme may be prepared from top or bottom yeast. One kilo of pressed yeast is kneaded well with 1 liter of tap water and 50 to 60 cc of toluene at room temperature. Liquefaction begins in a few hours, and the autolysis is complete in about five days. Neutral lead acetate

[93] J. Am. Chem. Soc., 36, p. 1566 (1914).

is then added until no further precipitate is formed and the solution is filtered. The excess of lead is removed by hydrogen sulphide or potassium oxalate and the filtrate is immediately dialyzed. The dialysis should be performed at once because the extracts are acid and often lose activity in this condition. A suitable membrane for the dialysis is the collodion sac described on page 63. A layer of toluene is poured on the surface of the extract to retard bacterial action. Dialysis is frequently complete over night, the time required depending much upon the quality of the membrane.

The dialyzed solutions may be preserved with toluene at room temperature and preserve their activity well. During the first month's keeping Hudson's [94] solutions showed no loss in activity and at the end of a year lost but one-half of it. Their inverting strength is sufficient to cause inversion of sucrose solutions over night under the usual analytical conditions. (See p. 63.)

10. MODIFICATIONS OF THE CLERGET METHOD [95]

(*a*) INVERSION BY ACID

At the 1916 meeting of the Association of Official Agricultural Chemists, in the report on sugar, C. A. Brown, referee, presented a study of certain modifications of the Clerget method. It is shown that excellent results may be obtained by using the original Clerget procedure. This has the advantage that in diluting the solution from 50 cc to 55 cc any errors in reading the inverted solution are increased by only one-tenth, whereas in the modifications which dilute from 50 cc to 100 cc these errors are multiplied by two.

The referee, Dr. Browne, believes that one great cause of the difficulty which has been experienced with the old Clerget procedure has been the neglect of a very serious error, viz, the diminution in volume which takes place in the 55 cc of solution during inversion. This diminution of volume is due to three causes: (1) The contraction in volume which all sucrose solutions undergo during inversion and which for 13 gms of sucrose in 55 cc is about one-fourth of a cubic centimeter; (2) the elevation in temperature produced by the addition of the HCl, which, for 5 cc of concentrated HCl to 50 cc of sugar solution, is about 3° C, the cooling of the solution from 23° C at the beginning to 20° C at the end of the inversion producing a further slight contraction; (3) the evaporation of water from the neck of the flask during inversion, the amount of such evaporation depending upon the diameter of the neck of flask and the time and temperature of inversion. The combined influence of these three factors causes the volume of the 55 cc of solution at the end of inversion to be about one-third of a cubic centimeter too small for the half normal weight of 13 g.

It is essential to the accuracy of any method of double polarization that the volume of the solution after inversion be fixed with the utmost accuracy. The sources of error just mentioned are easily overcome if the volume of the inverted solution be brought to 55 cc at the end of inversion and not at the beginning. If this precaution be followed, more accurate results can be secured by the process of making the inverted solution up to 55 cc than by any of the modifications which dilute to 100 cc. The control of temperature by this procedure is easily carried out by means of a thermometer placed in a control flask containing 55 cc of blank solution. There is no danger of irregular mixing of the acid with the sugar solution, as the diffusion of the HCl through the body of the liquid takes place quickly without shaking.

In employing this method Dr. Browne makes all his inversions at room temperature. Five cc of concentrated HCl are added to the 50 cc of sugar solution in a 50-cc to 55-cc flask, and after standing over night the volume is completed to exactly 55 cc at 20° C, after gently tapping the walls of the flask to detach any air bubbles which may have accumulated. The solution is then mixed and read in a polariscope, which is also at a

[94] J. Am. Chem. Soc., 36, p. 1570 (1914).

[95] To be published in the Journal of the Association of Official Agricultural Chemists.

temperature of 20° C. The invert reading is then corrected by adding the necessary one-tenth.

The formula for calculating the sucrose of this method of inversion, when a normal weight of 26 gms pure sucrose is taken, is

$$S=\frac{100\,(A-B)}{144.9-\frac{t}{2}} \tag{69}$$

The above formula corrected for the differences in specific rotation of invert sugar due to the varying concentration, when less than 26 gms of sucrose are dissolved to 100 cc, is

$$S=\frac{100\,(A-B)}{144.9-\frac{t}{2}-0.01\,(144.9-\frac{t}{2}-(A-B))} \tag{70}$$

In which S is the percentage of sucrose.

A is the direct polarization.

B is the corrected invert polarization.

t is the temperature of the invert solution.

The application of the method to determinations of sucrose in presence of dextrose is given in Table 36.

TABLE 36

Application of Clerget Modified Procedure to Solutions of Sucrose and Dextrose

No.	Dextrose (100 cc)	Direct polarization (A)	Corrected invert polarization (B)	Temperature (t)	Sucrose (S)	
					Found	Taken
	g			°C	Per cent	Per cent
1	4.8	91.70	−11.88	20	76.96	76.92
2	4.8	72.45	− 5.06	20	57.70	57.69
3	4.8	53.15	+ 1.60	20	38.45	38.46
4	4.8	33.90	+ 8.20	20	19.23	19.23

The importance of using a formula which corrects for the differences in specific rotation of invert sugar due to varying concentration may be illustrated by taking the case of determination No. 3 in Table 36. This determination, using the uncorrected formula, gives 38.21 per cent sucrose, which is a quarter of a per cent too low.

The correction of the Herzfeld factor 142.66 for concentration has been done in several ways.

The Herzfeld formula, as thus modified, becomes

$$S=\frac{100\,(A-B)}{142.66-\frac{t}{2}-0.0065\,(142.66-\frac{t}{2}-(A-B))} \tag{71}$$

(*b*) INVERSION BY INVERTASE.

A great deal of work has been done by different investigators during the past few years upon methods of double polarization in the effort to make them better adapted to the analysis of sugar mixtures. In the ordinary methods of procedure any levulose, or other sugar, whose optical activity is changed by the addition of the inverting acid has a different rotation before and after inversion, so that a considerable error may be introduced in the calculation of sucrose. The possible magnitude of this error may be seen from the determinations given in Table 37, which were made upon known mixtures of sucrose and invert sugar. The modified procedure of the original Clerget method was used.

TABLE 37

Application of Clerget Modified Procedure to Solutions of Sucrose and Invert Sugar

No.	Invert sugar (100 cc)	Direct polarization (A)	Corrected invert polarization (B)	Temperature (t)	Sucrose (S)	
					Found	Taken
	g			°C	Per cent	Per cent
1	1.10	94.60	−35.20	19.8	96.18	96.15
2	2.74	73.35	−30.42	20.0	77.10	76.92
3	5.48	50.70	−27.28	20.4	58.14	57.69
4	8.21	28.15	−24.04	20.4	38.99	38.46
5	9.86	6.90	−19.58	20.4	19.82	19.23

It is seen that as the amount of invert sugar increases there is a corresponding increase in the sucrose error. In case of honeys and other products containing a high percentage of levulose the error in the sucrose determination due to this cause may exceed 1 per cent.

