METHODS OF ANALYSIS AND LABORATORY CONTROL

OF THE

GREAT WESTERN SUGAR COMPANY

BY THE
CHEMICAL DEPARTMENT
OF THE GREAT WESTERN SUGAR COMPANY

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PREFACE

This book is an outgrowth of a 20-page pamphlet, ''Methods of Analysis for Beet Sugar Factories,'' published in 1903, and reissued in revised form in 1908. With the development of a highly specialized system of chemical control, the need for a more up to date and comprehensive treatise has been increasingly felt. The present book has accordingly been prepared as a handbook and reference book for the laboratories of the Great Western Sugar Company.

It has seemed desirable to include not only directions for the process control, but also methods for the analysis of raw materials and for such other analyses as the chemist in our organization is commonly called on to make. This has resulted in the expansion of the book to a considerable size, but at the same time an effort has been made to employ a certain conciseness of treatment and style. Hence very little explanation is ordinarily given of the reasons for various steps or procedures, except where the reason is likely to be obscure or where it is desired to emphasize the importance of the matter in the reader's mind. It is expected that the chemist will be able readily to figure out such things for himself, and to profit if any mental exercise is involved. For the sake of keeping the book within reasonable bounds, directions for purely numerical or statistical calculations have also, with a few exceptions, been purposely omitted.

A great number of chemists of this company, past and present, too numerous to mention, are responsible for the development of our methods of analysis and laboratory control to their present status. The writer's thanks are due in particular to Mr. P. Koller for assistance in preparing a considerable portion of the manuscript and for having read over the text in its entirety.

The following books have been consulted and found especially helpful: Browne's ''Handbook of Sugar Analysis,'' Hillebrand's

"The Analysis of Silicate and Carbonate Rocks" (Bulletin 700 of the U. S. Geological Survey), Scott's "Standard Methods of Chemical Analysis," the "Methods of Analysis" of the Association of Official Agricultural Chemists, and Circular 44, "Polarimetry," and numerous other publications of the Bureau of Standards. For the methods for the analysis of diatomaceous earth we are indebted to Messrs. S. C. Meredith and P. B. Caster, of the Western Sugar Refining Company.

The writer will especially welcome criticisms from any source which will assist him in correcting errors or making improvements in a future edition.

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The Great Western Sugar Company.

Denver, Colorado, July 29, 1920.

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I. GENERAL METHODS

1. DEGREES BRIX

The Brix scale represents the percentage of sugar in a pure sugar solution. The reading of a Brix hydrometer in a solution at the standard temperature (20° C.) is known as the "degrees Brix," or simply the "Brix," which is employed as an approximate measure of the percentage of dry substance.

(a) Direct Method

Determine the density of all solutions up to 75° Brix as follows: Transfer the solution to a suitable glass cylinder (hydrometer jar), and, if necessary, immerse in a cooling bath to reduce the temperature to approximately 20°. If air bubbles are present, remove them by the action of a vacuum. Mix the solution in the cylinder to equalize the temperature and immerse a clean, dry hydrometer about one-quarter of an inch below the point where it floats naturally and then allow it to assume its normal position. Read the scale by bringing the eye upon a level with the surface of the solution so that the latter appears as a straight line and not an ellipse, and note where the border line forming the bottom of the meniscus intersects the scale. Dark or opaque solutions may have to be read from above, by estimating the distance of the level of the solution below the top of the meniscus. When the reading is taken, the liquid and hydrometer must be free from air bubbles and at rest, and the hydrometer must not be in contact with the bottom or walls of the cylinder.

Take the temperature of the solution with a thermometer; if it is not exactly 20°, apply the correction indicated in Table 3 or 3-A. Hydrometer readings should not be made below 15° or above 25°.

To insure strict accuracy, the cylinder should be filled so full that the insertion of the hydrometer causes the liquid to overflow.

This minimizes the effect on the reading of the formation of surface films of impurities.

(b) Double Dilution Method

In the case of molasses, massecuite, etc., weigh out 400 grams in a copper beaker, add about 350 grams of hot water, and stir with a glass rod until completely dissolved. Cool to approximately 20°, remove and rinse the rod, make up to 800 grams with water, and *mix well.* Pour into a glass cylinder, rinsing it first with a little of the solution if the cylinder is wet, and obtain the Brix reading as under (a). Apply the temperature correction, if necessary, and then multiply by 2. Other weights may be used if the final dilution is in the same ratio.

See under "4. Apparent Purity Determination" regarding the quality of the water used for dilution.

2. DRY SUBSTANCE AND MOISTURE

Special directions for particular products will be found under "Sugar," "Dried Pulp," etc. Where this determination is important in itself, other than as an incidental figure for obtaining the true purity, etc., it should not be made on material which has been placed under vacuum for any great length of time, because a considerable increase in concentration sometimes occurs under this condition.

(a) By Oven Drying

(1) *Apparatus:* A double-walled drying oven containing a glycerin solution in the jacket, of such a strength that a temperature of 100-105° is maintained in the interior of the oven. The boiling point is kept constant by means of a reflux condenser. See Chap. XXIII, 7.

Aluminum dishes 2 in. diameter by 1½ in. high, as described in Chap. XXIII, 6, provided in each case with an aluminum cover and a glass rod of such a length that it will not interfere with the proper position of the cover.

A desiccator containing sulphuric acid as the dehydrating agent. The acid should be renewed as soon as it shows any sign of discoloration or loss of absorptive power. Renew the acid at least once a week when the desiccator is in constant use.

(2) *Reagents:* Sea sand prepared as described in Chap. XXV, 17.

(3) *Method*: Place 25-30 grams of sea sand in an aluminum dish and dry it, together with the cover and glass rod, in an oven at 100-105° C. for at least one hour. Remove from the oven, put on the cover, and cool in a desiccator.

Weigh out, in the covered aluminum dish, an amount of the material under examination which is equivalent to approximately one gram of dry substance. Warm the dish on top of the drying oven, remove the cover, and mix the contents well. Warm again, add 1 ml of *hot water and stir until a perfectly homogeneous mixture is obtained. Dry at 100-105° C. for 5-6 hours, replace the cover, cool in the desiccator, and weigh. Repeat the drying for one hour periods until the loss in weight in any period is less than 0.1%. Keep the thermometers in the desiccator and balance case, and do not make the weighings until the difference in temperature is 2 degrees or less.

Make all determinations in duplicate. The duplicates should ordinarily check within 0.1%; if they differ by more than 0.2% repeat the determination.

Sugar, dried pulp, and filter press cakes are dried directly without the use of sand.

(b) By Refractometer

The Abbé sugar refractometer uses the refractive index as a measure of the percentage of dry substance, and in the case of ordinary sugar factory products gives results which are close to those found by oven drying.

Use the original material in the case of juices, syrups, and molasses, and "double diluted" material in the case of sugar and massecuite. Place 1 or 2 drops on one of the prisms, close quickly, and circulate water at 20° through the instrument. Read directly from the scale the percentage of dry substance. Multiply the reading by two if "double diluted" material has been used. If the reading is not made at exactly 20°, apply the correction indicated in Table 4. Check the zero point of the instrument frequently with distilled water. See also Chap. XXIII, 16 and XXIV, 8.

3. SUGAR

The polarization (direct polarization) is defined as the percentage of sugar indicated by the polariscope.

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*Thin solutions do not require the addition of water.

In the absence of other optically active bodies the polarization represents the true percentage of sugar. In the presence of another optically active substance, such as raffinose, the method of double polarization (before and after inversion) is used to. determine the two sugars accurately. The percentage of sugar obtained in this manner is known as the "sugar by inversion."

(a) Sugar by Direct Polarization

Weigh out 26 grams (or a *fraction or multiple thereof, depending on the nature of the material) in a counterpoised nickel dish, and dissolve in a small amount of water. Use hot water if difficult to dissolve. Rinse into a 100 ml flask and add sufficient basic lead acetate solution to decolorize, avoiding any great excess. (See Table 5.) Where the amount of the lead precipitate is small, as in the case of products of high purity, the addition of a few drops of alumina cream will aid in securing a clear filtrate. Cool to approximately 20° if necessary, and make up to the mark with water, using one or two drops of ether, if necessary, to break the foam. Shake well and filter, rejecting the first portion of the filtrate and returning the remainder to the filter until it is perfectly clear. Polarize in a 200 mm tube, first rinsing the tube two or three times with the solution. If the normal weight, 100 ml flask, and 200 mm tube have been used, the reading gives directly the percentage of sugar. If the weight, volume, or length of tube differs from these standards, calculate the percentage of sugar proportionally.

When great accuracy is required, make up to the mark with water at exactly 20° and polarize in a jacketed tube at the same temperature. For ordinary work it is sufficiently accurate to approximate the above temperature conditions.

See also Chap. XXIII, 13, regarding the use of the polariscope.

(b) Sugar by Inversion

(1) Polarize as above.

(2) Weigh out 13 grams of the original material (or 26 grams of the double diluted solution) in a counterpoised nickel dish, dissolve in a small amount of water, and rinse into a thin walled 100 ml Kohlrausch flask, marked at the point at which it holds 75 ml. Add from a pipette 10 ml of hydrochloric acid

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*In the case of molasses use 13 grams of the original molasses, or 26 grams of the "double diluted" solution. In the case of other products of higher purity use ordinarily 26 grams of the original material, or 52 grams of the "double diluted" solution.

(D $\frac{20^\circ}{4^\circ}$1.029—see Chap. XXV, 10), make up immediately to the 75 ml mark with water, and mix thoroughly. Place a thermometer in the flask, and immerse in a water bath at 70° with frequent *agitation. The solution should reach a temperature of 67° in not more than five minutes, and preferably in 2—3 minutes. When the temperature reaches 67°, note the time, and maintain the temperature for exactly five minutes between 67 and 70°. Shake the flask occasionally with a rotary motion in order that the temperature may be uniform throughout the solution. Then place the flask immediately in a cold water bath and cool as rapidly as possible to 20°. Remove the thermometer, rinsing the adhering liquid into the flask, and make up to the 100 ml mark with water at exactly 20°.

Next add 2-4 grams of zinc dust, according to the amount of decolorization required, and allow to stand for half an hour, shaking at frequent intervals. Filter and polarize at exactly 20° in a 200 mm jacketed tube.

In making the polarization, place the tube in the trough of the polariscope and insert a thermometer graduated in one-tenths of one degree, allowing the bulb to rest against the bottom of the inner tube. Circulate the cooling water at 20° (or at 19-20°, but never below 19°) until the thermometer indicates that the 20° point has been reached, then remove the thermometer and take a sufficient number of readings with as little delay as possible. If the solution is cooled in this manner, the temperature will not change appreciably during the time that the readings are made. Do not handle the tube during the final adjustment of the temperature.

All the conditions prescribed must be rigidly followed to obtain accurate results. The total volume during inversion must be approximately 75 ml; the hydrochloric acid must be measured accurately and be of the proper strength; the conditions regarding the temperature and time of heating must be observed; and the solution in the polariscope tube must be cooled in the manner described in order that the reading may be made at exactly 20° and that this temperature may prevail uniformly throughout the solution. Means should be provided for a sufficient supply of cooling water at constant temperature.

Multiply the reading by 2, since the half-normal weight has been used.

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*Mix constantly until the solution has attained a temperature of 67°.

(c) FORMULAS

(1) *Raffinose Formula* (For the determination of sugar in the presence of raffinose): This formula is generally used in beet sugar work.

Let P = direct polarization
J = polarization after inversion (expressed as a positive number)
S = % sugar by inversion
R = % raffinose

$$\text{Then } S = \frac{(.5124 \times P) + J}{.839}$$

$$\text{And } R = .54 \times (P - S)$$

(2) *Clerget Formula* (For the determination of sugar in the presence of invert sugar): This formula is not commonly used in beet sugar work, but is given here for the sake of completeness:

Let T = temperature at which polarization is made

$$\text{Then } S = \frac{100\ (P + J)}{142.66 - .5\ T}$$

Or, if T = 20

$$S = \frac{100\ (P + J)}{132.66}$$

4. APPARENT PURITY

(a) DEFINITION

The "purity" (coefficient of purity) of a juice, syrup, etc., is the percentage of sugar in the total solid matter, and is calculated by multiplying the percentage of sugar by 100 and dividing by the percentage of solids. If the direct polarization is used to represent the percentage of sugar and the degrees Brix to represent the percentage of solids, the result is known as the "apparent" purity. If the "sugar by inversion" is used for the percentage of sugar and the actual dry substance for the percentage of solids, the figure is known as the "true" purity.

(b) DETERMINATION

If too thick, dilute the material with water to approximately 23° Brix as follows: Put a suitable amount of *hot* water in a copper can or sample bucket, and add a suitable amount of the juice or syrup; the proportions to be used should be such as will yield a solution of the required density and will be learned by experience.

Stir vigorously until completely dissolved and then pour the solution into a cylinder (hydrometer jar). The solution prepared in this manner should have a density of not less than 21° nor more than 24° Brix. If, after cooling as described below, the density is found to be a little too high, add the necessary small amount of cold water, and mix thoroughly by inverting the cylinder at least half a dozen times; only under this condition is it permissible to make any dilutions in cylinders or with the use of cold water, and care should be taken then that a thorough mixture is obtained.

''Double diluted'' solutions, if available, may be used in place of the original material, but the dilution should be made by mixing with hot water as described above and not in a cylinder. It may be preferable, however, in order to save time, to prepare a separate solution for the apparent purity determination from the original material.

Cool in the cylinder under vacuum to remove air bubbles, and obtain the Brix reading as described in section 1, ''Degrees Brix,'' making correction for temperature if necessary. Measure out 100 ml in a 100-110 ml flask, rinsing the latter first with a small portion of the solution, and add sufficient basic lead acetate solution for decolorization, but avoid any great excess. (See Table 5.) Fill to the 110 ml mark with water, using 1 or 2 drops of ether, if necessary, to break the foam. Shake well and filter, rejecting the first portion of the filtrate and returning the remainder to the filter until it is perfectly clear. Polarize in a 200 mm tube, first rinsing the tube two or three times with the solution.

Multiply the polariscope reading by the factor corresponding to the corrected Brix, as found in Table 2, to obtain the apparent purity. To simplify this calculation, *tables have been prepared covering a range of 8-25° Brix, in which the purity is derived directly from the Brix and the polariscope reading.

It may sometimes be necessary to use a 100 mm tube for the polarization of molasses and dark syrups; this should be avoided, however, if possible.

(c) QUALITY OF WATER USED FOR DILUTION

The quality of water used for dilution must be closely investigated and watched. Most water is not high enough in solids to affect a purity determination, but some factory water supplies are unsuitable even for this purpose and in such cases distilled water should be used. If the alkalinity of the product is to be subse-

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*"Laboratory Tables," The Great Western Sugar Company, 1917.

quently determined, only neutral water should be employed for dilution; and, if the soap test is to be made, distilled water of a small and determined soap value should be used.

5. TRUE PURITY

Obtain the percentage of sugar by inversion as described in section 3, "Sugar," and the percentage of dry substance by oven drying or by the refractometer as in section 2, "Dry Substance and Moisture."

Let S = % sugar by inversion
D = % dry substance
P = true purity

Then $P = \frac{100\,S}{D}$

6. INVERT SUGAR

(a) In Thick Juices, Syrups, and Solid Products

Determine the amount of material to be used by reference to Table 10. Weigh out the number of grams indicated, dissolve in hot water and rinse into a 200 ml flask. Cool if necessary, and add sufficient neutral lead acetate solution for clarification, avoiding any great excess, fill to the mark with water, shake well, and filter. Measure out 100 ml of the filtrate in a 100-110 ml flask, add enough of a strong sodium carbonate solution to precipitate all the excess of lead, complete the volume to 110 ml with water, shake well, and filter. Transfer 50 ml of the filtrate (representing 10 grams of dry substance of the original material), measured with a pipette, to an Erlenmeyer flask of about 250 ml capacity containing 50 ml of Fehling's Solution, i. e. 25 ml each of the copper sulphate and Rochelle salt solutions. Heat the flask with a flame so regulated that the solution begins to boil in at least 3½-4 minutes; take the time at which boiling commences as the point at which bubbles begin to rise not only in the middle, but also at the sides of the flask. Boil for exactly 2 minutes, and then cool by adding 100 ml of cold, distilled water. Allow to stand for not more than 2 minutes to let the precipitate settle, and filter at once through an ashless filter paper. Wash with hot water, distribute the precipitate over the filter as evenly as possible with a glass rod, and ignite in a porcelain crucible. Or use an alundum crucible for both the filtration and the ignition. From the weight of cupric oxide obtained find the corresponding percentage of invert sugar in Table 12.

If the amount of cupric oxide is beyond the limit of the table, use 25 ml of the second filtrate with 25 ml of water and 50 ml of Fehling's solution, carrying out the determination as before, and obtain the percentage of invert sugar from Table 13.

Note that the percentage found is based on 100 parts dry substance or Brix, and not on the original material.

If the cupric oxide weighed is in excess of 300 mg, the results cannot be relied on because of the difficulty of oxidizing all the copper. In such a case the precipitate may be collected on an asbestos filter in a glass filter tube, ignited in a current of hydrogen and weighed as metallic copper; or the copper may be determined by the Low volumetric method given in Chap. XIV, 6.

For larger percentages of invert sugar beyond the limit of the cupric oxide table use a *modified Soxhlet volumetric method.

(b) IN THIN JUICES

Determine the amount of material to be used by reference to Table 11. Weigh out the number of grams indicated, rinse into a 200 ml flask, and proceed as in (a). The final 50 ml taken for treatment with Fehling's Solution will contain 5 grams of dry substance. Obtain the "Invert per 100 Brix" from Table 13.

7. ASH

(a) SULPHATED ASH

Where the term "ash" is employed without any qualifying expression, sulphated ash is understood to be meant.

Use 2 grams of molasses and larger amounts of products containing less ash. Weigh out quickly in a platinum crucible, or better a porcelain evaporating dish of about 35 ml capacity, making no attempt to weigh a definite amount. Do not use silica ware. Place on a †Hillebrand radiator, add, if necessary, enough water to reduce to the consistency of thick juice, and evaporate until the bubbles start to puff up in the dish. At this point remove the dish, and add concentrated sulphuric acid a drop at a time around the edge of the dish until the entire mass is black and ceases to boil.

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*Browne's "Handbook of Sugar Analysis," p. 391.

†Chap. XXIII, 15.

Replace on the radiator, drive off the excess of sulphuric acid, and ignite at a *dull red* heat in a muffle till the carbon is completely consumed. The resulting ash should be white or nearly so and should not be allowed to fuse. After cooling, resulphate the ash with 3 or 4 drops of dilute sulphuric acid (1:10), heat first on the radiator, and then ignite at a dull red heat for a minute or two over a flame. Cool in a desiccator and weigh.

Subtract one-tenth of the weight of the ash to compensate for the conversion of other salts to sulphates. This correction is known to be seriously in error but is maintained in accordance with general practice.

(b) LIXIVIATED ASH

Weigh out the same amount as prescribed under "Sulphated Ash" in a platinum dish; the use of either porcelain or silica ware is inadmissible. Heat over a flame, applying it around the outer edge to prevent material being pushed over the side of the dish by the escape of steam and gases. After most of the volatile matter has passed off and the organic matter is completely carbonized, crush the mass to a fairly fine powder by means of an agate pestle and heat again at a dull redness. A too high temperature of heating, which will cause some of the salts to fuse and volatilize, will usually be indicated by the formation of white spots on the dish, which are more easily seen on the addition of the water. Remove from the flame when the carbon ceases to glow, cool, add 20 ml of water, place on a hot plate and allow to simmer for about fifteen or twenty minutes, replacing the evaporated portion with hot water previous to filtration. Filter through an ashless filter paper into a 100 ml beaker, washing all of the carbon possible into the filter, wash twice with hot water, and evaporate to a small volume.

Dry the platinum dish carefully and ignite it until any adhering particles of carbon are burnt, then place the filter paper in the dish and ignite over a full flame until free from carbon. (If fusion takes place, either the time of lixiviation has not been long enough, or an insufficient amount of water has been used to remove the fusible salts.) Cool, add the solution from the beaker, using as little water as possible for rinsing, and evaporate to dryness on a water bath or Hillebrand radiator. Heat carefully, first on the radiator or in a drying oven, and then over a free flame, bringing the ash *just to the fusing point,* then cool in a desiccator, and weigh as rapidly as possible.

Ordinary distilled water may contain enough solids to cause an appreciable error in this determination where the amount of ash weighed is small, as in the case of cossettes and diffusion juice. Water of as high a degree of purity as possible should be prepared by redistillation for this purpose, and the results should be corrected, if necessary, by blank tests made on the water.

8. ORGANIC COEFFICIENT

Calculate by either of the following methods:

(a) Add together the percentages of raffinose, invert sugar, and undetermined, and divide by the percentage of ash (all percentages on dry substance).

(b) Add together the percentages of sugar by inversion and ash, and subtract the sum from 100. Divide this result by the percentage of ash (all percentages on dry substance).

9. SULPHURIC ACID (SO_3)

Weigh on a pulp balance 20 grams of thick juice, sugar, or saccharate products, and in the case of other products more or less, depending on their SO_3 content. Transfer to a 250 ml beaker, add about 150 ml of water and a few ml of hydrochloric acid, heat until all soluble matter is dissolved, filter off the insoluble matter, and wash with hot water. Heat to boiling and add slowly, drop by drop, 10 ml of a hot 10% barium chloride solution. After standing for at least three hours, filter, wash with hot water, dry, ignite, and weigh as $BaSO_4$. Test the filtrate by adding a few drops of barium chloride. Conduct the ignition at as low a temperature as possible to avoid reduction to sulphide. Heating the crucible in an inclined position will reoxidize any sulphide formed to sulphate; do not use a blast lamp as too high a temperature will decompose barium sulphate. Multiply by .3430 to convert $BaSO_4$ to SO_3. To obtain "SO_3 per 100 Brix" multiply the percentage of SO_3 found by 100 and divide by the Brix.

10. ALKALINITY

Use N/28 sulphuric acid (1 ml = .001 g CaO) for juices, syrups, etc., and nitric acid (1 ml = .05 g CaO) for Steffen liquors. Employ phenolphthalein as indicator in all cases. Use only neutral water for all dilutions.

(a) JUICES

Transfer 10 ml with a pipette to a porcelain dish, dilute with neutral water if dark, add a few drops of indicator solution, and add the standard acid until the pink color entirely disappears; test for the end point by adding a drop of the indicator. If the solution is acid, add an excess of N/28 sodium hydroxide solution, and titrate back to neutrality with the standard acid; subtract from the number of ml of alkali added the number of ml of acid required. In the case of highly colored products where it is difficult to observe the end reaction, transfer 10 ml to a test tube or a tumbler and dilute with about 50-100 ml of water; fill a second vessel in the same manner. Add phenolphthalein to one and titrate with the standard acid until a color match for the two solutions is obtained.

Express the result as "grams of CaO per 100 ml," by dividing the number of ml of acid required by 100. Express acidity as negative alkalinity on the same basis.

(b) MASSECUITE

Use 10 ml of the double diluted solution prepared for the Brix determination, titrate as in (a), and multiply the result by 2.

(c) STEFFEN LIQUORS

Measure out 50 ml with a pipette, add a few drops of indicator, and titrate to neutrality with the standard nitric acid (1 ml = .05 g CaO). Express the result as "grams of CaO per 100 ml" by dividing the number of ml of acid required by 10.

11. CaO BY TITRATION

Use standard nitric acid and sodium hydroxide (1 ml = .05 g CaO), and phenolphthalein indicator.

Dilute the weighed sample with 50-100 ml of neutral water in a porcelain casserole, add an excess of the standard acid, and boil for 3-5 minutes to expel all carbon dioxide. (The amount of dilution and time of boiling must be maintained within the prescribed limits in order to drive off all carbon dioxide produced from the decomposition of carbonates and at the same time not to volatilize any nitric acid.) Add a few drops of indicator and titrate to neutrality with the standard alkali.

If 5 grams of the sample is used for the determination, the number of ml of acid used, less the number of ml of alkali required, gives directly the percentage of calcium oxide.

12. CaO BY SOAP SOLUTION

Use a soap solution prepared and standardized as described in Chap. XXV, 21, and adjusted to a strength of 1 ml = .001 g CaO (twenty-eighth normal).

(a) DETERMINATION IN THICK JUICE, SYRUPS, MASSECUITE, ETC

Use a portion of the 23° Brix solution prepared for the apparent purity determination. Transfer 10 ml with a pipette to an 8 oz. glass bottle provided with a ground stopper and marked at the point at which it holds 50 ml. Fill to this mark with water and add a drop of phenolphthalein solution. If the reaction is not alkaline, add N/28 sodium hydroxide a drop at a time until a permanent pink color is produced. Then add the soap solution in small quantities from a burette; after each addition stopper the bottle and shake vigorously. Take as the end point the formation of a fine foam 5 mm in depth which will last five minutes. Make a blank test on each lot of water prepared for dilution, first adding phenolphthalein and then N/28 sodium hydroxide a drop at a time until a permanent pink color is produced. Subtract from the number of ml of soap solution used in the determination the number of ml of soap solution required by 40 ml of the water in the blank test. Obtain the "CaO to 100 Brix" from Table 15.

The quality of water used for dilution should be the best available, in order that the correction may be kept as small as possible.

The recognition of the end point is a matter of experience. Usually a granular or curdy precipitate is formed at the beginning of the addition of the soap solution; when the amount of this is large, it collects on the surface and may be mistaken for the final foam. As the end point is approached, the precipitate breaks up and yields a uniformly opaque solution. Practice will enable the end point to be recognized immediately by the fact that, as long as the bubbles show any marked sign of breaking, the amount of soap solution is insufficient.

(b) DETERMINATION IN THIN JUICES

Determine as in (a), using 20 instead of 10 ml of juice. Correct for the number of ml of soap solution required by 30 ml of the water in the blank test. Obtain the "CaO to 100 Brix" from Table 14.

13. DETECTION OF SUGAR BY MEANS OF ALPHA-NAPHTHOL

Employ the following method for the detection of sugar in condensed waters.

Use 6x⅝ inch test tubes graduated at ¾ inch and 1½ inches from the bottom. Fill the tube to the upper mark with the water under examination, add 5-10 drops of alpha-naphthol solution, and mix thoroughly. Cool if the water is hot, then add concentrated sulphuric acid (a 250 ml dispensing burette is convenient), holding the tube in an inclined position so that the acid will run to the bottom and form a separate layer, and continuing the addition until the acid layer reaches the ¾ inch mark.

If a lilac or purple ring appears at the intersection of the two layers during the addition of the acid or immediately thereafter, polarize the water as follows: Cool if the water is hot, filter if necessary, and read directly in a 400 mm tube without the addition of lead acetate. To obtain the percentage of sugar multiply the reading by .13, or use Table 8. If the polariscope reading is less than .2, record as a ''heavy trace,'' which should represent a concentration of at least 1 part of sugar in 10,000 parts of water.

If the color does not appear immediately upon the addition of the acid, roll the test tube once in an upright position between the palms of the hands. If no purple or lilac ring appears within 15 seconds, report sugar as absent. If the characteristic color appears within this time, report as a ''light trace,'' which should signify that the water contains from 1 part of sugar in 10,000 to 1 part in 100,000.

Previous to the campaign and frequently during the campaign, test the stock of alpha-naphthol with freshly prepared sugar solutions of known concentration, as follows:

Per Cent Sugar	Concentration
1.0	1:100
.1	1:1000
.01	1:10000
.001	1:100000

The conditions of the test may be modified accordingly, if necessary. Any alpha-naphthol, however, which is not sufficiently sensitive to give a reaction in a 1:100,000 sugar solution after 15 seconds standing should be discarded or repurified. Chemists should familiarize themselves with the shade of color produced by each of the above standard sugar solutions.

The following résumé will be found convenient for reference:

Designation	Abbreviation	Approximate Percentage of Sugar Indicated
Zero	0	Less than .001%
Light Trace	L	.001 to .010%
Heavy Trace	H	.010 to .026%
A figure		The percentage indicated.

II. REGULAR FACTORY CONTROL

1. COSSETTES

Determine:

(a) Sugar every hour.
(b) Apparent Purity, every 2 hours.
(c) Lixiviated Ash, every 24 hours.

SAMPLING

Fill a 2-gallon pail *by holding it in the stream of cossettes* as they fall from the conveyor, or from the slicers. Pay particular attention to securing a sample free from contamination with steam or water. See also below under "Tailings."

As a check upon the cossette test, an extra sample should be taken every 2 hours in the same manner as the regular sample, but at a different time, preferably half an hour before or after the time of a regular sample. The sugar should be determined by a different operator from the one who handles the regular samples.

PREPARATION OF SAMPLE

Grind the entire sample without delay in an Enterprise Meat Chopper No. 41 fitted with a plate containing one-eighth inch perforations and running at the rate of 300 revolutions per minute. When all the sample has been introduced, return a handful of the ground material to the machine and allow the machine to run until no more material or juice is forced through the perforated plate. Do not add to the sample the small portion of the material remaining in the machine. Mix the ground sample thoroughly with the hands, take out a small portion for analysis, and place it in a covered bucket. Use the remainder of the ground sample for the purity determination. After the sample has been ground, open the machine and wash it out well with hot water. Be sure that it is dry before it is used again. Use this machine only for grinding cossettes.

Obtain the juice for the purity determination as follows: Place a suitable amount of the ground sample in a clean, dry cloth and subject it to a pressure of 240 lbs. per sq. in. in a hydraulic press. Measure the pressure with a suitable high pressure gage; the gage pressure to be carried depends on the dimensions of the basket and the ram, and is calculated as described in Chap. XXIII, 14. Bring up the pressure gradually and maintain the prescribed pressure until juice ceases to flow. Collect the *entire amount* of juice expressed and mix it well. Use the press and the cloths exclusively for cossettes, wash them well with hot water after use, and see that they are dry before they are used again. A small drying closet, heated by steam pipes, should be employed for drying cossette and pulp cloths.

ANALYSIS

(a) *Sugar:* Weigh out 26 grams of the ground cossettes as rapidly as possible, and rinse with a jet of water into a 200.6 ml Kohlrausch flask. Add 6 ml of basic lead acetate solution and sufficient water to make a volume of about 160-170 ml. Digest in a water bath at 80°, keeping the body of the flask entirely immersed but not in contact with the bottom of the bath. Remove the flask from time to time and mix with a rotary motion. At the end of exactly 30 minutes fill to the mark, or slightly above it, with water at 80° and continue the digestion for exactly 10 minutes longer. Then cool to approximately 20° in a cold water bath and make up to the mark with the necessary small amount of water. Use a few drops of ether to break the foam, adding it either just previous to the second period of digestion or after the solution has been cooled. Shake, filter, and polarize in a 400 mm tube. The reading gives directly the percentage of sugar.

In the case of beets of abnormally low purity, 8-10 ml of basic lead acetate solution may be needed for clarification.

(b) *Apparent Purity:* Place the juice in a cylinder under vacuum until all air has been removed and determine as described in the "General Methods," 4 (b). Use a stronger lead solution for clarification, if necessary, and, if this is insufficient, proceed as follows: Transfer 50 ml with a pipette to a 100-110 ml flask, add sufficient basic lead acetate for clarification, and make up to the

110 ml mark with water. Multiply the polariscope reading by 2 before applying the formula or the table. The use of the last mentioned method should very seldom be necessary, and then only in the case of beets of abnormally low purity.

(c) *Lixiviated Ash:* Weigh out 5-10 grams in a platinum dish from the sample of ground cossettes used for one of the hourly sugar determinations on which the apparent purity is also determined. Follow the "General Methods," 7 (b).

TAILINGS

If beet tailings are introduced and pass through the automatic scales with the beets, no particular attention need be paid to them, as the cossette samples will, in the long run, include a proportional amount of the tailings.

If tailings are introduced which do not pass through the automatic scales, they may be handled by one of the following methods:

(1) If the tailings are mixed with the cossettes at a reasonably uniform rate, take the cossette samples as above, so that they will include a proportional amount of the tailings. Add the weight of tailings introduced to the weight of beets which passes through the scales.

(2) Take the cossette samples at a point where none of the tailings will be included in the sample; sample the tailings also once a shift, grind, and determine the percentage of sugar as in the case of "Cossettes." Add the "equivalent in beets" of the weight of tailings to the weight of beets which passes through the scales.

In either of the preceding two cases determine the amount of tailings introduced by actual weighing for a 24 hour period at least once a week.

2. DIFFUSION JUICE

Determine every 2 hours:

(a) Brix.

(b) Apparent Purity.

Determine every 24 hours:

(c) Lixiviated Ash.

SAMPLING

Take a catch sample from a full measuring tank, or from the pipe line or pump before the juice enters the heaters.

ANALYSIS

(a) *Brix:* Follow the "General Methods," I (a).

(b) *Apparent Purity:* Determine as in (b) under "Cossettes."

(c) *Lixiviated Ash:* Weigh out 7-10 grams of one of the catch samples and proceed as in the "General Methods," 7 (b).

SPECIAL DETERMINATIONS

(d) *Acidity:* Measure out 10 ml in a porcelain dish, add two or three times its volume of neutral water to lighten the color, and a few drops of phenolphthalein. Add an excess of standard sodium hydroxide (1 ml = .001 g CaO), then titrate to neutrality with standard sulphuric acid of the same strength. Express the result in grams of CaO per 100 ml. See "General Methods," 10 (a).

(e) *Invert Sugar:* Use one of the samples on which the previous determinations have been made, but do not allow it to stand for any length of time before starting this determination. Follow the "General Methods," 6 (b).

3. PULP AND PULP WATER

Determine hourly in a sample from each diffusion battery:

(a) Sugar.

SAMPLING

The workman under the battery should take from each cell dumped a small portion of the mixture of pulp and pulp water, using a long handled dipper. The sample should be taken from the first pulp and water discharged. The individual sample should be transferred at the time to a covered container of the customary type, so arranged that the water will drain into the bottom of the receptacle and not stand in contact with the pulp.

PREPARATION OF SAMPLE

Grind the entire sample of pulp in an Enterprise Meat Chopper No. 41 in the same manner as described under "1. Cossettes," and press in a clean, dry cloth in a suitable hand press. Collect the entire amount of juice that can be expressed and mix it well. Keep the grinding machine, press, and cloths clean, and use them only for pulp.

Analysis

(a) *Sugar:* Measure out 100 ml of the expressed juice in a 100-110 ml flask, add 2-4 ml of basic lead acetate solution, fill to the 110 ml mark with water, shake, filter, and polarize in a 200 mm tube. Obtain the percentage of sugar from Table 6. Analyze the pulp water in the same way, using 1-2 ml of lead acetate.

4. FLUME PULP AND PULP WATER

Determine every 2 hours:

(a) Sugar.

Sampling

The sample should be taken by a laboratory employe and should be as nearly representative as possible of the pulp leaving the battery at the time. Obtain the sample from the discharge of the pit, from the flume leading to the pump, or from the return line of the pump, using a long handled dipper. Take the sample while a good sized stream of pulp is flowing in order to avoid excessive admixture of washout water, transferring it to the same kind of container which is used for the regular pulp samples.

Preparation of Sample

Grind and prepare the sample in the same manner as the regular pulp sample.

Analysis

(a) *Sugar:* Determine the sugar in the pulp and the water in the same manner as in the regular pulp and pulp water samples.

5. FIRST SATURATION JUICE

Determine every hour on a catch sample:

(a) Alkalinity.

Determine every 4 hours on a composite sample:

(b) Brix.

(c) Apparent Purity.

SAMPLING

Take a catch sample every hour from the cocks or troughs of the first presses, avoiding any admixture of wash water. Make up the composite sample by mixing equal portions of the four hourly samples. Keep the container for the composite sample clean, and add a few drops of formaldehyde to prevent decomposition.

ANALYSIS

(a) *Alkalinity:* Follow the "General Methods," 10 (a).

(b) *Brix:* Follow the "General Methods," 1 (a), using the original juice, and not the carbonated sample described in (c) below.

(c) *Apparent Purity:* Heat to 80° in a water bath and carbonate at this temperature to faint alkalinity with phenolphthalein. Then heat to at least 85°, filter, cool, redetermine the Brix, and determine the apparent purity according to the "General Methods," 4 (b).

NOTE: When the melted sugar is added at the blow-ups or at a point beyond the second saturation, a composite sample of Second Saturation Juice may be used for the apparent purity determination without laboratory carbonation

6. SECOND AND THIRD SATURATION JUICE

Determine every hour on a catch sample:

(a) Alkalinity.

Determine every 4 hours on a composite sample:

(b) Brix.

SAMPLING

Take a catch sample every hour from the cocks or troughs of the respective filters, avoiding any admixture of wash water. Make up the composite sample by mixing equal portions of the four hourly samples. Keep the containers for the composite samples clean, and add a few drops of formaldehyde to prevent decomposition.