In mixtures of sucrose with invert sugar alone it is possible to correct this error in the determination of sucrose by means of an empirical factor. Such a method of correction is not adapted, however, to the analysis of complex mixtures of optically active substances.

Browne finds that of the various methods which he has tested in this connection the one which has given the most satisfactory results was that by means of invertase. A discussion of the invertase method and Hudson's formula for the calculation of the sucrose is given on pages 62 and 173 of this circular. The assertion has been made that the influence of concentration upon the Clerget factor would practically disappear provided the inverting agent was without influence upon the rotation of the invert sugar. This, however, is not the case and can not be the case, since the specific rotation of invert sugar necessarily increases with the concentration. Browne has subjected the invertase method to a careful examination and finds that the influence of concentration is just as pronounced as with the methods which employ hydrochloric acid.

The invertase solution employed by him was prepared according to the original procedure of Hudson.

In using the invertase solution for the Clerget determination Browne followed the method proposed by Hudson, except that the 50 cc of sugar solution was treated with 10 cc of invertase reagent instead of 5 cc and the solution was warmed to 50° C to hasten the inversion. The solution after standing over night was made up to 100 cc and 20° C and polarized at this temperature. The invert polarization was then increased by 0.0065 to correct for the dextro rotatory effect of the 10 cc of invertase solution and then multiplied by 2 to correct for the dilution to 100 cc. The formula for calculating the percentage of sucrose by this method, as calculated from the average of many determinations upon sugar solutions of different concentration, was found to be

$$S=\frac{100\,(A-B)}{142-\frac{t}{2}-0.0065\,(142-\frac{t}{2}-(A-B))} \qquad (72)$$

It will be noted that the concentration factor 0.0065 is the same as that found for the Herzfeld method, which follows the same method of diluting the 13 gms of inverted product to 100 cc.

The application of the above formula to the determination of sucrose in various mixtures with invert sugar is given in Table 38.

TABLE 38

Application of Invertase Method to Solutions of Sucrose and Invert Sugar

No.	Invert sugar (100 cc)	Direct polarization (A)	Corrected invert polarization (B)	Temperature (t)	Sucrose (S)	
					Found	Taken
	g			° C	Per cent	Per cent
1	0.00	99.80	−31.83	20	99.72	99.80
2	0.18	95.85	−30.83	20	95.99	95.96
3	0.43	89.75	−29.33	20	90.27	90.20
4	0.67	85.60	−28.23	20	86.31	86.37
5	0.92	79.50	−26.73	20	80.58	80.61
6	2.44	47.00	−18.63	20	49.89	49.90
7	2.44	27.90	−12.43	20	30.69	30.71

The results show that the invertase method gives far more accurate results than the method of acid inversion in the analysis of complex mixtures which contain sucrose and levulose.

Determination.—Dissolve the normal weight (26 grams) of substance in water, clarify, make up to volume, and take the direct polarization (P) as under section (*a*), p. 61. Remove the excess of lead from the filtrate, if lead has been used as a clarifying agent, with anhydrous sodium carbonate or potassium oxalate and filter. To 50 cc of the filtrate in a 100-cc flask add acetic acid by drops until the reaction is acid to litmus, add 10 cc of the stock invertase solution, and let stand in a warm place (about 40° C) over night. Cool and make up to 100 cc at 20° C. Polarize at 20° C in a 200-mm tube. Allow the solution to remain in the tube for an hour and repeat the polarization. If there is no change from the previous reading, the inversion is complete. The reading and temperature of the solution are then carefully noted. The reading is corrected for the optical activity of the invertase solution and then multiplied by 2. The percentage of sucrose is then calculated by the formula on page 176.

(*c*) DETERMINATION OF SUCROSE AND RAFFINOSE

When it is desired to determine sucrose in the presence of raffinose, Browne recommends that the following formula be substituted for equation (19), page 62:

$$S=\frac{0.5124\,P-I}{0.839} \tag{73}$$

If the temperature (T) be other than 20° C

$$S=\frac{P\,(0.4724+0.002\,T)-I}{0.899-0.003\,T} \tag{74}$$

should be used. Having calculated S

$$R=\frac{P-S}{1.852} \tag{75}$$

APPENDIX 4.—POLARIZATION OF LOW-GRADE PRODUCTS

The analytical work on low-grade materials such as molasses and the cruder massecuites should be modified in order to avoid serious errors. These errors arise, in increasing degree, from the volume of the lead precipitate, the change in temperature coefficient, and the difficulty of clarification. The accumulation of impurity in these materials causes so voluminous a precipitation during clarification that it is no longer permissible to ignore the error caused.

1. POLARIZATION IN FIFTH-NORMAL SOLUTION[96]

(*a*) DIRECT POLARIZATION

The normal weight of substance is transferred to a 500 cc flask, dissolved, clarified by the minimum quantity of basic lead acetate solution, and made to volume. An alternative method is to make to volume and clarify by the addition of dry basic lead acetate. These two methods of clarification give but little difference when the substance is in fifth normal solution.

The solution is now filtered and a portion is taken in a volumetric flask, acidified with acetic acid, made up to one-tenth greater volume, and polarized. The polarization must be performed with great care, as the errors in reading are multiplied by over five. It is well to make a series of zero-point readings and a series of readings on the solution and take an average of each set of observations. The zero-point displacement must be subtracted from the solution readings before correcting for the dilution. The actual rotation is then multiplied by 1.1×5.

The temperature of the solution should be as near 20°0 C as is attainable. If not at approximately this temperature, it is inadvisable to apply any correction for temperature unless the coefficient has been determined or computed. (See page 39.)

It must be borne in mind that the direct polarization signifies little in respect to the sugar content of the substance. It is, however, of considerable utility in ascertaining and controlling daily variations in the products and is also utilized in the determination of "apparent purities." In beet products which are free from reducing sugars and in which raffinose has not yet accumulated the direct polarization represents closely the sucrose content.

(*b*) INVERT POLARIZATION

A portion of the filtrate is freed from lead by adding anhydrous sodium carbonate, sodium sulphate, or potassuim oxalate and filtering. Seventy-five cubic centimeters of the filtrate is transferred by a pipette to a 100 cc flask. Five cubic centimeters of hydrochloric acid (containing 38.8 per cent of the acid), is then added, little by little, while rotating the flask. Invert and proceed as described on page 61.

2. POLARIZATION IN HALF-NORMAL SOLUTION

The normal weight of material is transferred to a 200 cc flask, dissolved, adjusted to a temperature as near 20°0 C as is attainable, and the solution completed to volume. The clarifying agent is added in a dry form. The quantity of dry basic lead acetate required depends upon the grade of the material analyzed. As an illustration of the extreme amount required, "black strap" molasses requires about 8 to 10 g of dry lead for each normal weight of sample.

In the opinion of this Bureau it is not allowable to perform the clarification of molasses in half-normal solution by the lead solution unless the volume of the lead precipitate is computed and deducted from the apparent volume of the solution.

The solution must be shaken thoroughly to make certain that the clarifier reacts. It is then filtered, a portion acidified with acetic acid for the direct polarization, and a 75 cc portion inverted with HCl as usual. It frequently happens in this concentra-

[96] Sawyer J., Am. Chem. Soc., 27, 691; 1905.

tion that the solution becomes too dark to read after inversion. To remedy this the inverted solution is made up to volume and a small quantity of zinc dust (0.5 to 1 g) is added. This brightens the solution satisfactorily. It is then filtered and polarized.

The constant 142.66 is strictly applicable to analytical determinations in which the half-normal weight is contained in 100 cc when the invert reading is taken. Inasmuch as the specific rotation of invert sugar varies slightly with concentration, the exact value of the constant should be selected after an approximate knowledge of the concentration of the solution has been obtained. If the substance contained invert sugar before the sucrose has been inverted, its amount may be determined by a reducing sugar test. Table 30, page 151, gives the constants within the range usually required.

The object of removing the excess of lead from the solution before making the invert reading is to prevent the crystallization of lead chloride in the polariscope tube. The reagents commonly employed for this purpose are anhydrous Na_2CO_3, K_2SO_4, Na_2SO_4, or $K_2C_2O_4$, less frequently $Na_2C_2O_4$. The reagent may be added in a solid form, provided it is not added in too great excess. If this is done with care the removal is accomplished without change in the concentration of the solution.

An alternative method is to take a measured volume of the solution, add the reagent either as solid or in strong solution, and make up to 1/10 greater volume.

A method which is convenient but requires much caution depends upon the precipitation of the excess of lead by the hydrochloric acid used in the inversion. From a pipette 75 cc of the clarified filtrate are transferred to a 100 cc flask, hydrochloric acid added, and the sucrose inverted in the usual way. The acid solution is then cooled and placed in the thermostat to adjust its temperature before making to volume. Lead chloride now crystallizes out in well-formed crystals. The solution is then made to volume and given a few seconds vigorous shaking to mix. Under these conditions lead chloride has not time to reach saturation, and, since the crystals are large, enough of the solution may be filtered in a few seconds to fill the polariscope tube. This method has been used frequently at this Bureau and no difficulty experienced from precipitation in the polariscope tube.

In addition to the convenience of this method it possesses the advantage of avoiding the addition of excess of precipitants (sodium carbonate, potassium oxalate, etc.), which tend to neutralize the hydrochloric acid required for the inversion. It is obvious that an excess of Na_2CO_3 partially neutralizes the acid. It is equally true that an excess of $K_2C_2O_4$ produces the same effect owing to the relatively slight dissociation of oxalic acid. $K_2C_2O_4+2HCl=H_2C_2O_4+2KCl$, the reaction occurring from left to right until the dissociation constant of oxalic acid is satisfied.

3. DIRECT ESTIMATION OF SUCROSE

The following method for the direct estimation of sucrose depends upon rendering the reducing sugars inactive and is being investigated [97] by the Association of Official Agricultural Chemists:

"Determine true sucrose content of the samples by the following direct method: Dissolve normal weight of molasses and make up to 100 cc. Transfer 50 cc of the solution to another 100 cc flask; add 6.3 cc of sodium-hydroxid solution (36° Baumé) and 7.5 cc of hydrogen peroxid (30 per cent by weight, 100 per cent by volume). Careful cooling is necessary to prevent a too violent effervescence. (Ether from a dropping funnel can be used to advantage in preventing excessive foaming.) Cooling in water or ice is helpful in moderating the somewhat vigorous reaction. After effervescence has almost stopped immerse the flask in a bath at 55° C for 20 minutes. Cool the liquid, make slightly acid with acetic acid, and make up to mark. After clarification with dry lead subacetate, filter and polarize the solution. The reading multiplied by 2 gives the percentage of true sucrose in the molasses."

[97] Journ. Association of Official Agricultural Chemists, 1, p. 315; 1915.

APPENDIX 5.—RÉSUMÉ OF THE WORK OF THE INTERNATIONAL COMMISSION FOR UNIFORM METHODS OF SUGAR ANALYSIS

ALEXANDER HERZFELD, Chairman; F. G. WIECHMANN, American Secretary

FIRST SESSION,[98] HAMBURG, GERMANY, JUNE 12, 1897

1. *Kinds of quartz plates to be selected.*—At the start only quartz plates of high polarizing value shall be tested, later, however, such also as will cover the entire scale range of saccharimeters.

2. *Method of examination of quartz plates.*—Their examination is to be conducted in the same manner as has been done heretofore by the Commission of Trades Chemists under guidance of the Society of the Beet Sugar Industry of the German Empire, with the participation of the Imperial Normal Testing Bureau and the Physical Technical Reichsanstalt.

3. *Temperature to be adopted as the normal temperature for polarization.*—For the examination of quartz plates 20° C is to be chosen as the normal temperature, and the metric liter is to be adopted. The normal weight to be adopted is hence to be 26.00 g where 26.048 g is the normal weight valid for Mohr's liter at the temperature 17°.5 C.

4. *Additional methods and means suggested in order to decrease differences in polarization work.*—In consideration of the well-known difficulties in sampling bagged sugar, sampling each bag does not offer sufficient advantages to justify a departure, in the interests of trade, from the customary method of sampling 20 bags in every 100 bags.

5. *Desirability of an endeavor to introduce uniformity of analytical methods for beet-sugar work in all countries concerned.*—Such an endeavor shall be made. For the computation of sugars, analyses shall be admissible only of such chemists as shall have pledged themselves to execute the analysis of sugar in accordance with the methods prescribed by the International Commission.

6. *The determination of invert sugar.*—The determination of invert sugar is to be made only in solutions which have been clarified with lead solution and from which the lead has then been removed. If volumetric determinations are made, the amount of reduction due to the chemically pure sucrose must be deducted.

SECOND SESSION,[99] VIENNA, AUSTRIA, JULY 31, 1898

1. *Results of the international examination of quartz plates.*—In general, such examinations proved satisfactory. Certain discrepancies were undoubtedly due to the fact that the examinations had not always been made at 20° C, as prescribed.

Reference was made to the observations of Herzfeld, Wiechmann, and Wiley that pressures, due to varying temperatures affecting their mountings, exercise an influence on the rotation values of fixedly mounted quartz plates and quartz wedges. Whereas the quartz plates heretofore used—owing to the fact of their being firmly held in their mountings—are apt to be strained when their temperature is raised, and whereas such strains cause irregularities in the polarizing values of these plates, it was resolved that the investigation above referred to should be repeated, making use of other quartz plates not subject to the defect mentioned.