ANALYSIS

Follow the "General Methods," 10 (a) and 1 (a).

7. EVAPORATOR THIN JUICE

Determine every 4 hours on a composite sample:

(a) Brix.
(b) Apparent Purity.
(c) Lime Salts (CaO to 100 Brix).

SAMPLING

Take a catch sample every hour from the pump, or at a suitable point in the pipe line between the thin juice filters and the first body of the evaporators. Make up the composite sample by mixing equal portions of the four hourly samples. Keep the container for the composite sample clean, and add a few drops of formaldehyde to prevent decomposition.

ANALYSIS

Follow the "General Methods," 1 (a), 4 (b), and 12 (b). Add 1-2 ml of alumina cream before making up to the mark, if trouble is encountered in obtaining a clear filtrate.

8. EVAPORATOR THICK JUICE.

Determine every hour on a catch sample:

(a) Alkalinity.

Determine every 4 hours on a composite sample:

(b) Brix.
(c) Apparent Purity.
(d) Lime Salts (CaO to 100 Brix).

SAMPLING

Take a sample every hour from the pump, or from the line between the evaporator outlet and the blow-up inlet. Do not take the sample from the last body of the evaporators, because the sample so drawn is not always representative of the juice leaving the evaporators. Make up the composite sample by mixing equal portions of the four hourly samples.

ANALYSIS

(a) *Alkalinity* and (b) *Brix:* Follow the "General Methods," 10 (a) and 1 (a).

(c) *Apparent Purity:* Dilute to the approximate density of the evaporator thin juice and determine according to "General Methods," 4 (b). The dilution is prescribed in this case in order to eliminate the small variation in the purity test which would be caused if the thin and thick juice were analyzed at different densities.

(d) *Lime Salts (CaO to 100 Brix):* Use 20 ml of the solution diluted to thin juice density as in (c), and follow the "General Methods" for the determination of CaO by Soap Solution in *thin* juices, 12 (b).

9. BLOW-UP THICK JUICE

Determine every hour on a catch sample:

(a) Alkalinity.

Determine every 4 hours on a composite sample:

(b) Lime Salts (CaO to 100 Brix).

SAMPLING

Take a catch sample every hour from the cocks or troughs of the thick juice filters. Make up the composite sample by mixing equal portions of the four hourly samples.

ANALYSIS

(a) *Alkalinity:* Follow the "General Methods," 10 (a).

(b) *Lime Salts (CaO to 100 Brix):* Dilute to approximately 23° Brix, determine the Brix, and use 10 ml, following the "General Methods," 12 (a). Or dilute to thin juice density, determine the Brix, and use 20 ml, following the "General Methods," 12 (b).

10. LIME KILN GAS

Determine every 4 hours:

(a) Carbon dioxide (CO_2).

(b) Oxygen (O).
(c) Carbon monoxide (CO).

SAMPLING

Obtain the gas by means of a pipe leading to the laboratory from a point in the main gas line between the gas washer and the carbonators. Provide the laboratory line with a vent leading outside the building by means of which the line may be exhausted and kept filled with fresh gas.

ANALYSIS

Use an Orsat apparatus provided with three pipettes and a water jacketed burette. First make sure that the vent line has been open for several minutes, to insure a supply of fresh gas. Fill the Orsat burette with water by raising the leveling bottle, then put it into communication with the gas supply, lower the leveling bottle below the zero point of the burette, and allow the gas to fill the burette. Then expel the gas sample and draw in another in the same manner, to rinse out connections, etc., or allow the gas to bubble for a few moments through the water in the leveling bottle; in the latter case be sure that no gas is left trapped in the rubber tube between the burette and the leveling bottle. Put the three-way cock into communication with the atmosphere, at the same time raising the leveling bottle until the level of the water in it is at the level of the zero point on the burette. When equilibrium has been reached, i. e., when the water in the burette has reached the zero mark while the water in the bottle is at the same level, the apparatus contains 100 ml of gas measured at atmospheric pressure; turn the three-way cock so that no gas can enter or leave the apparatus. Be careful never to allow the level of the water in the burette to fall while the three-way cock is open to the atmosphere, otherwise air will be drawn into the apparatus which will dilute the gas and render the analysis inaccurate. Raise the leveling bottle, open the stopcock of the first absorption pipette, and force the greater part of the gas into it, then lower the bottle and draw most of the gas back into the burette. Repeat this twice, the last time bringing the absorption liquid to the mark on the absorption pipette, then close the stopcock. Bring the leveling bottle to the point where its water level corresponds to that of the burette, then read off the percentage of carbon dioxide. Repeat the absorption process until the variation is not over 0.2%.

Absorb the oxygen and carbon monoxide in a similar manner in the other two pipettes, obtaining the percentages by difference.

Renew the solutions in the absorption pipettes every two weeks, or as often as is found to be necessary. See Chap. XXV, 14, regarding the preparation of the absorption solutions.

11. LIME TO SLACKER

Determine every 24 hours:

(a) CaO by Titration.

SAMPLING

Obtain a one-pint sample every 2 hours, from the pile of lime from which the slacker is being fed, by breaking off small pieces, approximately one inch cubes. In taking the sample reject such material as sand, coke, unburned limestone, etc., which will be eliminated in the form of discard from the slacker. Keep the samples sealed and in a dry place.

PREPARATION OF SAMPLE

Crush the twelve pints representing the average sample for the 24 hours to one-quarter inch size in a jaw crusher, mix and quarter, repeating the mixing and quartering until the sample is reduced to about one pint. Grind this sample to 60 mesh on a bucking board or in a disc pulverizer. Mix the 60 mesh material and fill a four ounce bottle by taking small portions from various parts of the sample. Seal this sample and take it to the laboratory. Handle the lime as rapidly as possible during the preparation of the sample to avoid absorption of moisture.

ANALYSIS

Determine the CaO by Titration, according to the "General Methods," Chap. I, 11.

12. MILK OF LIME

Determine every hour:

(a) Brix.

(b) CaO (grams in 100 ml).

SAMPLING

Take a catch sample from the discharge line of the pump.

ANALYSIS

(a) *Brix:* Cool under vacuum, mix by inverting the cylinder gently a few times, and determine the Brix in the regular manner, obtaining the reading immediately after mixing before the insoluble material has had time to settle.

(b) *CaO:* Measure out 10 ml of the cooled liquid with a pipette into a porcelain casserole. Add 50-100 ml of water and proceed as in the "General Methods," 11. Subtract the number of ml of alkali from the number of ml of acid used, and divide by 2.

13. LIME CAKE, FIRST PRESSES

Determine every 3 hours:

(a) Total Sugar.
(b) Free Sugar.
(c) CaO.
(d) Sugar to 100 CaO.

SAMPLING (PLATE AND FRAME PRESSES)

All samples are to be taken by a laboratory employe, who should receive the following instructions:

(1) Visit the press floor at irregular intervals.

(2) Sample any press or presses which are being dumped.

(3) As a rule, do not sample a press the washing of which is finished while the employe is on the press floor.

(4) Use a special closed can provided with a tube which cuts a plug one inch in diameter from the cake.

(5) Sample several frames selected at random in each press.

(6) Distribute the points in each frame where samples are taken equally over the face of the cake, taking one plug from each corner and one from the middle of the frame.

(7) At least five presses shall enter into each sample taken to the laboratory for analysis.

NOTE: If conditions warrant it, a man under laboratory supervision should be stationed permanently on the press floor so that all presses dumped may be sampled.

SAMPLING (KELLY PRESSES)

Where the manner of installation permits, catch a portion of the cake discharged from each frame by laying a board diagonally across the hopper before the press is opened, placing one end of the board flush against a corner of the hopper near the press in order that a small portion of any cake which may have fallen off into the drum and may not have been properly washed may be included in the sample. When the press has been emptied, obtain an average sample of the material on the board by means of a sampling device of the kind used for sampling plate and frame presses, or by means of a piece of tubing about 1¼ inches in diameter.

Where the presses are set too low to admit of the board being used, employ a rectangular metal box attached to a long curved handle, the whole of rigid construction, by means of which samples may be caught underneath the several frames as the cake drops off; preserve the various samples taken in a covered container. In catching the samples be careful to avoid any water from the hose used for washing the cake off the frames.

If an appreciable amount of cake falls off into the drum, endeavor to include a proportionate amount of this in the sample. Follow also the general instructions under "Sampling (Plate and Frame Presses)" as far as they can be made to apply to Kelly presses, but do not under any circumstances obtain the sample by scraping the cake from the sides of the outer frames or from the top of the several frames.

PREPARATION OF SAMPLE

Transfer the entire sample to a large iron mortar and mix thoroughly with an iron pestle.

ANALYSIS

(a) *Total Sugar—Method I:* Weigh out 53 grams in a counterpoised Monel metal cup, or "capsule," of about 350 ml capacity. Add from an automatic pipette 177 ml of a 10% solution of commercial zinc nitrate. Put in a piece of metal chain, cover with an aluminum disc enclosed in a rubber envelope, and shake vigorously until the cake has been completely disintegrated. Filter and polarize in a 200 mm tube. The reading gives directly the percentage of total sugar.

Total Sugar—Method II: Weigh out 54 grams in a counterpoised metal cup and add slowly 177 ml of dilute acetic acid (see

Chap. XXV, 1), stirring with a glass rod until most of the foaming has ceased. Put in a piece of metal chain, cover, and shake as in the previous method. Then add 3 ml of basic lead acetate solution, shake again, filter, and polarize in a 200 mm tube. The reading gives directly the percentage of total sugar.

(b) *Free Sugar—Method I:* Weigh out 53 grams and determine as in "Total Sugar—Method I," adding, in place of the zinc nitrate solution, 177 ml of water containing 3 ml of lead acetate in each 177 ml.

Free Sugar—Method II: Weigh out 54 grams, and determine as in "Total Sugar—Method II," adding 177 ml of water without any acetic acid, followed by 3 ml of lead acetate.

(c) *CaO:* Weigh out 5 grams and proceed as in the "General Methods," 11.

(d) *Sugar to 100 CaO:* Multiply the percentage of total sugar by 100 and divide by the percentage of CaO.

14. LIME CAKE, SECOND PRESSES

Determine every 8 hours:

(a) Total Sugar.
(b) CaO.

Sampling and Preparation of Sample

Take and prepare the sample in the same manner as the first lime cake.

Analysis

Determine total sugar and CaO in the same manner as in the first lime cake.

15. LIME SEWER

Determine every 2 hours:

(a) Total Sugar.
(b) CaO.
(c) Sugar to 100 CaO.

Sampling

Obtain a continuous sample if a suitable device is available. In the absence of this take a catch sample at least every hour from the mud mixer, or, in the absence of a mud mixer, at some point in the line leading to the sewer, or if possible at the point of discharge into the sewer. Mix the sample thoroughly until any lumps are broken up, and take a portion to the laboratory. Make up a composite sample every 2 hours.

ANALYSIS

If the material is thin enough to measure readily, use Method II for total sugar. If the material is thick, use Method I.

(a) *Total Sugar—Method I:* Mix the sample well, and determine as in the case of "Lime Cake, First Presses," Method I or Method II.

Total Sugar—Method II: Mix the sample well, measure out 100 ml in a 100-110 ml flask, add a few drops of phenolphthalein and neutralize with acetic acid. Add 3 ml of lead acetate, make up to the 110 ml mark with water, shake, filter, and polarize in a 200 mm tube. Obtain the "grams of sugar in 100 ml" from Table 6.

(b) *CaO:* If the total sugar has been determined by taking a definite weight of the material, mix the sample well, weigh out 10 grams, and determine as in the case of "Lime Cake, First Presses." Subtract the number of ml of alkali from the number of ml of acid used, and divide by 2.

If the total sugar has been determined by measuring out a definite volume, use 10 ml, or a multiple thereof, and determine as in the case of "Lime Cake, First Presses." If 10 ml is used, subtract the number of ml of alkali from the number of ml of acid used, and divide by 2.

(c) *Sugar to 100 CaO:* Multiply the percentage of total sugar by 100 and divide by the percentage of CaO.

16. EXCESS WATER

Determine every 4 hours:

(a) Brix.
(b) Total Sugar.

SAMPLING

Obtain the sample from the excess water tank or pump.

ANALYSIS

(a) *Brix:* Follow the "General Methods," 1 (a).

(b) *Total Sugar:* Determine as in the case of "Lime Sewer, Total Sugar—Method II."

17. SWEET WATER.

Determine every 4 hours on a catch sample:

(a) Brix.

Determine every 8 hours on a catch sample:

(b) Apparent Purity.

(c) Lime Salts (CaO to 100 Brix).

SAMPLING

Take a catch sample from the sweet water tank every 4 hours.

ANALYSIS

(a) *Brix:* Follow the "General Methods," 1 (a).

(b) *Apparent Purity:* Evaporate to approximately thin juice density, and carbonate and proceed as in the case of "5. First Saturation Juice."

(c) *Lime Salts (CaO to 100 Brix):* Use the carbonated solution prepared for the apparent purity determination, and follow the "General Methods," 12 (b).

18. FILTER CLOTH WASH WATER

Determine every 8 hours:

(a) Sugar.

SAMPLING

Take a small sample from each tank or washing machine emptied to the sewer, and keep in a covered container. Do not include in the sample any water returned to the process.

ANALYSIS

Mix well and determine as in the case of "Lime Sewer, Total Sugar Method II."

19. MAIN SEWER

Determine every 2 hours:

(a) Sugar.

SAMPLING

Take a catch sample every 2 hours at a point where it will represent all sewer water leaving the main factory, but avoiding the pulp silo drainage if possible. Or take more frequent samples and composite every 2 hours.

ANALYSIS

Mix well and determine as in the case of "Lime Sewer, Total Sugar—Method II." Polarize in a 400 mm tube and obtain the percentage of sugar from Table 7.

20. WHITE PAN STORAGE TANKS

Determine at least every 8 hours:

(a) Brix.
(b) Alkalinity.
(c) Apparent Purity.

SAMPLING

Take samples from each tank on the pan floor at the beginning of every shift. Special samples sent to the laboratory at any time during the shift may be used in lieu of these samples.

ANALYSIS

Follow the "General Methods."

21. WHITE MASSECUITE

Determine on every pan dropped:

(a) Brix.
(b) Alkalinity.
(c) Apparent Purity.
(d) Lime Salts (CaO to 100 Brix).

Sampling

Take the sample from the pan or from the spout leading to the mixer before the pan is steamed out.

Analysis

Follow the "General Methods."

22. HIGH GREEN AND WASH SYRUPS

Determine either once or twice during the spinning of every pan, or at regular intervals of every 2 hours:

(a) Apparent Purity.

Sampling

Take the samples from the machine receiving tanks where such tanks are in use, otherwise from the troughs leading from the machine spouts to the pumps, or from the pumps. Whenever possible obtain samples that have been mixed by steam. Do not take the samples from the machine spouts.

Analysis

Follow the "General Methods."

23. MOISTURE IN WHITE SUGAR

Determine moisture every 8 hours in the following samples:

(1) Wet Sugar.
(2) Sugar leaving upper granulator.
(3) Standard granulated.
(4) Table granulated.

Sampling

Provide a sufficient number of 1 x 3 inch test tubes and rubber stoppers; it is advisable to heat both the test tubes and stoppers in a drying oven to make sure that they are perfectly dry. Sample each kind of sugar every 2 hours by filling a test tube, and stopper immediately. Make up a composite sample every 8 hours for each kind of sugar sampled by emptying the four individual samples into a wide mouth, glass stoppered bottle and mixing thoroughly.

Obtain the wet sugar from the discharge into the wet box or from the feed of the wet box to the upper granulator. Sample the "sugar leaving upper granulator" at the discharge from the upper to the lower granulator. Obtain the Standard and Table granulated at the discharge from the dry boxes into the bag. If the factory has only a single granulator system, omit sample (2).

ANALYSIS

Place approximately 5 grams in the case of wet sugar, and 10 grams in the case of granulated, in a 2 x 1½ inch aluminum dish provided with a cover, which has been previously dried at 100-105°. Cover the dish, and weigh accurately, but as rapidly as possible, on an analytical balance. Remove the cover and dry at 100-105° in a glycerin oven for 5 hours. Replace the cover, cool in a desiccator over sulphuric acid, and weigh. Keep thermometers in the desiccator and balance case, and do not make the weighings until the difference in temperature is 2° or less. The loss in weight after 5 hours heating is considered to represent the amount of moisture.

NOTE: *The concentrated sulphuric acid in the desiccator must be renewed once every week, experience having shown that sugar, after drying for 5 hours or more, is capable of absorbing water from strong acid after it has become diluted with small amounts of moisture. The acid should be renewed also at any time when it becomes discolored from contamination with organic matter. The cover of the desiccator should be frequently cleaned and coated with fresh vaseline.*

24. PERCOLATION TESTS OF WHITE SUGAR

If the white sugar is not up to standard, make percolation tests occasionally to obtain an approximate idea of how much of the color is due to adhering syrup which should have been washed out in the centrifugal machines.

Close the bottom of a one-pint Oldberg percolator with a loosely fitting cotton plug, put in 250 grams of sugar and add 250 ml of distilled water. Catch the percolate in 1 x 6 inch text tubes in four or five successive portions, and compare the color of the solutions.

25. DUST BOX

Determine every 8 hours:

(a) Brix.

(b) Alkalinity.
(c) Apparent Purity.

SAMPLING

Take a catch sample of the liquid in the dust box.

ANALYSIS

Follow the "General Methods."

26. REMELT PAN STORAGE TANKS

Determine at least every 8 hours:

(a) Brix.
(b) Apparent Purity.

SAMPLING

See "White Pan Storage Tanks."

ANALYSIS

Follow the "General Methods."

27. REMELT MASSECUITE FROM PAN

Determine on every pan dropped:

(a) Brix.
(b) Alkalinity.
(c) Apparent Purity.
(d) Lime Salts (CaO to 100 Brix).

Determine every 24 hours:

(e) True Purity.
(f) Raffinose (% on dry substance).

SAMPLING

Take the sample from the pan or from the trough leading to the crystallizers before the pan is steamed out.

ANALYSIS

Follow the "General Methods." Obtain the dry substance for the true purity determination either by the refractometer or by oven drying.

28. REMELT MASSECUITE FROM CRYSTALLIZER.

Determine on every crystallizer dropped:

(a) Brix.
(b) Alkalinity.
(c) Apparent Purity.

SAMPLING

Take a sample from the discharge of the crystallizer a few minutes after the gate has been opened.

ANALYSIS

Follow the "General Methods."

29. LOW GREEN AND WASH SYRUPS.

Determine either once or twice during the spinning of every crystallizer, or at regular intervals of every 2 hours:

(a) Apparent Purity.

SAMPLING

Sample in the same manner as "High Green and Wash Syrup."

ANALYSIS

Follow the "General Methods."

30. REMELT SUGAR

Determine every 4 hours:

(a) Apparent Purity.
(b) Polarization.

Determine every 24 hours:

(c) Sulphuric Acid (SO_3).

SAMPLING

A laboratory employe should take samples at irregular intervals, preferably from the discharge of the scroll into the melter, or at some other suitable place if this is not possible. Keep in a covered can, and mix thoroughly before analysis, taking care to break up any lumps. For the sulphuric acid determination make up a 24 hour composite sample by mixing equal portions of the samples prepared every 4 hours for the regular laboratory analysis.

ANALYSIS

(a) *Apparent Purity:* Weigh out 130 grams in a counterpoised copper beaker, dissolve in hot water, pour into a 500 ml Kohlrausch flask, rinsing the beaker with water, cool to approximately 20°, make up to the mark with water, shake well, and determine the apparent purity as in the "General Methods."

(b) *Polarization:* Increase the polariscope reading obtained in the apparent purity determination by one-tenth of its value.

(c) *Sulphuric Acid (SO_3):* Follow the "General Methods," using 20 grams of material.

31. SUGAR MELTER

Determine every 8 hours:

(a) Brix.

(b) Apparent Purity.

Determine every 2 hours, when lime is added to the melter:

(c) Alkalinity.

SAMPLING

Take a catch sample from the melter or melter pump.

ANALYSIS

(a) *Brix* and (b) *Apparent Purity:* Follow the "General Methods." In case lime is added to the melter, the sample should be carbonated and filtered before the purity is determined, as in the case of "First Saturation Juice."

(c) *Alkalinity:* Measure out 10 ml and titrate in the cold with N/28 sulphuric acid according to the "General Methods."

32. MOLASSES PRODUCED

Determine every 8 hours:

(a) Brix.

(b) Sugar.

(c) Apparent Purity.

Determine at least every 24 hours:

(d) True Purity.

(e) Raffinose (% on dry substance).

SAMPLING

Draw at least one sample from every scale tank weighed, and if possible take several samples at intervals during the period when the tank is being filled or emptied. Composite the individual samples in a large bucket and mix well before analysis.

ANALYSIS

Follow the "General Methods." Obtain the dry substance for the true purity determination either by the refractometer or by oven drying.

33. CONDENSED WATERS

Examine every hour:

(a) Boiler feed water (both the "tank" and "returned direct"), press wash water, pure and impure battery supply water.

Examine every 2 hours:

(b) All individual pan and evaporator tail pipes.

SAMPLING

Collect continuous samples with an automatic sampling device. Protect the samples from contamination both during the time when they are being drawn and when they are being brought to the laboratory.

See Chap. XVII, 2, regarding the collection of campaign samples for analysis, and of weekly samples of battery supply water.

EXAMINATION

Test with alpha-naphthol as described in the "General Methords," I, 13. As the reagents employed frequently become contaminated, check them up every day with water of negative reaction.

NOTE: If sugar is found, determine the source at once and report it to the operating department. It is desirable to have in use a "board" or some system representing a flow chart of the condensed waters, in order that the source of sugar may be readily and quickly located.

34. BOILER WATER.

Determine every 8 hours on each boiler in service:

(a) Alkalinity.

SAMPLING

Draw from the sampling line, first allowing the water to run a few moments to rinse out the pipe.

ANALYSIS

Measure out 10 ml with a pipette into a porcelain dish and follow the "General Methods," 10 (a), using phenolphthalein as indicator. Dilute with sufficient neutral water to make the color reaction distinct.

35. WEEKLY COMPOSITE SAMPLES

Determine:

(a) Brix.
(b) Apparent Purity.
(c) Dry Substance (by oven drying).
(d) Sugar (direct polarization).
(e) Sugar by Inversion.
(f) Raffinose.
(g) Invert Sugar.
(h) Ash (Sulphated).
(i) Undetermined.
(j) Lime Salts (CaO to 100 Brix).
(k) Sulphuric Acid (SO_3).
(l) Organic Coefficient.
(m) Dry Substance (by refractometer, if available).

SAMPLING

Make up an average sample of each of the following products by taking equal portions of each sample brought to the laboratory during the week and preserving in a sealed jar or stoppered bottle.

(1) Evaporator Thick Juice.
(2) White Massecuite.
(3) Remelt Massecuite (from pan).
(4) Remelt Sugar.
(5) Molasses Produced.
(6) Molasses Worked.
(7) Cold Saccharate Cake.
(8) Cold Perfectly Washed Saccharate Cake.
(9) Hot Saccharate Cake.
(10) Hot Perfectly Washed Saccharate Cake.
(11) Saccharate Milk.

In the case of the saccharate cakes and milk, use the thick syrup obtained by evaporating the thin juice from the apparent purity determination to 60-70° Brix on a water bath. Concentrate this juice as soon as it is available, not allowing it to stand in a thin condition. When the massecuite samples are desired for analysis, heat the containers by immersion in hot water, remove the contents, and mix thoroughly in order to obtain a uniform mixture of sugar crystals and mother syrup.

ANALYSIS

Follow the "General Methods." Analyses may be made, if desired, on "double diluted" solutions in the case of massecuites, raw sugar, and molasses, using twice the amount of material as when analyzing original material direct. Preserve the double diluted solutions from decomposition with 3 to 4 drops of a 40% formaldehyde solution, but do not use any double diluted material which has stood for more than eight hours. Determine the dry substance in Remelt Sugar by heating approximately 5 grams without dissolving in water and without the use of sand.

Make all the prescribed determinations except as follows:

(1) Omit the Brix determination in the case of Remelt Sugar.

(2) In the case of the Cold and Hot Perfectly Washed Cakes determine only the Brix, dry substance, sugar, sugar by inversion, raffinose, ash, and apparent purity.

To obtain the "percentage on dry substance" in any case, multiply the "percentage on original" by 100 and divide by the percentage of dry substance. Use the dry substance found by oven drying in calculating percentages on dry substance.

To obtain (i) Undetermined, subtract from 100 the sum of the percentages of (e) Sugar by Inversion, (f) Raffinose, (g) Invert Sugar, and (h) Ash (all percentages on dry substance).

Calculate (1) Organic Coefficient as described in the "General Methods," I, 8.

NOTE: See Chap. XVII, 2 (b) regarding the collection of weekly average samples of pure and impure battery supply water for the determination of total solids.

36. TEMPERATURE DATA.

GENERAL

Obtain the necessary temperature data either from the charts of recording thermometers or by averaging readings taken every 2 hours by a laboratory employe. Check recording thermometers previous to every campaign, and if possible at occasional intervals during the campaign. It is advisable to have provision for a well near each recording thermometer, by means of which the latter may be checked *in situ* with an accurate indicating thermometer.

The following directions apply to particular cases.

DIFFUSION BATTERY TEMPERATURE READINGS

A laboratory employe should take a series of readings of the thermometers on each battery, starting in every case at the "cossette cell" and continuing successively along the other cells in circulation. Do not record readings of any cells not in circulation at the time. Take the readings at least every 2 hours.

In order that the figures obtained may be comparable at all factories, observe also the following precautions:

(1) Commence the readings immediately after the period of "sending over" begins and not during the period of diffusing a fresh cell.

(2) The figure reported for the temperature of cell No. 1 should represent the temperature of the juice entering the cossette cell and not the temperature of the juice from the cossette cell which goes to the measuring tank.

(3) The last temperature reading should represent the temperature of the battery supply water entering the "pulp" or "water" cell. The arrangement of thermometers on the batteries

is such that in most cases this reading can be obtained from a battery thermometer.

(4) As the position of the thermometers on different batteries varies, the matter should be gone over individually at each factory and arrangements should be made to have the readings properly taken.

Obtain the "average maximum temperature of the battery" by averaging the temperature readings of those cells carried at the maximum temperature.

Juice Leaving First Presses

Obtain every 2 hours by filling a sample bucket from the press cocks and taking a reading immediately with a mercury thermometer.

Sugar Leaving Upper Granulators

Fill a sample bucket every 2 hours from the discharge from the upper to the lower granulator and insert the bulb of a mercury thermometer into the middle of the mass of sugar.

Sugar as Sacked

Take readings every 2 hours by inserting a mercury thermometer deeply into a bag of sugar just filled at the sacking station.

Remelt Massecuite as Dropped

Insert a mercury thermometer in the sample taken for the laboratory analysis; obtain the reading immediately after the sample is taken. Or obtain the information from the pan recording thermometer or the sugar boiler's record.

Remelt Massecuite as Spun

Take a sample every 2 hours from the goosenecks of the mixer and insert a mercury thermometer.

III. SULPHATE CONTROL

1. INTRODUCTION

Whenever the concentration of sulphuric acid in the remelt massecuite exceeds the amount which can be held in solution and eliminated in the molasses (usually 1.0—1.5 per cent SO_3 on molasses dry substance), the excess crystallizes out, mostly as potassium sulphate, in the remelt sugar. This not only impairs the quality of the remelt sugar, but may even in extreme cases lead to the presence of small amounts of SO_3 in the white sugar. The usual practice to control this is the treatment of the melted sugar, when necessary, with barium oxide, calcium chloride, or lime. The special sulphate control described in this chapter is designed to throw light on the amount of sulphuric acid in the various products, including the amount formed in sulphuring the juice, and on the efficacy of the melted sugar treatment when used.

The determination of sulphuric acid (SO_3) in the remelt sugar (see section 7) is prescribed as a regular daily test. The determination should be made also in the white sugar (section 6) whenever the SO_3 in the remelt sugar exceeds 1.00 per cent. The determinations described in sections 7—10 should be made whenever treatment for the removal of sulphates is being employed. The determinations described in sections 2—6 are for use on special occasions when it is desired to investigate the amount of sulphuric acid formed at the sulphur stations.

2. SECOND SATURATION JUICE

Determine:

(a) Sulphuric Acid (SO_3 to 100 Brix).

SAMPLING

Make up a composite sample by mixing equal amounts of the composite samples prepared every 4 hours for the regular laboratory analysis. (See Chap. II, 6.) Use a few drops of formaldehyde to preserve the samples.

ANALYSIS

(a) *Sulphuric Acid (SO_3 to 100 Brix):* Follow the "General Methods," Chap. I, 9. Either determine the Brix or use the average of the regular Brix determinations.

3. THIRD SATURATION JUICE

Determine:

(a) Sulphuric Acid (SO_3 to 100 Brix).

SAMPLING AND ANALYSIS

Make up a composite sample and analyze in a similar manner to "2. Second Saturation Juice."

4. BLOW-UP THICK JUICE BEFORE SULPHUR

Determine:

(a) Sulphuric Acid (SO_3 to 100 Brix).

SAMPLING AND ANALYSIS

Make up a composite sample from the samples of evaporator thick juice prepared every 4 hours for the regular laboratory analysis, and analyze in a similar manner to "2. Second Saturation Juice."

Note: If melted sugar is added to the blow-ups, this determination is of no value.

5. BLOW-UP THICK JUICE AFTER SULPHUR

Determine:

(a) Brix.

(b) Sulphuric Acid (SO_3 to 100 Brix).

Sampling and Analysis

Make up a composite sample from the samples prepared every 4 hours for the regular laboratory analysis, and analyze in a similar manner to "2. Second Saturation Juice." Determine the Brix in the regular manner.

6. WHITE SUGAR

Determine every 24 hours:

(a) Sulphuric Acid (SO_3 on original).

Sampling

Make up a composite sample by mixing equal amounts of the samples of Standard granulated sugar prepared every 8 hours for the moisture determination.

Analysis

Follow the "General Methods," I, 9. Make a blank SO_3 test on the distilled water and reagents, and deduct the correction found from the amount found in the analysis of the sugar.

7. REMELT SUGAR

Determine every 24 hours:

(a) Sulphuric Acid (SO_3 on original).

Sampling

Make up a composite sample by mixing equal portions of the samples prepared every 4 hours for the regular laboratory analysis.

Analysis

Follow the "General Methods," making sure that an excess of barium chloride solution is added.

Note: This is a test required in the "Regular Factory Control." See Chap. II, 30, (c).

8. MELTED SUGAR BEFORE TREATMENT

Determine every hour:

(a) Alkalinity. (Determine only when lime or barium oxide is used for treatment.)

Determine every 24 hours:

(b) Brix.

(c) Sulphuric Acid (SO_3 to 100 Brix).

SAMPLING

If lime or barium oxide is being used for treatment, which is usually continuous, take a catch sample from the melter every hour. If calcium chloride is used for treatment, which is usually intermittent, take a catch sample of each lot treated previous to the addition of the calcium chloride. Make up a composite sample by mixing equal portions of the individual samples.

ANALYSIS

(a) *Alkalinity:* If the alkalinity is 0.2 or less, titrate 10 ml with N/28 acid according to the general method for alkalinity. If the alkalinity is higher, titrate 50 ml with Steffen acid; in this case divide the number of ml of acid used by 10 to obtain the alkalinity in terms of "grams of CaO per 100 ml."

(b) *Brix* and (c) *Sulphuric Acid* (SO_3 *to 100 Brix*)*:* Follow the "General Methods."

9. MELTED SUGAR AFTER TREATMENT

Determine every 8 hours, as in regular factory control:

(a) Brix.

(b) Apparent Purity.

Determine every 24 hours:

(c) Sulphuric Acid (SO_3 to 100 Brix).

SAMPLING

Take a catch sample every 2 hours, if possible, from the cocks or trough of the filter press. Mix equal amounts of these samples to obtain the composite samples when needed.

ANALYSIS

(a) *Brix* and (b) *Apparent Purity:* Follow the "General Methods." In case lime or barium oxide is added to the melter, the sample should be carbonated and filtered before the purity is determined, as in the case of "First Saturation Juice." (See Chap. II, 5.)

(c) *Sulphuric Acid (SO_3 to 100 Brix):* Follow the "General Methods."

10. SULPHATE CAKE

Determine every 24 hours:

(a) Sugar.

(b) Sulphuric Acid (SO_3).

SAMPLING

Follow in general the method of sampling outlined under "Lime Cake, First Presses," Chap II, 13.

ANALYSIS

(a) *Sugar:* Use either of the methods for "total sugar" described under "Lime Cake, First Presses," Chap. II, 13 (a).

(b) *Sulphuric Acid (SO_3):* Weigh out 2—5 grams of cake, add 100 ml of water, neutralize with hydrochloric acid, and add 3 ml in excess. Boil for a few minutes, filter, and proceed as in the "General Methods," Chap. I, 9, making sure that an excess of barium chloride solution is added.

IV. STEFFEN PROCESS CONTROL

1. GENERAL

All samples in connection with the Steffen Process control must be taken by a laboratory employe.

2. MOLASSES WORKED

Determine every 8 hours:

(a) Brix.
(b) Sugar.
(c) Apparent Purity.

Determine every 24 hours:

(d) Sugar by Inversion (Per cent on original).

Sampling

Take a catch sample at least every 2 hours, and preferably every hour, at the molasses scale tank. Keep the individual samples in a covered container, and mix thoroughly previous to analysis.

Analysis

Follow the "General Methods." Determine the direct polarization and the polarization after inversion on a composite sample representing the molasses worked during the entire 24 hours, and calculate the percentage of "sugar by inversion" in the molasses.

3. SOLUTION FOR COOLER

Determine every 3 hours:

(a) Brix.

(b) Alkalinity.

(c) Sugar (grams in 100 ml).

SAMPLING

Take a catch sample of the solution in the cooler after the propeller has been started and immediately preceding the beginning of the lime addition.

ANALYSIS

(a) *Brix:* Follow the "General Methods."

(b) *Alkalinity:* Mix the sample well and transfer 50 ml with a pipette to a 100 ml flask. Add a few drops of phenolphthalein and titrate to neutrality with Steffen standard acid (1 ml = .05 g CaO). Divide by 10 the number of ml of acid required. See "General Methods," I, 10 (c).

(c) *Sugar:* Add 3—6 ml of basic lead acetate to the neutralized solution obtained in (b), fill to the 100 ml mark with water, shake, filter, and polarize in a 200 mm tube. Multiply the reading by .52 or use Table 9, to obtain the grams of sugar in 100 ml.

4. LIME POWDER

Determine every 8 hours:

(a) Loss on Ignition.

(b) CaO by Titration.

(c) Percentage Coarser than 200 mesh.

SAMPLING

Take a catch sample every hour from the discharge of each mill in operation, taking an equal amount of material from each mill. Composite the hourly samples by transferring to glass bottles provided with tightly fitting rubber or ground stoppers, keeping separate samples for each mill. For (a) *Loss on Ignition* and (b) *CaO by Titration,* make up a composite sample by taking equal portions from each mill composite and mixing thoroughly.

ANALYSIS

(a) *Loss on Ignition:* Weigh out approximately 1 gram on an analytical balance, in a covered platinum crucible. Ignite to constant weight in an electric furnace or over a good blast lamp, cool in a desiccator, and weigh. Multiply the loss in weight by 100 and divide by the weight of the sample.

(b) *CaO by Titration:* Weigh out 5 grams, transfer to a porcelain casserole, and follow the "General Methods," I, 11.

(c) *Percentage Coarser than 200 mesh:* Determine for each mill separately. Weigh out 20 grams on a pulp balance, and transfer to a 200 mesh, brass wire sieve (width of opening = .0029 inch). Brush the material carefully with a two-inch flat camel hair brush until practically no more fine powder passes through. Weigh the coarse residue on a pulp balance. Multiply the weight of the residue by 5 to obtain the percentage. When the sieve becomes clogged, clean it with hydrochloric acid, rinse it well with water, and dry it in a warm place.

SPECIAL DETERMINATIONS

(d) *Sugar-soluble CaO:* Rinse 5 grams of lime powder into a 200 ml flask, and add 150 ml of a freshly prepared, 25° Brix sugar solution. (Or add approximately 40 grams of sugar and dissolve by the addition of water.) Fill to the mark with water, stopper the flask and shake vigorously, repeating the shaking at short intervals as the lime settles to the bottom. Filter at the end of thirty minutes, and titrate 100 ml with the standard nitric acid (1 ml = .05 g CaO), using phenolphthalein as indicator. Multiply by 2 the number of ml of acid required, to obtain the percentage of CaO.

(e) *Slacking Test:* Into a beaker of 250 ml capacity measure out 100 ml of water at exactly 20°. Add 25 grams of the lime powder, using a thermometer as a stirring rod, and continue to stir until there is no further rise in temperature. Record the number of degrees increase in temperature over the original 20°, and the number of minutes required to attain the maximum temperature.