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[98] Wiechmann's Sugar Analysis, p. 217, 1914; Zs. Ver. Zuckerind., 47, I, p. 235, 1897.

[99] Zs. Ver. Zuckerind., 48, I, p. 389; 1898.

On the motion of Messrs. Dupont and Jobin it was resolved to employ plates the rotation values of which shall cover the entire scale of the saccharimeter, one levo-rotatory and four dextro-rotatory plates, the thickness of which is at the same time to be given, so that the plates shall remain serviceable when the normal weights shall be changed.

In determining the value of the plates there shall be employed not only the normal temperature of 20° C but, on the motion of Messrs. Wiley and Wiechmann, also of 30° C, in order to take into due account the condition of warmer countries. In employing apparatus with quartz-wedge compensation the changes shall be studied which the saccharimeter itself suffers in consequence of variations of temperature. As source of light there shall be employed only yellow sodium light or light sufficiently purified by ray filters.

Upon the motion of Dr. Hermann, of Hamburg, it was furthermore agreed to emphasize specifically in the protocol that the commission had thus far made no such changes in the normal weight for polariscopes which could influence the results of polarization in the least. This had been mentioned already in the protocol of the Hamburg session of June 12, 1897.

2. *Desirability of examining raw beet sugars for trade purposes according to the inversion method.*—Those present were unanimously of the opinion that the question should, in general, be decided in the negative. Exception should be made only in case of the products obtained in making sugar from molasses; with these it was recommended to make determinations of sugar and of raffinose.

3. *Discussion of applications of the Deutsche Zucker Export Vereine.*—Dr. Hermann suggested that uniformity in analytical methods should even now be striven for as much as possible, and the presiding officer was requested to prepare, with the assistance of the members of the commission, a clear compilation of analytical methods which are in vogue in the different countries, and also to prepare a résumé of the directions which are to be followed in cases of differences in analysis. Basing on these documents, the attempt shall be made to secure international acceptance of a uniform method of procedure.

THIRD SESSION,[100] PARIS, FRANCE, JULY 24, 1900.

1. *Normal sugar weight to be adopted for saccharimeters of German make when the metric flask is used.*—The Imperial Physical Technical Institute has, by its communication dated October 19, 1898, called attention to the fact that an exact conversion of the normal weight 26.048 g for Mohr's cubic centimeters at 17.5° C corresponds to 26.01 g (not 26.00) metric volume at 20° C, determined in air with brass weights.

The commission decided that in consideration of the insignificance of the deviation the normal weight of 26.00 g shall henceforth be adopted for 100 metric cubic centimeters at 20° C, determined in air with brass weights.

2. *Examination and disposal of quartz plates.*—Prof. Herzfeld reported briefly on the results of the examination of quartz plates, and the commission agreed that these quartz plates should be divided among the nations represented. For the United States, the plates were to be sent to the Department of Agriculture, at Washington; for France, to the Syndicate of Sugar Manufacturers; for Belgium, Holland, Austria-Hungary, and Russia, to the Associations of Sugar Manufacturers represented in the session by delegates.

3. *General principles governing the adjustment of saccharimeters.*—On motion of Messrs. Camuset and Saillard, the following was adopted:

"The convention declares it to be necessary that the rotation of chemically pure sugar be accepted as the fundamental basis in saccharimetry.

[100] Zs. Ver. Zuckerind., **50**, I, p. 357; 1900.

"The chemically pure sugar which is to be employed for this purpose shall everywhere be prepared according to the same method, which is as follows (method of the English chemists):

"Purest commercial sugar is to be further purified in the following manner: A hot saturated aqueous solution is prepared and the sugar precipitated with absolute ethyl alcohol; the sugar is carefully spun in a small centrifugal machine and washed in the latter with some alcohol. The sugar thus obtained is redissolved in water, again the saturated solution is precipitated with alcohol and washed as above. The product of the second centrifugaling is dried between blotting paper and preserved in glass vessels for use. The moisture still contained in the sugar is determined and taken into account when weighing the sugar which is to be used."

The convention furthermore decided that central stations shall be designated in each country which are to be charged with the preparation and the distribution of chemically pure sugar. Wherever this arrangement is not feasible, quartz plates, the values of which have been determined by means of chemically pure sugar, shall serve for the control of saccharimeters.

Mention should be made of the fact that in the discussion on this topic it was remarked, on the one hand, that the preparation of chemically pure sugar is not an easy task, and that in countries having hot climates sugar is dried with difficulty and hence is not stable and hardly available for transportation. Thereupon it was pointed out that the above control, by means of chemically pure sugar, should, as a rule, apply only to the central stations which are to test the correctness of saccharimeters; for those who execute commercial analyses, the repeated control of the instruments is to be accomplished, now as before, by means of quartz plates.

Concerning the working temperature the following resolution of Mr. François Sachs was unanimously adopted:

"In general, all sugar tests shall be made at 20° C.

"The adjustment of the saccharimeter shall be made at 20° C. One dissolves (for instruments arranged for the German normal weight) 26.00 g of pure sugar in a 100 metric cubic centimeters flask,[101] weighing to be made in air, with brass weights, and polarizes the solution in a room the temperature of which is also 20° C. Under these conditions the instrument must indicate exactly 100.00.

"The temperature of all sugar solutions to be tested is always to be kept at 20° C while they are being prepared and while they are being polarized.

"However, for those countries the temperature of which is generally higher, it is permissible that the saccharimeters be adjusted at 30° C (or at any other suitable temperature), under the conditions specified above, and providing that the analysis of sugar be made at that same temperature."

Objections were raised against the universal normal weight 20.00 g by Mr. François Sachs as well as by Mr. Strohmer. In consequence, it was resolved not to undertake the introduction of the same, but to adopt the resolution:

"The general international introduction of a uniform normal weight is desirable."

It was furthermore resolved, on the basis of the proposition of Mr. Strohmer, to observe the following rules in raw sugar analysis:

I. POLARIZATION

In effecting the polarization of substances containing sugar, half-shade instruments only are to be employed.

During the operation the apparatus must be in a fixed, unchangeable position, and so far removed from the source of light that the polarizing nicol is not warmed by the same.

[101] Or during the period of transition, 26.048 g in 100 Mohr's cubic centimeters.

As source of light there are to be recommended lamps with intense flame (gas triple burner with metallic cylinder, lens, and reflector; gas lamp with Auer burner; electric lamp; petroleum duplex lamp; sodium light).

The chemist must satisfy himself, before and after the observation, of the correctness of the apparatus (by means of correct quartz plates) and in regard to the constancy of the light; he must also satisfy himself as to the correctness of the weights, of the polarization flasks, the observation tubes, and the cover glasses. (Scratched cover glasses must not be used.)

Several readings are to be made and the mean thereof taken, but any one individual reading must not be selected.

II. SUGAR ANALYSIS

1. *Sucrose.*—To make a polarization, the whole normal weight for 100 cc is to be used, or a multiple thereof for any corresponding volume.

As clarifying and decolorizing reagents there may be used: Subacetate of lead, prepared according to the German Pharmacopœia (three parts by weight of acetate of lead, one part by weight of oxide of lead, ten parts by weight of water), Scheibler's alumina cream, concentrated solution of alum. Bone black and decolorizing powders are to be absolutely excluded.

After bringing the solution exactly to the mark and after wiping out the neck of the flask with filter paper, all of the well-shaken, clarified sugar solution is poured upon a dry, rapidly filtering filter. The first portions of the filtrate are to be thrown away and the balance, which must be perfectly clear, is to be used for polarization.

2. *Water.*—In normal beet sugars the water determination is to be made at 105° to 110° C.

For abnormal beet sugars, there is no commercial method for the determination of water.

3. *Ash.*—To determine the ash content in raw sugars the determination is to be made according to Scheibler's method, employing pure concentrated sulphuric acid. For an ash determination at least 3 gr. of the sample are to be used. The incineration is to be carried out in platinum dishes, by means of platinum or clay muffles, at the lowest possible temperature (not above 750° C.).

From the weight of the sulphated ash thus obtained 10 per cent is to be deducted and the ash content, thus corrected, is to be recorded in the certificate.

4. *Alkalinity.*—As, according to the most recent investigations, the alkalinity of raw sugars is not always a criterion of their durability, the commission abstains from proposing definite directions for the execution of the investigations.

5. *Invert sugar.*—The quantitative determination of invert sugar in raw sugars is to be made according to the method of Dr. A. Herzfeld. (Zeitschrift des Vereins für die Rübenzucker-Industrie des Deutschen Reiches, 1886, pp. 6 and 7.)

Furthermore the following resolutions were adopted:

The commission declares that only well-closed glass vessels will insure the stability of samples.

To obtain correct results it is desirable that the samples contain at least 200 gr. of material.

All of the above resolutions were adopted unanimously by those present.

FOURTH SESSION,[102] BERLIN, GERMANY, JUNE 4, 1903

1. *Professor Herzfeld outlined the previous work of the commission.*—The sets of quartz plates which had been selected by the Physikalisch-Technische Reichsanstalt in Berlin, and which had been tested in the laboratory of the Verein der Deutschen Zuckerindustrie as to their sugar value, have been distributed to proper central

[102] Zs. Ver. Zuckerind., 53, II, p. 889; 1903.

stations of the countries interested, and there kept at the disposal of chemists. These plates have been tested in almost all of the countries which have received the sets, and have been found correct. Some of these stations have thus far not made a report as to the result of this reexamination, and such a report is therefore requested.

Execution of the Paris agreement, according to which chemically pure sugar is to be used for the adjustment of polariscopes and for the testing of plates, has in some countries met with difficulties because they could not succeed in preparing chemically pure sugar. The laboratory at Berlin, therefore, offers to furnish chemically pure sugar.

In the determination of invert sugar a difficulty has arisen, inasmuch as the English chemists have of late again declared against the clarification with basic lead acetate; the commission will therefore have to seek means and methods to prevent, in this respect, loss of uniformity now secured in the methods of analysis.

The day's proceedings furthermore covered reports, concerning:

I. Practical experiences made with the uniform methods of analysis agreed upon in Paris..

II. The valuation of "sand" and "krystallzucker" in international trade.

III. Introduction of international uniform directions for sampling raw sugars.

IV. and V. Influence of temperature on the specific rotation of sucrose, and introduction of temperature-corrections when the temperature of observation differs from the temperature of 20° C, which has been accepted as the normal temperature.

VI. Determination of the sugar subject to duty or bounty contained in saccharine products and fruit preserves.

VII. Chemical control as an aid to the "entrepôt" system, sanctioned by the Brussels Convention.

FIFTH SESSION,[103] BERN, SWITZERLAND, AUGUST 3 AND 4, 1906

1. *The chairman in a review of the achievements of the commission designated the duties of the commission to be purely analytical.*—The commission has for its object the regulation of the methods of sugar analysis and endeavors to secure the working of chemists according to uniform and the best methods, but the commission does not undertake to establish trade customs. The commission does not recognize resolutions carried by majority vote, it is in fact necessary that at least the representatives of the most important countries interested in sugar be in accord on a question before the same is presented for acceptance, as otherwise no reliance can be placed on the recognition of the resolutions by chemists.

2. *Determination of a method of preparing Fehling's solution as well as the manner of making invert-sugar determinations.*—Messrs. Watt and Wiechmann communicated the results of their investigations. Mr. Watt preferred the volumetric method, Mr. Wiechmann the gravimetric method for commercial analyses. The latter moved that clarification with basic lead acetate shall be obligatory for the examination of sirups. This recommendation was indorsed by Messrs. Watt and Prinsen Geerligs and thereupon also by the entire commission.

The chairman reported on tests made for the comparison of Violette's and Fehling's solution, which had not yet been completed. He announced that Mr. Munson, the chairman of the Association of American Agricultural Chemists had, through intervention of Mr. Wiechmann, sent him a resolution of the association named, wherein the same expressed the wish to work hand in hand with the commission in the matter of securing a uniform alkaline copper solution.

Mr. Pellet also presented a paper on this subject which was published in the Sucrerie Indigène, as well as in the Deutsche Vereinszeitschrift.

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[103] Zs. Ver. Zuckerind., 56, II, p. 317, 1906; 57, I, p. 6, 1907; Int. Sugar. J., 9, p. 5, 1907.

Mr. Strohmer promised a later report of his experiments bearing on this question which are not yet completed. He recommended retaining for the present the so-called Herzfeld method.

Mr. Watt declared himself against basic lead acetate clarification for solid sugars.

Mr. Sachs refrained from voting.

Mr. Saillard, as well as Mr. Dupont, expressed himself in favor of retaining basic lead acetate clarification as long as the present method was used.

Mr. Pellet declared himself against the use of basic lead acetate as a clarifying reagent.

Mr. Schukow favored this clarification in commercial analysis.

Mr. Watt handed in the following declaration:

"The difference between the amount of the reducing substances in the clarified and the nonclarified solution of beet sugar lies so closely within the limits of the errors of observation that a clarification is unnecessary; but in products which contain a large amount of glucose a clarification is of great importance."

Mr. Herzfeld was of the opinion that he could not accept the first half of the declaration, the difference being, indeed, a small one but giving rise to considerable annoyance in trade.

Mr. von Buchka proposed to defer the question of the composition of Fehling's solution and to have the same studied further by a separate commission.

Mr. Geerligs expressed himself in favor of the basic lead acetate clarification for sirups.