5. COOLER WASTE WATER

Determine every hour:

(a) Sugar (grams in 100 ml).

SAMPLING

Take a catch sample, *just previous to the time it is required for analysis,* from a finished cooler, after all the lime has been added, and just before the finished cooler is dropped.

ANALYSIS

Filter a portion immediately through filter paper. Transfer 50 ml of the filtrate with a pipette to a 100 ml flask, add a few drops of phenolphthalein, neutralize with Steffen standard acid, and proceed as in the determination of sugar in "Cold Press Waste Water," 6 (c).

6. COLD PRESS WASTE WATER

Determine every 2 hours:

(a) Brix.
(b) Alkalinity.

Determine every hour:

(c) Sugar (grams in 100 ml).

SAMPLING

Collect a continuous sample from the cold waste water line in the manner described below under "7. Total Waste Water," or take a catch sample every hour from the discharge of the cold presses. Mix the sample well before analysis.

ANALYSIS

(a) *Brix:* Follow the "General Methods."

(b) *Alkalinity:* Transfer 50 ml with a pipette to a 100 ml flask. Add a few drops of phenolphthalein and titrate to neutrality with Steffen standard acid (1 ml = .05 g CaO). Divide the number of ml of acid required by 10. See "General Methods," I, 10 (c).

(c) *Sugar:* Add 2—4 ml of basic lead acetate to the neutralized solution obtained in (b), fill to the 100 ml mark with water, shake, filter, and polarize in a 200 mm tube. Multiply the reading by .52, or use Table 9, to obtain the grams of sugar in 100 ml.

7. TOTAL WASTE WATER

Determine every 2 hours:

(a) Brix.
(b) Alkalinity.

Determine every hour:

(c) Sugar (grams in 100 ml).

SAMPLING

Collect an average sample from the pipe line which conducts the final waste water outside the factory, by means of a continuous, automatic sampling device which delivers into a large vessel provided with an overflow at the top and a drain at the bottom. Mix the entire sample, take a small portion for analysis, and empty out the remainder by opening the drain valve.

If for any reason it is impossible to secure a continuous sample, take a catch sample every hour. Mix the sample well before analysis.

ANALYSIS

Analyze as in the case of "Cold Press Waste Water," cooling first if necessary.

8. COLD WASH WATER (FINAL)

Determine every 4 hours:

(a) Brix.

SAMPLING

Sample the wash water coming from the presses at the time when the washing is finished. The sample used for analysis should preferably represent a composite of samples obtained from at least three presses. This sample cannot be obtained at factories equipped with vacuum filters.

ANALYSIS

Determine the Brix in the regular manner.

9. COLD WASH WATER (AVERAGE)

Determine every 4 hours:

(a) Brix.
(b) Alkalinity.
(c) Sugar (grams in 100 ml).

SAMPLING

Take a sample from the wash water tank.

ANALYSIS

Analyze as in the case of "Cold Press Waste Water."

10. HOT WASH WATER (FINAL)

Determine every 4 hours:

(a) Brix.
(b) Alkalinity.
(c) Sugar (grams in 100 ml).

Sampling

Sample in the same manner as the final cold wash water. The sample must represent the wash water coming from the hot presses at the time when the washing is finished. At factories equipped with vacuum filters, where this sample cannot be obtained, substitute the ''average'' hot wash water.

Analysis

Analyze as in the case of ''Cold Press Waste Water.''

11. COLD SACCHARATE CAKE

Determine every 3 hours:

(a) Apparent Purity.
(b) Lime Salts (CaO to 100 Brix).

Determine every 8 hours:

(c) Apparent Purity (Perfectly Washed).
(d) Sugar.
(e) CaO.
(f) CaO to 100 Sugar.

Determine every 24 hours:

(g) Moisture.
(h) True Purity.
(i) Raffinose (Per cent on dry substance).
(j) True Purity (Perfectly Washed).

Sampling

Take a sample once an hour from various parts of the cake in several frames, using a spoon and bucket. In the case of vacuum filters take small portions of the material dropping from the drums of all the units in operation. Sample Kelly Presses in the manner described under II, 13, ''Lime Cake Sampling (Kelly Presses).''

Preserve the samples in a covered container and make up composite samples at the times when the various determinations are due, except as otherwise noted. Mix all composite samples well.

ANALYSIS

(a) *Apparent Purity:* The following special apparatus is needed: A carbonator with steam and carbon dioxide gas connections, and an evaporator heated by steam, both so constructed as to obviate any possibility of burning the juice.

Mix a suitable amount of the cake with 4—5 parts of water until a homogeneous mixture is obtained. Transfer to the laboratory carbonator, heat to 80—85°, and carbonate at this temperature to faint alkalinity with phenolphthalein. Do not carbonate to neutrality or acidity. When the carbonation is finished, heat to boiling, and filter. Concentrate sufficient of the filtrate to about 23° Brix in the laboratory evaporator, being careful not to carry the evaporation much beyond this point on account of the danger of burning the juice. Draw off the liquid into a copper can or suitable vessel, and carbonate again to faint alkalinity. Filter, preferably under vacuum through a Buechner funnel. Cool the filtrate in a cylinder and determine the apparent purity as described in the "General Methods."

(b) *Lime Salts (CaO to 100 Brix):* Use 10 ml of the solution prepared for the apparent purity determination, and follow the "General Methods," 12 (a).

(c) *Apparent Purity (Perfectly Washed)—Apparatus:* Use the regular equipment which consists of a closed cylindrical reservoir, a small filter press, a vacuum leaf filter, and a rectangular tank divided into two sections, each of which is subdivided into two compartments by partitions extending nearly to the bottom. The reservoir has the necessary fittings at the bottom for connecting it to the small press or the vacuum leaf. Vacuum, air pressure, charging lines, and a relief valve are provided at the top of the tank. Clean the filter cloths frequently with hydrochloric acid and water.

Use whichever of the following methods is found to give the most consistent results:

Method I (Elutriation): Add 3 parts of the coldest water obtainable to 1 part of the sample, and stir until all lumps are broken up and a perfectly homogeneous mixture is obtained. Filter immediately through the laboratory press, allowing the pressure to rise gradually to 40 pounds per square inch and maintaining this pressure until the filtrate ceases to flow or comes in slow drops. Mix the cake thus obtained with 4—5 parts of water, and proceed exactly as under (a) "Apparent Purity."

Method II (Vacuum Filtration): Fill one section of the rectangular tank of the equipment described above with finished cooler solution and submerge the leaf in one of the compartments. Open the valves in the vacuum line at the top of the reservoir and in the line connecting the leaf to the bottom of the reservoir, keeping all other valves closed. Maintain a vacuum of at least 15 inches on the gage and allow the cake to form until it is flush with the guide, stirring the solution continually during filtration in order to insure the formation of an even cake. When cake of the required thickness has formed, transfer the leaf to the other section of the tank which has been filled with *cold water,* and allow 8 liters of wash water to pass through the cake; this is most easily measured by observing the level of the water at the time when washing is commenced and gradually adding 8 liters of cold water. When the same level is reached after the addition of the 8 liters, remove the leaf from the tank and allow the cake to dry for 5 minutes with the vacuum on. Shut off the vacuum, remove the cake, mix it with 4—5 parts of water, and proceed exactly as under (a) "Apparent Purity." If the cake cracks before the washing is completed, discard it and repeat the test. Clean the leaf frequently by washing it first with hydrochloric acid and then with water.

Method III (Combined Elutriation and Washing): Take a catch sample of finished cooler solution (about 10 liters is required), and filter it immediately through the 3¾ inch frame of the laboratory filter press under 30 pounds air pressure; do not allow air to go through the cake by permitting the reservoir to run empty. This will produce a cake weighing 5¾ pounds. Mix this cake thoroughly and quickly with 100% of cold water, 5¾ pounds or 2600 ml, and filter through the 2½-inch frame of the small press at 30 pounds pressure; again, do not allow air to pass through the cake. This will produce a cake weighing 4¾ pounds. Drain and wash out the reservoir, then *introduce 100% of cold water, 4¾ pounds or 2150 ml, and force it through the cake at 15 pounds pressure, allowing air to pass through the cake for one-half minute after the water has all gone through. This yields a final cake of uniform weight and moisture content. Mix this cake with 4—5 parts of

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*It will facilitate the washing if the plug at the top of the 2½ inch frame is removed and a small rod is forced through the cake to the port.

water, and proceed exactly as under (a) "Apparent Purity." If the two frames used are not of exactly the dimensions given, obtain a sufficient number of weights of cake to establish the amount of water required for elutriation and washing, which should be 100% on the weight of the cake in each case.

(d) *Sugar:* Weigh out 13 grams of the cake in a counterpoised nickel dish, reduce to a thin cream with water, and rinse into a 100 ml flask. Add a few drops of phenolphthalein and neutralize with dilute acetic acid, avoiding any great excess. Cool, add 3—5 ml of lead acetate, fill to the mark with water, shake, filter and polarize in a 200 mm tube. Multiply the polariscope reading by 2 to obtain the percentage of sugar.

(e) *CaO:* Weigh out 10 grams of the cake, transfer to a porcelain casserole, and follow the "General Methods," I, 11. Subtract the number of ml of alkali from the number of ml of acid used, and divide by 2 to obtain the percentage of CaO.

(f) *CaO to 100 Sugar:* Multiply the percentage of CaO by 100 and divide by the percentage of sugar.

(g) *Moisture:* Weigh out approximately 10 grams of the composite cake sample in a covered aluminum dish, and dry for 5—6 hours at 100—105° as under the determination of dry substance in the "General Methods," repeating the drying for one hour periods until the loss in any period is not over 0.2%.

(h) *True Purity:* Evaporate on a water bath to approximately 50° Brix a sample composed of equal portions of the 23° Brix juice used for the apparent purity determinations. Determine the true purity as in the "General Methods." Obtain the dry substance either by the refractometer or by oven drying.

(i) *Raffinose (Per cent on dry substance):* This is obtained in connection with the true purity determination.

(j) *True Purity (Perfectly Washed):* Make up a composite sample and determine as under (h), using equal portions of the 23° Brix juice prepared for the determination of the apparent purity of the perfectly washed cakes.

12. HOT SACCHARATE CAKE

Determine every 8 hours:

(a) Apparent Purity.
(b) Lime Salts (CaO to 100 Brix).
(c) Apparent Purity (Perfectly Washed).

(d) Sugar.
(e) CaO.
(f) CaO to 100 Sugar.

Determine every 24 hours:

(g) Moisture
(h) True Purity.
(i) Raffinose (% on dry substance).
(j) True Purity (Perfectly Washed).

Sampling

Follow the methods described under "11. Cold Saccharate Cake." In the case of Vallez presses, obtain the sample from the discharge of the press scroll before the water is turned on. If two different kinds of filters are in use, adjust the system of sampling so as to show the relative efficiency of the two types.

Analysis

Follow the methods under "11. Cold Saccharate Cake." In making the perfectly washed cake, use Method I with the following modifications and precautions: (1) Use a catch sample of the hot saccharate cake, not allowing it to cool any more than can be avoided; (2) Elutriate with hot water (nearly boiling); (3) Heat up the apparatus with hot water before starting the filtration.

13. SACCHARATE MILK

Determine every hour:

(a) Brix.
(b) CaO (grams in 100 ml).

Determine every 4 hours:

(c) Apparent Purity.

Sampling

Take a catch sample from the discharge line of the pump. For the purity determination make up a composite sample from equal amounts of the four previous hourly samples.

Analysis

(a) *Brix* and (b) *CaO:* Determine as in the case of "Milk of Lime," Chap. II, 12.

(c) *Apparent Purity:* To a composite of the previous hourly samples add 3—4 parts of water, mix well, and proceed with the carbonation, etc., as under 11 (a), "Cold Saccharate Cake—Apparent Purity."

14. SMALL COOLER TESTS

Make occasional tests with the laboratory cooler to check up the efficiency of the factory coolers. See Chap. XXIII, 5 and 17, for directions regarding the speed and operation of the cooler.

Determine:

(a) Sugar in "Solution for Cooler."
(b) Lime Added to 100 Sugar.
(c) Sugar in Waste Water.
(d) Percentage of Sugar Precipitated.

Record also the temperature at start and finish, and the time required to add the lime.

SAMPLING

Use a sample of molasses and dilute with water to the required density or take a sample of the "Solution for Cooler" from the factory coolers. Take also a sample of the lime powder being used in the Steffen House at the time.

OPERATION OF COOLER TEST

See that the cooler is clean and well drained, and pour in 14,050 ml of the molasses solution. Commence the circulation of the cooling water. Allow the solution in the cooler to come to perfect rest, in order to prevent the formation of foam when the propeller is started, then start the propeller, and, when the solution has become well mixed, remove 50 ml for the determination of the sugar content, leaving a volume of 14,000 ml of solution in the cooler.

When the solution is sufficiently cold, place in the hopper the weighed amount of lime which is estimated to be sufficient, or a little less than this amount, and introduce it into the solution through the bolter. When the lime has all been added, remove a small amount of the finished cooler solution without stopping the propeller, filter it immediately, and determine the sugar in the regular manner, using 50 ml of the filtrate. If the result shows the lime addition to be insufficient, estimate the additional amount required, add this, test the finished cooler solution again as before, and repeat this procedure until the sugar in the waste water is reduced to the desired percentage. Wash out the cooler thoroughly immediately after each test to prevent the tubes from becoming stopped up, being careful to avoid wetting the bolter.

In general follow the current factory practice with regard to such conditions as the temperature of precipitation, the concentration of the cooler solution, and the sugar content of the waste water. It may often be desirable, however, to vary some of these conditions to obtain special information. The time of adding the lime may also be varied by changing the speed of the conveyor, or by feeding the lime to the conveyor by hand, and it will often be found that the rate of adding the lime has a great influence on the efficiency of the precipitation.

ANALYSIS

Use the regular methods given elsewhere in this chapter. Calculate the percentage of sugar precipitated as follows:

Let a = sugar (grams in 100 ml) in Solution for Cooler
b = sugar (grams in 100 ml) in Waste Water
x = percentage of sugar precipitated

Then $$x = \frac{100\ (a - b)}{a}$$

Calculate the lime addition as follows:

Let c = grams of lime powder used
d = volume of cooler solution in milliliters (14000)
y = lime to 100 sugar

Then $$y = \frac{c}{.0001\ ad}$$

If, however, the sample of "solution for cooler" has been obtained from the factory coolers and therefore contains lime from the previous cooler, determine the alkalinity and correct the lime addition as indicated in the following formula:

Let e = alkalinity (grams of CaO in 100 ml) of Solution for Cooler
f = % CaO in lime powder

Then $$y = \frac{c + \dfrac{de}{f}}{.0001\ ad}$$

EXAMPLE

Let $a = 5.41$

$b = .52$

$c = 765$

$d = 14000$

$e = .70$

$f = 94.5$

$$\text{Then } x = \frac{100\ (5.41 - .52)}{5.41} = 90.4$$

$$y = \frac{765 + \dfrac{.70 \times 14000}{94.5}}{.0001 \times 5.41 \times 14000} = 115$$

15. TEMPERATURE DATA

GENERAL

Refer to the general instructions in the section of the same title in Chapter II, 36. The following directions apply to particular cases in the Steffen Process Control.

COOLER SOLUTION, AVERAGE MAXIMUM TEMPERATURE

Record the maximum temperature reached in each case during the cycle of a sufficient number of coolers to give a fair average, and derive the average of these figures. Obtain the data from a recording thermometer or from the cooler man's record.

COLD WASTE WATER, AVERAGE TEMPERATURE

Obtain every 2 hours by filling a sample bucket from the discharge of the cold presses and taking a reading immediately with a mercury thermometer. Or obtain from a thermometer installed in the line leading from the cold presses to the heating system.

HOT SOLUTION

This should represent the temperature at which the heated waste water leaves the heating system and should be obtained from a thermometer suitably installed to indicate this.

HOT WASTE WATER

Obtain every 2 hours by filling a sample bucket from the discharge of the hot presses and taking a reading immediately with a mercury thermometer.

ADDITIONAL TESTS REQUIRED IN CONNECTION WITH DORR THICKENER—VACUUM FILTER INSTALLATIONS

16. FEED TO THICKENER

Determine every 2 hours:

(a) Brix.
(b) Alkalinity.
(c) Sugar (grams in 100 ml).

Sampling

Take a catch sample every 2 hours from the hot solution feed line to the Dorr Thickener, and filter immediately through paper.

Analysis

Cool and analyze the filtrate as in the case of "6. Cold Press Waste Water."

17. OVERFLOW FROM THICKENER

Determine every 2 hours:

(a) Brix.
(b) Alkalinity.
(c) Sugar (grams in 100 ml).

Sampling

Take a catch sample every 2 hours, consisting of an equal amount from each of the pipe lines leading from the overflow boxes to the heat exchanger.

Analysis

Mix the sample, cool, and analyze as in the case of "Cold Press Waste Water."

18. DISCHARGE FROM THICKENER.

Determine every 4 hours:

(a) Brix.

SAMPLING

Take a catch sample of the thickened discharge every 4 hours, consisting of an equal amount from each of the discharges into the hot filter tanks.

ANALYSIS

Mix the sample well, and transfer to a hydrometer jar. After cooling to approximately 20°, mix again and determine the Brix in the regular manner, taking the reading as quickly as possible before the suspended matter has time to settle.

19. HOT FILTER WASTE WATER

Determine every 2 hours:

(a) Brix.
(b) Alkalinity.
(c) Sugar (grams in 100 ml).

SAMPLING

Take a catch sample every 2 hours from the discharge into the heat exchanger.

ANALYSIS

Cool and analyze as in the case of "Cold Press Waste Water."

V. PULP DRYER CONTROL

1. GENERAL.

All samples in connection with the Pulp Dryer Control must be taken by a laboratory employe.

On account of the large number of moisture determinations it is advisable to have two drying ovens. A vacuum oven is recommended for the determination of moisture in "Pulp Leaving Dryer" and "Pulp as Sacked," and a double walled glycerin drying oven for the other moisture and dry substance determinations; the temperature should be carried at 100—105° C. in both kinds of ovens. Aluminum dishes, 3 inches in diameter x ⅝ inch high, provided with covers of the same material, should be used.

As the determination of moisture in dried pulp requires several hours, a rapid method is employed to give the operating men better control. This method is to heat for 1 hour in the oven and multiply the loss found by a factor, which is calculated from determinations made in the regular manner by heating for 5—6 hours and then for successive periods of one hour until the loss of weight in one hour is not over 0.1%. This factor varies from 1.05 to 1.15, and it is recommended that a factor of 1.10 be used until a more accurate factor is found for each laboratory.

2. MOLASSES TO PULP DRYER

Determine every 8 hours:

(a) Brix.

SAMPLING

Take a sample every 2 hours from the molasses scale tank in the Dryer House. Transfer the individual samples to a covered container and mix thoroughly previous to analysis. Do not take any samples if molasses is not being used.

ANALYSIS

Follow the "General Methods," I, 1 (b).

3. WATER FROM PRESSES

Determine every 4 hours:

(a) Sugar.

Determine every 8 hours:

(b) Dry Substance (grams in 100 ml).

SAMPLING

Take a catch sample of the water leaving the presses, being careful not to include water from any other source in the sample, and analyze immediately.

ANALYSIS

(a) *Sugar:* Determine as under "Pulp and Pulp Water," Chapter II, 3.

(b) *Dry Substance:* Mix the sample well and transfer 50 ml to a weighed porcelain evaporating dish, being careful to include a proper proportion of the suspended matter. Evaporate to dryness on a water bath and complete the drying in an oven at 100—105° ; about 1½ hours in the oven is required. Multiply the weight of dry substance by 2 to obtain the percentage.

4. WATER FROM PULPEFANGER

Determine every 8 hours:

(a) Dry Substance (grams in 100 ml).

SAMPLING

Take a catch sample of the water leaving the pulpefanger, and analyze immediately.

ANALYSIS

(a) *Dry Substance:* Mix the sample and determine as under "Water from Presses."

Note: Special tests on this and other waters, to determine the amount of fine particles of pulp in suspension, may be made as follows:

Determine the dry substance after filtration through paper; the difference between this and the total amount of dry substance will show the maximum amount that can be removed. Determine the dry substance also after pouring the water through a sieve having the same width of opening as the pulpefanger screen; this will give an approximate idea of the amount that it is possible to recover under working conditions.

5. PULP ENTERING PRESSES

Determine every 8 hours:

(a) Moisture.

SAMPLING

Take a good-sized sample (several quarts) from the discharge of the separator, in such a manner as to secure as representative a sample as possible of the material discharged, using a dipper which will catch all of the accompanying water as well as the actual pulp. If it is impossible to obtain the sample at this place, take the sample from the slide to the presses, sampling from at least two presses which are running and using care to get an average sample.

Put the entire sample in a "pulp can" of the same type used for the samples of pulp from the diffusion battery, and after allowing it to drain for 15 minutes, or longer, weigh separately the drained pulp and water thus obtained. (The water may be measured instead of weighed, if desired.) Grind the drained pulp in an Enterprise Meat Chopper and mix it well. Save portions of the pulp and the water for analysis.

ANALYSIS

Weigh out 10 grams of the ground pulp in a 3x⅝-inch aluminum dish, and dry at 100—105° in a glycerin oven for 6—8 hours, or for a period which has been found to be long enough to give constant weight. In establishing this period consider the weight constant when the loss after an additional heating for one hour is not over 0.1%. Check the accuracy of this period at least once a week.

Evaporate 50 ml of the drained water and determine the dry substance as under "Water from Presses."

Calculate the percentage of moisture in the "pulp entering presses" as a weighted average from the weights and moisture content of the drained pulp and water. E. g., if 4,000 grams of drained pulp and 1,000 grams of drained water are obtained containing respectively 94.80 and 99.70% moisture, the result is

$$\frac{(4000 \times 94.80) + (1000 \times 99.70)}{4000 + 1000} = 95.8\%$$

6. PULP LEAVING PRESSES

Determine every 4 hours:

(a) Moisture.

Sampling

Take a sample every hour from the discharge of the pulp conveyor, if it is possible to secure the sample at this point without danger. Otherwise take the sample from the discharge spouts of the presses, but distribute the sampling well among all the presses in operation. Make up a composite sample every 4 hours and mix it well.

Analysis

(a) *Moisture:* Weigh out 10 grams in a 3x⅝-inch aluminum dish, and dry at 100—105° in a glycerin oven for 6—8 hours, or for a period which has been found to be long enough to give constant weight. In establishing this period consider the weight constant when the loss after an additional heating for one hour is not over 0.1%. Check the accuracy of this period at least once a week.

7. DRIED PULP LEAVING DRYERS

Determine every 3 hours for each drum separately:

(a) Moisture.

Sampling

Take representative catch samples from the discharge of each drum and analyze immediately.

Analysis

(a) *Moisture:* Weigh out 10 grams in a 3x⅝-inch aluminum dish and dry in a vacuum oven at 100—105° for exactly 1 hour. Cool in a desiccator and weigh. Multiply the percentage loss by the factor which has been established, and report as the percentage of moisture. To control the factor make frequent tests by heating samples for 2 or 3 hours longer, and then for successive periods of one hour until the loss of weight in one hour is not over 0.1%. At the beginning of the campaign use a factor of 1.10 until a more accurate figure is established.

8. DRIED PULP AS SACKED

Determine every 3 hours:

(a) Moisture.
(b) Polarization.

SAMPLING

Take a sample every hour from at least three bags as they are filled at the sacking station, and keep in a tight container. Mix the hourly samples to make composite samples when needed. If plain and molasses pulp are produced on the same day, save samples of each and analyze separately. Save portions of each composite sample for a weekly composite sample. (See "Weekly Analysis of Dried Pulp," below.)

ANALYSIS

(a) *Moisture:* Weigh out 10 grams of the mixed composite sample and dry for 3—4 hours in a vacuum oven at 100—105°. Cool in a desiccator and weigh. Report the percentage loss at the percentage of moisture. As the time of drying necessary to eliminate all the moisture varies considerably, the length of the drying period should be frequently checked and regulated accordingly.

(b) *Polarization:* Weigh out *12.6 grams, transfer to a 200.6 ml flask, add 12—15 ml of basic lead acetate, and fill about three-fourths full with water. Digest exactly as in the determination of sugar in cossettes, Chapter II, 1 (a). Polarize in a 400 mm tube and multiply the reading by two to obtain the percentage of sugar.

9. WEEKLY ANALYSIS OF DRIED PULP

Make a weekly analysis of plain and molasses pulp separately, comprising the following determinations:

(a) Moisture.
(b) Crude Protein.
(c) Crude Fat.
(d) Crude Fiber.

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*This weight is figured as the equivalent of the half-normal weight after allowing 7 ml as the volume of the marc in 13 grams of Molasses Pulp containing 15 per cent sugar. Plain Pulp is so low in polarization that the same weight may be used without appreciable error.

(e) Ash.
(f) Nitrogen-free Extract.

SAMPLING

Save 15 grams of each sample used for the analysis of "Dried Pulp as Sacked," and keep in a tight container. Save separate samples of plain and molasses pulp if both are produced during the same week.

PREPARATION OF SAMPLE

Mix the sample well with the hands and save a portion for the determination of moisture. Crush at least 50 grams of the remainder in an iron *mortar, crusher, or disc pulverizer, to pass a sieve having circular openings 1 mm in diameter. (Or use a regular 20-mesh sieve.) Preserve both samples in tight containers.

ANALYSIS

Follow the methods in Chap. XX, "Foods and Feeding Stuffs." Determine the moisture in duplicate in both the original and the ground material. Make all other determinations on the ground material, and correct the results for the loss of moisture during grinding.

For example:

Let a = percentage of moisture in original material
b = percentage of moisture in ground material
c = percentage of crude protein in ground material
x = percentage of crude protein in original material

$$\text{Then } x = \frac{c\ (100 - a)}{100 - b}$$

NOTE

As the amount of crude fat in dried pulp is small and very constant, this determination may be omitted on the weekly samples, but should be made on a campaign average sample. When the crude fat is not determined, allow 0.2 for the percentage of crude fat in calculating the nitrogen-free extract.

10. TEMPERATURE DATA

GENERAL

Refer to the general instructions in the section of the same title in Chapter II, 36.

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*Plain pulp of normal moisture content can be easily ground in a disc pulverizer. Molasses pulp is best crushed in an iron mortar.

MOLASSES TO PULP DRYER

Obtain every 2 hours from the line leading to the drying drum.

PULP ENTERING PRESSES

Obtain every 2 hours the temperature of the pulp just previous to entering a press which is in operation.

GAS LEAVING FURNACE

Obtain from the recording pyrometer at the furnace.

GAS LEAVING DRYER

Obtain from the recording thermometer at the exit of the dryer.

VI. PULP SILO CONTROL

1. GENERAL

Sample and analyze "pulp entering silo" once a day during campaign. Sample and analyze "pulp sold" once a day (except on Sundays and holidays during intercampaign) as long as any unsold pulp is on hand, but only on days when wagons are being loaded at the silo.

2. PULP ENTERING SILO

Determine:

(a) Dry Substance.

SAMPLING

Take a good-sized sample from the discharge of the pulpefanger, enough to fill a ten-quart bucket three-fourths full, in such a manner as to obtain as nearly as representative a sample as possible of the mixture of pulp and water discharged into the silo. Drain in a "pulp can" as in the case of "Pulp Entering Presses," Chapter V, 5, "Pulp Dryer Control."

ANALYSIS

Analyze as under "Pulp Entering Presses," Chapter V, 5, "Pulp Dryer Control."

3. PULP SOLD

Determine:

(a) Acidity.

(b) Dry Substance.

SAMPLING

Take three samples from the top of the wall of pulp where the wagons are being loaded; take another set of three samples from the middle; and take a third set of three samples from the bottom. Mix the nine samples to form a composite sample for analysis.

ANALYSIS

(a) *Acidity:* Weigh out 10 grams of the well mixed sample, and rinse into a beaker or casserole with a little neutral, distilled water. Add a few drops of phenolphthalein and then N/28 alkali in excess, and dilute to a total volume of about 200 ml. Cover with a watch glass and boil gently for 15 minutes. Cool and titrate with N/28 acid, continuing the addition of the acid until the solution remains colorless for 15 minutes. The amount of standard alkali originally added should be such that not less than 5 ml nor more than 10 ml of the standard acid is subsequently required for neutralization. Subtract the number of ml of acid from the number of ml of alkali used, and divide by 100 to obtain the acidity (in terms of per cent CaO by weight).

(b) *Dry Substance:* Weigh out 10 grams of the sample, the acidity of which has been previously determined as in (a), using a tared aluminum moisture dish provided with a cover and a small glass rod. Add 8—10 ml of water and the exact weight of freshly ignited C. P. calcium oxide indicated by the acidity test to be required for neutralization. Stir with heating until a uniform mixture is obtained. (Add a drop of phenolphthalein to show when all the particles of pulp have come in contact with the calcium oxide; the phenolphthalein will retain its pink color, which will be uniformly distributed when the mixing is perfect). Dry in a glycerin oven at 100—105° for 5—6 hours, and then for successive periods of one hour until the loss in weight in any period is less than 0.1%.

Obtain the percentage of dry substance by the following formula:

Let a = weight of pulp used
b = acidity of pulp (grams of CaO in 100 ml)
c = weight of dried material
x = weight of CaO required
y = percentage of dry substance

$$\text{Then } x = \frac{b}{10}$$

$$\text{And } y = \frac{100\,(c - .68\,x)}{a}$$

Or, as a = 10,

$$y = 10\,(c - .68\,x)$$

The values of "x" and "y" can be conveniently obtained by the use of Table 16.

The factor .68 in the above formulas is derived as follows: Assuming acetic acid to be the principal acid present, the acetic acid of the original material is converted to calcium acetate in the dried sample in the ratio of the molecular equivalents, i. e. of 120 to 158. Then, since the molecular equivalent of calcium oxide is 56, (158 — 120) ÷ 56 = .68, which represents the factor by which the amount of calcium oxide used must be multiplied to obtain the deduction necessary to convert the calcium acetate back to free acetic acid.

VII. BOILER HOUSE CONTROL

1. GENERAL

No definite routine should be followed in the boiler house control work; irregularity in the time of sampling and testing the individual boilers will tend to give more nearly average results. The boiler house control man should take and prepare all the necessary coal and ash samples, make the flue gas analysis, and obtain the draft and temperature readings and any other necessary data. If a boiler house control man is not employed, the man in charge of unloading the coal should take the coal samples, and the Assistant Chemist should obtain the ash samples; the other data on flue gas analysis and temperature, draft, etc., will not be obtained except for what average figures are available from the recording instruments.

2. SAMPLING OF COAL

Use a sampler consisting of a piece of 2-inch pipe about 4 feet long, provided with a spring valve at one end to retain the coal in the sampler. Sample all cars unloaded, just previous to unloading, by driving the sampler through the coal in the car and collecting the coal retained in the pipe. Take 3 samples from each car, one in a corner about two feet equally distant from the sides of the car, one in the center of the car, and one in the corner diagonally opposite the position of the first sample. Preserve all the samples in a can provided with a tightly fitting cover, such as a milk can, or in a number of such containers, and keep in a cool place.

Sample cars loaded from the storage pit in the same manner as cars received from the mine; if coal is hauled from the storage piles, take one sample from every fifth wagonload. Take no samples from cars loaded from the drippage pit, or from cars into which any drippage has been loaded; pay special attention to this point to avoid contaminating the regular sample with drippage. If coal from different sources (mine, storage pit, etc.) is being used, include in the gross sample amounts from each source in approximate proportion to the amounts from each source used.

Sample the coal used in the Pulp Dryer in exactly the same manner. The sampling should be done in this case by the man who unloads the coal for the dryer but should be under the supervision of the boiler house control man.

3. PREPARATION OF COAL SAMPLES

When all the coal for a day's use has been sampled, crush the entire gross sample to ¼-inch size and reduce to 1 to 2 quarts by mixing and quartering on a large piece of canvas; do this as rapidly as possible to avoid loss of moisture. Keep the sample in a fruit jar closed with a tightly fitting cover provided with a rubber gasket.

At the end of the week grind the entire seven samples representing the week's run of coal to 60-mesh size in the pebble mill described in Chap. XXIII, 9. Put up and seal a 4-oz. sample of the ground material, and forward it without delay to the central laboratory for analysis. Be careful to clean the mill thoroughly after each week's sample is prepared, and employ it exclusively for grinding coal.

4. SAMPLING OF ASHES

(a) In Boiler Houses Equipped with Chain Grate Stokers

Obtain samples of grate and flume ashes as follows:

(1) *Grate (Stoker) Ash:* Use a sampler consisting of a rectangular box with hinged cover fastened to a long handle. Obtain 3 samples per shift, if possible, from the discharge of each stoker in operation, taking a sufficient quantity so that the total sample for the 8 hours will amount to about one gallon. Save separate samples for each shift for the set of boilers in charge of each fireman. This will make 6 samples per 24 hours at the large factories and 3 at the small factories.

(2) *Flume Ash:* Obtain the sample by holding a closely woven sack over the discharge of the flume ash line, or over the special sampler provided for this purpose, in such a manner as to obtain an average of all solid material delivered through the line. Take a sample at least twice a shift and make up a composite

sample for each shift by mixing at least 1 quart of each of the individual samples.

(b) IN BOILER HOUSES EQUIPPED WITH HAND FIRED FURNACES

Obtain samples of pan, grate, and flume ashes as follows:

(1) *Pan Ash:* Take a small sample of the ash in the pan of each boiler in operation at least 3 times per shift; the total sample for the shift should be about one gallon. Save separate samples for each shift. If a boiler house control man is not employed, obtain a 1-quart sample once a shift representing an average of the ash in the pans at the time of sampling.

(2) *Grate Ash:* Take samples only when the fires are being pulled and before the ash is wet down. Obtain an average sample of at least 1 gallon once a shift, or oftener if a boiler house control man is employed. Crush the gross sample to break up large lumps, mix, and save a 1-quart sample representing the work of each shift.

(3) *Flume Ash:* Obtain at least twice a shift as described in "(a), (2)," above. If a boiler house control man is not employed, obtain at least once a shift.

(c) IN PULP DRYERS

The boiler house control man or the Assistant Chemist should obtain an average sample of the grate ash at least once per shift, as described in (a) (1).

5. PREPARATION OF ASH SAMPLES

Break up any large lumps by crushing, mix well, take out 1 quart and crush to 10 mesh size in a jaw crusher. Mix the crushed sample and grind at least one-fourth of it to 60 mesh size in a disc pulverizer. Mix well and save 4 ounces for analysis.

As the samples of ash are analyzed on a dry basis, no care need be taken to avoid loss or gain of moisture during the preparation of the sample. Any samples which are very wet, however, such as the flume ashes, should first be dried in a shallow tray in a warm place before being prepared for analysis.

If the special boiler house control is carried on, the samples of ashes collected to represent the work of each shift should be analyzed separately. Otherwise a composite sample of each kind of ashes should be prepared at the end of every week and sent to the central laboratory, together with the coal sample, for analysis. See Chapter XV, 10, regarding the analysis of ash samples.

6. DRAFT

Take draft readings, both "furnace" and "differential," on the individual boilers at the time when samples of the grate ash are collected. Check all the draft gages at the zero point at least once a shift, and test all connectious for air leaks frequently.

The liquid used in Ellison and in Blonck differential draft gages is, unless otherwise specified, mineral oil of .834 specific gravity at 60° F., colored red or blue. The best temporary substitute is kerosene, having nearly the same specific gravity. Water must not be used.

In the absence of a boiler house control man or the necessary differential gages, no readings will be recorded.

7. FLUE GAS ANALYSIS.

Immediately after the ash sample is taken and the draft readings are made, determine the percentage of carbon dioxide in the flue gas, using an Orsat apparatus or one of the modified forms of the same, and following the method prescribed for the analysis of lime kiln gas, Chap. II, 10. Change the caustic alkali solution every 2 days. The addition of a few drops of phenolphthalein to the water in the measuring burette will be of value to indicate contamination from the alkali solution. Rinse out the sampling pipe thoroughly before drawing gas into the apparatus. Do not make any flue gas analyses on banked boilers.

The gas sampling pipe should pass through a hole drilled in the brickwork, and the open end through which the gas enters should be close to the point where the gases leave the boiler and where the velocity of the gas stream is a maximum. Leakage around the sampler should be stopped with asbestos packing. The proper position of the sampler is of great importance.

It is also advisable, especially when the CO_2 is high, to make some complete analyses in which oxygen and carbon monoxide (CO) are determined.

In the absence of the special boiler house control, no individual flue gas analyses will ordinarily be made.