Mr. Main spoke against the basic lead acetate clarification in raw sugars.

The chairman proposed to request the chemists of Great Britain to discuss this question in a separate conference once more with delegates of the commission in order to try in this manner to bring about an agreement.

The proposition of the chairman was accepted by the commission and a subcommission was appointed, consisting of Messrs. Strohmer, Saillard, Sachs, Schukow, Van Ekenstein, Watt, Main, Von Buchka, and Herzfeld, this subcommission to take part in the conference with the chemists of Great Britain.

The chairman agreed to ask for the intervention of the German export societies to the end that the conference might soon be called in London.

The question of Fehling's solution should be subjected to further study.

3. *Uniform international directions for sampling sugar products.*

4. *Resolution concerning a uniform form and manner of expression of certificates of analysis for the international sugar trade.*

Mr. Saillard presented the following resolutions:

1. As long as it is not settled that the degree of alkalinity is a sure criterion for the keeping qualities of sugars, the determination of alkalinity shall not be considered in international commerce.

2. The commission shall determine upon a uniform method by which the trade yield (rendement) for the sugar is to be calculated, in establishing scientific molasses coefficients for the impurities (ash and invert sugar) the relation of which is used in the certificates of analysis.

3. The State laboratories shall also take part in the endeavors to bring about uniformity, in order to cause a disappearance of the differences between trade ash determinations and Regie ash determinations. (France.)

These resolutions were accepted by the commission, and the commission also decided, for the present, not to indorse any specific form of certificate of analysis.

5. *Avoidance of the precipitate error in optical sugar analysis.*

6. *Suggestions for the preparation of unchangeable color standards in place of the raw sugar used for the Dutch standards.*

After a report by the chairman on the substitution of samples of colored glasses for the Dutch standards and a discussion of the question, the commission unanimously

expressed the wish that the valuation of sugar according to its color might soon be abandoned altogether, because this practice was to be condemned from the scientific as well as from the practical point of view.

7. *Concerning a method to be recommended for the determination of the sugar content of beets.*—The commission was of the opinion and unanimously adopted the resolution that the aqueous digestion method for the determination of the sugar content of the beets, if it be executed with due regard to the precautions suggested by Pellet, Sachs, and others, was to be recommended in preference to the alcohol method. The commission charged Messrs. Pellet, Sachs, and Herles with presenting detailed working directions of the method.

8. *A uniform international sugar weight.*—After a review by the chairman of the prior discussions on this topic, the introduction by Mr. Dupont of a proposition to accept 20.00 gr. as the normal weight, and a thorough debate of the proposition, the chairman put the question to those present concerning the desirability of retaining 26.00 gr. as the normal sugar weight for saccharimeters.

Mr. Sachs replied in the affirmative.

Mr. Saillard did not consider it necessary that all countries should have the same normal weight in order to have a uniform method.

On the question being put by the chairman, the representatives present of America, Java, Great Britain, Russia, and Austria-Hungary declared themselves against the normal weight of 20.00 g and for the normal weight of 26.00 g.

Mr. Sachs declared himself in accord with Mr. Saillard to admit 20.00 g, but not to prescribe it.

9. *Conference regarding measures to secure an internationally valid uniform method of beet-seed valuation.*—On the recommendation of the chairman the proposition was accepted that the commission should not occupy itself with the establishment of standards (Normen), but only with the establishment of methods of investigation.

Hereupon a subcommission was chosen to work out uniform methods of examination; Mr. F. Strohmer was appointed chairman of the same.

The following were elected members of the subcommission: Messrs. Strohmer, president; Saillard, Boussaud (Paris), Sachs, Schukow, Müller (Halle), Krüger (Bernburg), Herzfeld, Raatz, von Dippe, Heine, Briem, Neumann, and Herles.

The commission was authorized to increase its numbers by the election of further members.

SIXTH SESSION,[104] LONDON, ENGLAND, MAY 31, 1909

1. *Report of the work of the International Commission since its last session.*—Mr. Herzfeld reported that the results of newer investigations speak against the views expressed by the members of the commission in Bern, making obligatory the clarification with basic lead acetate for the determination of invert sugar in sirups. For this reason this matter was therefore that day given place on the program to permit of another resolution. All other resolutions taken in Bern have been put into practice.

Prof. Villavecchia in Rome has agreed, in a letter addressed to the chairman, that the commission shall be called in consultation in case an international commission of the Government works out directions for sugar analysis.

Agreeable to the resolution taken in Bern, a compilation of the proceedings to date of the commission has thus far been printed only in German. Copies of this pamphlet will be sent to the members of the commission by the chairman if they so desire. A compilation of the resolutions adopted thus far by the commission, which had been prepared by Mr. Wiechmann, of New York, was distributed. Messrs. François Sachs and Saillard promised to publish such a compilation in French.

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[104] Zs. Ver. Zuckerind., 59, I, p. 434, 1909; Int. Sugar Journ., 11, p. 428, 1909.

Mr. Strohmer, Vienna, then reported on the doings of the Subcommission for Uniform Methods of Beet-Seed Analysis appointed in Bern, which had met under his direction in Vienna on May 24, 1907, but which had taken definite resolutions only with regard to uniform methods for the determination of water and the determination of impurities. A report concerning the session of the subcommission has already been published in the technical journals.

At the suggestion of the referee, the International Commission decided that the introduction of uniform methods of beet-seed examination was to be postponed until it should be settled whether, and in what manner, the present standards (Normen) are to be changed.

2. *Unification of the tables for the calculation of the contents of sugar solutions from their density.*—Messrs. Saillard, Paris, and von Buchka, Berlin, reported on this topic. Their findings will be published in full in the technical journals.

On the motion of Mr. Sachs, seconded by Messrs. Saillard, Prinsen Geerligs, Strohmer, Neumann, and Pellet, the commission voted unanimously to accept a single table as standard at the temperature of 20° C, which is to be based upon the official German table. From this, other tables may be calculated at other temperatures, for instance, at 15° C, 17.5° C, 30° C, etc., as well as a table according to the Mohr system, 20° C : 20° C.

3. *Propositions for the use of uniform clarifying reagents for the analysis of sugar products.*—Referees: Messrs. Prinsen Geerligs, Java, and François Sachs, Brussels. Their findings will also be published in the technical journals. In this connection Mr. Herles recommended basic lead nitrate as a clarifying reagent.

After an extensive debate in which all delegates took part, the commission unanimously decided that for the direct polarization of solutions of raw sugar products basic lead acetate shall also in future be used for clarification, but not in excess. For fluid sugars (sirup and molasses) basic lead acetate may not be employed for the determination of invert sugar, but only neutral lead acetate as a clarifying reagent.

An agreement could not be reached concerning the clarifying of solutions of solid raw sugars for the purpose of the determination of invert sugar, as the English chemists remained firm in their former position to effect no clarification whatever for the determination of invert sugar.