8. TEMPERATURE OF AIR AND FLUE GAS

(a) Air Entering Furnaces

Take readings at the time when the flue gas is analyzed, of thermometers in different parts of the boiler room hung near the point where the air enters below the stokers but not so close that they will be heated by radiation from the fire.

(b) FLUE GAS

If the boilers are equipped with individual thermometers or if a suitable pyrometer is available, determine the temperature of the flue gas at the point where it leaves the boiler at the time when the gas is analyzed. If only a general recording instrument is available, take several readings during the period of ash sampling and gas analysis, and use the average of these readings as a basis for figuring the heat loss.

9. CALCULATION OF HEAT LOSSES

(a) DATA REQUIRED

(1) *Moisture, Ash, and Calorific Value of Coal.* On account of the fact that the results of the coal analysis are not available until several days after the samples are taken and then only for weekly samples, use the average analysis to date of the coal burned during the campaign, recalculating these averages when each new set of figures is received from the central laboratory. During the first few days of the campaign, or until figures have been received from the central laboratory, use the average coal analysis of the preceding campaign.

(2) *Carbon and Hydrogen in Coal.* Use average figures obtained from the analyses of the Bureau of Mines. (See references in Section 10.) For northern Colorado lignite (sub-bituminous) coal the percentage of carbon may be taken as 57 and the percentage of hydrogen as 6, if the amount of combustible is approximately 75 per cent.

(3) Other data required are obtained from the daily determinations.

(b) LOSS IN DRY FLUE GAS

Obtain from the chart (*drawing S-1756 or S-132-M) the "B. T. U. lost in dry flue gas per pound of carbon burned," according to the average flue gas analysis, and the average temperature of the air and of the flue gas.

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*The Lovell factory, where natural gas is used, should employ the chart in drawing S-126-M.

Let T = temperature (° F) of flue gas
t = temperature (° F) of air entering furnaces
B = B. T. U. found from the chart
A = calorific value (B. T. U.) of the coal as fired
C = % carbon in coal as fired
L_1 = percentage loss of heat in dry flue gas

Then $L_1 = \frac{C\ B}{A}$

Example

Assume 12% CO_2 in flue gas and temperature of 500° F., boiler room temperature of 80° F., and 9000 B. T. U. in coal containing 57% carbon. From the chart $T - t = 420$, and $B = 2120$.

$$L_1 = \frac{57 \times 2120}{9000} = 13.4$$

For coal containing 57% carbon, the calculation may be shortened by the use of Table 17. The value found in the table multiplied by 100 and divided by the B. T. U. in the coal gives the percentage loss desired. If the percentage of carbon in the coal is not taken as 57, the table may still be used by multiplying by a factor equal to $\frac{C}{57}$, where C is the percentage of carbon in the coal.

Example

For 12% CO_2 and $T - t = 420$, Table 17 gives 1208 B. T. U.

$$\text{Then } \frac{1208 \times 100}{9000} = 13.4$$

Note that the chart gives "B. T. U. per pound of *carbon* burned" and the table "B. T. U. per pound of *coal* burned."

(c) Loss Due to Moisture

The loss due to moisture is composed of:

(1) Loss due to moisture in the coal as fired.

(2) Loss due to moisture resulting from the *burning of the hydrogen component of the fuel.

In addition to the symbols previously used,

Let M = % moisture in coal as fired
H = % hydrogen in coal as fired

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*The Lovell factory, where natural gas is used, should calculate this loss in accordance with the chart in drawing S-153-M.

$w =$ boiling point (° F.) of water (202 for 5000 feet elevation)

$L_2 =$ percentage loss of heat due to moisture

$$\text{Then } L_2 = \frac{M + 9\ H}{A} \times [(w - t) + 976.6 + .47\ (T - w)]$$

EXAMPLE

Assume in addition to the figures in the preceding example, 16% moisture and 6% hydrogen in the coal, and boiling point of water as 202° F.

$$L_2 = \frac{(16 + 54) \times [122 + 976.6 + .47\ (500 - 202)]}{9000} = 9.6$$

This calculation may be shortened as follows by the use of Tables 18 and 18—A.

Let $F =$ factor as found in Table 18.

$F' =$ factor as found in Table 18—A.

$$\text{Then } L_2 = \frac{FF'}{A}$$

EXAMPLE

According to the data previously given, $F = 70.0$ and $F' = 1239$

$$\text{Then } L_2 = \frac{70 \times 1239}{9000} = 9.6$$

(d) TOTAL LOSS IN FLUE GAS

Let $L_3 =$ total percentage loss of heat in flue gas

Then $L_3 = L_1 + L_2$

EXAMPLE

$$L_3 = 13.4 + 9.6 = 23.0$$

(e) LOSS DUE TO COMBUSTIBLE IN ASH

This is based on the analysis of the coal and of the grate (stoker) ashes, the combustible matter in the ashes being assumed to consist of pure carbon of a calorific value of 14600 B. T. U.

Let $D =$ % ash in coal as fired

$E =$ % ash in ashes

$L_4 =$ percentage loss of heat due to combustible in ashes

$$\text{Then } L_4 = \frac{14600\ D\ (100 - E)}{A\ E}$$

Or if $k = \frac{14600\ D}{A}$ a factor which can be used for a number of calculations

$$\text{Then } L_4 = k \times \frac{(100 - E)}{E}$$

EXAMPLE

Assume the coal to contain 12% ash, and the ashes 60% ash.

$$L_4 = \frac{14600 \times 12 \times 40}{9000 \times 60} = 13.0$$

(f) TOTAL KNOWN LOSSES

If L_5 = total known heat losses,

Then $L_5 = L_3 + L_4$

EXAMPLE

$$L_5 = 23.0 + 13.0 = 36.0$$

10. BIBLIOGRAPHY

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VIII. POTASH CONTROL (BEET CAMPAIGN)

1. GENERAL

Each factory engaged in potash recovery should send to the Central Laboratory weekly average samples of Molasses Worked, Saccharate Cake, and Total Waste Water, which should represent in each case an average of all laboratory samples taken during the week, as described in Chapter II, 35, "Weekly Composite Samples." The samples and information, as specified in detail below, should be forwarded to the Central Laboratory as soon as possible after the end of every week, at least not later than Monday noon.

(a) Molasses Worked

Forward 100 grams of the average sample of the molasses worked during the week.

(b) Saccharate Cake

Forward an amount equivalent to 100 grams of dry substance, of an average sample of Saccharate Cake, representing a weighted average of the cold and hot cakes made up as in the following example:

Brix of Cold Saccharate Cake	62.0
Brix of Hot Saccharate Cake	55.0
Tons of Dry Sub. in Cold Saccharate cake for Week	450
Tons of Dry Sub. in Hot Saccharate Cake for Week	60
Tons of Dry Sub. in Total Saccharate Cake for Week	510

Then the number of grams of the original material of Cold Cake to be used for the sample is

$$\frac{450}{510} \times \frac{100}{.620} = 142.3$$

And the number of grams of Hot Cake is

$$\frac{60}{510} \times \frac{100}{.550} = 21.4$$

The material referred to above is of course the syrup obtained after the carbonation and evaporation of the cake from the saccharate presses.

(c) Total Waste Water

Forward 100 grams of the weekly average samples.

(d) Data Required

Forward also the following data, both for the week and to date:

Tons of Molasses Worked.

% Sugar in Molasses Worked.

Sugar in Total Waste Water, per cent on Sugar in Molasses Worked.

Cubic Feet of Total Waste Water Produced.

Cubic Feet of Waste Water Actually in Reservoir.

Total Waste Water, Brix.

Total Waste Water, Alkalinity.

Total Waste Water, Sugar.

2. ANALYSIS

The Central Laboratory will make the necessary analyses according to the standard methods described in Chapter IX, 12, and elsewhere in the "Methods of Analysis."

IX. POTASH CONTROL (POTASH CAMPAIGN)

This chapter relates to the laboratory control work which is to be carried on during the potash campaign at every factory engaged in potash recovery.

1. LIQUOR ENTERING FACTORY

Determine every 4 hours:

(a) Brix.
(b) Alkalinity.
(c) Sugar.

SAMPLING

Take a catch sample every 4 hours from the line from the reservoir to the factory before the liquor has passed through any heater.

ANALYSIS

Determine as in the case of Steffen Waste Water, Chap. IV, 6.

2. FIRST SATURATION LIQUOR

Determine every hour:

(a) Alkalinity.

SAMPLING

Take a catch sample from the cocks or troughs of the first presses, avoiding any admixture of wash water.

ANALYSIS

Determine the alkalinity in the regular manner with N/28 acid.

NOTE: If double carbonation is not employed, this determination is necessarily omitted.

3. THIN LIQUOR ENTERING EVAPORATORS

Determine every 4 hours:

(a) Brix.

Determine every hour:

(b) Alkalinity.

(c) Reaction with CO_2.

SAMPLING

Take a catch sample from the pump, or at a suitable point in the line between the filters and the evaporators.

ANALYSIS

(a) *Brix:* Determine in the regular manner.

(b) *Alkalinity:* Determine as in the case of "First Saturation Liquor."

(c) *Reaction with CO_2:* Pass carbon dioxide gas for a few minutes through a portion of the sample in a 1 x 6 inch test tube. If any cloudiness results, report as "P" indicating the formation of a precipitate, and if no cloudiness appears report as "O."

4. EVAPORATOR THICK LIQUOR PRODUCED

Determine every 4 hours:

(a) Brix.

Determine every 24 hours:

(b) Sugar.

SAMPLING

Take a sample from the pump, or from the line to the potash scale tank. Do not take the sample from the last body of the evaporators or from the scale tank. Take a sample each time when liquor is let out of the evaporators, and composite equal portions of the individual samples.

ANALYSIS

(a) *Brix:* Follow the "General Methods," 1 (a).

(b) *Sugar:* Transfer 13 grams to a 100 ml flask, add a few drops of phenolphthalein, and neutralize with dilute acetic acid.

Add 4—6 ml of basic lead acetate, make up to the mark, filter, and polarize in a 200 mm tube. Multiply the reading by 2.

5. FILTER PRESS CAKE

Determine every 8 hours:

(a) Weight per cake.

Sampling

Take a representative sample at least every 8 hours in the manner described in Chap. II, 13, "Lime Cake." Save equal portions for the weekly composite sample described below.

Determination

Determine the average weight of one cake in pounds once a shift by catching and weighing two or three cakes taken at random. In the case of Kelly presses the amount of cake is best calculated from the difference in alkalinity between the original and carbonated liquor and the CaO content of the cake.

6. CONDENSED WATERS

Examine, by the *alpha-naphthol test, the boiler feed water every hour, and the press wash and evaporator tail pipe waters every 2 hours. Test also the drips from each evaporator body as frequently as practicable.

See Chap. XVII, 2 (c) regarding the collection of campaign samples for analysis.

7. BOILER WATER

Determine every 8 hours on each boiler in service:

(a) Alkalinity.

Sampling

Draw from the sampling line, first allowing the water to run a few moments to rinse out the pipe.

Analysis

Measure out 10 ml with a pipette into a porcelain dish and follow the "General Methods," I, 10 (a), using phenolphthalein

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*See Chapter I, 13.

as indicator. Dilute with sufficient neutral water to make the color reaction distinct.

8. CARBONATION GAS

Determine every 4 hours:

(a) CO_2.

SAMPLING AND ANALYSIS

Obtain the sample and determine the percentage of CO_2 as described in Chap. II, 10, ''Lime Kiln Gas.''

9. EVAPORATOR THICK LIQUOR ENTERING FURNACE

Determine every 2 hours:

(a) Brix.

Determine every 24 hours:

(b) Dry Substance.

(c) Lixiviated Ash.

SAMPLING

Take a sample every 2 hours from the line leading from the storage tank to the furnace. Make up a composite sample for the dry substance and ash determinations.

ANALYSIS

Follow the ''General Methods.''

10. CRUDE ASH AS SACKED

Determine every 24 hours:

(a) Acid Insoluble.

(b) Lixiviated Ash.

SAMPLING

The man at the sacking station should take a small measureful from each bag filled and transfer it to a covered container. A laboratory employe should mix the gross sample well and transfer a suitable amount to a tightly stoppered bottle.

If the material is shipped as fast as it is sacked, this sampling can be combined with the collection of samples representing each car-load lot described in Chapter X.

ANALYSIS

(a) *Acid Insoluble* and (b) *Lixiviated Ash:* Follow the methods given under "Crude Potash," Chap. X, 6 and 8.

11. TEMPERATURE DATA

Take readings every 2 hours of the thermometers indicating the temperature of the liquor entering and leaving each set of heaters; record also the kind of steam or vapor used in each case. Take readings also every 2 hours of the temperature of the liquor in each body of the evaporators.

12. WEEKLY COMPOSITE SAMPLES

SAMPLING

Make up a composite sample of each of the products mentioned below by taking equal portions of each sample brought to the laboratory during the week and preserving in a sealed jar or stoppered bottle.

(a) LIQUOR ENTERING FACTORY
Determine dry substance (after carbonation) and K_2O.

(b) THIN LIQUOR ENTERING EVAPORATORS
Determine dry substance and K_2O.

(c) FILTER PRESS CAKE
Determine dry substance and K_2O.

(d) EVAPORATOR THICK LIQUOR PRODUCED
Determine dry substance, lixiviated ash, K_2O, and NH_3.

(e) CRUDE ASH AS SACKED
Determine lixiviated ash, K_2O, and NH_3.

ANALYSIS

(1) *Dry Substance:* Determine in uncarbonated liquors (waste water entering factory) as follows: Transfer 50 ml to a 100 ml flask and carbonate at 80° to faint alkalinity with phenolphthalein. Heat to at least 85°, cool, and make up to the 100 ml mark. Mix and filter through a dry filter. Determine the dry substance in the filtrate by drying on sand according to the "General Methods," Chap. I, 2. Double the percentage found to obtain the percentage in the original liquor.

Determine in "thin liquor entering evaporators" and in thick liquor by drying on sand without preliminary carbonation.

Determine in filter press cake by drying 10 grams directly as in the case of Saccharate Cake, Chap. IV, 11 (g).

(2) *Lixiviated Ash:* Follow the "General Methods," I, 7 (b).

(3) *Potash (K_2O):* Directions for the determination in crude ash will be found in Chap. X, 9.

In the case of liquors and filter press cake proceed as follows: Weigh out a suitable amount (20 grams of thin liquors, 1 gram of thick liquor, and 10 grams of filter press cake) in a platinum dish, add a little water and 1 ml of sulphuric acid (1 to 1). Evaporate on a water bath and heat cautiously on a *Hillebrand radiator until the sulphuric acid is expelled. Then ignite at a dull red heat until the ash is white. Add a little strong hydrochloric acid, warm slightly in order to loosen the mass from the dish, and dissolve in about 25 ml of water. Add a slight excess of ammonium hydroxide, heat to boiling, and add sufficient ammonium oxalate to precipitate all the lime present. After standing for at least one-half hour, filter, and wash well with hot water. Then proceed as in the determination of potash in crude ash, Chap. X, 9.

(4) *Nitrogen as Ammonia (NH_3):* Determine the total nitrogen as in the analysis of crude potash, Chap. X, 10.

13. STEAM CALCULATION

Calculate a heat balance every week. The manner of calculating the heat units in the steam theoretically required can best be explained by the following example, which is based on 100 kilograms of waste water entering the factory. The value of the latent heat of steam is taken as 540 calories per kilogram or 971 B. T. U. per pound.

	Live or Exhaust	1st Vapor	2nd Vapor
HEATERS BEFORE CARBONATION			
100 kg of liquor heated from 10° to 80° $\frac{100\ (80-10)}{540}$ = 13.0 kg 2nd vapor.			13.0

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*See Chap. XXIII, 15.

	Live or Exhaust	1st Vapor	2nd Vapor
HEATERS AFTER CARBONATION OR AT CARBONATION			
100 kg of liquor heated from 75° to 90° $\frac{100\ (90-75)}{540}$ = 2.8 kg 1st vapor.		2.8	
HEATERS BETWEEN PRESSES AND EVAPORATORS			
Quantity = Weight of liquor plus weight of wash water minus (lime cake minus CO_2) = 103 kg. 103 kg of liquor heated from 85° to 105° $\frac{103\ (105-85)}{540}$ = 3.8 kg 1st vapor.		3.8	
HEATING IN EVAPORATORS			
103 kg of liquor heated in 1st body from 105° to 110° $\frac{103\ (110-105)}{540}$ = 1.0 kg exhaust	1.0		
Totals	1.0	6.6	13.0

EVAPORATION

Assume that, according to actual scale weights, 6.0 kg of thick liquor has been produced per 100 kg of thin liquor introduced.

Then kg of water evaporated = 103 — 6.0 = 97.0

Another method by which the amount of evaporation may be calculated is from the percentage of dry substance in the thin and thick liquors.

STEAM CONSUMPTION	kg of Steam
97.0 total kg of water evaporated	
6.6 kg evaporated single effect	6.6
90.4	
26.0 kg evaporated double effect (2 × 13.0)	13.0
64.4 kg evaporated quintuple effect	12.9
	32.5
Live or exhaust steam used for heating	1.0
Total Steam Required	33.5

The total steam theoretically required is then 33.5 kg per 100 kg of thin liquor, or 33.5 tons per 100 tons of thin liquor introduced.

Now let A = tons of thin liquor introduced.

B = tons of steam required per 100 tons of thin liquor (33.5 in the above example).

C = tons of coal burned.

D = calorific value (B. T. U. per lb.) of coal burned.

X = B. T. U. theoretically required.

Y = B. T. U. in coal burned.

Then tons of steam required is $\frac{AB}{100}$

And $$X = \frac{AB}{100} \times 2000 \times 971 = 19420\ AB$$

where 971 is the latent heat of steam in B. T. U. per pound,

Also $Y = 2000\ CD$.

The ratio of X to Y is then a measure of the combined efficiency of the boiler house and the heat utilization.

X. CRUDE POTASH

1. SAMPLING

Take a large sample representing each car of crude ash shipped. If the potash is shipped at the time when it is sacked, obtain the sample by taking a small measureful from each sack before it is sewed, until the number of sacks required to load the car has been filled. A suitable measure can be made by riveting a handle on a 20 ml sheet iron crucible, or a tin measure of similar size (38 x 32 mm) may be used.

If the potash is not shipped at the time when it is sacked, obtain the sample at the time of shipment by drawing a sample from each bag by means of a suitable trier, preferably of the ''Indiana type.'' The latter consists of two telescoping, slotted brass tubes terminating in a solid, pointed end. This enables the sampler to be inserted full length into the bag before any material can enter the sample chamber. The latter is then opened and the sample is allowed to flow in, whereupon the sampler is closed and then withdrawn, so that a complete core of the entire bag is removed. The sampler should be about 18 inches long, or long enough to extend all the way through the bag.

Transfer the samples, as they are taken, in every case to a covered container, and employ every possible precaution to prevent unnecessary exposure to the air.

2. PREPARATION OF SAMPLES

(a) General Method

Reduce the gross sample to two portions of about 2 pounds each by means of a riffle sampler. Save one of these portions for the screen test. Reduce the other portion further, and put up three 4 ounce samples and seal them immediately, as described below. Handle the sample as rapidly as possible throughout in order to prevent absorption of moisture. See section 3 regarding the further preparation of the sample for analysis.

(b) Optional Method

This method may be used only for crude ash consigned within the company for refining or other purposes, and not for fertilizer material sold to other concerns.

Proceed as in (a) up to the point where the sample is reduced to two portions of about 2 pounds each. Save one of these for the screen test, as before, but grind the other portion, the full 2 pounds, in a porcelain *pebble mill for two hours, or sufficiently long to reduce it to 60 mesh size. After grinding, open the mill and put up immediately the three samples described below.

(c) Description of Samples

Put up three samples for each car, labeled with the name of the factory, the name and address of the consignee, the car number, the weight of material, and the date of shipment. Designate them respectively "Seller's No. 1," "Seller's No. 2," and "Seller's No. 3." Save an additional sample of the unground material for the screen test, as previously described.

Use "Seller's No. 1" sample for the local laboratory analysis, and seal and save for future reference the portion of this sample left over from the analysis. Hold the other two seller's samples subject to the receipt of instructions. Do not destroy or break the seals of any of the Seller's No. 2 or No. 3 samples without authorization from the General Office.

As the container for Seller's No. 2 and No. 3 samples, use a seamless tin salve box of four ounces capacity, provided with a slip cover, also seamless. Immediately after filling seal with a double layer of adhesive tape, to exclude moisture, and impregnate the tape with at least two coats of paraffin by rotating the box with the edge immersed in melted paraffin; allow each coat to cool and harden before applying the next coat which is used to close the blowholes in the previous coat. Attach a wax seal also as a guarantee against tampering.

The container for Seller's No. 1 sample may be:

(1) A seamless tin box sealed with tape and paraffin as described above.

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*The mill should be of the size which has a jar 8.75 x 9.65 inches (outside) rotating at the rate of 60-75 R. P. M.

(2) A glass bottle with ground glass stopper, sealed with at least two coats of paraffin.

(3) A glass bottle with a flat cork stopper, inserted so that the top of the stopper is at least 1/8 inch below the top of the neck of the bottle, and covered with at least two coats of paraffin.

3. PREPARATION OF SAMPLE FOR ANALYSIS

If the sample has been prepared as in 2 (b), no further preparation is required before analysis. Otherwise prepare the sample for analysis by putting the entire sample through a sieve having circular openings 1 mm in diameter, grinding in a mortar the portion remaining on the sieve until all the particles pass through. Grind and sift *as rapidly as possible* to prevent absorption of moisture, and avoid exposing any of the material unnecessarily to the air.

4. ANALYSIS (GENERAL)

Make the following determinations for each carload shipped: moisture, acid insoluble, lixiviated ash, potash, ammonia, and screen test. Make complete analysis of a composite sample representing the entire season's production.

Use due care in weighing on account of the hygroscopic nature of the material. Weigh in covered dishes or watch glasses, or from a weighing bottle, and as a rule make no effort to secure an even fraction or multiple of a gram.

5. MOISTURE

Weigh out approximately 2 grams in a covered aluminum "moisture dish." Heat for about 5 hours at 130° C., cool in a desiccator and weigh. Repeat the heating for one hour periods until the loss of weight is not over 0.2%. Consider the loss in weight to represent the moisture.

6. ACID INSOLUBLE.

Weigh out approximately 1 gram, transfer to a 250 ml beaker, and add 150 ml of water and 15 ml of concentrated hydrochloric acid. Keep the beaker covered with a watch glass during the addition of the acid and add the acid slowly. Digest on a hot plate for 30—45 minutes. Filter through a tared filter or Gooch crucible which has previously been washed with water and dried to constant weight. Wash with hot water, and dry to constant weight at 100—105°.

7. WATER INSOLUBLE

Determine as in "6," adding water but no hydrochloric acid.

8. LIXIVIATED ASH

Weigh out approximately 1 gram and transfer to a platinum dish. Heat to a *dull redness* to carbonize any organic matter present, then cool, extract with water, etc., following the procedure given in the "General Methods," Chap. I, 7 (b), and observing all the precautions there prescribed.

9. POTASH

(*Lindo-Gladding Method)

REAGENTS

(a) *Ammonium Chloride Solution:* Dissolve 100 grams of ammonium chloride in 500 ml of water, add 5—10 grams of pulverized potassium-platinic chloride, and shake at intervals for 6—8 hours. Allow the mixture to settle over night and filter. The residue may be used for the preparation of a fresh supply.

(b) *Platinum Solution:* A platinic chloride solution containing the equivalent of 1 gram of metallic platinum (2.65 grams of $H_2PtCl_6.6H_2O$) in every 10 ml. (Note that the salt sold commercially as "platinic chloride" has the formula $H_2PtCl_6.6H_2O$).

(c) *80% Alcohol:* Grain alcohol of sp. gr. 0.8645 at 15°/15° C.

DETERMINATION

Boil 5 grams of the sample with 300 ml of water for thirty minutes. Add to the hot solution a slight excess of ammonium hydroxide and then sufficient ammonium oxalate (1 or 2 ml) to precipitate all the lime present. After standing for one-half hour, cool, make up to a volume of 500 ml, mix, and pass through a dry filter. Evaporate †25 ml of the filtrate nearly to dryness, add

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*The method is, with a few additions and modifications, that of the Association of Official Agricultural Chemists.

†The pipette and flask used should be carefully standardized against each other.

1 ml of dilute sulphuric acid (1 to 1), and evaporate to dryness on a water bath. Finish the evaporation on a *Hillebrand radiator and ignite until all ammonium salts are expelled. Maintain a full red heat until the residue is perfectly white. Dissolve the residue in hot water, using at least 20 ml for each decigram of potassium oxide present. Filter if there is any insoluble residue. Add a few drops of hydrochloric acid, and platinum solution in excess (5 ml). Evaporate on a water bath to a thick paste. Treat the residue with 80% alcohol, avoiding exposure to ammonia. Filter through a Gooch crucible which has been previously washed with 80% alcohol and dried to constant weight. Wash the precipitate thoroughly with 80% alcohol both by decantation and on the filter, continuing the washing after the filtrate is colorless. Then wash with 10 ml of the ammonium chloride solution to remove impurities from the precipitate and repeat 5 or 6 times. Wash again thoroughly with 80% alcohol, dry the precipitate for 30 minutes at 100° C., cool in a desiccator, and weigh. Repeat the drying until constant weight is attained. The precipitate should be perfectly soluble in water. Use the factor .1938 to convert K_2PtCl_6 to K_2O.

Gooch Crucibles

The ignited asbestos for the felt is †prepared as follows: Cut long-fibered crysolite asbestos across the fibres into pieces 3/16 inch long, and ignite in a crucible or dish at a low red heat for at least 30 minutes. When cool, transfer to a porcelain mortar and macerate to a pulp with strong hydrochloric acid. Dilute this paste with a large amount of water, pour into a tall beaker, and allow to settle until the fibrous mass collects at the bottom, leaving the fine, milky silt in suspension. Remove all of this fine, milky material by repeated washing and decantation until the wash water becomes practically clear. Asbestos prepared in this manner makes a felt that filters rapidly. Preserve in water in a stoppered bottle. Form the filter by pouring enough of the suspended asbestos into the crucible to form a layer 1/16 inch thick when drawn down by suction. Exactly the right amount must be learned by experience. A properly prepared felt will filter rapidly and yet retain the finest precipitate. Before commencing a filtration, moisten the dry filter with a little 80% alcohol.

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*Chap. XXIII, 15.

†Bureau of Mines, Technical Paper 212, p. 13.

10. TOTAL NITROGEN AS AMMONIA

Determine total nitrogen by the Kjeldahl or Gunning method, both modified to include the nitrogen of nitrates. Calculate the nitrogen as ammonia (NH_3).

The *Gunning Modified Method is as follows:

REAGENTS

For ordinary work N/2 acid is recommended. For work in determining very small amounts of nitrogen N/10 acid is recommended. In titrating mineral acids against ammonium hydroxide solution use cochineal or methyl red as indicator.

(a) *Standard Sulphuric Acid:* Determine the absolute strength of the acid by precipitation with barium chloride solution as follows: Dilute a measured quantity of the acid to be standardized to approximately 100 ml, heat to boiling and add drop by drop a 10% solution of barium chloride until no further precipitation occurs. Continue the boiling for about 5 minutes, allow to stand for 5 hours or longer in a warm place, pour the supernatant liquid on a tared Gooch or on an ashless filter, treat the precipitate with 25—30 ml of boiling water, transfer to the filter and wash with boiling water until the filtrate is free from chlorine. Dry, ignite over a Bunsen burner and weigh as barium sulphate. See also Chap. XXV, 21 (a) (3). A normal solution of sulphuric acid has the following equivalents:

1 ml = .04904 gram H_2SO_4
1 ml = .01401 gram N
1 ml = .01703 gram NH_3

(b) *Standard Alkali Solution:* Accurately determine the strength of this solution by titration against the standard acid. N/10 solution is recommend.

(c) *Sulphuric Acid:* Of sp. gr. 1.84 and free from nitrates and ammonium sulphate.

(d) *Sodium Hydroxide Solution:* A saturated solution, free from nitrates.

(e) *Cochineal Solution:* Digest, with frequent agitation, 3 grams of pulverized cochineal in a mixture of 50 ml of strong alcohol and 200 ml of water for 1 or 2 days at ordinary temperature, and then filter.

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*Methods of Anal. of the Assoc. of Off. Agric. Chemists.

(f) *Methyl Red Solution:* Dissolve 1 gram of methyl red (dimethyl-amino-azo-benzene-ortho-carbonic acid) in 100 ml of 95% alcohol.

(g) *Potassium Sulphate:* Pulverized.

(h) *Sodium Thiosulphate.*

(i) *Commercial Salicylic Acid.*

APPARATUS

(a) *Kjeldahl Flasks for both Digestion and Distillation:* Total capacity of about 550 ml, made of hard, moderately thick, and well-annealed glass.

(b) *Distillation Flasks:* For distillation any suitable flask of about 550 ml capacity may be used. It is fitted with a rubber stopper through which passes the lower end of a Kjeldahl connecting bulb to prevent sodium hydroxide being carried over mechanically during distillation. The bulb should be about 3 cm in diameter, and the tubes should be of the same diameter as the condenser tube with which the upper end of the bulb tube is connected by means of rubber tubing.

DETERMINATION

Place 0.7—3.5 grams, according to the nitrogen content, of the substance to be analyzed in a digestion flask. Add 30—35 ml of salicylic acid mixture (30 ml of sulphuric acid to 1 gram of salicylic acid); shake until thoroughly mixed, and allow to stand for at least 30 minutes with frequent shaking. Add 5 grams of sodium thiosulphate and heat the solution for 5 minutes; cool; add 10 grams of potassium sulphate and heat very gently until foaming ceases, then strongly until nearly colorless. Do not add either potassium permanganate or potassium sulphide.

After cooling dilute with about 200 ml of water. Next add sufficient sodium hydroxide solution to make the reaction strongly alkaline (50 ml is usually enough), pouring it down the side of the flask so that it does not mix at once with the acid solution. Before neutralizing it is convenient to add a few drops of phenolphthalein indicator or a piece of litmus paper. The pink color given by phenolphthalein indicating an alkaline reaction is, however, destroyed by a considerable excess of strong fixed alkali.

Connect the flask immediately with the condenser, mix the contents by shaking, distil into a measured quantity of the standard acid until all ammonia has passed over, and titrate with the standard alkali. The first 150 ml of the distillate will generally contain all the ammonia.

BLANKS

Previous to use the reagents should be tested by blank experiments, and correction made if found necessary.

11. SCREEN TEST

Weigh out 500 grams and determine the percentage retained by a 12 and 20 mesh sieve, and the percentage finer than 20 mesh. Determine the percentage of the finest fraction by subtracting from 100.0 the sum of the percentages of the other fractions.

Vary this test, if necessary, to suit the specifications of each sale contract.

12. COMPLETE ANALYSIS

The constituents usually reported are moisture, acid insoluble, potassium chloride, potassium sulphate, potassium sulphide, potassium carbonate and sodium carbonate. Directions for moisture, acid insoluble, and potash have previously been given. The following additional determinations are required.

(1) TOTAL ALKALI AS CO_2

Extract a weighed amount with hot, neutral water, filter and wash. To the filtrate add a few drops of phenolphthalein and an excess of standard sulphuric acid. Boil until all of the carbon dioxide has been expelled, then titrate back with standard sodium hydroxide.

(2) CHLORINE

(*Volhard Method)

REAGENTS

(a) *N/10 or N/20 silver nitrate.*

(b) *N/10 or N/20 ammonium or potassium sulphocyanate.*

(c) *Ferric Indicator:* A saturated solution of ferric alum (ferric ammonium sulphate).

(d) *Nitric Acid:* Free from lower oxides of nitrogen, secured by diluting the usual pure acid with about ¼ part of water, and boiling till perfectly colorless.

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*Methods of Anal. of the Assoc. of Off. Agric. Chemists.

STANDARDIZATION

Standardize the silver nitrate solution by titrating in the presence of nitric acid against weighed amounts of freshly ignited C. P. sodium chloride (finely powdered and heated for five minutes, not quite to redness) or a standard solution of the same. Standardize the sulphocyanate solution by titrating against the silver nitrate solution. Make the titrations as described below under "Determination."

DETERMINATION

Extract a weighed amount of the sample with 50 ml of water in a 200 ml beaker. Add 5 ml of colorless nitric acid of 1.42 sp. gr., heat, filter, and wash with hot water. Add about 2 ml of the ferric indicator to the filtrate. Then add a few drops of the sulphocyanate solution from a burette, noting the quantity. Titrate with the silver nitrate solution, adding it drop by drop and stirring constantly, to decolorization. Add about 0.5 ml more of the silver nitrate solution, filter off the silver chloride, and wash thoroughly with hot water. Titrate the combined filtrate and washings to a permanent pink color with the sulphocyanate solution. Find the amount of chlorine by difference from the total amounts of the silver nitrate and sulphocyanate solutions used.

(3) SULPHURIC ACID

Dissolve 1 gram of the sample in about 100 ml of water and 5 ml of concentrated hydrochloric acid, in a flask in an atmosphere of carbon dioxide. Boil the hydrochloric acid solution, maintaining the atmosphere of carbon dioxide, until any hydrogen sulphide evolved is completely expelled. Filter and wash well with hot water. Add drop by drop to the boiling solution an excess of hot 10% barium chloride solution. After standing over night, filter, wash free from chlorine with hot water, ignite, and weigh as barium sulphate ($BaSO_4$). Add a drop of sulphuric and hydrofluoric acids before finishing the ignition; this will remove any silica, if present, and convert any reduced barium sulphide back to sulphate. Multiply the weight of $BaSO_4$ by .7465 to convert to K_2SO_4.

(4) HYDROSULPHURIC ACID

Digest 1 gram of the sample with about 100 ml of water, and 20 ml of bromine water to oxidize sulphides. Acidify with hydrochloric acid, and boil to complete solution and expel the excess of bromine. Filter, wash, and precipitate the sulphate sulphur in the filtrate with barium chloride as in (3). From the total sulphur thus determined, expressed as "% K_2SO_4", subtract the percentage of K_2SO_4 found in (3), and multiply the difference by .6327 to obtain the percentage of potassium sulphide (K_2S).

(5) HYPOTHETICAL COMBINATIONS

Calculate all of the chlorine, sulphuric acid, and hydrosulphuric acid as potassium chloride, potassium sulphate, and potassium sulphide respectively. Calculate the remaining potassium as potassium carbonate. Subtract the CO_2 in the potassium carbonate from the "total alkali as CO_2", and figure the remaining CO_2 as sodium carbonate.

XI. MOLASSES

This chapter relates to the sampling and testing of molasses in storage and of molasses shipments. Methods relating to molasses in connection with the factory process or the Steffen process will be found in an appropriate place.

1. STEFFEN MOLASSES BOUGHT OR SOLD

Determine on every car on the top sample:

(a) Brix.

Determine on every car on the average sample:

(b) Brix.
(c) Polarization.
(d) Apparent Purity.

SAMPLING

Obtain a continuous sample through a small tap in the pipe line while each car is being loaded or unloaded. After the car is loaded, or before it is unloaded, take another sample from the top of the car.

ANALYSIS

(a) and (b) *Brix:* Determine by the double dilution method, I, 1 (b).

(c) *Polarization:* Weigh out the half-normal weight and determine the sugar by direct polarization as in Chap. I, 3 (a).

(d) *Apparent Purity:* Follow the "General Methods," I, 4.

2. DISCARD MOLASSES BOUGHT OR SOLD

Determine on every car on the top sample:

(a) Baumé at 100° F.

Determine on every car on the average sample:

(b) Baumé at 100° F.

(c) Polarization.

SAMPLING

Sample in the same manner as Steffen molasses.

ANALYSIS

(a) and (b) *Baumé at 100° F.:* Transfer approximately one quart of the molasses to a copper vessel about 6 inches in diameter by 8 inches high. Immerse the vessel for one hour in a *water bath to such an extent that the level of the molasses in the vessel is below that of the water in the bath, and keep the water at a gentle boil, or within a few degrees of the boiling point, for one hour. Remove any foam, fill a glass cylinder carefully with the molasses, and insert a thermometer. Allow the molasses to cool, with occasional stirring. When the temperature has fallen to almost 100° F. (38° C.), insert a Baumé hydrometer standardized as described in Chap. XXIV, 3 (d), and take the reading at exactly 100° F. Be sure that the hydrometer has come to rest before the reading is made.

(c) *Polarization:* Determine as in the case of Steffen molasses.

3. MOLASSES IN STORAGE

SAMPLING

Sample each molasses storage tank once a week, securing one sample from the top and, if possible, another from the bottom.

If the top layer contains little or no foam, secure the sample by dipping three inches beneath the surface with an ordinary sample bucket. If foam is present, use a suitable sampling device by means of which a sample of the molasses immediately beneath the foam may be obtained. If the top sample shows a density of less than 42° Baumé, take additional samples at gradually increasing depths to determine the extent of this condition.

Secure the bottom sample from the pump or pipe line, or from a cock located near the bottom of the tank.

ANALYSIS

Determine the "Baumé at 100° F." on each sample according to the method described under "2. Discard Molasses Bought or Sold."

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*This is for the purpose of removing air bubbles, and under the conditions and time of heating specified the amount of evaporation has been found to be unimportant.

XII. BEET LABORATORY TESTS

1. GENERAL

The purpose of the beet laboratory tests is to determine the quality of the beets during the latter part of the growing season and at the time of delivery during the harvest season.

Determine on each sample:

(a) Sugar by Cold Water Digestion.

Determine as often as required:

(b) Sugar by Hot Water Digestion.

(c) Apparent Purity.

As beets are subject to both evaporation and deterioration on standing, the samples should be worked up as soon after receipt as possible and should not be allowed to accumulate.

2. PREPARATION OF SAMPLE

As each sample of beets is brought to the beet laboratory in a sack composed of such material as will best prevent evaporation, the sample should not be removed from the sack until shortly before it is to be analyzed. The samples should be cleaned, if necessary, and freed from dirt with a wire brush or other suitable apparatus, avoiding as much as possible injury to the outside surface. Delivery samples will have been previously tared and will require no cleaning at the beet laboratory. Field samples, and sometimes ''piled'' samples, will require cleaning.

If a record of the average weight is desired, count and weigh the beets constituting the sample, and enter the data on the envelope or ticket accompanying the sample.

Reduce a segment of each beet of the sample to a fine pulp by passing the beet through the Keil-Dolle rasp. A conical rasp, such as the Keil disc, has been found by us by careful tests to take, in the long run, an average sample of the entire beet, but the accuracy of the sample obtained is dependent on the observation of the following points.

(a) Place the beet in position firmly, and so that the edge of the wedge shaped segment removed coincides with the axis of the beet.

(b) Take the segment from the first beet at the smaller diameter, that from the second beet at the larger diameter, or *vice versa,* and so on alternately with the remaining beets of the sample.

(c) See that all the beets in each sample are rasped and that the disc and pan are properly cleaned between samples.

The reliability of the cold water digestion method in giving the correct percentage of sugar depends on the fineness of the pulp, as too coarse pulp will give low results because of incomplete extraction of the sugar. The production of sufficiently fine pulp is dependent on the observation of the following points.

(d) Push each beet through the rasp at a slow, uniform rate of speed which has been found by experience to give pulp of the proper fineness. The operator should never be allowed to force the beet so violently against the disc as to retard its rotation momentarily.

(e) See that the rasp is always up to the required speed of 600 revolutions per minute.

(f) Keep the rasp in proper mechanical condition, as described under section 3, ''Care of the Rasp.''

When all of the beets of the sample have been rasped, clean the disc by the momentary application of a fiber brush to each side. Transfer the pulp to a 10 inch, round bottomed, enameled mixing bowl by means of a metal or rubber spatula which fits the rasp pan closely. Cover the bowl if the balance man is not ready to handle the sample immediately.

3. CARE OF THE RASP

The disc must be mounted on the shaft so that the edge will run true without oscillation. New discs should be tested to see that they are true, as otherwise it will be impossible to mount them properly.

The disc should rotate at the rate of 600—700 revolutions per minute.

The *ease of rasping* is dependent on the *sharpness of the teeth,* but the *fineness of the pulp* is dependent on an *even contour of the edges of the teeth.* If a rasp is found to give too coarse pulp, the disc should be faced by holding a file or carborundum stone against both the sides and the edge of the rotating disc. Very often this procedure can be improved upon by first going over the disc and filing down all teeth which project perceptibly above the general contour; large side teeth close to the edge of the rasp are particularly objectionable and should be reduced by filing. After this treatment very little facing will usually be necessary to put the rasp into such condition that it will produce pulp of the proper fineness. The facing should be done gradually and the character of the pulp tested by comparative cold and hot water digestion, until a point is reached where the rasp yields fine pulp, but is still sufficiently sharp so that the beets may be ground without undue effort. New discs will commonly require facing before the pulp is satisfactory. The quality of the pulp can be judged only approximately by observation and must be determined by the average difference between series of comparative hot and cold water digestion tests. This difference should be less than 0.1 per cent on the weight of the beets, and, if it exceeds this figure, the rasp should be given attention.

When the disc becomes dull, the edge teeth should be sharpened with a cant file, care being taken to keep the teeth of as uniform size and even contour as possible. The edge should then be faced lightly, if necessary, as previously described. As the edge becomes wider from wearing down, it will be found increasingly difficult to obtain fine pulp, until a point is eventually reached where the disc will have to be discarded.

A scale of calcium oxalate frequently deposits on the disc, especially when immature beets are being rasped. As this forms a polished surface, its presence is easily overlooked. It has the effect of filling up the interstices between the teeth and thereby making the rasp dull. This scale can be removed mechanically, or very readily by immersing the disc in strong nitric acid diluted with an equal volume of water. The scale formation will be lessened if the disc is washed with hot water whenever the rasp is shut down for any length of time.

The rasp pan should not be allowed to come into contact with the rotating disc when it is removed after the grinding of each sample. For the same reason fiber brushes are preferable to wire brushes for cleaning the discs between samples.

At the end of every day the rasp should be thoroughly washed and scrubbed, and then dried well.

4. DETERMINATION OF SUGAR BY COLD WATER DIGESTION

Special Apparatus

(a) A pulp balance of suitable capacity and sensibility.

(b) A sufficient number of Monel metal capsules about 3 inches high by 3 inches in diameter, all adjusted to the same tare.

(c) Automatic pipettes which have been carefully standardized to deliver 177 ml, as described in Chap. XXIV, 2 (d).

(d) Aluminum discs with a round hole in the middle, provided with rubber envelopes, to serve as capsule covers.

Special Reagent

(a) *Dilute lead acetate:* Mix one part of basic lead acetate solution of standard strength (55° Brix) with 30 parts of water. The milky solution may be used without being allowed to settle.

Determination

Mix the sample of fine pulp *thoroughly* with a spoon or spatula, or by other suitable means. Weigh out 26 grams in a clean, dry capsule, discarding any fragments of skin, rootlets, etc., which may be occasionally discovered. Weigh the pulp within an accuracy of 20 milligrams, and do not waste time in attempting to weigh any more closely. Add 177 ml of the dilute lead acetate solution from the automatic pipette, cover, and shake vigorously for a few seconds. Let the covered capsule stand for at least 20 minutes, again shake vigorously, remove the cover, filter, and polarize in a 400 mm continuous tube. The reading gives directly the percentage of sugar.

Check the zero point of the polariscope at least four times a day, check the tare of the capsules once a day, and check the normal weight frequently. Check the thoroughness of the mixing occasionally by making sugar determinations on several samples taken at random from different parts of the same bowl of pulp.

5. DETERMINATION OF SUGAR BY HOT WATER DIGESTION

Check the accuracy of the cold water digestion tests by making hot water digestions on some of the regular samples of pulp. In general aim to check about 5% of the total samples in this way, and in particular use these tests to keep track of the performance of each rasp in service. The average difference between the hot and cold water tests should not exceed 0.1%.

Carry out the hot water digestion exactly as in the case of cossettes, as described in Chap. II, 1 (a), with the following modification occasioned by the fact that pulp from the Keil-Dolle rasp is apt to contain occluded air which is not removed by ether or by prolonged heating during digestion. After transferring the pulp to the 200.6 ml flask and adding the strong lead acetate, fill the flask about half full with water and place under vacuum for 3 or 4 minutes, carefully at first until frothing has ceased. Then disengage the flask, add more water, and proceed with the digestion in the prescribed manner.

6. APPARENT PURITY.

Make up a composite sample by taking equal portions of pulp from a number of the regular samples after rasping and mixing. Test at least 6 composite samples a day, and make it a rule that each composite sample shall represent the same number of individual samples, in order that a correct average of the daily work may be readily obtained. Do not hold any pulp for more than 2—3 hours, however, on account of the danger of deterioration.

Obtain the pressed juice and determine the apparent purity exactly as described in Chap. II, 1, ''Cossettes,'' under ''Preparation of Sample'' and under ''Analysis, (b) Apparent Purity,'' paying due regard to the standard pressure specified.

XIII. ASH ANALYSIS OF SUGAR FACTORY PRODUCTS

1. PREPARATION AND DETERMINATION OF LIXIVIATED ASH

Weigh out approximately 3 grams of molasses (in the case of other products an amount equivalent to about 0.5 gram of ash) in a platinum dish, and char at a low temperature, never employing a full red heat because of the danger of volatilizing alkali chlorides and of fusing the ash. Follow exactly the procedure for the determination of lixiviated ash as described in Chap. I, 7 (b).

It will probably be most convenient to prepare at one time sufficient ash for all the determinations, and then, after grinding and mixing, preserve it in a tightly stoppered bottle. Avoid unnecessary exposure to the air in preparing the sample, so that it will not absorb moisture. As the anhydrous ash is very hygroscopic, no attempt should be made to weigh out even multiples or fractions of a gram; weighing by difference, from a weighing bottle, is recommended.

To save time, the ash used for the determination of silica, iron and aluminum, calcium, and magnesium; of potassium and sodium; and of phosphoric acid may be prepared by adding sulphuric acid to a weighed amount of the original molasses or juice in each case, and igniting as in the determination of sulphated ash, I, 7 (a). In this case the percentages of the various constituents must be figured on the percentage of lixiviated ash in the molasses or juice as determined. It will probably be preferable, however, to use a prepared sample of lixiviated ash for all the determinations, as described above.

2. SILICA AND INSOLUBLE

Dissolve approximately 0.5 gram of the ash, prepared as in "1," with water, cover with a watch glass, and add cautiously a slight excess of hydrochloric acid. Heat till effervescence has ceased, then remove and wash the watch glass, and evaporate to dryness on the water bath. Moisten the residue with 5—10 ml of concentrated hydrochloric acid, cover the dish, and digest for 5—10 minutes on the bath. Add sufficient water to dissolve the salts, and heat again on the bath until solution is complete. Filter, wash first with cold water or with hot dilute hydrochloric acid, and then with hot water. Evaporate the filtrate to dryness, digest the residue with acid as before, but in smaller amount, and repeat the previous procedure. The second evaporation will usually complete the removal of all the silica. Ignite the two filters over a good burner, followed by a blast if necessary, and weigh as SiO_2.

3. IRON AND ALUMINUM

(a) *In the absence of phosphoric acid:* Oxidize any ferrous iron in the filtrate from "2" by adding several milliliters of bromine water, and boil off the bromine. Then cool somewhat, add enough hydrochloric acid to insure a total of 10—15 ml of strong acid, make *slightly alkaline with ammonium hydroxide, and boil for a few moments. The ammonia should not be in such excess as to require long boiling to expel the most of it, nor is the expulsion of the whole of it necessary or desirable. Filter as soon as the precipitate settles, wash with hot water, ignite, and weigh as $Fe_2O_3 + Al_2O_3$. Multiply by .6994 to obtain the iron (Fe) equivalent.

(b) *In the presence of phosphoric acid:* After oxidizing the iron with bromine water and boiling as in (a), nearly neutralize with a sodium carbonate solution, adding it drop by drop until a slight permanent precipitate is produced, which is then redissolved by the addition of a few drops of hydrochloric acid. Add 2—3 grams of sodium acetate (or 5—10 ml of a 30% solution), then add a ferric chloride solution of known iron content drop by drop from a burette as long as any precipitate is formed, avoiding any excess. As soon as the phosphoric acid is all precipitated, the blood-red ferric acetate is formed. If the solution turns red without the addition of any ferric chloride, none should be added, for in that case the iron is in excess of the phosphoric acid. Up to this point the volume should be kept as small as possible. Now dilute to a volume of at least 150 ml with boiling water, and boil for

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*See Hillebrand, U. S. Geol. Surv. Bull. 700, p. 107.

not more than two or three minutes. Filter while hot, and wash with hot water containing a little sodium acetate. Redissolve the precipitate in hydrochloric acid, using enough to insure a total of 10—15 ml of strong acid, and reprecipitate with ammonium hydroxide as in (a), combining the filtrate with the filtrate from the basic acetate precipitation. Ignite and weigh as $Fe_2O_3 + Al_2O_3 + P_2O_5$. From the weight of the precipitate deduct the Fe_2O_3 equivalent of the ferric chloride added, deduct also the amount of P_2O_5 present as determined in "9," then multiply by .6994 to obtain the iron equivalent of the iron and aluminum present.

(c) *Determination of iron and aluminum separately:* Fuse, in a platinum crucible, the ignited precipitate obtained as in (a) or (b) with about 4 grams of fused potassium hydrogen sulphate. This fusion takes but a few minutes and must not be continued unnecessarily. After cooling, add 5 ml of concentrated sulphuric acid and heat until copious fumes of sulphuric acid are given off. Cool, transfer to a flask, add water, and digest till the solution is clear. Reduce with zinc, cool, titrate with N/50 potassium permanganate (standardized against sodium oxalate), and calculate to iron (Fe). Obtain the aluminum by difference.

4. CALCIUM

Use the filtrate from 3 (a), or the two combined filtrates from 3 (b), which should be slightly alkaline with ammonia. To the boiling solution add drop by drop, from a pipette, burette, or capillary tube, 10 ml of hot ammonium oxalate solution, or sufficient to precipitate all the calcium present. Filter after standing for at least one hour, wash with hot water, and determine as oxide or sulphate as described under "Limestone," Chap. XVI, 5. Multiply the weight of CaO by .7146, or of $CaSO_4$ by .2944, to convert to calcium (Ca).

For very accurate work, the ignited calcium oxide is dissolved in hydrochloric acid and reprecipitated with ammonia and ammonium oxalate.

5. MAGNESIUM

To the filtrate from "4" add 10 ml of sodium ammonium phosphate or disodium hydrogen phosphate solution. After vigorous stirring add ammonium hydroxide in considerable excess. After standing over night, filter, and wash with dilute ammonium hydroxide (ammonium hydroxide of 0.90 sp. gr. diluted to ten times its volume). Char the paper slowly without allowing it to ignite, burn off the carbon over a gradually increasing flame, then apply a weak blast for a long time and repeat to constant weight to insure volatilization of any excess of P_2O_5 over and above that required for the pyrophosphate formula. Weigh as $Mg_2P_2O_7$ and multiply by .2184 to convert to magnesium (Mg).

For very accurate work, the precipitate on the filter is dissolved in dilute hydrochloric acid, and the magnesium is reprecipitated by adding a few drops of sodium or sodium ammonium phosphate and ammonia, which is added gradually with stirring and finally in slight excess.

6. POTASSIUM AND SODIUM

Extract approximately 0.2 gram of ash, prepared as in "1," with water and hydrochloric acid as in "2." Remove the soluble silica as described in "2," evaporate the filtrate and washings to dryness, dissolve in hot water, add 5 ml of barium hydroxide solution, and heat to boiling; let settle for a few minutes, and determine if the precipitation is complete by the addition of barium hydroxide solution to a little of the clear liquid. When no further precipitate is produced, filter and wash thoroughly with hot water. Heat the filtrate to boiling, add ammonium hydroxide and ammonium carbonate to complete the precipitation of the barium, calcium, etc., let stand a short time on the water bath, filter, and wash the precipitate throughly with hot water; evaporate the filtrate and washings to dryness, expel ammonium salts by heating below redness, treat with a little hot water, add a few drops of ammonium hydroxide, 1 or 2 drops of ammonium carbonate, and a few drops of ammonium oxalate; let stand a few minutes on the water bath, set aside for a few hours, filter, evaporate to complete dryness on the water bath, and heat to dull redness until all ammonium salts are expelled and the residue is nearly or quite white. Dissolve in a minimum amount of water, filter into a tared platinum dish, add a few drops of hydrochloric acid, evaporate to dryness on the water bath, heat to dull redness, cool in a desiccator, and weigh as potassium and sodium chlorides. Repeat the heating until constant weight is obtained. Dissolve in a small amount of water; if any residue remains, the separation must be repeated until the residue of potassium and sodium chlorides is entirely soluble.

Dissolve the residue with water, using at least 20 ml for each decigram of potassium oxide present, add 5 ml of platinic chloride solution, and proceed as in the determination of potash by the Lindo-Gladding method, Chap. X, 9. Calculate the sodium by difference from the weight of the combined potassium and sodium chlorides.

If the determination of potassium alone, and not sodium, is required, this may be made by saturating the original juice or molasses with sulphuric acid, and proceeding as in the determination of potash in liquors as described in Chap. IX, 12 (3).

7. CHLORINE

(*Volhard Method)

REAGENTS

(a) *N/10 or N/20 silver nitrate.*

(b) *N/10 or N/20 ammonium or potassium sulphocyanate.*

(c) *Ferric indicator:* A saturated solution of ferric alum (ferric ammonium sulphate).

(d) *Nitric Acid:* Free from lower oxides of nitrogen, secured by diluting the usual pure acid with about ¼ part of water, and boiling till perfectly colorless.

STANDARDIZATION

Standardize the silver nitrate solution by titrating in the presence of nitric acid against weighed amounts of freshly ignited C. P. sodium chloride (finely powdered and heated for five minutes, not quite to redness) or a standard solution of the same. Standardize the sulphocyanate solution by titrating against the silver nitrate solution. Make the titrations as described below under "Determination."

DETERMINATION

Dissolve a weighed amount of ash, prepared as in "1," in 50 ml of water in a 200 ml beaker. Add 5 ml of colorless nitric acid of 1.42 sp. gr., heat, filter if there is any important amount of insoluble matter, and wash with hot water. Add about 2 ml of the ferric indicator to the filtrate. Then add a few drops of the sulphocyanate solution from a burette, noting the quantity. Titrate with the silver nitrate solution, adding it drop by drop and stirring constantly to decolorization. Add about 0.5 ml more

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of the silver nitrate solution, filter off the silver chloride, and wash thoroughly with hot water. Titrate the combined filtrate and washings to a permanent pink color with the sulphocyanate solution. Find the amount of chlorine by difference from the total amounts of the silver nitrate and sulphocyanate solutions used.

8. SULPHURIC ACID

Extract approximately 1 gram of ash, prepared as in "1," with water and hydrochloric acid as in "2." Filter, wash with hot water, heat the filtrate to boiling and add drop by drop 5—10 ml of a hot, 10% barium chloride solution, or sufficient to precipitate all the sulphuric acid. After standing over night, filter, wash free from chlorine with hot water, ignite, and weigh as barium sulphate ($BaSO_4$). Add a drop of sulphuric and hydrofluoric acids before finishing the ignition; this will remove any silica, if present, and convert any reduced barium sulphide back to sulphate. Multiply by .4115 to convert to SO_4.

9. *PHOSPHORIC ACID

REAGENTS

(a) *Molybdate solution:* Dissolve 100 grams of molybdic acid in dilute ammonium hydroxide (144 ml of ammonium hydroxide of 0.90 sp. gr. and 271 ml of water); pour this solution slowly and with constant stirring into dilute nitric acid (489 ml of nitric acid of 1.42 sp. gr. and 1148 ml of water. Keep the mixture in a warm place for several days or until a portion heated to 40° deposits no yellow precipitate of ammonium phosphomolybdate. Decant the solution from any sediment and preserve in glass-stoppered vessels.

(b) *Ammonium nitrate solution:* Dissolve 200 grams of commercial ammonium nitrate, phosphate free, in water and dilute to 2 liters.

(c) *Magnesia mixture:* Dissolve 22 grams of recently ignited calcined magnesia in dilute hydrochloric acid, avoiding an excess of the latter. Add a little calcined magnesia in excess, and boil a few minutes to precipitate iron, aluminum, and phosphoric acid; filter; add 280 grams of ammonium chloride, 261 ml of ammonium hydroxide (sp. gr. 0.90) and dilute to 2 liters. Instead of the solution of 22 grams of calcined magnesia, 110 grams of crystallized magnesium chloride ($MgCl_2.6H_2O$) dissolved in water

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may be used, then add 280 grams of ammonium chloride and proceed as above.

(d) *Dilute ammonium hydroxide for washing:* Dilute 100 ml of ammonium hydroxide (sp. gr. 0.90) to 1 liter.

DETERMINATION

Extract a weighed amount of ash, prepared as in "1," with water and hydrochloric acid as in "2." Remove the soluble silica as described in "2," neutralize the filtrate and washings with ammonium hydroxide, clear with a few drops of nitric acid, and add about 15 grams of dry ammonium nitrate or a solution containing that amount. To the hot solution add 60—80 ml of the molybdate solution for every decigram of phosphoric acid (P_2O_5) that is present. Digest at about 65° C. for an hour, and determine if the phosphoric acid has been completely precipitated by the addition of more molybdate solution to the clear supernatant liquid. Filter and wash with cold water or, preferably, ammonium nitrate solution. Dissolve the precipitate on the filter with ammonium hydroxide and hot water, and wash into a beaker to a bulk of not more than 100 ml. Nearly neutralize with hydrochloric acid, cool, and add magnesia mixture from a burette; add slowly (about 1 drop per second) stirring vigorously. After 15 minutes add 12 ml of ammonium hydroxide of 0.90 sp. gr. Let stand till the supernatant liquid is clear (2 hours is usually enough), filter, and wash with the dilute ammonium hydroxide until the washings are practically free from chlorine. Ignite the precipitate as described under the determination of magnesium, and weigh as magnesium pyrophosphate, $Mg_2P_2O_7$. Multiply by .6379 to convert to P_2O_5 and by .8534 to convert to PO_4.

10. CARBONIC ACID

Carbonic acid (CO_3) is usually calculated by difference, as the amount necessary to saturate the excess of basic over acid ions. It may be accurately determined by the method described in Chap. XIV, 16.

11. HYPOTHETICAL COMBINATIONS

Join phosphoric acid to calcium; if there is any uncombined phosphoric acid remaining, join it to magnesium and sodium respectively. Then assign the residual basic ions in the following order: potassium, sodium, magnesium, calcium, and iron, to the residual acid ions in the following order: chlorine, sulphuric acid, and carbonic acid.

Sometimes the total of all the constituents or the direct determination of carbon dioxide will indicate that the silica should be calculated to the silicic acid ion (SiO_3) and combined with calcium.

12. STATEMENT OF ANALYSIS

Report the analysis in the following form:

Molasses Ash

....................Factory. (Date)

Description of Sample:

Molasses Analysis

	% on Original	% on Dry Sub.	% on Lix'd. Ash
Dry Substance	80.12		
Lixiviated Ash	11.46	14.30	
Sulphated Ash	12.02	15.00	
Factor, Sulph'd to Lix'd Ash	.953		
Potassium Oxide, K_2O	5.83	7.28	50.87
Sodium Oxide, Na_2O	1.00	1.25	8.73

Ash Analysis

		% on Lix'd Ash
Silica and Insoluble...............		
Iron and Aluminum, as Iron.....	Fe	
Calcium	Ca	
Magnesium	Mg	
Potassium	K	
Sodium	Na	
Chlorine	Cl	
Sulphuric Acid	SO_4	
Phosphoric Acid	PO_4	
Carbonic Acid	CO_3	
Total		

Combinations

Silica and Insoluble...............		
Potassium Chloride	KCl	
Potassium Sulphate	K_2SO_4	
Potassium Carbonate	K_2CO_3	
Sodium Carbonate	Na_2CO_3	
Magnesium Carbonate	$MgCO_3$	
Calcium Carbonate	$CaCO_3$	
Ferrous Carbonate	$FeCO_3$	
Sodium Phosphate	Na_3PO_4	
Magnesium Phosphate	$Mg_3(PO_4)_2$	
Calcium Phosphate	$Ca_3(PO_4)_2$	
Total		

(NOTE: Omit combinations not required.)

XIV. SCALES AND DEPOSITS

The composition of scales varies so widely that it is difficult to prescribe methods for everything which may be encountered. The following methods will, however, generally cover the important constituents of scales deposited from water or juice in a beet sugar factory.

1. SAMPLING

Obtain samples before the apparatus is boiled out, or, if this is not possible, take samples after boiling out and include a notation to this effect in the record. In obtaining the sample observe caution to avoid contamination with the underlying metal. To this end chipping will be found more reliable than scraping. Take samples from several parts of the apparatus in which the scale is found, and endeavor in every case to get portions which accurately represent the entire thickness of the incrustation.

Note the average thickness of the scale (in decimal inches) using calipers where practicable. Note also the hardness and other physical characteristics of the scale.

2. PREPARATION OF SAMPLE

If the sample is moist, dry it before grinding. Reduce the entire sample to 60 mesh, mix thoroughly, dry 20—50 grams to constant weight in an oven at 100—105°, cool in a desiccator, and preserve in a stoppered bottle. From this one general sample take all weighed portions for analysis.

3. QUALITATIVE EXAMINATION

Previous to any quantitative determinations, examine portions of the sample for the following: insoluble, soluble silica, copper, iron and aluminum, manganese, zinc, calcium, magnesium, potassium, and sodium; and for the following acids: hydrochloric, hydrosulphuric, sulphurous, sulphuric, phosphoric, carbonic, oxalic, acetic, tartaric, and citric. The methods for the qualitative examination are so well known that they need not be repeated here.

Since the presence of manganese, or of the other metals not mentioned, will be quite unusual, as also acetic, tartaric, and citric acids, the quantitative methods for them will not be given.

QUANTITATIVE EXAMINATION

4. INSOLUBLE

Ignite 1 gram of the thoroughly dried sample in a platinum crucible at a *moderate heat* to decompose organic acids, never heating above a dull redness on account of the danger of volatilizing alkalies. Transfer to a beaker, add 20 ml of 1:1 hydrochloric acid, 5—10 ml of concentrated nitric acid, and water to a volume of about 150 ml. Digest on a hot plate for one hour, replacing the water lost by evaporation. Filter, wash with hot water, ignite and weigh the residue.

5. SOLUBLE SILICA

Evaporate the filtrate from "4" to dryness on a water bath in a platinum or porcelain dish. Add 5—10 ml of concentrated hydrochloric acid, cover the dish, and digest for 5—10 minutes on the bath. Add sufficient water to dissolve the salts, and heat again on the bath until solution is complete. Filter, wash first with cold water or with hot dilute hydrochloric acid until the absence of any yellow color in the precipitate or paper indicates the removal of the iron, then finish the washing with hot water. Evaporate the filtrate to dryness, digest the residue with acid as before, but in smaller amount, and repeat the previous procedure. The second evaporation will usually complete the removal of all the silica. Ignite the two filters over a good burner, followed by a blast if necessary, and weigh as SiO_2.

6. COPPER

If more than a trace of copper is present, remove it from the filtrate from "5" by the following procedure. Heat the solution, which is already acid with hydrochloric acid, to boiling, and saturate with washed hydrogen sulphide gas, continuing the saturation until the solution has cooled to room temperature. Filter off the copper sulphide, washing well with hydrogen sulphide water. Do not allow the filter to run dry, as traces of the sulphide will be oxidized to sulphate on exposure to the air and will pass into the filtrate.

If the amount of copper is very small, it may be estimated with sufficient accuracy by igniting and weighing as cupric oxide (CuO). Otherwise use the following volumetric method.

*Low Volumetric Method

Reagents

(a) *Standard Sodium Thiosulphate Solution:* A solution containing 19 grams of the pure crystals in 1 liter.

(b) *Starch Indicator:* Mix about 0.5 gram of finely powdered potato starch with cold water to a thin paste; pour into about 100 ml of boiling water.

Standardization

Weigh accurately about 0.2 gram of pure copper foil and transfer to a 250 ml flask. Dissolve by warming with 5 ml of a mixture of equal volumes of strong nitric acid and water. Dilute to 50 ml, boil till all brown oxides of nitrogen have been expelled, add 5 ml of strong bromine water, and boil until the bromine is completely driven off. Cool somewhat and add a slight excess of strong ammonium hydroxide (about 7 ml). Again boil until the excess of ammonia is expelled, as shown by a change of color of the liquid and a partial precipitation. Then add a slight excess of strong acetic acid (3 or 4 ml of 80% acid) and boil for a minute. Cool to room temperature and add 10 ml of 30% potassium iodide solution. Titrate at once with the thiosulphate solution until the brown tinge has become weak, then add sufficient starch indicator to produce a marked 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 allowed for complete reaction after each addition, there is no difficulty in determining the end point within a single drop. One ml of the thiosulphate will be found to correspond to about 0.005 gram of copper.

Determination

Place the filter containing the copper sulphide precipitate in a small flask, add 4—5 ml of concentrated sulphuric acid and the

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same amount of nitric acid and heat until white fumes appear. Continue the oxidization, adding a little nitric acid from time to time, until the liquid remains colorless upon heating to the appearance of white fumes. Cool, dilute with about 30 ml of water, add an excess of bromine water, boil until all bromine is expelled, and proceed exactly as above under "Standardization."

7. IRON AND ALUMINUM

Boil the filtrate from "6" to expel hydrogen sulphide, then add bromine water (use the filtrate from "5" if copper has not been determined) and proceed as in Chap. XIII, 3 (a) or (b), according to whether phosphoric acid is present or not. Employ the latter method (basic acetate separation) in any case, if zinc is to be subsequently determined.

8. ZINC

Having precipitated the iron, aluminum, and phosphoric acid by the basic acetate method as in Chap. XIII, 3 (b), pass hydrogen sulphide into the filtrate until all the zinc sulphide, which should be pure white, is precipitated. Filter, and wash with hydrogen sulphide water containing a little ammonium nitrate. Char the paper at a low temperature, heat to 800—900° in a muffle for one hour, and weigh as ZnO. Multiply by .8034 to convert to zinc (Zn.)

9. CALCIUM AND MAGNESIUM

Boil the filtrate from "8" to expel hydrogen sulphide (use the filtrate from "7" if zinc has not been determined), make alkaline with ammonia, and determine as in Chap. XIII, 4 and 5.

10. POTASSIUM AND SODIUM

Determine as in Chap. XIII, 6, or as follows:

Weigh out, from the dried sample, enough material to give approximately 0.2 gram of the combined sulphates of magnesium, potassium, and sodium. Dissolve in hydrochloric acid and remove silica as in "4" and "5." Concentrate the filtrate and add a few milliliters of dilute sulphuric acid. Continue the evaporation over a Hillebrand radiator until fumes of SO_3 come off copiously, repeating the addition of sulphuric acid, if necessary, to decompose organic matter. Drive off the excess of sulphuric acid, take up with hot water and a few drops of hydrochloric acid, then remove iron, aluminum, and calcium as in "7" and "9." (This can be done in one operation.) Evaporate the filtrate in a platinum dish, adding toward the last a drop or two of sulphuric acid, and drive off the ammonium salts and the last traces of sulphuric acid by gentle ignition. Finally heat to dull redness, preferably in a muffle, to decompose bisulphates. Cool and weigh as $MgSO_4 + K_2SO_4 + Na_2SO_4$. Repeat the ignition to constant weight. From this point on avoid exposure to ammonia fumes.

Dissolve the residue in water, acidify with a few drops of hydrochloric acid, add chloroplatinic acid solution in excess and proceed as in the determination of potassium, Chap. X, 8. Multiply the weight of potassium platinic chloride, converted to percentage, by .3854 to convert to potassium sulphate, and multiply the percentage of magnesium, determined as in "8," by 4.9498 to convert to magnesium sulphate. Subtract the sum of these two from the percentage of combined sulphates to obtain the sodium sulphate, which multiplied by .3238 gives the percentage of sodium (Na). Multiply potassium platinic chloride by .1609 to obtain potassium (K).

11. CHLORINE.

Determine as in Chap. XIII, 7. It sometimes happens that the solution is too dark to permit the chlorine to be determined volumetrically. In this event proceed as follows:

Prepare a nitric acid solution of a weighed portion of the material, as for the volumetric method, and filter. Add a sufficient amount of silver nitrate solution to precipitate all the chlorine, avoiding any great excess. Heat to 50° and allow to stand for about one hour in a dark place. Filter through a Gooch crucible, and wash the precipitate several times by decantation with cold water slightly acidified with nitric acid. Transfer the precipitate to the Gooch and wash free from silver nitrate. Dry for half an hour at 100°, and finally at 130° to constant weight. Multiply silver chloride by .2474 to convert to chlorine (Cl).

12. SULPHURIC ACID (SULPHATE SULPHUR)

(a) *Method I:* Digest 1 gram of the sample with about 100 ml of water, and an excess of bromine water or sodium peroxide to oxidize sulphides and sulphites. Acidify with hydrochloric acid, and boil to complete solution and expel the excess of bromine. Filter and wash well with hot water. Add drop by drop to the boiling solution an excess of hot, 10% barium chloride solution. After standing over night, filter, wash free from chlorine with hot water, ignite, and weigh as barium sulphate. Add a drop of sulphuric and hydrofluoric acids before finishing the ignition; this will remove any silica, if present, and convert any reduced barium sulphide back to sulphate. From the total sulphur thus determined subtract the sulphite and sulphide sulphur determined as in "13" and "14" to obtain the sulphate sulphur.

(b) *Method II:* Dissolve 1 gram of the sample in about 100 ml of water and 5 ml of concentrated hydrochloric acid, in a flask in an atmosphere of carbon dioxide. Boil the hydrochloric acid solution, maintaining the atmosphere of carbon dioxide, until the hydrosulphuric and sulphurous acids have been completely expelled. Filter, wash, and precipitate the sulphate sulphur in the filtrate with barium chloride as in Method I. Multiply the weight of barium sulphate by .4115 to convert to SO_4.

13. SULPHUROUS ACID (SULPHITE SULPHUR)

Apparatus

A distillation flask, set above a burner, and fitted with a 3-hole rubber stopper. Through one hole of the stopper passes a dropping funnel or thistle tube, the stem of which reaches nearly to the bottom of the flask. Through another hole a glass tube extends nearly to the surface of the liquid in the flask and connects at the upper end to a carbon dioxide generator through a washing bottle. Through the third hole a short tube leads through a safety bulb to a short Liebig condenser which is so inclined that the lower end reaches well into the receiving vessel. The details of the generator are not important as long as the rate of flow of the gas can be regulated and the gas passes through a washing bottle.

Determination

Transfer 10 grams of the material to the distillation flask, fit in the stopper, and connect to the condenser and the gas generator; then introduce through the funnel or thistle tube 250 ml of recently boiled, distilled water. Start a current of gas through the apparatus, and place a receiving flask or beaker containing 100 ml of nearly saturated bromine water under the end of the condenser with the tip of the condenser extending below the surface of the bromine water. When all the air has been displaced by carbon dioxide gas, introduce a sufficient amount of copper sulphate solution to prevent the distillation of sulphide sulphur, and add 10—20 ml of a 20%, glacial phosphoric acid solution, introducing it through the dropping funnel slowly until frothing has ceased. Start the distillation and continue until 150 ml of distillate has passed over, watching that the bromine does not become too weak in the receiving solution. More bromine water may be added from time to time if necessary. When the distillation is completed, disconnect the condenser from the flask and rinse with water into the distillate. Transfer the distillate to a beaker, boil off the excess of bromine, add 5 ml of dilute hydrochloric acid (1 to 3), and precipitate with barium chloride, etc., as in "12." Multiply the weight of barium sulphate by .3430 to convert to SO_3.

14. HYDROSULPHURIC ACID (SULPHIDE SULPHUR)

Determine the sulphide sulphur by repeating the determination for sulphurous acid on a fresh 10 gram sample, following exactly the method outlined in "12" with the exception that no copper sulphate is added. By this procedure the hydrosulphuric acid will be distilled over with the sulphurous acid and be weighed as barium sulphate. Multiply the weight of barium sulphate thus found by .3430 to convert to SO_3, and subtract the SO_3 determined as in "13" to obtain the SO_3 equivalent of the sulphide sulphur. Multiply this by .4004 to convert to sulphur (S).

15. PHOSPHORIC ACID

Ignite 1 to 5 grams of the sample to destroy organic matter, dissolve in dilute hydrochloric acid, add a few ml of nitric acid, and boil. Then remove the silica and proceed as in Chap. XIII, 9.

16. CARBONIC ACID

The carbon dioxide in the carbonates is liberated by the action of dilute sulphuric acid, purified by bubbling through a mixture of concentrated sulphuric and chromic acids, and caught in a weighed potash bulb.

*Apparatus

A wide mouth extractor (CO_2) flask of 60 ml capacity, fitted with a 3-hole rubber stopper through which pass: (1) a glass tube leading to an acid reservoir; (2) a connection with an absorption tower filled with soda-lime to remove carbon dioxide from the air drawn through the apparatus; (3) the end of a short Liebig reflux

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*An illustration of a suitable arrangement of apparatus is given on Page 104 of W. W. Scott's "Standard Methods of Chemical Analysis."

condenser clamped in a vertical or inclined position. The second tube should extend well down into the flask so that the incoming air will pass directly over the surface of the liquid in the flask. The upper end of the condenser is connected by a bent tube to a bottle of sulphuric-chromic acid mixture, through which the gas bubbles on its way to the potash bulb; this serves to oxidize SO_2 and H_2S, and to remove the moisture in the gas from the condenser. A calcium chloride tube is attached to the potash bulb to catch any moisture carried over from the potash solution. The exit from the calcium chloride tube is connected, through a guard tube of soda-lime and calcium chloride and a catchall bottle, to a water pump which serves as a source of suction.