4. *Agreement as to a uniform nomenclature for the products of sugar manufacture, especially in view of the food laws.*—Referee: Mr. Strohmer, Vienna, made a report on this topic which will be published in the technical journals. On the motion of the referee and of Messrs Saillard and Silz a resolution in this matter was, for the present, postponed.

5. Dr. Wiley, of Washington, read two articles by Messrs. A. Hugh Bryan and C. A. Browne, New York, concerning the conditions of basic lead acetate clarification and on temperature corrections in raw-sugar polarizations, which are to be published at once. In consequence of the declaration of Dr. Wiley that in order to avoid temperature corrections the American Government laboratories for sugar analysis are soon to be provided with cooling arrangements in order that the polarizations shall be made exclusively at the normal temperature of 20° C, the commission avoided voting on the resolution of Mr. Browne, New York, in which the avoidance of any and every temperature correction in raw-sugar analysis is demanded. (See article by Mr. Browne in the technical journals.) Prior to this, this resolution had been fully established by Mr. Horne, representing Mr. Browne.

An article by Mr. Horne, on the use of dry basic lead acetate clarification in sugar analysis, could not be read in this session of the commission. This article has been published in the Zeitschrift des Vereins der Deutschen Zucker-Industrie.

SEVENTH SESSION [105]

NEW YORK, *September 10, 1912.*

1. *Report on the work done since the last session.*—Mr. Saillard reported that he and Mr. Sachs have conferred about the publication of a compilation of the proceedings of all sessions of the commission in French, and expressed the belief that this will be achieved in time for the next session.

The German Imperial Bureau of Standards (Normaleichungsamt) promised to prepare tables for the determination of the percentage composition of sugar solutions from their specific gravity at different temperatures, as was requested at the London conference.

The following resolution was unanimously adopted:

"Owing to the declaration of Dr. Wiley at the Sixth Session of the International Commission for Uniform Methods of Sugar Analysis, in London, 1909, that, in order to avoid temperature corrections the American Government laboratories for sugar analysis are soon to be provided with cooling arrangements in order that polarizations shall be made exclusively at the normal temperature of 20° C, and to the fact that this declaration has not yet been carried into effect this commission again expresses the opinion that official polarizations of raw sugar products shall be made only at the constant standard temperature 20° C, the presence of invert sugar and other impurities precluding the use of formulas and tables, which have been elaborated for correcting the polarization of pure sucrose for changes of temperature."

2. *Uniform methods of sucrose determination in the raw materials of sugar manufacture.*—Mr. Saillard, at the behest of the syndicate of sugar manufacturers, of France, explained that the trade in beets and the trade with molasses does not, for France, bear the same international character as the trade in sugar and requested that the international commission treat analytical methods for beets and molasses only from the viewpoint of analytical chemistry.

Upon the recommendation of Mr. Herzfeld, after a short debate, the commission refrained from officially indorsing uniform methods of sucrose determination in beets and in sugar cane. It was agreed, by publication in the technical journals of the various countries, to bring the reports of Messrs. Strohmer, Sachs, Saillard, Wiechmann, Prinsen Geerligs, and Herles, which were read before the meeting, to the notice of those interested and to call attention to the propositions of the referees.

3. *Uniform methods for the determination of the specific gravity of sugar solutions.*—Mr. Saillard and Mr. von Buchka presented reports on this topic. These reports are to be published. Messrs. Weinstein, Strohmer, and Saillard participated in the debate which followed.

It was agreed to publish the reports of the referees, and the following resolutions were adopted. On motion of Mr Strohmer, that—

"The International Commission for Uniform Methods of Sugar Analysis expresses the wish that the various countries may prescribe a uniform temperature for the density determinations of sugar solutions.

"In trade analyses the use of temperature correction tables should be dispensed with as far as possible."

On motion of Mr. von Buchka, that—

"The normal temperature of +20° C is to be retained for trade analyses.

"In density determinations of aqueous sugar solutions the density obtained at normal temperature shall be referred to the density of water at +4° C and to vacuo.

"In density determinations made by weighing the results must be calculated to $\frac{20}{4}$ °C and to vacuo. To effect this, it will be desirable to use tables prepared for the purpose."

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[105] Zs. Ver. Zuckerind., 63, I, p. 25,1913; Int. Sugar Journ., 15, p. 7, 1913; Amer. Sugar Ind., November, 1912, p. 62.

Mr. Saillard agreed to the latter part of the resolution, provided that in France the normal temperature there customary—namely, $\frac{15}{4}$ °C—be retained in place of $\frac{20}{4}$ °C.

4. *Resolution concerning a further examination of the inversion constants of the double polarization (Clerget-Herzfeld) method.*—Mr. Herzfeld reported that although the correctness of the constant 132.66 at 20° C for a solution which contains the German half-normal weight of pure sucrose has been confirmed by numerous chemists and, finally, by an international commission of chemists, who worked in Berlin in 1910, yet, on the basis of more recent investigations, it seems to him desirable to retest the accuracy of this constant in as far as its application in the analysis of beet molasses is concerned. A committee, consisting of Messrs. Bates, Bryan, Browne, Prinsen Geerligs, Saillard, Sachs, and Strohmer, is appointed to retest this constant.

The following reports were also made and the following resolutions adopted:

Mr. A. Hugh Bryan made a report on the necessity of using light-ray filters for polarizing high-grade sugars, and, on his motion, the following resolution was adopted:

"Wherever white light is used in polarimetric determinations, the same must be filtered through a solution of potassium dichromate of such a concentration that the percentage content of the solution multiplied by the length of the column of the solution in centimeters is equal to nine."

Furthermore, Mr. Bates reported on investigations[106] conducted by the Bureau of Standards which led to the conclusion that the 100 point of saccharimeters provided with Ventzke scales at present accepted is not quite correct. On his motion the following resolution was adopted:

"Inasmuch as recent investigations tend to question the validity of the present 100° point of saccharimeters, and inasmuch as it is desirable that the commission recognize and fix a transformation factor from absolute degrees to Ventzke degrees, the chairman is hereby empowered to appoint a committee of three to fully investigate this question and report at the next official meeting."

At the suggestion of the chairman, Messrs, Bates, Schönrock, and Strohmer were elected as members of this subcommittee.

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[106] Bates and Jackson, Bull. Bur. Standards, 13, p. 68, 1916 (Scientific Paper No. 268).

APPENDIX 6.—AMENDMENTS TO UNITED STATES TREASURY DEPARTMENT SUGAR REGULATIONS, ETC.