The Vanier potash bulb is preferable to the older Liebig and Geissler forms. In place of the potash bulb may be used a pair of soda-lime U-tubes, the first of which is filled with soda-lime, while the second is filled one-third with soda-lime, followed by calcium chloride; in this case the sulphuric acid bulb serves to indicate the rate of gas flow.

DETERMINATION

Weigh into the extractor flask a portion of sufficient size to give 0.1—.2 gram of CO_2, fit in the stopper, connect all the apparatus except the potash bulb, and test for air leaks. Start a slow current of air through the apparatus by means of the suction pump, and, when all the air in the system has been displaced by CO_2—free air, connect the potash bulb, which has been previously weighed. Thirty minutes should be ample time to displace the air. Then introduce, very slowly at first, about 30 ml of 10 per cent sulphuric acid from the acid reservoir. Be sure that the acid is not allowed to liberate so much carbon dioxide at first that there will be a backward current through the soda-lime tower, thereby resulting in the loss of some carbon dioxide. The current of air through the apparatus should not be faster than a safe working velocity for the type of potash bulb used. When all the acid has been introduced boil the contents of the flask for about 15 minutes to expel the last traces of carbon dioxide, remove the source of heat, and let the air current continue a few minutes more, then disconnect the potash bulb and weigh it, together with its calcium chloride tube. The increase in weight gives CO_2 directly, and, multiplied by 1.3636, the equivalent CO_3.

Alternative Method: Employ the same apparatus and manipulation as just described, but in place of the potash bulb use three small bottles filled with a measured amount of standard barium hydroxide solution. See W. W. Scott, "Standard Methods of Chemical Analysis," page 107, for details.

17. OXALIC ACID

REAGENTS

(a) *Calcium acetate solution:* A 5 to 10% solution.

(b) *N/10 potassium permanganate:* Prepared and standardized as described in Chap. XVI, 9.

DETERMINATION

Method I: Transfer 1 gram of the dried sample to a beaker, add 20 ml of 1:1 hydrochloric acid and water to a volume of about 150 ml. Digest on a hot plate until solution is complete, filter, and wash with hot water. Make the filtrate slightly alkaline by adding a potassium hydroxide solution, then make slightly acid with acetic acid. Heat the solution to boiling and add slowly a hot calcium acetate solution in excess. After standing over night, filter and wash the precipitate with hot water. Determine the oxalic acid by dissolving the precipitate in dilute sulphuric acid and titrating with permanganate exactly as described in Chap. XVI, 9.

Method II: Weigh out 1 gram of the dried sample, and add 10 grams of sodium carbonate and 75 ml of water. Boil for about 30 minutes, filter, and wash with hot water. Boil the residue again with 2—3 grams of sodium carbonate and a small amount of water, filter, and wash with hot water. Boil with sodium carbonate a third time in the same manner; the third extraction will complete the decomposition of the oxalates. By this procedure the oxalic acid will all be found in the filtrates and will be separated from the iron, aluminum, and other bases. Make the combined filtrates acid with acetic acid, heat to boiling, and proceed as in Method I, above.

18. AMMONIA

In certain scales considerable percentages of ammonia will be found. Determine by distilling with strong sodium hydroxide into standard acid in the usual manner and titrating the excess of acid with standard alkali, using cochineal as indicator. No detailed description is necessary as the method is well known.

19. SUGAR

Scales formed in the presence of saccharates may contain considerable sugar. Weigh out the half-normal weight of the sample, rinse into a 50 ml flask, make slightly acid with acetic acid, add sufficient basic lead acetate solution for clarification, and dilute to the 100 ml mark. Shake, filter, and polarize. The reading gives directly the percentage of sugar.

20. OIL

Oil will be found in many sugar factory scales and is determined by extraction with ether. It is advantageous to make the determination on a dry sample which has been lightly ground but not pulverized, owing to the fact that a fine powder containing oil has a great tendency to float on the ether and be carried over into the extraction flask.

Wash a paper thimble with ether, dry in an oven at 100°, and weigh into it 1 gram of the sample. Place the thimble in an extraction apparatus and extract with ether until extraction is complete. If the ether is free from sediment or suspended matter after the extraction, dry the thimble as before and weigh. The loss in weight represents the amount of oil. If particles of the sample have been carried over into the extraction flask, instead of weighing the thimble filter the ether solution through paper and evaporate at 40—50°, weighing the residue after the odor of ether has completely disappeared. Evaporate a similar volume of ether to determine the necessary correction and deduct from the weight of the residue. Call the difference "oil."

21. GRAPHITE AND FREE CARBON

Finely pulverize the dry residue from the oil determination and weigh out an amount equivalent to 1 gram of the original dry sample, treat with strong nitric acid and digest until the evolution of gas ceases. Repeat this nitric acid treatment adding a little concentrated sulphuric acid, then dilute till the acid is not too strong, and filter on an asbestos mat in a Gooch. Wash successively with a little water, alcohol, alcohol-ether mixture, alcohol, hot potassium hydroxide solution, hot water, dilute hydrochloric acid and finally with hot water. (In the absence of carbonaceous organic matter the washing with alcohol and ether may be omitted.) The residue should now contain only graphite and free carbon and possibly some silica.

Dry the Gooch and its contents in an electric muffle at 180° to constant weight. By this procedure the moisture in the graphite and free carbon will be driven out and all but a negligible amount from the silica. Cool and weigh. Next ignite the crucible in an electric muffle at 850° to 950° to constant weight. Obtain the graphite and free carbon together by difference.

For greater accuracy transfer the contents of the Gooch to a decomposition flask and determine the graphite and free carbon by the wet combustion method for the determination of carbon, using sulphuric and chromic acids and weighing the carbon dioxide absorbed in potassium hydroxide. For details of the method consult Scott's Standard Methods of Chemical Analysis, pages 102—103.

XV. COAL AND COKE

1. GENERAL

Prepare a weekly average sample of the coal burned during campaign for shipment to the Central Laboratory in accordance with the directions in Chap. VII, "Boiler House Control." The Central Laboratory should make the following determinations: moisture, volatile matter, fixed carbon, ash, and calorific value.

Analyze a sample representing each car of coke received, making the following determinations: moisture, volatile matter, fixed carbon, and ash. Determine sulphur on a composite sample of every five cars, but make up separate composite samples for each different kind of coke.

The methods of analysis are, with a few modifications, *those of the U. S. Bureau of Mines.

2. SAMPLING OF COAL AND PREPARATION OF SAMPLE

Directions for the sampling of coal burned during campaign will be found in Chap. VII, "Boiler House Control."

Special samples may be required at times for carload deliveries or boiler tests. The Bureau of Mines recommends a gross sample of †1,000 pounds as necessary, whether it is to represent a lot of 1 ton or 500 tons; a gross sample of ‡500 pounds is permissible if the size of the largest piece of coal or impurities is ¾ inch, or 250 pounds if ½ inch. While these requirements are not usually complied with, it should be remembered that considerable variations may occur in the analysis to the extent to which the size of the gross sample is below the figures above given.

The gross sample should be quickly crushed and reduced in acordance with the ‡methods of the Bureau of Mines. When the sample has been reduced to 25 pounds, or if the gross sample does not exceed this amount, it may conveniently be ground to 60 mesh

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*Bureau of Mines, Technical Papers 8 and 76.

†Bureau of Mines, Bulletin 116, pp. 13-15.

‡Bureau of Mines, Bulletin 116, p. 25, and Technical Paper 133, p. 9.

size in the pebble mill described in Chap. XXIII, 9. About 6 hours is required for grinding 25 pounds.

Smaller samples, which have to be ground in a mortar or other apparatus exposed to the air, should first be air dried in the following manner: After breaking up any large lumps, place the unground sample in a shallow pan, which has been previously weighed and is again weighed after being filled with the coal. Expose the sample to the atmosphere of the room, or to a current of air raised somewhat above the ordinary temperature (30—35° C.), until two successive weighings, made 6 to 12 hours apart, show a loss in weight of not over 0.2%. (The purpose of the drying is to reduce the moisture in the sample to such an extent that rapid change in weight will not take place while the sample is being handled in the course of analysis.) Then crush the sample, reduce if necessary, and grind to 60 mesh. Calculate the results of the analysis to coal of the original moisture content.

Any samples which are excessively wet should be air dried, as just described, before being ground.

3. SAMPLING OF COKE AND PREPARATION OF SAMPLE

Approximately 75 small pieces, equivalent to a total weight of 1,000 to 1,500 grams, obtained by being broken off from larger pieces with a hammer, should be taken to represent as nearly as possible an average of the car. There is room for a certain amount of personal equation, but the effort should be made to obtain as representative a sample as possible, neither intentionally selecting nor rejecting any coke which differs in appearance from the remainder.

Reduce the 75 pieces constituting the original sample to 10—12 mesh size with a jaw crusher. If a crusher is not available use a hammer, but crush by impact with the avoidance of any grinding. Mix thoroughly, being careful to avoid uneven distribution of the fine material which is lower in ash than the coarser part, and grind 15 grams in an agate mortar to pass a 60 mesh sieve; to avoid contamination, reserve a 60 mesh sieve for this purpose. Mix the ground sample well and transfer it to a stoppered bottle.

Do not use bucking boards, disc pulverizers, or any kind of mortar except an agate mortar for grinding the crushed sample, on account of the danger of contamination.

4. MOISTURE

Weigh out 1 gram of the 60 mesh sample in a covered porcelain or silica *capsule 7/8 inch deep and 1¾ inches in diameter, and heat for exactly one hour at 105° in a constant temperature oven. The Bureau of Mines uses an oven of a special design through which a current of dry, preheated air is passed. It will be admissible to employ a glycerin oven of the regular type as described in Chap. XXIII, 7, without the use of an air current. Cool the covered capsule in a desiccator over sulphuric acid and weigh. Call the loss in weight "moisture at 105°."

Moisture in coke can also be determined quickly and with adequate accuracy by simply heating to constant weight a large sample of lump coke, in any convenient oven, or on a stove, hot plate, or steam coil at a temperature of 100—200° C.

5. ASH

Determine ash in the same sample on which moisture has previously been determined. Place the porcelain capsule containing the sample in a cool muffle and raise the temperature gradually to about 750°; the object of this slow heating is to avoid mechanical loss from the rapid escape of volatile matter, and to avoid coking the sample and thus make its burning difficult. Continue the ignition in the muffle, with occasional stirring of the ash, until all particles of carbon have disappeared. Cool in a desiccator, weigh, and repeat the ignition for periods of half an hour until the difference in weight between two successive ignitions is less than 0.0005 gram. In the absence of a muffle, ignite over a flame, but be careful first to drive off the volatile matter slowly at a low temperature.

6. VOLATILE MATTER

Employ a bright, well burnished, 10 ml platinum †crucible with a closely fitting capsule cover; the crucible should be 1 inch in diameter at the top and 1 3/16 inches high, and the crucible and cover together should weigh about 15 grams. Weigh out 1 gram of the 60 mesh sample, and heat for 4—6 minutes over a *low flame* in order to avoid mechanical loss from the rapid escape of steam and volatile matter. (This preliminary heating is necessary for all kinds of coal analyzed by The Great Western Sugar

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*Bureau of Mines, Technical Paper 76, p. 16, fig. 1, a.

†Bureau of Mines, Technical Paper 76, p. 18, fig. 3, a and b.

Company, and for petroleum coke, but may perhaps be dispensed with in the case of coke which is low in volatile matter.)

Follow the preliminary heating by heating for exactly 7 minutes in an electric muffle furnace at *850°. Control the temperature preferably with a pyrometer. Where pyrometers are not available, the Central Laboratory will furnish standard samples of coal and coke on which the volatile matter has been determined at 850° in a pyrometer-controlled furnace. The temperature of the furnace may be regulated by making determinations on the standard samples. Seger pyrometer cones may also be found useful.

If an electric furnace is not available, follow the preliminary heating by heating for exactly 7 minutes on a platinum or nichrome triangle in the full flame of a No. 3 Meker or Scimatco burner. The bottom of the crucible should be 2 cm above the top of the burner, and, to protect it from drafts, it should be enclosed in a sheet-iron †chimney of special design. Adjust the height of the flame so that the temperature in the interior of the crucible will be 850°; this is done by making determinations with varying lengths of flame on the standard samples furnished by the Central Laboratory.

After heating for 7 minutes at 850°, cool in a desiccator and weigh. The loss in weight minus the weight of moisture represents the amount of "volatile matter" (at 850°).

7. FIXED CARBON

Subtract from 100 the sum of the percentages of moisture, ash and volatile matter.

8. SULPHUR

Reagent

Eschka Mixture is composed of two parts of light calcined magnesium oxide and one part of anhydrous sodium carbonate. It may be purchased in the form of an analyzed chemical.

Determination

Mix 1 gram (or for convenience of calculation 1.373 grams) of the 60 mesh coal with 6 grams of Eschka Mixture in a No. 1

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*The Bureau of Mines uses a temperature of 950°. This temperature is sometimes difficult to reach in an ordinary electric furnace and is hard on the life of it. The temperature adopted in any case is a matter of arbitrary selection.

†Bureau of Mines, Technical Paper 76, p. 18, fig. 3.

porcelain crucible and heat gradually in an electric muffle, with free access of air, until all the carbon has been consumed. If an electric muffle is not available, place on a triangle in a slanting position and burn out the mixture over an alcohol, gasoline, or natural gas flame; artificial gas as a rule contains so much sulphur that its use may introduce an error in the determination. Start the ignition in any case at a very low heat to avoid driving off volatile matter so fast that unburned sulphur escapes; even a small loss of sulphur dioxide may be detected by its pungent odor. The temperature should never be high enough to cause blackening of the top of the Eschka Mixture in the crucible.

After the crucible has been heated very slowly and cautiously for about 30 minutes, increase the heat, and after the crucible becomes red hot stir the contents occasionally until all black particles are burned out, a condition which indicates that the reaction is finished. Cool, transfer the crucible with its contents to a 200 ml beaker, and digest with 75 ml of hot water for at least 30 minutes. Filter into a 300 ml beaker, wash the insoluble residue twice with hot water by decantation and then on the filter until the volume of solution in the 300 ml beaker is about 200 ml. Add about 4 ml of saturated bromine water, or a slight excess, and enough concentrated hydrochloric acid to make the solution slightly acid. Boil off the bromine and add slowly to the boiling solution from a pipette 10 ml of a hot 10% barium chloride solution. After standing for at least 3 hours, filter, dry, ignite, and weigh as $BaSO_4$, as described in Chapter I, 9. To obtain the percentage of sulphur multiply the weight of barium sulphate by 13.73 if 1 gram of material was used, or by 10 if 1.373 grams was used.

9. CALORIFIC VALUE

Determine the heat of combustion with a bomb calorimeter, by burning one gram of the 60 mesh sample in compressed oxygen gas and absorbing the total heat evolved in a weighed quantity of water in which the bomb is immersed. Measure the rise in temperature of the water with a thermometer that is graduated in hundredths of 1° C. and can be read by a telescope to .002° C. Make corrections for radiation, combustion of the iron wire, oxidation of nitrogen to aqueous nitric acid, and oxidation of sulphur dioxide to aqueous sulphuric acid. The calorific value obtained in this manner is the total heat of combustion with water vapor condensed to liquid water at the temperature of the calorimeter, i. e., 20—25° C.

For detailed directions consult Technical Paper 8 of the Bureau of Mines and Circular 11 of the Bureau of Standards, also the pamphlet of directions furnished with the calorimeter. On page 13 of the Bureau of Mines Paper is given an explanation and example of the customary method of calculating the radiation correction; a shorter method is described on page 15 of the Bureau of Standards circular.

The correction for iron wire is 1.7 calories (3.1 B. T. U.) per milligram. The correction for sulphur burned to sulphuric acid is 13 calories (23 B. T. U.) per 0.01 gram of sulphur. The correction for nitrogen to aqueous nitric acid is made by titrating the acidity of the bomb liquor with standard ammonia solution (0.00574 gram NH_3 per ml), using methyl orange as indicator, and is equivalent to 5 calories (9 B. T. U.) per milliliter. These corrections need be determined only occasionally for each different type of coal.

Use only thermometers which have been tested by the Bureau of Standards and make the necessary corrections according to the certificate. The thermometers may be either of the regular kind with a scale range of about 20—30° C., or of the Beckmann or ''differential'' type. Use only oxygen which is made by a liquid air process; do not use electrolytic oxygen, which contains small amounts of hydrogen. Check the water equivalent of the calorimeter by burning weighed amounts of the standard ''combustion samples'' (benzoic acid, napthalene, and sucrose) of the Bureau of Standards of known calorific value.

10. ANALYSIS OF BOILER HOUSE ASHES

See Chap. VII, 4 and 5, regarding the sampling of boiler house ashes and the preparation of the samples.

Dry a sufficient amount of the sample to approximately constant weight at 105°. Determine the percentage of actual ash by igniting 1 gram, or approximately this amount, of the dried sample, as described in the determination of ash, section 5 of this chapter. Figure the percentage of ash on the weight of the dried sample.

11. BIBLIOGRAPHY

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XVI. LIMESTONE

1. GENERAL

Sample every car of limestone and determine by the "rapid method:"

(a) Insoluble, and iron and aluminum oxides (together).
(b) Calcium carbonate.

At the end of every week make up a composite sample representing the week's deliveries by mixing equal portions of the samples of the individual cars. If more than one kind of limestone has been received, make up and analyze separate composite samples for each kind. On the weekly average samples make the complete analysis by the gravimetric method, determining:

(a) Insoluble.
(b) Iron and aluminum oxides.
(c) Calcium carbonate.
(d) Magnesium carbonate.
(e) Calcium sulphate, if present.

Keep the individual car samples for at least two weeks before discarding, for possible reference.

2. SAMPLING AND PREPARATION OF SAMPLE

Approximately 75 small pieces, obtained by being broken off from larger pieces with a hammer, should be taken as uniformly as possible over the top of the car before it is unloaded, or during the unloading. There is room for a certain amount of personal equation, but the effort should be made to obtain as representative a sample as possible, neither intentionally selecting nor rejecting any stone which differs in appearance from the remainder. If a piece which is sampled contains a coating of surface material, the small sample taken should be broken off in a direction which will include an approximately proportional amount of this surface material.

It is quite essential to take the number of pieces specified. Even under these conditions two samples from the same car taken by different operators will occasionally differ as much as one per cent in calcium carbonate, though they will generally be much closer.

Reduce the 75 pieces constituting the original sample to ¼ inch size with a jaw crusher. Mix the crushed sample well and quarter it. Reduce one of the quarters to 60 mesh size with a disc pulverizer. Mix the finely ground sample well, and preserve a suitable amount in a stoppered bottle.

GRAVIMETRIC METHOD

3. INSOLUBLE

Dissolve 0.4—.5 gram in 50 ml of water and 20 ml of concentrated hydrochloric acid, in a beaker covered with a watch glass. When effervescence has ceased, heat to boiling and digest on a hot plate for 10—15 minutes. Filter, wash thoroughly with hot water, ignite and weigh the "insoluble."

4. IRON AND ALUMINUM

To the filtrate from "3" add several milliliters of bromine water, or a few drops of concentrated nitric acid, and boil. Then cool somewhat, make slightly alkaline with ammonium hydroxide, and boil for a few moments. The ammonia should not be in such excess as to require long boiling to expel the most of it, nor is the expulsion of the whole of it necessary or desirable. Filter as soon as the precipitate settles, wash with hot water, ignite, and weigh as $Fe_2O_3 + Al_2O_3$.

5. CALCIUM

Dilute the filtrate from "4" to a volume of at least 150 ml, heat to boiling, and to the boiling solution add drop by drop, from a pipette, burette, or capillary tube, 20 ml of hot ammonium oxalate solution. By adding the reagent in this manner the calcium oxalate will be precipitated in a granular form which will permit of rapid filtration and it will not pass through the filter paper. Filter after standing for at least one hour, wash two or three times with hot water, and convert to oxide or sulphate, as described below.

(a) *Determination as Oxide:* Ignite over a burner of the Meker type for one-half hour or longer, in a platinum crucible which has been weighed together with its cover. After the carbon is all burnt off, put on the cover, and keep the crucible covered during the balance of the ignition, and during cooling, weighing, and subsequent ignitions. Blast for successive periods of 5 minutes until the weight is constant, or heat in an electric furnace. Cool in a desiccator over concentrated sulphuric acid, which should be renewed frequently, especially when it begins to show any sign of discoloration, and do not let the crucible stand in the desiccator for more than half an hour before weighing. Weigh as calcium oxide, and multiply by 1.7848 to convert to calcium carbonate ($CaCO_3$).

(b) *Determination as Sulphate:* Ignite in a platinum crucible until all carbon is burnt off, but not necessarily until all carbonate is decomposed. After cooling, slack cautiously with a little water and add a slight excess of sulphuric acid. Evaporate on a *Hillebrand radiator until all the free acid is expelled, heat to *dull redness* over a flame, and weigh as calcium sulphate. Multiply by .7351 to convert to calcium carbonate.

Sulphuric acid may be added before the filter paper is burnt, but in this case a second addition of sulphuric acid must be made after the carbon is all burnt off, in order to reconvert any sulphate reduced to sulphide by the carbon of the paper.

When calcium is weighed as the sulphate, certain precautions are necessary as calcium sulphate is partially converted to oxide at a red heat. After the final addition of sulphuric acid the crucible must not be heated above a dull redness, i. e., a redness which is barely visible in daylight. When sulphuric acid is added before the filter paper is burnt off, this degree of heat must not be exceeded at any time during the ignition. After weighing, a drop of phenolphthalein should be added; if the precipitate has been properly handled it should not give a pink color with the indicator. If a pink color is produced, add a little sulphuric acid and repeat the previous procedure until the precipitate fails to give a pink color with phenolphthalein.

In the ignition of precipitates in general, the paper is most easily burnt if high temperatures are avoided, especially at first. The best results are probably obtained by charring the paper without allowing it to break into flame, and then raising the tem-

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*See Chap. XXIII, 15.

perature to the point where the charred residue just begins to glow nicely. After the carbon is all burnt off, the crucible may be raised to whatever temperature the conditions of the particular determination require.

6. MAGNESIUM

To the filtrate from "5" add 10 ml of sodium ammonium phosphate or disodium hydrogen phosphate solution. After vigorous stirring add ammonium hydroxide in considerable excess. After standing over night, filter, and wash with dilute ammonium hydroxide (ammonium hydroxide of 0.90 sp. gr. diluted to ten times its volume). Char the paper slowly without allowing it to ignite, burn off the carbon over a gradually increasing flame, then apply a weak blast for a long time and repeat to constant weight to insure volatilization of any excess of P_2O_5 over and above that required for the pyrophosphate formula. Weigh as $Mg_2P_2O_7$ and multiply by .7572 to convert to magnesium carbonate ($MgCO_3$).

7. SULPHURIC ACID

Sulphur seldom occurs in important amount in limestone used by beet sugar factories. If this determination is necessary, it may be made as follows: Dissolve 1—2 grams in water and hydrochloric acid, filter, and wash with hot water. Determine the sulphuric acid in the filtrate as in Chap. XIII, 8. If sulphuric acid is found present, calculate it as calcium sulphate, and subtract its calcium carbonate equivalent from the calcium carbonate equivalent of the total calcium determined as in "5."

Limestone from new or unfamiliar quarries should always be examined for sulphuric acid.

RAPID METHOD

8. INSOLUBLE, AND IRON AND ALUMINUM OXIDES

Dissolve 0.4—.5 gram in 50 ml of water and 20 ml of concentrated hydrochloric acid, in a beaker covered with a watch glass. When effervescence has ceased, heat to boiling and digest on a hot plate for 10—15 minutes. Add several milliliters of bromine water, or a few drops of concentrated nitric acid, and boil. Then cool somewhat, make slightly alkaline with ammonium hydroxide, and boil for a few moments. Filter, wash well with hot water, ignite, and weigh as "insoluble" + Fe_2O_3 + Al_2O_3.

9. CALCIUM

REAGENT

N/5 or N/10 Potassium Permanganate: For a N/5 solution, dissolve 6.32 grams of the pure crystals in water, filter through asbestos, and make up to 1 liter. One ml of this solution will be found to be equivalent to about .01 gram of calcium carbonate. Keep in a dark bottle well protected from the light. The solution should be allowed to stand several days, if possible, before it is standardized, and its value will vary but little after this time. As a matter of precaution, however, it is well to restandardize it once a month.

STANDARDIZATION

Weigh out 1.34 grams of sodium oxalate of the *highest purity obtainable, dissolve in water, add 50 ml of dilute sulphuric acid (1 to 10), dilute to a volume of about 150 ml, heat to 70°, and titrate to a permanent pink with the permanganate solution. From several such titrations determine the calcium carbonate equivalent of one ml of the permanganate.

Sodium oxalate of the Bureau of Standards may be used for a primary standard. Traces of moisture can be removed from sodium oxalate by heating at 120° for two hours.

DETERMINATION

Dilute the filtrate from "8" to a volume of at least 150 ml, heat to boiling, and to the boiling solution add drop by drop from a pipette, burette, or capillary tube, 20 ml of hot ammonium oxalate (4% solution). By adding the reagent in this manner the calcium oxalate will be precipitated in a granular form which will permit of rapid filtration and it will not pass through the filter paper. Filter after standing for at least one-half hour, and wash thoroughly, but not excessively, with hot water.

Wash the precipitate into a beaker with a jet of hot water, allowing the open paper to cling to the side of the beaker above the liquid. Add 50 ml of dilute sulphuric acid (1 to 10), pouring it over the surface of the paper. Dilute to a volume of about 150 ml, heat to 70°, and titrate with the permanganate solution. The reaction requires a short time after the addition of the permanganate, but, after it once begins, the permanganate may be added quite rapidly until the end point is nearly reached. Continue the

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*Use the grade "C. P. Special for Standardizing" and not the ordinary "C. P."

titration drop by drop until a faint pink color persists, then introduce the filter paper and add a few drops more of the permanganate, if necessary, until the permanent end point is reached.

10. CARBONIC ACID

Ignite 0.5 gram in a platinum crucible to constant weight over a good burner, followed by a blast, or in an electric furnace. The loss on ignition is considered to represent the amount of carbon dioxide. Check the efficiency of the furnace or burner occasionally by the ignition of pure calcium carbonate.

If moisture is present in the original sample, it must first be dried for one hour at 100—105° and then weighed. This precaution is, however, hardly ever necessary.

11. CALCULATION OF RESULTS

Multiply the percentage of CO_2 (loss on ignition) by 2.2742 to obtain the percentage of total carbonates as calcium carbonate. Subtract the percentage of calcium carbonate, as determined in "9," and multiply the difference by .8426 to obtain the percentage of magnesium carbonate.

XVII. WATER

1. SAMPLING OF WATER FOR BACTERIOLOGICAL EXAMINATION

(a) Apparatus

Use sterilized bottles provided with glass stoppers and with cloth caps secured by a rubber band. The bottles are cleansed with great care, rinsed in clean water, and sterilized, together with the stoppers and caps, by heating to 180—190° C. A suitable shipping case, containing compartments for the bottles and for icing, is also required.

(b) Procedure

Adhere strictly to the following procedure:

(1) Allow a good stream to run from the faucet or source of supply for at least 10 minutes before the sample is taken, in order that one may be sure of obtaining fresh water and not water which has been standing in the pipe.

(2) Remove the rubber band and the cloth cap from the bottle, being careful not to drop the cap or to allow anything to touch the inside of it.

(3) Rinse the outside of the bottle, with the stopper in place, with water from the source of supply which is to be sampled.

(4) Remove the stopper, being careful not to touch any part of it except the portion which projects outside the bottle.

(5) Fill the bottle completely with the water to be tested.

(6) Holding the bottle in one hand and the stopper, in an inverted position, in the other hand, invert the bottle and allow some of the water to run out over the stopper. Insert the stopper while pouring, thus leaving some air space to allow the bottle to be shaken before plating.

(7) Rinse the outside of the bottle again.

(8) Put the cap on the bottle, and secure with the rubber band.

(9) Label the bottle with regard to the source of sample, time when taken, etc.

Observe care to omit none of the steps in the procedure above described. Number Seven, which calls for rinsing the stopper and the outside of the bottle after the stopper has been inserted, is probably the one which is most apt to be forgotten.

Immediately after the samples have been taken, ship them on ice to the laboratory where they are to be tested.

2. SAMPLING OF WATER FOR CHEMICAL ANALYSIS

No particular directions are needed with regard to the collection of special samples. The following instructions relate to the collection of weekly and campaign average samples for analysis:

(a) Campaign Average Samples

A composite sample of each kind of water of importance, as described below, should be made up during the campaign and analyzed after the end of the campaign. The Chief or Assistant Chemist should once a shift obtain the required samples, and, in order to avoid contamination with sulphuric acid, he should use a different set of test tubes or receptacles from that used by the sample carrier who obtains samples for the alpha-naphthol tests. A measured volume of each kind of water should be transferred to a bottle of suitable size, appropriately labeled, to form the composite sample. Sufficient water should be taken so that the final volume will amount to at least 2 liters, and preferably more in the case of waters low in solids. It is advisable to make up several composite samples of each water, representing successive periods of three or four weeks each during the campaign, and to test these for contamination before mixing to form the general composite sample.

The collection of these samples should be started as soon after the beginning of the campaign as possible, when it is certain that the waters are running in a normal manner. Samples should be taken of all "condensed water," "main supply waters," etc., and will include the following:

Water from Boiler Feed Tank
Condensed Water Pumped Direct to Boilers
Water in Boilers

Water Used for Washing Hot Presses and Saccharate Presses
Pure Battery Supply Water
Impure Battery Supply Water
All Condensed Waters (including all that are tested regularly)
All Main Supply Waters, such as Ditch, Well, River, and City Water
All Cooling Waters, including Tail Pipe Waters
In addition to the above, any waters that may be necessary to complete the record.

Analyses of different samples representing the same water need not be unnecessarily duplicated. Thus if all or a number of the pan condensers are supplied with the same water, a single composite sample may be made up for analysis from the composites of the individual tail pipes. Separate samples should be saved, however, so that they will be available if any change is made in the water system during the campaign.

(b) Weekly Average Samples of Battery Supply Water

Weekly composite samples of the battery supply water should also be collected in the same manner as the campaign average samples, separate samples of the "pure" and "impure" water being taken if a dual system is in use. At the end of every week filter the water and determine the total solids, as described below.

(c) Average Samples During Potash Campaign

Factories engaged in potash recovery should also collect average samples for the potash campaign of all waters sampled for the same purpose during the beet campaign, as described in (a) above, and in addition should obtain average samples of the condensed water from the steam chamber of each evaporator body. These samples should be analyzed in full, and, in any water which may be contaminated with potash liquors by leaks or entrainment, potassium should be determined separately as described in Chap. XIV, 10.

ANALYSIS

The methods are taken from various sources, following in many cases those of the Association of Official Agricultural Chemists. Make all determinations on water which has been freed from suspended matter by filtration.

3. TOTAL SOLIDS

Allow the sample to stand until all sediment has settled, and filter if necessary to secure a perfectly clear liquid. Evaporate *500 ml (preferably more if the water is low in solids) in a weighed platinum dish on a water bath. Additional platinum and porcelain dishes may be used to hasten the evaporation, the various concentrated portions being finally rinsed into the weighed platinum dish, with the aid of a "policeman" to remove crystallized salts. After evaporation to dryness, heat to constant weight at 105° C. in a constant temperature oven.

Where the complete analysis is not required and the determination of total solids alone is necessary, as in the case of the weekly samples of battery supply water, evaporate 100 ml as above, and dry at 105° C.

4. TOTAL SULPHATES

Dissolve the residue from "3" in the least possible amount of distilled water, and acidify with 3-5 ml of dilute sulphuric acid (1:10). Evaporate first on the water bath, and then carefully at a †temperature sufficiently high to expel the excess of sulphuric acid without loss. Heat finally to a redness which is barely visible in daylight until the residue is white; cool, and weigh.

This treatment is prescribed to destroy organic matter, and for the indirect determination of the sodium. Subtract from the weight of "total sulphates" the amount of calcium and magnesium (as sulphates) and of silica, and iron and aluminum oxides (as such); the remainder is considered to be sodium sulphate and is multiplied by .3238 to convert it to sodium (Na).

5. SILICA

Moisten the residue from "4" with concentrated hydrochloric acid and evaporate to dryness on a water bath. Moisten again with concentrated hydrochloric acid, cover the dish, and digest for 5—10 minutes on the bath. Add sufficient water to dissolve the salts and heat again on the bath until solution is complete. Filter, wash with hot water, dry, ignite, and weigh the silica (SiO_2).

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*The amount should be sufficient to give, if possible, 0.5 gram of total solids and in any case not less than 0.2 gram. A preliminary determination made by evaporating 50 ml of the water will show the amount required.

†The "radiator" recommended by Hillebrand is especially good for volatilizing sulphuric acid. See Chap. XXIII, 15.

6. IRON

To the filtrate from "5" add several milliliters of bromine water, or a few drops of concentrated nitric acid, and boil. Then cool somewhat, add enough hydrochloric acid to insure a total of 10—15 ml of strong acid, make slightly alkaline with ammonium hydroxide, and boil for a few moments. The ammonia should not be in such excess as to require long boiling to expel the most of it, nor is the expulsion of the whole of it necessary or desirable. Filter as soon as the precipitate settles, wash with hot water, ignite, and weigh as $Fe_2O_3 + Al_2O_3$. Report the iron and aluminum together as iron. Multiply the weight of the precipitate by .6994 to obtain the iron (Fe) equivalent.

7. CALCIUM

Heat the filtrate from "6" to boiling, and to the boiling solution add gradually about 10 ml of ammonium oxalate solution. Filter after standing for at least one hour, wash two or three times with hot water, and determine gravimetrically as oxide or sulphate as described under "Limestone," Chap. XVI, 5. Multiply the weight of CaO by .7146, or of $CaSO_4$ by .2944 to convert to calcium (Ca).

8. MAGNESIUM

To the filtrate from "7" add 10 ml of sodium ammonium phosphate or disodium hydrogen phosphate solution. After vigorous stirring add ammonium hydroxide in considerable excess. After standing over night, filter, and wash with dilute ammonium hydroxide (ammonium hydroxide of 0.90 sp. gr. diluted to 10 times its volume). Char the paper slowly without allowing it to ignite, burn off the carbon over a gradually increasing flame, then apply a weak blast for a long time and repeat to constant weight. Weigh as $Mg_2P_2O_7$ and multiply by .2184 to convert to magnesium (Mg).

9. CHLORINE

REAGENTS

(a) *Sulphuric acid of about N/28 strength:* This solution does not have to be standardized.

(b) *Sodium carbonate solution of about N/28 strength:* This solution does not have to be standardized.

(c) *Potassium chromate indicator:* Dissolve 5 grams of potassium chromate in water, add a solution of silver nitrate drop by drop until a slight permanent red precipitate is produced, filter, and dilute to 100 ml.

(d) *Standard sodium chloride solution:* Several grams of C. P. sodium chloride are finely powdered and heated for five minutes, not quite to redness. When cold, 0.8243 gram is dissolved in water and made up to 500 ml. Each ml = 0.001 gram chlorine.

(e) *Standard silver nitrate solution:* Dissolve about 5 grams of C. P. silver nitrate in water and dilute to 1 liter.

STANDARDIZATION

Transfer 25 ml of the standard sodium chloride solution to a porcelain dish, or a beaker standing on a white surface. Dilute with 75 ml of chlorine-free water. Add 1 ml of the potassium chromate, and introduce the silver nitrate from a burette until a faint red color of silver chromate remains permanent on stirring. Correct for the amount of silver nitrate necessary to give in 100 ml of chlorine-free water, with 1 ml of the chromate, the shade obtained at the end of the titration of the sodium chloride solution. From 2 or 3 of such titrations calculate the strength of the silver nitrate solution.

DETERMINATION

To 100 ml of the water add a few drops of phenolphthalein. If a red color appears, titrate the carbonates thus indicated to bicarbonates with the sulphuric acid solution (a). If the water is acid to methyl orange, add the sodium carbonate solution (b), from a burette until the acidity is neutralized. Add 1 ml of the chromate and titrate with the standard silver nitrate. Correct for the amount of silver nitrate necessary to give in 100 ml of chlorine-free water, with 1 ml of the chromate, the shade obtained at the end of the titration of the sample.

NOTE: Greater accuracy is secured by operating in yellow light. Gas or electric light is better than daylight.

10. SULPHURIC ACID

Acidify 300 ml, or a suitable amount, of the water slightly with hydrochloric acid. Heat to boiling and add drop by drop 5—10 ml of a hot, 10 per cent barium chloride solution. After standing over night, filter, wash free from chlorine with hot water, ignite, and weigh as barium sulphate ($BaSO_4$). Add a drop of sulphuric and hydrofluoric acids before finishing the ignition; this will remove any silica, if present, and convert any reduced barium sulphide back to sulphate. Multiply by .4115 to convert to SO_4.

11. CARBONIC ACID

Carbonic acid (CO_3) is determined by difference, as the amount necessary to saturate the excess of basic over acid ions.

12. ORGANIC AND VOLATILE MATTER.

This is taken as the difference between the "total solids" and the sum of the other constituents determined.

13. SUSPENDED MATTER

This determination need not be made except in the case of raw waters for new factory sites or of other waters where the amount is visibly excessive. Determine by making a total solids determination on the unfiltered water, being careful that the sample is well mixed so that the portion taken will contain its proper proportion of insoluble matter. The difference between the total solids determined in this manner and determined as in "3" represents the amount of "suspended matter." Record the "suspended matter" as a separate figure and do not include in the "total solids" in the statement of the analysis.

14. HYPOTHETICAL COMBINATIONS

Report the basic and acid ions and the hypothetical combinations in terms of parts per 100,000. In calculating the hypothetical combinations join the basic ions in the following order: potassium, sodium, magnesium, calcium, and iron, to the acid ions in the following order: chlorine, sulphuric acid, and carbonic acid. Report silica as free SiO_2.

15. EXAMPLE

An analysis showed the following (parts per 100,000):

Total Solids	45.22	
Total Sulphates	50.26	
SiO_2	3.80	
Fe_2O_3 and Al_2O_3	.20	(× .6994 = .14 Fe)
CaO	5.12	(× .7146 = 3.66 Ca)
$Mg_2P_2O_7$	6.77	(× .2184 = 1.48 Mg)
Cl	2.17	
$BaSO_4$	29.74	(× .4115 = 12.24 SO_4)

CALCULATION OF SODIUM

5.12 $CaO \times 2.4279 = 12.43\ CaSO_4$
6.77 $Mg_2P_2O_7 \times 1.0810 = 7.32\ MgSO_4$
$50.26 - (3.80 + .20 + 12.43 + 7.32) = 26.51\ Na_2SO_4$
26.51 $Na_2SO_4 \times .3238 = 8.58\ Na$

CALCULATION OF SALTS AND CARBONIC ACID

2.17 $Cl \times .6486 = 1.41\ Na$
2.17 $Cl + 1.41\ Na = 3.58\ NaCl$
8.58 $Na - 1.41\ Na = 7.17\ Na$ (uncombined)
12.24 $SO_4 \times .4789 = 5.86\ Na$
12.24 $SO_4 + 5.86\ Na = 18.10\ Na_2SO_4$
7.17 $Na - 5.86\ Na = 1.31\ Na$ (uncombined)
1.31 $Na \times 2.3045 = 3.02\ Na_2CO_3$
1.48 $Mg \times 3.4673 = 5.13\ MgCO_3$
3.66 $Ca \times 2.4975 = 9.14\ CaCO_3$
.14 $Fe \times 2.0746 = .29\ FeCO_3$
$(3.02 + 5.13 + 9.14 + .29) - (1.31 + 1.48 + 3.66 + .14) = 10.99\ CO_3$

16. STATEMENT OF ANALYSIS

The above analysis will then be stated as follows:

		Parts per 100,000
Silica	SiO_2	3.80
Iron	Fe	.14
Calcium	Ca	3.66
Magnesium	Mg	1.48
Sodium	Na	8.58
Chlorine	Cl	2.17
Sulphuric Acid	SO_4	12.24
Carbonic Acid	CO_3	10.99
		43.06
Organic and Volatile Matter (by difference)		2.16
Total Solids		45.22

Hypothetical Combinations		Parts per 100,000
Silica	SiO_2	3.80
Sodium Chloride	NaCl	3.58
Sodium Sulphate	Na_2SO_4	18.10
Sodium Carbonate	Na_2CO_3	3.02
Magnesium Carbonate	$MgCO_3$	5.13
Calcium Carbonate	$CaCO_3$	9.14
Ferrous Carbonate	$FeCO_3$	.29
		43.06
Organic and Volatile Matter (by difference)		2.16
Total Solids		45.22

XVIII. DIATOMACEOUS EARTH (KIESELGUHR)

For judging the suitability of diatomaceous earth for filtration work, no chemical analysis will probably be of as much value as an actual fitration test, but in most cases the apparent specific gravity will furnish a good index. The lower the apparent specific gravity, the better is the quality of the material. The silica determination will give only a general idea of the purity.

1. SAMPLING

Take an average sample of each lot received, mix well, and preserve a suitable amount in a stoppered bottle.

2. APPARENT SPECIFIC GRAVITY (POUNDS PER CUBIC FOOT)

The weight per cubic foot is taken as the weight of the material which occupies one cubic foot of space under the conditions specified, without packing, and is obtained as follows:

Shake the material through a 20 mesh sieve held 1 inch above the top of a 25 ml porcelain crucible of known weight and capacity, returning to the sieve the portion which falls outside the crucible, until the crucible is completely filled. Then level off with a spatula, avoiding any packing, and weigh to the nearest centigram. Make this determination in triplicate.

If $W =$ weight in grams of the material in the crucible, $V =$ volume of the crucible in milliliters, and $X =$ apparent specific gravity of the material in "pounds per cubic foot," then

$$X = \frac{62.43\ W}{V}$$

Or, if the crucible holds exactly 25 ml, then

$$X = \frac{10\ W}{4}$$

3. MOISTURE

Heat 0.5 gram for 3 hours in a porcelain crucible in a drying oven at 100—105°, and then for successive periods of one hour until the weight is constant. Report the loss in weight as moisture.

4. ORGANIC AND VOLATILE MATTER

Heat the crucible containing the dried sample from "3" to full redness over a good burner or in an electric furnace, and ignite to constant weight. The loss in weight of the dried sample represents the amount of "organic and volatile matter."

5. SILICA

Mix 0.5 gram of the material thoroughly with 4—6 parts of sodium carbonate in a platinum crucible, and fuse. When the fusion is complete, allow to cool, and extract the melt with water and hydrochloric acid. Evaporate to dryness on the water bath, and proceed as in Chap. XIII, 2, repeating the evaporation and filtration until all the silica is removed. Ignite the residue to constant weight, using a blast lamp or electric furnace for the final ignition, and weigh as SiO_2.

XIX. SULPHUR

1. SAMPLING AND PREPARATION OF SAMPLE

A laboratory employe should sample each car of sulphur received, by taking representative samples from different parts of the car. Crush the entire sample to ¼ inch size with a jaw crusher. Mix the crushed sample, and reduce it by quartering. Grind to 60 mesh size in a mortar or on a bucking board, and preserve a suitable amount in a stoppered bottle. A disc pulverizer is not suitable, because the friction heats the sulphur and causes it to become viscous.

2. MOISTURE

Heat 1 gram for exactly one hour in a porcelain crucible in a drying oven at 100—105°. Report the loss in weight as moisture.

3. ASH

Heat the crucible containing the dried sample from "2" until the sulphur ignites, then remove the flame and allow the sulphur to burn. When combustion has ceased, heat to full redness to constant weight, cool, and weigh the residue.

4. SULPHUR

(a) *Method I:* Weigh out about 0.1 gram and transfer to a flask of 250 ml capacity. Add 25 ml of a strong potassium hydroxide solution, and heat in a water bath until the sulphur is all dissolved (about one-half hour is required). Cool, add 200 ml of freshly prepared bromine water and heat until the sulphur is all oxidized, adding more bromine water if necessary. Transfer to a beaker, make slightly acid with hydrochloric acid and boil until the excess of bromine is expelled, then filter and wash with hot water. Precipitate the sulphuric acid in the filtrate with barium chloride, following the procedure in Chap. XIII, 8.

(b) **Method II:* Dissolve about 0.1 gram in 1 ml of dry liquid bromine and add 10 ml of concentrated nitric acid. Remove the excess of bromine and the nitrous fumes by heat, add 100 ml of water and several ml of hydrochloric acid, and boil to expel the rest of the nitric acid. Then precipitate the sulphuric acid with barium chloride in the regular manner.

5. ARSENIC

Test qualitatively for arsenic as follows: Shake approximately 1 gram of the ground sample with 15 drops of strong ammonium hydroxide and 2 ml of water. Filter after half an hour, and to the clear filtrate in a test tube add 30 drops of concentrated hydrochloric acid and 15 drops of a 10 per cent solution of oxalic acid. Place a strip of bright copper foil in the solution and heat to 60—100°; in the presence of arsenic an iron-colored to black film forms immediately on the copper. If the presence of arsenic is indicated, always check the reagents by a blank test.

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*Bjerregaard, Jour. Ind. and Eng. Chem., 11, 1055.

XX. FOODS AND FEEDING STUFFS

The methods are in general those of the Association of Official Agricultural Chemists.

1. PREPARATION OF SAMPLE

Grind the sample so that it will pass through a sieve having circular openings 1/25 inch (1 mm) in diameter. If the sample cannot be ground, reduce it to as fine a state as possible. Determine moisture in both the original and the ground sample, and correct the results of the analysis for any change in the moisture content during grinding.

2. MOISTURE

Weigh out 10 grams in a 3 x ⅝ inch aluminum dish, provided with a cover, and dry in vacuo at 100—105° for 3—4 hours, and then for successive periods of one hour until the loss of weight in one hour is not over 0.1%.

3. CRUDE PROTEIN

Determine nitrogen by one of the following methods, and multiply the result by 6.25 to convert to protein.

Kjeldahl Method

Reagents

For ordinary work N/2 acid is recommended. For work in determining very small amounts of nitrogen N/10 acid is recommended. In titrating mineral acids against ammonium hydroxide solution use cochineal or methyl red as indicator.

(a) *Standard sulphuric acid:* Determine the absolute strength of the acid by precipitation with barium chloride solution as follows: Dilute a measured quantiy of the acid to be standardized to approximately 100 ml, heat to boiling and add drop by drop a 10% solution of barium chloride until no further precipitation occurs. Continue the boiling for about 5 minutes, allow to stand for 5 hours or longer in a warm place, pour the supernatant liquid on a tared Gooch or on an ashless filter, treat the precipitate with 25—30 ml of boiling water, transfer to the filter and wash with boiling water until the filtrate is free from chlorine. Dry, ignite over a Bunsen burner and weigh as barium sulphate. See also Chap. XXV, 21 (a) (3). A normal solution of sulphuric acid has the following equivalents:

1 ml = .04904 gram H_2SO_4
1 ml = .01401 gram N
1 ml = .01703 gram NH_3

(b) *Standard alkali solution:* Accurately determine the strength of this solution by titration against the standard acid. N/10 solution is recommended.

(c) *Sulphuric acid:* Of sp. gr. 1.84 and free from nitrates and ammonium sulphate.

(d) *Metallic mercury, or mercuric oxide:* Mercuric oxide should be prepared in the wet way, but not from mercuric nitrate.

(e) *Copper sulphate:* Crystallized.

(f) *Potassium permanganate:* Finely pulverized.

(g) *Granulated zinc or pumice stone:* Added to the contents of the distillation flask if necessary to prevent bumping.

(h) *Potassium sulphide solution:* Dissolve 40 grams of commercial potassium sulphide in 1 liter of water.

(i) *Sodium hydroxide solution:* A saturated solution, free from nitrates.

(j) *Cochineal solution:* Digest, with frequent agitation, 3 grams of pulverized cochineal in a mixture of 50 ml of strong alcohol and 200 ml of water for 1 or 2 days at ordinary temperature, and then filter.

(k) *Methyl red solution:* Dissolve 1 gram of methyl red (dimethyl-amino-azo-benzene-ortho-carbonic acid) in 100 ml of 95% alcohol.

APPARATUS

(a) *Kjeldahl flasks for both digestion and distillation:* Total capacity of about 550 ml, made of hard, moderately thick, and well-annealed glass.

(b) *Distillation flasks:* For distillation any suitable flask of about 550 ml capacity may be used. It is fitted with a rubber stopper through which passes the lower end of a Kjeldahl connecting bulb to prevent sodium hydroxide being carried over mechanically during distillation. The bulb should be about 3 cm in diameter, and the tubes should be of the same diameter as the condenser tube with which the upper end of the bulb tube is connected by means of rubber tubing.

DETERMINATION

Place 0.7—3.5 grams, according to the nitrogen content, of the substance to be analyzed in a digestion flask with approximately 0.7 gram of mercuric oxide, or its equivalent in metallic mercury, and add 20—30 ml of sulphuric acid 0.1—0.3 gram of crystallized copper sulphate may also be used in addition to the mercury, or in place of it). Place the flask in an inclined position and heat below the boiling point of the acid until frothing has ceased. (A small piece of paraffin may be added to prevent excessive foaming.) Then raise the heat until the acid boils briskly and digest for a time after the mixture is colorless or nearly so, or until oxidation is complete. Remove the flask from the flame, hold it upright, and while still hot add carefully potassium permanganate in small quantities at a time until, after shaking, the liquid remains green or purple.

After cooling dilute with about 200 ml of water, add a few pieces of granulated zinc or pumice stone, if necessary to prevent bumping, and 25 ml of potassium sulphide solution with shaking. Next add sufficient sodium hydroxide solution to make the reaction strongly alkaline (50 ml is usually enough) pouring it down the side of the flask so that it does not mix at once with the acid solution. Connect the flask immediately with the condenser, mix the contents by shaking, distil into a measured quantity of the standard acid until all ammonia has passed over, and titrate with the standard alkali. The first 150 ml of the distillate will generally contain all the ammonia.

The use of mercuric oxide in this operation greatly shortens the time necessary for digestion, which is rarely over an hour and a half in case of substances most difficult to oxidize, and is more commonly less than an hour. In most instances the use of potassium permanganate is quite unnecessary, but it is believed that in exceptional cases it is required for complete oxidation, and in view of the uncertainty it is always used. The potassium sulphide removes all the mercury from the solution, and so prevents the formation of mercuro-ammonium compounds which are not completely decomposed by the sodium hydroxide. The addition of zinc gives rise to an evolution of hydrogen and prevents violent bumping.

Previous to use the reagents should be tested by a blank experiment with sugar. The sugar partially reduces any nitrates present that might otherwise escape notice.

GUNNING METHOD

REAGENTS

Potassium sulphate: Pulverized.

The other reagents and standard solutions used are described above.

APPARATUS

The apparatus used is described above.

DETERMINATION

Place 0.7—3.5 grams, according to the nitrogen content, of the substance to be analyzed in a digestion flask. Add 10 grams of powdered potassium sulphate and 15—25 ml (ordinarily about 20 ml) of sulphuric acid (0.1—0.3 gram of crystallized copper sulphate may also be added). Conduct the digestion as in the Kjeldahl process, starting with a temperature below the boiling point and increasing the heat gradually until frothing ceases. Digest for a time after the mixture is colorless or nearly so, or until oxidation is complete. Do not add either potassium permanganate or potassium sulphide. Cool, dilute, neutralize, distil, and titrate with the standard alkali. In neutralizing before distilling it is convenient to add a few drops of phenolphthalein indicator or litmus paper. The pink color given by phenolphthalein indicating an alkaline reaction is destroyed by a considerable excess of strong fixed alkali.

KJELDAHL-GUNNING-ARNOLD METHOD

REAGENTS AND APPARATUS

Described above.

DETERMINATION

Place 0.7—3.5 grams, according to the nitrogen content, of the substance to be analyzed in a digestion flask. Add 15—18 grams of potassium sulphate, 1 gram of copper sulphate, 1 gram of mercuric oxide, or its equivalent in metallic mercury, and 25 ml of sulphuric acid. Heat gently until frothing ceases, then boil the mixture briskly, and continue the digestion for a time after the mixture is colorless or nearly so or until oxidation is complete. Cool, dilute with about 200 ml of water, add 50 ml of potassium sulphide solution, make strongly alkaline with sodium hydroxide solution and complete the determination as directed in the Kjeldahl method.

4. CRUDE FAT

REAGENTS

(a) *Anhydrous Ether:* Use particular care in the purification of the ether. Wash ethyl ether, containing not more than 4% alcohol, with 4 or 5 successive portions of distilled water, add solid sodium or potassium hydroxide, and let stand until most of the water has been abstracted from the ether. Decant into a dry bottle and add small pieces of carefully cleaned metallic sodium. It will be found that a considerable quantity of sodium is needed to remove the last traces of water although little of the sodium appears to be used up in the process; the sodium should therefore be added on each of several different days until no more hydrogen is liberated from the fresh pieces. Keep the ether, thus dehydrated, over metallic sodium in lightly stoppered bottles. Use glass stoppered, and not cork stoppered bottles. If a brown precipitate develops, which indicates that the washing was incomplete, repurify the ether. Test each lot of ether for insoluble residue by evaporating a measured volume.

APPARATUS

Use an extraction apparatus attached to the flask by a ground glass joint or a mercury seal, and not by a cork or rubber stopper. Alundum extraction shells are recommended.

DETERMINATION

Large quantities of soluble carbohydrates may interfere with the complete extraction of the fat. In such cases extract with water before proceeding with the determination.

Dry about 2 grams of the material thoroughly in a drying oven at 100—105°. Extract with the anhydrous ether for 16 hours. Filter the extract through filter paper to remove solid particles, using ether for washing. Evaporate the extract and washings carefully to dryness, and dry at 100—105° for 30 minutes, cool in a desiccator, and weigh. Continue the drying by half-hour periods until a minimum weight is obtained. For most feeds a period of 1 to 1½ hours is required. Save the residue for the crude fiber determination.

5. CRUDE FIBER

Reagents

(a) *1.25% Sulphuric Acid Solution:* Exact strength, determined by titration.

(b) *1.25% Sodium Hydroxide Solution:* Exact strength, determined by titration.

Determination

Extract a quantity of the substance, representing about 2 grams of the dry material, with ordinary ether, or use the residue from the determination of the ether extract. To this residue in a 500 ml flask add 200 ml of boiling 1.25% sulphuric acid; connect the flask with an inverted condenser, the tube of which passes only a short distance beyond the rubber stopper into the flask, or simply cover a tall conical flask, which is well suited for this determination, with a watch glass or short stemmed funnel, boil at once and continue boiling gently for 30 minutes. A blast of air conducted into the flask will serve to reduce the frothing of the liquid. Filter through linen and wash with boiling water until the washings are no longer acid; rinse the substance back into the flask with 200 ml of boiling, 1.25% solution of sodium hydroxide, free or nearly free from sodium carbonate, boil at once, and continue boiling gently for 30 minutes as directed above for the treatment with acid, filter at once rapidly, and wash with boiling water until the washings are neutral. The last filtration may be performed upon a Gooch crucible, a linen filter, or a tared filter paper. If a linen filter is used, rinse the crude fiber, after washing is completed, into a flat-bottom platinum dish by means of a jet of water; evaporate to dryness on a steam bath, dry to constant weight at 110° C., weigh, incinerate completely, and weigh again. The loss in weight is considered to be crude fiber. If a tared filter paper is used, weigh in a weighing bottle. In any case the crude fiber after drying to constant weight at 110° C. must be incinerated and the amount of the ash deducted from the original weight.

6. ASH

Weigh out about 2 grams and determine ash by the lixiviation method as described in Chap. I, 7 (b).

7. NITROGEN-FREE EXTRACT

Subtract from 100 the sum of the percentages of moisture, crude protein, crude fat, crude fiber, and ash.

XXI. COTTON SEED CAKE

Sample each car of cotton seed cake received, and determine moisture and protein.

1. SAMPLING

Take a *handful of cake from each of at least 25 bags selected promiscuously throughout the car, the total sample amounting to at least 10 pounds. If possible, sample a greater number of bags. Mix the sample, remove a quart with a scoop, and preserve in a suitable container as a reference sample for *size only,* and so labeled.

2. PREPARATION OF SAMPLES

If the original sample exceeds 15—20 pounds, reduce to this amount, but not below, by halving or quartering; otherwise grind the entire remainder of the original sample on a bucking board, or by means of other suitable apparatus, to such an extent that the largest lumps will not exceed ¼ inch in size, mix thoroughly, and quarter once. Repeat the procedure of grinding and quartering until about 3 pints of material remain. Mix thoroughly and make up 3 samples of about 1 pint each, using fruit jars or other suitable, tightly sealed containers. Label each sample with the car number, date of receipt and the name of the factory where received.

Retain two of the above samples as referee samples for analysis, subject to shipping instructions from the General Office. Use a third sample for the laboratory analysis, and seal and save for future reference the portion of this sample left over from the analysis.

Prepare the sample for analysis by putting the entire sample through a sieve having circular openings 1 mm in diameter, grind-

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*The directions refer to "screened cracked cake."

ing the portion retained by the sieve until all the particles pass through, then mix the sample thoroughly to destroy the segregation of the hulls, which are more difficult to reduce to the necessary degree of fineness, from the other portion of the sample. To avoid change in moisture content, grind the material as rapidly as possible and do not allow it to stand exposed to the air unnecessarily.

3. ANALYSIS

Determine moisture and protein as described below. The methods are, with some unimportant modifications in wording, those of the Interstate Cotton Seed Crushers' Association.

4. MOISTURE

Heat 2 to 5 grams for 3 hours in an oven at a temperature of 100° C., using an aluminum dish 2 inches in diameter, provided with a cover. As soon as the dish is removed from the oven, cover and cool in a desiccator. Report the loss in weight as moisture.

5. PROTEIN

Digest 1.7512 grams of the sample with approximately 0.5 gram of metallic mercury or 0.7 gram of mercuric oxide, 10 grams of sodium or potassium sulphate, and 25 ml of sulphuric acid (sp. gr. 1.84). Place the flask in an inclined position and heat below the boiling point of the acid from 5 to 15 minutes, or until frothing has ceased. Increase the temperature and continue digestion until the liquid becomes colorless, or until complete digestion is obtained. The process is the same from now on as in the regular Kjeldahl method, except that no potassium permanganate is added.

Distillation: After cooling, add about 300 ml of distilled water, a few pieces of zinc to keep the contents of the flask from bumping, and 25 ml of a 4% solution of potassium or sodium sulphide, or a sufficient amount to precipitate all the mercury. After mixing thoroughly, add 60 ml of a sodium hydroxide solution of 1.50 sp. gr., or sufficient to make strongly alkaline, pouring it down the side of the flask so that it does not mix at once with the acid solution. Connect the flask with a condenser of glass or block tin, mix the contents of the flask by shaking and distil into an accurately measured quantity of standard sulphuric acid solution

(N/2 recommended) to which has been added 50 ml of distilled water, until at least 200 ml of distillate is obtained, taking care that the delivery tube reaches below the level of the standard acid. Then titrate the distillate with standard fixed alkali solution (N/4 sodium hydroxide recommended). To obtain the percentage of protein, multiply the number of milliliters of acid neutralized by the distillate by 2.5, if the acid is of exactly N/2 strength. The factor for the conversion of nitrogen to protein is 6.25.

Precautions: Be sure that the sample for analysis has been ground to pass a 1 millimeter sieve, as prescribed in "2." Test the reagents by a blank experiment with sugar, and make any correction found necessary.

Consult Chap. XX, 3, for fuller details regarding the protein determination.

XXII. SOIL

The methods are in the main those of the Association of Official Agricultural Chemists, which should be consulted for full details. Make only the determinations mentioned below.

If possible there should be recorded with each analysis a history of the soil, covering crop rotation, extent of manuring, the depth of the soil if less than 12 inches, and the nature of the subsoil.

1. SAMPLING OF SOIL

Sampling should be done preferably when the soil is reasonably dry. Remove from the surface all vegetable material not incorporated with the soil, and take out an amount about one square foot in section to the depth of the plowed soil; if virgin soil is sampled, sample to a depth of 6 inches, but not below the level of the subsoil. Mix on an oil cloth; if too wet, let it dry but not to form clods. Do this in different parts of the field, and take equal amounts of the individual samples. Mix the composite sample thoroughly, reduce by quartering to about 2—4 pounds, and air-dry in a cool, well-ventilated place.

If the soil is less than 6 inches deep, take and analyze a separate sample of the subsoil.

2. PREPARATION OF SAMPLE

Follow the method of the A. O. A. C.

3. MOISTURE, VOLATILE MATTER, AND TOTAL NITROGEN

Follow the methods of the A. O. A. C. The moisture found in the air-dry soil is reported as "hygroscopic moisture."

4. MISCELLANEOUS INORGANIC CONSTITUENTS

Make a strong acid digestion of the soil and determine, according to the A. O. A. C. methods:

(a) Insoluble residue.
(b) Iron, aluminum, and phosphoric acid (collectively).
(c) Manganese.
(d) Calcium.
(e) Phosphoric acid.
(f) Sulphuric acid.
(g) Potassium.
(h) Sodium.

5. CARBON DIOXIDE

Liberate the carbon dioxide with acid and determine by the increase in weight of a potash bulb, as in Chap. XIV, 16.

6. HUMUS

Place 10 grams of the sample in a Gooch crucible, extract with 1% hydrochloric acid until the filtrate gives no precipitate with ammonium hydroxide and ammonium oxalate, and remove the acid by washing with water. Wash the contents of the crucible (including the asbestos filter) into a glass stoppered cylinder, with 500 ml of 4% ammonium hydroxide, and allow to remain, with occasional shaking, for 24 hours. During this time the cylinder is inclined as much as possible without bringing the contents in contact with the stopper, thus allowing the soil to settle on the side of the cylinder and exposing a very large surface to the action of the ammonium hydroxide. Place the cylinder in a vertical position and leave for 12 hours, to allow the sediment to settle. Filter the supernatant liquid (the filtrate must be perfectly clear), evaporate an aliquot, dry at 100°, and weigh. Then ignite the residue and again weigh. Calculate the humus from the difference in weights between the dried and ignited residues.

7. WATER SOLUBLE

Transfer 50 grams of the air dried soil, with 500 ml of water, to a 1000 ml flask, boil for half an hour, and let stand for 24 hours with occasional shaking. Then make up to the mark, filter, evaporate an aliquot, and dry at 100—105° to constant weight.

8. MECHANICAL ANALYSIS

(*T. B. Osborne's Method)

The details of this method will be given with sufficient minuteness to make its practice possible by all analysts.

Selecting the Sample: Several pounds of air-dried, fine earth are secured by passing the soil through a sieve, the holes of which are three millimeters in diameter.

Sifting: Thirty grams of the above fine earth are stirred with from 300 to 400 milliliters of water and then thrown successively upon sieves with circular holes of 1, 0.5, and 0.25 millimeter diameter respectively. By means of successive additions of water and the use of a camel's hair brush, all the fine material is made to pass through the sieves and these at the last are agitated under water in a shallow dish in such a way that the soil is immersed. The finest sieve should be well wet with water on its lower surface just before using. The finest particles which render the water turbid are easily washed through. The turbid water is kept separated from the clear water which comes off with the last portions that pass the sieves. The turbid water usually does not amount to more than one liter.

Elutriation: The elutriation should be carried on so as to secure three grades of silt; the diameters of the particles ranging in the first grades from 0.25 to 0.05 millimeter, in the second grade from 0.05 to 0.01 millimeter, and in the third grade from 0.01 millimeter to the impalpable powder. The term sand is applied to the first grade, silt to the second, and dust or dust and clay to the third. After the turbid liquid from the sifting has stood a short time it is decanted from the sediment and after standing until a slight deposit is formed, is again decanted and the sediment examined with a microscope. If sand is present, the subsidence of the turbid liquid is continued until no more sand is deposited. As the sand subsides rapidly there is no difficulty in altogether freeing the liquid first decanted from this grade of particles. The sediment thus obtained contains all the sand, a part of the dust and much silt. As only dust and the finest silt render the water turbid the sediment is stirred a few times with a fresh quantity of water and decanted after standing long

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*From Wiley's "Principles and Practice of Agricultural Analysis," 2d ed., Vol. 1, p. 212.

enough to let all the sand settle. When the water decanted is free from turbidity, the last portions of the soil passing through the sieve with clear water are added to the sediment and the decantations continued so as to remove most of the silt. When no more silt can be easily removed from the sediment without decanting sand, the decantations are made into a different vessel and the subsidences so timed as to remove as much of the silt as possible. By using a little care, at least three-quarters of the sand are thus obtained free from silt. The rest of the sand is mixed with the greater part of the silt which has been decanted into the second vessel. The size of the smallest particle in this vessel is determined with the microscope, to make sure that its contents are free from dust as they usually will be if, after settling for a few moments, they leave the water free from turbidity.

The soil is thus separated into three portions, one containing sand, one sand and silt, and the other silt, dust, and clay. The sand and silt are separated from each other by repeating the subsidences and decantations in the manner just described.

In this way there is removed from the sediment, on the one hand, a portion of silt free from sand and dust, and on the other hand a portion of sand free from silt. Thus is obtained a second intermediate portion consisting of sand and silt, but less in amount than the first and containing particles of diameters much more nearly approaching 0.05 millimeter. By repeating this process a few times, this intermediate portion will be reduced to particles whose diameters are very near 0.05 millimeter and which may be divided between sand and silt, according to judgment. The amount of this is usually very small. As soon as portions are separated, which the microscope shows to be pure sand or pure silt, they are added to the chief portions of these grades already obtained.

The same process is applied to the separation of silt from dust. When all the silt has been removed from the dust and clay, the turbid water containing the dust and clay is set aside and allowed to settle in a cylindrical vessel for twenty-four hours. The vessel is filled to a height of 200 millimeters. According to Hilgard, the separation of the dust from clay during a subsidence of twenty-four hours, will give results of sufficient accuracy, although the clay then remaining suspended will not be entirely free from measurable fine particles up to 0.001 or 0.002 millimeter diameter.

Small beakers and small quantities of distilled water are used at first for the decantations, as thus the duration of subsidence is less and more decantations can be made in a given time than when larger quantities of water are employed. Beakers of about 100 milliliters capacity are convenient for the coarser grades, but it is necessary to use larger vessels for the fine sediments from which turbid water accumulates that cannot be thrown away, as may be done with the clear water, from which the coarse sediments settle out completely in a short time.

It is best to keep the amount of water as small as possible in working out the dust since loss is incurred in using too large quantities.

It is also necessary in most cases to subject the various fractions obtained during elutriation, to careful kneading with a soft rubber pestle so that the fine lumps of clay may be broken up and caused to remain suspended in the water. This treatment with the pestle should be done in such a way as to avoid as far as possible all grinding of the particles, the object being merely to pulverize the minute aggregations of clay and extremely fine particles which always form on drying a sample of soil after removing it from the field.

Measurement of the Particles: To determine the size of particles in suspension, a small glass tube is applied to the surface of the liquid in such a way as to take up a single drop which is transferred to a glass slide. This drop will contain the smallest particles in the liquid.

To obtain a sample of the coarsest particles, the liquid is allowed to stand long enough to form a very slight sediment, and a portion of this sediment is collected with a glass tube.

To determine the diameter of the particles in a sediment, it is stirred vigorously with a little water and the pipette at once applied to the surface of the water. On decanting the greater part of the sediment, the large particles remain at the bottom of the beaker and may be easily examined.

Time: The time required to make the separations, above described, is about two hours for each, so that an analysis including the siftings, is made in five or six hours, exclusive of the time necessary for collecting the dust and separating the clay, for which a subsidence of 24 hours is allowed.

Weighing the Sediments: The sediments are prepared for weighing by allowing them to subside completely, decanting the clear water as far as possible, rinsing them into a weighed platinum dish and igniting. The dish is cooled in a desiccator, and the ignited sediments are generally very hygroscopic.

Effect of Boiling: The analyses show a very decided increase in the particles smaller than 0.01 millimeter diameter at the expense of coarser particles as the result of boiling. The surfaces of the coarser particles are seen to be polished and of a lighter color than those not boiled. The surfaces of the unboiled particles are coated with a film of fine material probably cemented to them by clay. When these coarse particles which have not been boiled, are violently stirred with water for a short time, no fine particles are detached from them; and a careful examination under the microscope fails to reveal in any of the sediments more than an occasional grain exceeding the 0.05 millimeter limit by so much as 0.01 millimeter, or the 0.01 limit by as much as 0.005 millimeter. It would, therefore, appear that these small particles thus set free by long boiling are really a part of the larger ones and should be treated as such in a mechanical analysis of these soils.

9. WATER CAPACITY

The capacity of soil to take up water by capillary action is called the water capacity. This varies with the composition and especially with the mechanical fineness of the soil. In the field there are other influences, such as the manner in which the soil is deposited, the height of the ground and water, and other conditions.

As the laboratory test cannot imitate all these conditions, it is only of relative value.

For this determination a Hilgard ''sieve cylinder,'' which can be obtained from dealers in chemical apparatus, is used. It is a metal cylinder, open at the top and closed at the bottom by a fine wire sieve. The cylinder rests in a ring 2 cm high provided at the sides with holes which allow free access of water when immersed in a beaker containing water. The wire screeen is covered inside with a fine, circular linen cloth. The cylinder is 16 cm deep x 4 cm in diameter, so that its contents amount to 200 cubic centimeters.

Before the test moisten the linen cloth, and weigh the apparatus together with a small porcelain dish in which it stands. Then fill the cylinder up to the rim with the air-dry soil, adding it gradually with continual shaking until no further settling is noticeable. Then level with a spatula and weigh again. Place the cylinder in a good sized beaker, containing enough water at room temperature to submerge the sieve bottom of the cylinder to the extent of 5 to 10 millimeters, and cover the entire apparatus with a glass bell jar to prevent evaporation. The time required to reach the maximum water absorption will vary with the nature of the soil. As soon as moisture appears at the surface, take out the cylinder, allow it to drain for a few moments, wipe the outside, place it in the porcelain dish originally used, and weigh. Put the cylinder back in the water for some time and weigh again, repeating this procedure until the weight is constant, or nearly so. Calculate the increase in weight as the percentage on the weight of the air-dry soil.

10. STATEMENT OF ANALYSIS

Calculate all the results of the chemical analysis as percentages of the soil dried to constant weight at the temperature of boiling water, and report in the order given. Under "physical analysis" express the results as percentages on the air-dry soil.

Chemical Analysis

	% on Moisture-free Soil
Insoluble residue	
Lime (CaO)	
Carbon dioxide (CO_2)	
Potash (K_2O)	
Soda (Na_2O)	
Iron and aluminum oxides (Fe_2O_3 & Al_2O_3)	
Manganese oxide (Mn_3O_4)	
Phosphoric acid (P_2O_5)	
Sulphuric acid (SO_3)	
Volatile matter	
Humus	
Total nitrogen	
Water soluble	

PHYSICAL ANALYSIS

		% on Air-Dried Soil
Hygroscopic moisture		
Water capacity		
Temperature of absorption (°C.)		
Coarse sand,	1.0 —0.5 mm	
Medium sand,	0.5 —0.25 mm.	
Fine sand,	0.25—0.05 mm	
Silt,	0.05—0.01 mm	
Dust, less than	0.01 mm	

XXIII. APPARATUS

In addition to the data given in this chapter, many articles and arrangements of apparatus will be found described in connection with the directions for particular determinations.

1. BALANCES

Analytical balances of the standard grade and sensibility should be employed. Pulp balances should be rugged in construction and sensible to 2 milligrams.

2. BEET RASP

A rasp of the Keil-Dolle type is employed for the samples handled in the beet laboratory. This rasp removes a true radial segment from each beet and at the same time reduces it to a very fine pulp suitable for analysis by the cold water method. It has been found by a great number of tests that the portion of the beet removed by a rasp of this kind is on the average a very accurate sample of the whole beet. Special directions regarding the care and use of this rasp will be found in detail in Chap. XII, 2 and 3.

3. CAPSULES AND COVERS FOR ANALYSIS OF BEETS

Metal cups, so-called "capsules," are employed in the determination of sugar in the beet by the cold water digestion method. They are all adjusted to the same tare by grinding or by adding solder, and should be made of Monel metal (or nickel), as other common metals will be attacked by the lead acetate solution and the tare will, as a result, change rapidly. The capsules should be about 3 in. dia. x 3 in. high, or of about 350 ml capacity.

The cover consists of an aluminum disc, 4¼ in. dia. x ⅛ in. thick, which has a hole 1-¾ in. in diameter at the center, and over it is stretched a rubber envelope. When the cover is placed on the capsule, the rubber is pressed with the thumbs downward through the central opening. On releasing the pressure a slight vacuum is created, which holds the cover on firmly; this makes an air-tight joint which prevents evaporation, and also loss of the contents if the capsule is accidentally knocked over.

4. CARBONATOR

For carbonating saccharate, a carbonator of familiar construction is employed. It should have means for injecting steam and carbon dioxide gas, which, for convenience and to avoid local overheating of the juice, should preferably be introduced through connections at the bottom rather than through pipes running down through the liquid.