1. TARE OF SUGAR CONTAINERS

Article 2, relative to the tare of sugar containers, is hereby amended so as to read as follows:

"All tare shall be taken by mark. When sugar is in tierces, hogsheads, barrels, boxes, or other irregular packages, actual tare shall be taken of all such containers. When the sugar is in baskets or mats tare will be taken as follows:

	Per cent
"Marks of less than 1,000	4
"Marks of 1,000 and less than 4,000 (but in no such mark less than 40 receptacles)	3
"Marks of 4,000 and less than 10,000 (but in no such mark less than 120 receptacles)	2.5
"Marks of 10,000 and over	1 to 2

"However, when sugar is discharged and weighed at points other than refineries, actual tare shall be taken of the largest number of baskets and mats practicable and as nearly as possible the percentage above prescribed. When, in the opinion of the weigher, the condition of the receptacles is such as to make it advisable to tare a larger percentage than that above provided, he shall tare as many receptacles as in his judgment are necessary to secure a proper tare. All such receptacles are to be thoroughly cleaned by scraping and sweeping before the tare is taken.

"A schedule tare is hereby adopted of 2.5 pounds per bag for Cuban sugars imported in bags measuring 29 by 48 inches, and such schedule tare shall be verified from time to time by actual tare. When actual tare is taken the percentage of bags to be tared shall be as above prescribed.

"When the superficial area of the bag varies by more than 2 per cent from the standard area of 1,392 square inches, then the schedule tare of 2.5 pounds should be increased or decreased in the same proportion as the superficial area of the bags exceed or is less than 1,392 inches. Should the bags covered by any mark of an importation differ in size, the schedule tare to be allowed should be based on the average dimensions of the entire number of bags contained in such mark.

"The bags shall be first carefully cleaned by sweeping and scraping and then weighed. They shall then be boiled or soaked in water heated to or above the boiling point for two hours or for such time as may be necessary to dissolve or detach all adhering particles of saccharine matter. The bags will then be dried for 24 hours or until all moisture is removed therefrom, when they will be again weighed. The difference in the two weights thus found will represent the sugar recovered in the steaming process. From the weight of the dry-cleaned bags there shall be deducted such proportionate weight of the material recovered in the steaming process as the ratio between ninety-five one-hundredths of 1 cent per pound and the rate of duty chargeable against the cargo as shown by the regular polariscopic test. The weight per bag thus ascertained shall be the actual tare to be allowed upon the entire importation. For convenience in arriving at the proper amount of duty accruing on an importation when actual tare is taken, the following procedure will be observed:

"The weigher will report, in addition to the total weight of the importation, the weights of dry-cleaned and steam-cleaned bags separately. From the total weight of

the importation the liquidating clerk will deduct the weight of the dry-cleaned bags and will assess upon the net weight the proper rate of duty according to the polariscopic test. To the amount thus ascertained he will then add the duty at the rate of ninety-five one-hundredths of 1 cent per pound upon the quantity of sucrose material recovered in the steaming process, that is, the difference between the weights of the dry-cleaned bags and the steam-cleaned bags.

"Schedule tare of 2.5 pounds shall be allowed on all importations, except where the importers shall file a written application representing that the particular importation named in the application contains an excessive number of damaged bags and giving the approximate percentage of the damaged and undamaged bags, and also requesting that actual tare be taken, in which case the surveyor may, with the approval of the collector, if satisfied that the importation includes an excessive number of damaged bags, ascertain the actual tare on the importation in the manner above provided. If the actual tare thus found does not vary from the schedule tare hereinbefore established by more than 5 per cent, then schedule tare only shall be allowed on such importation."

2. SAMPLING OF SUGAR

Article 3 of the Customs Regulations of 1908 is hereby amended to read as follows:

"All sampling shall be done at the time of weighing. In sampling imported raw sugars a general sample shall be taken—that is, each cargo shall be sampled without regard to marks, except as provided in articles 954 and 955. In the event that a cargo is consigned to two or more consignees, any consignee's sugar shall be treated as a separate cargo, provided separate entry shall be made by such consignee. A separate general sample shall also be taken of (*a*) wet sugar, (*b*) damaged sugar not wet, (*c*) ship sweepings, (*d*) dock sweepings. In taking the general sample 100 per cent of the packages shall be sampled. It shall be the duty of all samplers to secure a thoroughly representative sample.

"In the event that bags are stained from lying in storage, or any other cause, but the sugar not damaged, the sampler in charge, as well as all other samplers, shall exercise every precaution to see that the bags come approximately alternately with the clean and stained sides up. When in the opinion of the sampler in charge the bags are not being so discharged, he shall direct the attention of the inspector to the fact, and it shall be the duty of the inspector to thereupon stop the discharge of the cargo until the instructions of the sampler are complied with. If, from any cause, in any cargo, the condition of the bags from the ground tier or any other tier shall differ markedly from the condition of the cargo as a whole, such bags shall be treated as damaged. In order to prevent any unnecessary labor and inconvenience in obtaining the sample the inspector shall direct that the packages when discharged from the vessel upon the wharf shall be so placed that the sampler can readily obtain a 100 per cent sample. All ship and dock sweepings shall be sampled before the sampler completes his half-day's work."

3. SAMPLING OF MOLASSES

Article 15, relative to the sampling of imported molasses, continued in force by article 532 of the Customs Regulations of 1915, is hereby amended by adding to the end thereof the following:

"When the molasses, which is represented by the importer to test by the polariscope 38° or less, is imported in barrels, a 10 per cent sample shall be taken. In the event that the samples thus obtained are found by the polariscopic test to be between 39° and 41°, a 100 per cent resample shall be taken."

4. BICHROMATE ABSORPTION CELL

Article 59 is hereby amended by the insertion at the end thereof of the following:

"The radiation from all white-light sources shall be filtered through a solution of potassium bichromate before it enters the polariscope. This solution shall be contained in a glass cell, placed as near as possible to the polarizing end of the instrument. The cell shall have parallel walls with an inside separation of 15 millimeters. The concentration of the solution shall be 6 per cent. If for any reason it should be necessary to use a cell which does not give a layer of liquid 15 millimeters thick, the concentration must be so altered that the product of the thickness in millimeters of the absorbing solution and the concentration in per cent shall equal 90."

5. ELIMINATION OF DUTCH STANDARD

Paragraph 177 of the tariff act of October 3, 1913, provides in part—

"* * * That so much of paragraph two hundred and sixteen of an act to provide revenue, equalize duties, and encourage the industries of the United States, and for other purposes, approved August fifth, nineteen hundred and nine, as relates to the color test denominated as number sixteen Dutch standard in color, shall be and is hereby repealed. * * *"

Pursuant to the foregoing provision, you will discontinue the practice of comparing sugar samples taken from importations with the Dutch color standards for the purpose of determining whether such samples shall be subjected to polariscopic test.

Articles 1 to 67, as amended by T. D. 33180 and T. D. 33228, relative to the weighing, taring, sampling, classification, and polarization of imported sugars and molasses, are hereby extended and made applicable to all sugars imported under the provisions of the tariff act of October 3, 1913.

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