5. COOLER

The laboratory cooler is a working model of the factory coolers. No particular description is necessary. See section 17 for the speeds of the various pulleys. Care should be taken to avoid wetting the bolter screen. When it becomes stopped up, the bolter should be removed and the screen cleaned by washing it first with hydrochloric acid, then with water, and drying in a warm place.

6. DISHES FOR MOISTURE DETERMINATIONS

Aluminum dishes 2 in. dia. x 1½ in. high should be employed for dry substance determinations in general; for dried pulp aluminum dishes 3 in. dia. x ⅝ in. high should be used. Each dish should have a loosely fitting aluminum cover provided with a knob of the same material, and both the dish and the cover should be numbered with a die.

7. DRYING OVENS

Electric ovens, even those of the best make, fall far short of the requirement of uniform temperature, as one will commonly find variations of 10—20° not only at different levels but also at different points on the same shelf. They are accordingly not to be recommended except possibly for drying empty dishes.

A double walled oven of suitable construction, the jacket of which is filled with a boiling glycerin solution, will give a temperature which is uniform within 2 to 3 degrees in all parts of the oven, provided the dishes are placed on shelves and not directly on the bottom of the oven. This type of oven is accordingly recommended for dry substance determinations.

The glycerin solution should be of such a strength that the required temperature (commonly 100—105°) will be maintained in the interior of the oven. For 630 mm barometric pressure (5000 feet elevation) a mixture of about 3 parts of glycerin and 1 part of water, which has a density of about 42° Brix, will give approximately the desired concentration. The boiling point of the glycerin solution should be kept constant by means of a reflux condenser. It will occasionally be necessary to add a little water to replace the water which is lost by evaporation and is not caught by the condenser.

8. EVAPORATOR

An open evaporator heated by a steam chamber at the bottom is the type of laboratory evaporator recommended and commonly employed.

9. GRINDING MACHINERY

For grinding cossettes employ an Enterprise Meat Chopper No. 41, with a plate containing 1/8 inch perforations, and running at the rate of 300 R. P. M. For grinding pulp use a second machine of the same description.

For preparing for analysis samples of material such as limestone, boiler house ashes, etc., a combination of a jaw crusher with a disc pulverizer is very satisfactory. Material of great hardness, such as coke, must not be ground in a disc pulverizer on account of the contamination which will affect the sample.

Large samples of coal are ground in a pebble mill, by means of which they may be ground to the necessary fineness during a long period of time without important loss of moisture. The mill for this purpose has a cast iron jar 18 x 18½ in., which should revolve at the rate of 40—50 R. P. M., and should contain 100 pounds of smooth, best grade flint pebbles. Inspect the contents occasionally for the presence of broken pebbles, which should be removed and discarded.

10. HYDROMETERS.

Laboratory Brix hydrometers should have a total length of about 12 inches and a range of 6° Brix each, starting at 0—6° and up to and including 72—78°. The scale should be graduated in one-tenths of one degree Brix and should cover a distance of not less than 4¼ inches on the stem. Baumé hydrometers, for testing molasses, should have enclosed thermometers, should have ranges of 30—40 and 40—50 degrees Baumé, a total length of 13 inches, a scale length of 4¾ inches, and should be graduated in one-tenths of one degree Baumé. The standard temperature for both Brix and Baumé hydrometers is 20°. All laboratory hydrometers must be verified as described in Chap. XXIV, 3, and any more than 0.1 degree in error at any point must be rejected or readjusted.

11. HYDROMETER JARS

The hydrometer jars used with the laboratory Brix hydrometers should be 12 inches long and 2 inches in diameter (inside dimensions).

12. PLATINUM, CARE OF

In making ignitions or fusions in platinum vessels by means of the Bunsen burner, only the upper non-luminous cone of the flame should be employed, and not the inner cone, nor should a smoky flame be used, as the action of a flame containing free carbon will result in the formation of a carbide of platinum, causing the metal to become brittle. At the best a tarnish will gradually develop, which should be removed by gentle rubbing with moist sea sand, the grains of which are rounded and do not scratch the metal. Platinum ware should be kept polished in this manner, as the tarnish increases more rapidly upon already tarnished surfaces, and will eventually lead to corrosion and cracking. Platinum surfaces may also be cleansed by fusing borax upon them and by digestion with nitric acid.

The following precautions should be observed in the use of platinum utensils:

(a) Platinum is insoluble in any single acid, but is readily soluble in a mixture of hydrochloric and nitric acids (aqua regia).

(b) Fusions in which the hydroxides of sodium, potassium, or barium are used should not be performed in platinum.

(c) All metals which may be reduced in a fusion—especially compounds of lead, bismuth, tin, and other metals easily reduced and melted—and all metallic compounds with reducing agents form fusible alloys with ignited platinum. Mercury, lead, bismuth, tin, antimony, zinc, etc., are liable to be rapidly reduced and immediately melt away platinum in contact with them.

(d) Free chlorine and bromine attack platinum at ordinary temperature, and free sulphur, phosphorus, arsenic, and iodine attack ignited platinum. Operations in which these elements are set free should not be performed in platinum. Hence the fusion of sulphides, sulphates, and phosphates with reducing agents should be avoided, and care should be exercised in igniting phosphates in the presence of carbon from burnt filters.

13. POLARISCOPES (SACCHARIMETERS)

No detailed explanation of the theory and construction of polariscopes will be given here, as this subject will be found treated at length in the various textbooks. See for example Browne's ''Handbook of Sugar Analysis'' and Circular 44, ''Polarimetry,'' of the Bureau of Standards. While the sugar chemist is advised to let the optical parts of the instrument alone as far as possible, it is desirable that he have a full understanding of the principles relating to the construction and use of saccharimeters. A few points are discussed below to which it is desired to direct special attention.

(a) Specifications

The type of polariscope to be preferred for general laboratory control work is the double field, single compensation, 400 mm tube length, mounted on a trestle support. The *report of the committee of the American Chemical Society covers in great detail the desirable features of a commercial saccharimeter.

(b) Saccharimetric Scale and Normal Weight

The 100 degree point is defined as the scale reading given by the polarization of the ''normal weight'' of pure sucrose, weighed in air with brass weights, and dissolved in water and made up to a volume of 100 ml at 20°, the temperature of the solution and of the optical parts of the instrument during polarization being 20°. The ''normal weight'' at present most commonly in use, and the standard employed in this book, is 26 grams. See also Chap. XXIV, 7 (a).

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*Jour. Ind. & Eng. Chem, 12, 440.

(c) VERIFICATION OF SCALE

See Chap. XXIV, 7 (a). When the accuracy of the scale has once been established, it suffices for ordinary purposes to keep the instrument in adjustment at the zero point and to check it occasionally with standard quartz plates. The Chief or Assistant Chemist should check the setting of the zero point at least twice a shift, and oftener if it appears desirable.

(d) EFFECT OF TEMPERATURE ON POLARIZATION

The polarization of a pure sugar solution decreases by about .03% for each degree increase in temperature. If the solution, when *made up to volume* and *polarized* at a given temperature (t), shows a polarization of S_t, the polarization of 20° (S_{20}) is given by the following formula:

$$S_{20} = S_t + .0003\ S_t (t - 20)$$

If the solution is made up to volume at 20° but is polarized in a glass tube at some other temperature, the temperature coefficient in the formula becomes .0006 instead of .0003; plainly this procedure will only increase the liability of error. On the other hand if the solution is both made up and polarized at 20° while the polariscope is at some other temperature, the temperature coefficient is that for the instrument alone, which is given by Schönrock as .000148 for the ordinary quartz wedge saccharimeter with nickelin scale, and as .000138 if the scale is of glass.

In the case of an impure sugar solution, the temperature coefficient is equal to the algebraic sum of the various influences, including those of the associated impurities, and may be more or less than the value for pure sugar, which it is therefore unsafe to apply in the polarization of an impure solution. According to *Browne the temperature coefficient for the direct polarization of beet molasses is almost negligible, and for raw beet sugars is about the same as for pure sucrose.

While work of the highest precision demands the use of a constant temperature room which can be kept at exactly 20°, sufficiently accurate results for ordinary control work are obtained by making up and polarizing the solutions at room temperature. It follows, however, that the room temperature should be kept as close to 20° as the heating and ventilating arrangements will

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*Jour. Ind. & Eng. Chem., 1, 567.

permit. The accuracy can be increased by making up and polarizing the solutions at 20°, in which case, if the room temperature is not 20°, the only correction is that due to the temperature coefficient of the saccharimeter, which, as given above, is not great and is a fairly definite figure for any single instrument; this procedure is not adapted for a large volume of work but is applicable in special cases.

As the specific rotation of *inverted solutions* varies greatly with the temperature, all such solutions must be *made up and polarized* at exactly 20°.

(e) INSTALLATION

The saccharimeter should be installed in a "polariscope box" of the customary construction, which should have a partition at the rear with a small hole at the proper height for illuminating the instrument without allowing bright light to strike the observer's eye, should be painted a dead black on the inside, and should be provided with a dark curtain at the front, open end to exclude outside light. The location should be free from excessive heat or cold drafts, and as little subject as possible to undue variations in temperature.

(f) ILLUMINATION

A Mazda C stereopticon lamp is the most satisfactory source of illumination. A finely frosted glass plate should be fastened so as to cover the opening in the partition of the polariscope box and the lamp should be placed as close behind this as possible. The lamp should be clamped on a firm bracket, or support, which has means for vertical and lateral adjustment. To avoid shifting of the zero point it is essential that the instrument be kept in alignment with the source of illumination, and for this purpose not only should the lamp be firmly mounted but the polariscope should also be kept in a fixed position by means of bolts or strips of wood, etc. Particular care should be taken to adjust the position of the lamp so that the brightest portion is in alignment with the optical axis of the saccharimeter.

Electric lamps will darken with use, and, when this has taken place to such an extent that the illumination is insufficient, they should be discarded.

The instrument should never be placed so close to the source of light as to permit overheating to take place and hence possible damage to the optical parts. The rule is that the polariscope should be placed at such a distance from the source of light that the image of the latter is clearly defined upon the analyzer diaphragm; this is best accomplished by fastening a needle or other sharp pointed object at the source of light (the frosted glass plate) and changing the position of the instrument until a clear inverted image of the point is obtained upon a piece of white paper placed before the analyzer diaphragm. The distance of Schmidt & Haensch instruments from the source of light is given by the manufacturers as 150 millimeters; it is also directed by them that, in the case of their 1909 model instrument provided with the "Blendrohr," when the light filter is in place the sleeve containing the condensing lens must be drawn out to the extent of 8.9 mm, i. e., up to the engraved mark, and the distance of the condensing lens from the source of light must then be adjusted to 150 mm.

(g) Light Filter

It is important that a light filter be constantly used. A common arrangement consists of a cell containing a solution of potassium dichromate. If "a" is the length of the cell in centimeters and "b" is the percentage strength of the dichromate solution, the proper value of the latter is found from the formula

$$a \times b = 9$$

For example, if the cell is 3 cm long, a 3% solution must be used.

In some instruments a glass plate is employed as a light filter, and in one make of saccharimeter means are provided by which a light filter of this kind may readily be thrown in or out of the optical system; in this case readings should always be made with the light filter in place except in the case of a very dark solution which contains enough coloring matter to serve as its own light filter.

(h) Tubes and Cover Glasses

In filling a tube for polarization, it is customary to rinse it first two or three times with the solution, then to fill it, put the cover glass in place, and attach the cap. The caps should not be screwed on too tight, as the strain on the glass thereby created may cause optical rotation.

Metal tubes are satisfactory for ordinary work, but they should be examined and tested frequently to see that they do not become bent. See Chap. XXIV, 7 (b). Glass tubes are free from this drawback.

Cover glasses must be kept clean and dry. It is impossible to do accurate work with smeary cover glasses. Scratched glasses should be discarded.

(i) CARE AND ADJUSTMENT OF POLARISCOPES

As an almost inflexible rule, the adjusting of the polariscope should be limited to the setting of the zero point, as mentioned under (b), and to careful cleaning of the splash glasses and exposed lenses.

The half-shadow angle, which is fixed, or not readily adjustable, in most commercial saccharimeters, represents a compromise between maximum sensibility and sufficient illumination for polarizing dark solutions; a decrease of the half-shadow angle results in increased sensibility but in decreased illumination. It varies from about 6 to 9 angular degrees in most commercial instruments, and may be determined by measuring the interval in sugar degrees between the points of maximum light extinction on each side of the zero point, and then multiplying by .3466 to convert to angular degrees. If it is necessary to change the half-shadow angle, this may be done, in instruments provided with the Lippich polarizing system, by rotating the large polarizing Nicol to a new position, and then, with the quartz wedge scale set at zero, rotating the analyzer till the two halves of the field show equality of brightness, or very nearly so; the zero point may then be adjusted, if necessary, by the usual arrangement for changing the position of the vernier.

14. PRESSES

Hydraulic presses, operated at a standard pressure, must be employed to obtain the juice from ground beets or cossettes for the determination of apparent purity. The standard pressure to be used upon the ground material is 240 lbs. per sq. in., and the corresponding gage pressure for different types of presses is calculated as follows:

Let a = diameter of ram in inches
b = inside diameter of basket in inches (if round)
c = area of basket in square inches (if square or rectangular)

P = gage pressure in pounds per square inch.

Then $P = \frac{240\ b^2}{a^2}$ or $P = \frac{306\ c}{a^2}$

E. g., if $a = 4$ and $b = 10$, $P = 1500$. In obtaining the dimensions, measure the ram at the cup leather across the entire effective surface.

As the percentage of sugar in the juice obtained from pulp at different pressures does not vary noticeably, a hand operated lard press is satisfactory for this purpose.

15. RADIATOR FOR VOLATILIZING LIQUIDS AND SOLIDS

The radiator described by Hillebrand in U. S. Geological Survey Bulletin 700, "The Analysis of Silicate and Carbonate Rocks," page 33, is frequently recommended in this book and will be found greatly superior to the hot plate or sand bath for evaporating such liquids as sulphuric acid rapidly without loss by decrepitation.

16. REFRACTOMETERS

The refractometer used in sugar work is of the Abbé type and is provided with a dry substance scale based on the *determinations of Schönrock. The standard temperature for the use of the instrument is 20°. No special directions for the use of the instrument beyond those given in Chap. I, 2 (b) and XXIV, 8, are probably necessary.

17. SPEEDS OF LABORATORY MACHINERY

The following résumé of the speeds at which the laboratory machinery should be operated will be found convenient for reference:

	R. P. M.
Beet Rasp (Keil disc)	600-700
Case Crusher	450-500
Cooler, Laboratory—	
Propeller	200
Bolter	40
Conveyor (auger type)	35

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*Bureau of Standards Circular 44, "Polarimetry," 2nd ed., p. 134.

	R. P. M.
Curtis Vacuum Pump and Air Compressor	250 (at least)
Enterprise Meat Chopper No. 41	300
Hydraulic Press (Hydraulic Press Mfg. Co.), countershaft	80
Iler Disc Pulverizer	350-450
McCool Disc Pulverizer	300
Pebble Mill (jar 18½ x 18 in.)	40-50
Samson Crusher	500

18. THERMOMETERS

The Centigrade scale alone should be employed. The only exception to this is the use of the Fahrenheit scale in recording boiler house temperatures. Unless otherwise expressly stated, all temperatures in this book are in degrees Centigrade. For determining the temperature correction in the apparent purity determination, a small floating thermometer, with enclosed paper scale, of 0—30° range, is recommended. Clerget thermometers, for inversion readings, must be of special construction and accurate within 0.1° at the 20° point.

19. VOLUMETRIC APPARATUS

All flasks, burettes, pipettes, and other volumetric apparatus should be standardized as described in Chap. XXIV, 2. ''Sugar'' flasks should be made heavier than the ordinary standard to save breakage, but the 100 ml flasks used for inversions should have sufficiently thin walls so that the solutions will reach the necessary temperature in the time required.

XXIV. STANDARDIZATION AND VERIFICATION OF LABORATORY APPARATUS

1. GENERAL

All kinds of laboratory apparatus used for quantitative measurements must be carefully verified before use. Saccharimeters, refractometers, and weights should be checked at frequent intervals. It should also be remembered that glass apparatus will gradually undergo a slight change in capacity until it has had several years' seasoning.

Tolerances: The "specifications for laboratory apparatus" give the limits of error allowable for each class of apparatus.

2. VOLUMETRIC APPARATUS

(a) General

Units of Capacity: The liter, defined as the volume occupied by a quantity of pure water at 4° C. having a mass of one kilogram, and the one-thousandth part of the liter, called the milliliter (cubic centimeter), are the units of capacity.

Standard Temperature: The standard temperature for the use of glass volumetric apparatus is 20° C.

The apparent weight in air of one liter of water at 20° C. (weighed with brass weights in air at 76 cm barometric pressure and 50% relative humidity) is 997.18 grams. At 63 cm barometric pressure (5,000 feet elevation) the apparent weight is 997.36 grams; the difference is so small that it may be disregarded in ordinary work.

Tables 35—47 of Bureau of Standards Circular 19, 5th ed., "Standard Density and Volumetric Tables," will be found useful in calibrating volumetric glassware.

Reading: In adjusting the meniscus to the graduation mark, the *lowest* point of the curve when viewed against a white surface should just touch the level of the mark.

(b) FLASKS

Clean and dry the flask thoroughly, and standardize by one of the following methods:

(1) Weigh the flask first empty and then filled with recently boiled, distilled water. Both the flask and the water should be at room temperature, and the temperature of the water should be accurately determined with a thermometer. Adjust the flask according to the tables in Bureau of Standards Circular 19. For example, a 100 ml flask must be graduated to hold 100 — .340 = 99.66 grams of water at 23° C. (See Table 38 of the Circular.)

(2) Fill the flask from a standardized pipette or burette, using clean water at room temperature. The pipette or burette employed for this purpose should be carefully standardized under definite conditions of manipulation and used under the same conditions. If the outflow is sufficiently *restricted by the size of the orifice in the tip, no period of drainage need be allowed; otherwise a definite period of drainage, e. g., 15 seconds, should be used. In either case the water remaining in the tip should not be blown out, but the emptying should be completed by †touching the tip to the wet surface of the receiving vessel.

(3) Employ a flask standardized by weight as under (1). Fill the clean, dry flask with clean mercury at room temperature, and transfer the latter with the aid of a small funnel to the flasks of the same capacity to be tested (previously cleaned and dried). Return the mercury occasionally to the standard flask to make sure that there has been no loss or alteration in volume due to change of temperature in handling. This method is convenient and safe only for flasks of small capacity.

(c) PIPETTES

Verify pipettes by weighing the water delivered. Use distilled water at room temperature, and obtain the capacity from the tables in Bureau of Standards Circular 19. If the graduation mark is found incorrect, make a new temporary mark and test again, re-

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*See Bureau of Standards Circular 9, 8th ed., p. 17, "Testing of Glass Volumetric Apparatus."

†Loc. cit., p. 26.

peating this procedure until the correct point for the graduation is found.

Pipettes should be standardized under the conditions under which they are to be used. Pipettes for analytical work of high precision should be standardized as described under "Flasks" (2). Pipettes for routine sugar laboratory work must necessarily have good sized orifices, but in use the tip is immediately touched to the wet surface of the receiving vessel to complete the emptying, without allowing any period of drainage.

(d) BURETTES AND AUTOMATIC PIPETTES

Burettes: Calibrate burettes in a similar manner to pipettes by weighing the water discharged. Empty them slowly and check at several different points in the scale, as well as for the largest amount which they will deliver. Burettes may also be verified by connecting them with a "standardizing pipette" by means of which successive portions of water of 5 ml each can be drawn off and measured.

Measuring Pipettes: Check measuring pipettes, so-called Mohr pipettes, in a similar manner to burettes.

Automatic Pipettes: The 177 ml automatic pipettes should deliver 177 ml of water within an accuracy of 0.25 ml.

Orsat Burettes: Check Orsat burettes at the 100 ml point and at intermediate points up to about the 35 ml graduation mark. If the ratios of the smaller capacities to the total capacity are correct the burette may be used without error, even if the measurements do not represent true milliliters.

(e) ETCHING GRADUATION MARKS

Stopper the flask, or other piece of glassware, and immerse the neck in melted paraffin. After the paraffin has hardened place the flask in a suitable apparatus, by means of which it can be rotated evenly about its axis and the graduation can be marked by a stylus attached to the apparatus. Then dip the flask in a hydrofluoric acid mixture, such as "Diamond Ink." After a few minutes wash off the acid and remove the paraffin with gasoline or by other suitable means. The graduation mark should be fine, exactly perpendicular to the axis, and should appear as a single straight line when viewed without parallax.

Where it is necessary to regraduate a flask or piece of volumetric apparatus which already has an incorrectly placed graduation mark, errors due to confusion of the two marks will be avoided by the use of a *colored mark applied as follows: Mix ceramic green 728 D (Roessler & Hasslacher Chemical Co.) intimately with a vehicle made up of 4 parts of copaiba balsam, 1 part of clove oil, and 1 part of lavender oil, using just enough of the vehicle so that the mixture will run slowly from a pen. After marking, heat with a flame the region where the mark has been made until the color begins to glow, being careful not to heat to the softening point of the glass. Allow to cool a little, then reheat until the markings, not the glass, again begin to glow.

3. HYDROMETERS

(a) Brix Hydrometers, General

Standard Temperature: Brix hydrometers indicate, in a solution of pure sugar at 20°, the direct percentage of sugar. The limit of error at any point on the scale should not exceed 0.1° Brix.

Cleansing: Wash the hydrometers thoroughly with soap and water, rinse, and dry with a clean linen cloth. In order to make the liquid adhere readily, dip the stems in strong alcohol, and wipe immediately with a soft, clean, linen cloth.

Points to be Checked: Check at least two points on every hydrometer, one near each end of the scale, and preferably an additional point at the middle.

Test Liquid: Use a sulphuric acid solution in every case for the test liquid.

(b) Pycnometer Method

A 50 ml pycnometer of the Bureau of Chemistry type (E. & A. Cat. No. 1086) is preferable. First determine the capacity of the pycnometer by weighing it empty, and filled with recently boiled, distilled water at 20°. Make at least three or four such determinations, which should agree closely. Then rinse and fill the pycnometer with the test solution, also at exactly 20°, and weigh, making at least two such determinations.

In obtaining these pycnometer weights, it is unnecessary to weigh to any greater degree of precision than the nearest milligram.

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*Bock, Jour. Am. Chem. Soc., XLI, 359.

Calculate the density of the test solution as follows: Divide the apparent weight of the test solution by the apparent weight of the water to obtain the "apparent specific gravity." Convert the latter to "true specific gravity" by the following formula, which gives results correct within four units in the fifth decimal place, equivalent to less than .01° Brix.

Let $D =$ true sp. gr.
$D' =$ apparent sp. gr.
Then $D = D' - .001\ (D' - 1)$

Then find the equivalent degree Brix from the 20°/20° column in Table 1.

EXAMPLE

Weight of water in pycnometer	50.014 g
Weight of test solution in pycnometer	66.043 g

$$\frac{66.043}{50.014} = 1.32049$$

$$1.32049 - .001\ (1.32049 - 1) = 1.32049 - .00032 = 1.32017$$

From the table, 1.32017 sp. gr. at 20°/20° C. is equivalent to 65.25° Brix.

Reading of Hydrometer: Use a cylinder provided with an overflow as shown in fig. 3, p. 12, Bureau of Standards Circular 16. Provide also a stirrer consisting of a glass rod slightly longer than the cylinder and bent into a spiral at the bottom.

Fill the cylinder with the test solution at a temperature of 20° C. Immerse the hydrometer carefully slightly beyond (about ¼ inch) the point where it floats naturally, and then allow it to float freely until it has assumed the temperature of the liquid. Raise the hydrometer, stir the liquid, and observe the temperature. If this is not exactly 20°, bring it to this temperature, then immerse the hydrometer as before. If the room temperature varies much from 20°, changes in temperature may be avoided by keeping the hydrometers immersed in a large jar of water at 20° and transferring them immediately, after wiping, to the cylinder containing the test solution. Make all readings at 20°, as the temperature corrections prescribed for sugar solutions will not be the same for sulphuric acid solutions.

To eliminate the effect on the reading of the formation of surface films of impurities, pour into the funnel sufficient of the test solution (at 20° C.) to cause the liquid to overflow through the spout. Then read the hydrometer. Test the completeness of the surface cleansing by repeating the operation; the readings will approach a constant value as the surface becomes normal.

Do not take the reading until the liquid and hydrometer are free from air bubbles and at rest. When the reading is taken, the hydrometer must not be in contact with the bottom or walls of the cylinder. Read the scale by bringing the eye upon a level with the surface of the solution so that the latter appears as a straight line and not an ellipse, and note where the border line forming the bottom of the meniscus intersects the scale.

The reading in a sulphuric acid solution also theoretically requires a correction due to the difference in surface tension between sulphuric acid and sugar solutions. This varies with the diameter of the stem of the hydrometer and the density of the solution, but for sugar hydrometers of the customary sizes and ranges the correction is so small that it may be disregarded.

(c) Comparison Method

Hydrometers may also be tested by comparison with standard hydrometers certified by the Bureau of Standards. Use a cylinder large enough to hold the standard hydrometer and the hydrometer to be tested at the same time, and employ a sulphuric acid solution at *room temperature* as the liquid.

Overflowing to remove surface contamination is unnecessary, since the effect of the latter on two hydrometers of similar dimensions will be the same.

Immerse and read the hydrometers otherwise as described before.

Until standard hydrometers are several years old, they are liable to change slightly in reading as the result of seasoning. Standard hydrometers should therefore be verified at least once a year by the pycnometer method until they have had several years' seasoning, or in case of doubt should be returned to the Bureau of Standards for re-test.

(d) Baumé Hydrometers

Verify Baumé hydrometers, for testing molasses, in a similar manner to Brix hydrometers. Use Table 1 for obtaining the density in degrees Baumé from the specific gravity at 20°/20° C. of the test solution, after converting the apparent specific gravity at 20°/20° to true specific gravity at 20°/20° by the formula previously given. This Baumé scale is based on a modulus of 145 and specific gravity at 20°/20° C. Check the enclosed thermometer as well as the areometric scale.

4. THERMOMETERS

Verify thermometers by comparison with suitable standards. Use water for temperatures up to its boiling point, and oil for higher ranges.

5. GRADUATION MARKS

The following methods may be found useful for making the graduation marks distinct on thermometers and volumetric glassware:

(a) Dip in a solution of asphaltum, wipe off the excess with a smooth piece of paper, and bake at a temperature sufficiently high to harden the asphaltum.

(b) Rub with a soft graphite pencil.

(c) Fill with a paste made by mixing lamp black and turpentine.

(d) Apply a mixture of oil and white lead, rub softly with tissue paper, then apply dry, powdered zinc oxide and again rub gently with the tissue paper.

6. WEIGHTS

Verify weights by comparison with suitable standards. The present standard saccharimetric normal weight is 26 grams. Check normal weights, including multiples and fractions, and counterweighted dishes at frequent intervals.

7. POLARISCOPES AND POLARISCOPE TUBES

(a) POLARISCOPES

Verify polariscopes from time to time with quartz plates which have been standardized by the Bureau of Standards, or have been carefully compared with such standard plates. Polariscopes which are sent to the Bureau of Standards will be tested by them at several points on the scale and a certificate of corrections furnished.

See Chap. XXIII, 13 (b) for the definition of the 100 degree point of the saccharimetric scale. The sugar scale now employed by the Bureau of Standards in standardizing saccharimeters and quartz plates is the Bates-Jackson scale, which differs by about 0.1° at the 100° point from the Herzfeld-Schönrock scale, the standard formerly in use. Pure sugar which polarizes 100.0 on the former scale will polarize 100.1 on the latter.

(b) Polariscope Tubes

Verify the length of polariscope tubes by measurement. Test for eccentricity of mounting of the caps by placing the tube, with the caps on, in the trough of a polariscope and, while revolving it, viewing the opening through the tube with reference to the polariscope field; if the tube has been properly centered and the caps are free from eccentricity, the tube opening will remain in the center of the field and show no movement during rotation. Test for plane parallelism of the ends of the tube and of cover glasses by repeating the experiment with the cover glasses in position and the tube filled with water; take readings also at different positions during rotation to make sure that any lack of plane parallelism causes no optical activity. Test metal tubes, which may become bent, frequently in this manner. (See Browne's ''Handbook of Sugar Analysis,'' pp. 154-5.)

8. REFRACTOMETERS

Test at the zero point with distilled water, and at other points with standard plates or solutions made up by weight from sugar of accurately determined polarization.

9. CALORIMETERS

Determine the water equivalent with the standard heat samples of the Bureau of Standards (benzoic acid, naphthalene, and sugar). All thermometers used in calorimetric work should be certified by the Bureau of Standards and the necessary corrections should be employed.

10. BIBLIOGRAPHY

Refer to the following publications of the Bureau of Standards:

Circular 3—''Design and Test of Standards of Mass.''
Circular 8—''Testing of Thermometers.''

Circular 9—"Testing of Glass Volumetric Apparatus."
Circular 11—"Standardization of Bomb Calorimeters."
Circular 12—"Verification of Polariscopic Apparatus."
Circular 16—"Testing of Hydrometers."
Circular 19—"Standard Density and Volumetric Tables."
Circular 25—"Standard Analyzed Samples."
Circular 44—"Polarimetry."
Miscellaneous—"Tables of Equivalents of the U. S. Customary and Metric Weights and Measures."

XXV. REAGENTS

This chapter covers the preparation and standardization of reagents which have a general application. Reagents used for special determinations will be found described in connection with the particular determinations.

1. ACETIC ACID, DILUTE, FOR LIME CAKE ANALYSIS

Mix 15 ml of the 99% acetic acid with 1 liter of water.

2. ACETIC ACID, DILUTE, FOR SACCHARATE CAKE ANALYSIS

Dilute 1 part of the 99% acetic acid with 4 parts of water.

3. ALPHA-NAPHTHOL

Dissolve 5 grams of alpha-naphthol in 100 ml of 95% alcohol. This solution should give the reactions described in Chap. I, 13. If the sensibility of the alpha-naphthol is poor, the strength of the solution may be increased to 10 or 20%, if necessary. As this solution does not keep well, and is liable to become contaminated, it should be made up in small quantities.

4. ALUMINA CREAM

(a) *Method I:* Add a slight excess of ammonium hydroxide to a cold saturated solution of alum; then bring to a faint acid reaction with a portion of the original alum solution retained for the purpose.

(b) *Method II:* A preparation free from dissolved salts is obtained as follows. Add a slight excess of ammonium hydroxide to a cold saturated solution of alum, allow the precipitate to settle, and wash by decantation with water until the wash water gives only a faint reaction for sulphates with barium chloride solution. Pour off the excess of water until the cream has the proper consistency.

5. AMMONIUM CARBONATE

Dissolve 1 part of the crystallized salt in a mixture of 3 parts of water and 1 part of ammonium hydroxide.

6. AMMONIUM OXALATE

Dissolve 1 part of the crystallized salt in 24 parts of water.

7. BARIUM CHLORIDE, GENERAL REAGENT

Dissolve 1 part of the crystallized salt in 10 parts of water.

8. BARIUM CHLORIDE SOLUTION, FOR STANDARDIZING SOAP SOLUTION

Dissolve 4.3574 grams of the C. P. crystallized salt ($BaCl_2.2H_2O$) in water and make up to 1 liter. This solution has a value of 1 ml = .001 g CaO. In case of doubt as to the purity of the barium chloride, the value may be accurately determined by precipitating with an excess of dilute sulphuric acid and weighing the barium sulphate. Before finishing the ignition add a few drops of sulphuric acid so that any barium present as occluded barium chloride will be converted to sulphate.

9. FEHLING'S SOLUTION

Fehling's Solution (Soxhlet's Modification) consists of the following two solutions which are mixed in equal volumes immediately before use.

(a) *Copper Sulphate Solution:* Dissolve 34.639 grams of C. P. crystallized copper sulphate in water, and dilute to a volume of 500 ml.

(b) *Alkaline Tartrate Solution:* Dissolve 173 grams of C. P. sodium potassium tartrate (Rochelle salt) and 50 grams of sodium hydroxide in water, and dilute to a volume of 500 ml. Do not use the commercial grade of Rochelle salt.

10. HYDROCHLORIC ACID FOR INVERSIONS

Dilute the ordinary C. P. acid to a density of 24.8—24.9° Brix at 20°. (1.1029 sp. gr. at 20°/4° or 1.1049 sp. gr. at 20°/20°.)

11. INDICATORS

(a) *Cochineal:* Digest, with frequent agitation, 3 grams of pulverized cochineal in a mixture of 50 ml of strong alcohol and 200 ml of water for 1 or 2 days at ordinary temperature, and then filter.

(b) *Methyl Orange:* Dissolve 1 part of the dye in 1000 parts of water.

(c) *Methyl Red:* Dissolve 1 gram of methyl red (dimethyl-amino-azo-benzene-ortho-carbonic acid) in 100 ml of 95% alcohol.

(d) *Phenolphthalein:* Dissolve 5 grams of the powder in 500—600 ml of 95% ethyl alcohol or refined methyl alcohol (Columbian Spirit), and dilute to 1 liter with water. Denatured alcohol or commercial "wood alcohol" must not be used. Then add a dilute solution of sodium hydroxide until a faint permanent pink color is produced.

12. LEAD ACETATE, BASIC

This solution is the clarifying agent commonly used in the preparation of solutions for polarization. Mix together 1 part of litharge, 3 parts of "sugar of lead," and 10 parts of water, using commercial chemicals of good quality. Boil for one-half hour by injecting steam, then let the solution cool and allow the undissolved material to settle. Decant the clear supernatant liquid and dilute it to a density of 55° Brix. Preserve the solution in wood, glass, or earthenware containers. If steam is not available, the solution may be prepared by using hot water with frequent stirring.

13. LEAD ACETATE, NEUTRAL

This solution is used as the clarifying agent in the determination of *invert sugar. Make up a concentrated aqueous solution of "sugar of lead," neutralize any free acid or alkali with sodium hydroxide or acetic acid, and dilute to a density of 55° Brix.

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*Chap. I, 6.

14. ORSAT REAGENTS

(a) *Potassium Hydroxide Solution:* To be used for the absorption of carbon dioxide (CO_2). Prepare a stock solution by adding *330 grams of potassium hydroxide (not purified by alcohol) to 1 liter of water, and preserve in a rubber-stoppered bottle. One filling of the Orsat pipette will make about 150 carbon dioxide determinations in flue gas.

(b) *Alkaline Pyrogallol Solution:* To be used for the absorption of oxygen (O). Dissolve 10 grams of pyrogallol (pyrogallic acid) in 25 ml of water. Transfer to the second pipette of the Orsat, and add potassium hydroxide solution, prepared as in (a), until both arms of the pipette are a little more than half filled. Attach the seal immediately and mix the two solutions in the pipette by circulating gas back and forth between the Orsat burette and the pipette. Renew the solution when the absorption of oxygen becomes slow. One filling of the pipette will make about 40 oxygen determinations in flue gas.

(c) *Acid Cuprous Chloride Solution:* To be used for the absorption of carbon monoxide (CO). Cover 53 grams of cupric chloride ($CuCl_2.2H_2O$) and 75 grams of copper turnings with 300 ml of concentrated hydrochloric acid, and allow to stand in a stoppered bottle, with occasional shaking, for 24 hours or longer, until the solution has become colorless or nearly so. Then dilute with 150 ml of water and preserve in a tightly stoppered bottle in contact with copper turnings. Avoid exposure of the solution to the air. When saturated with carbon monoxide, the solution may be renewed by heating to 60—70° to drive off the carbon monoxide, and will then be as efficient as it was originally.

15. PLATINIC CHLORIDE SOLUTION

The solution should contain 1 gram of metallic platinum, or 2.65 grams of chloroplatinic acid ($H_2PtCl_6.6H_2O$) in every 10 ml.

16. PLATINUM RECOVERY

Preserve all residues from potassium determinations which contain platinum, including both the precipitated potassium pla-

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*Some textbooks recommend a stronger solution, viz. 500 grams of potassium hydroxide dissolved in 1 liter of water.

tinic chloride as well as the filtrates and washings from platinic chloride precipitations. Dissolve the potassium platinic chloride off the Gooch mats by means of hot water.

Remove the alcohol from the alcoholic solutions by distillation, concentrate the solutions in a large porcelain dish on a water bath, and reduce to metallic platinum by the addition of hydrochloric acid and C. P. zinc or aluminum, heating until the zinc or aluminum is completely dissolved. Decant the supernatant liquid and wash the spongy platinum by decantation with water. Bring the platinum upon a filter and wash till the filtrate shows no acid reaction. Ignite the filter containing the platinum sponge in a platinum or porcelain crucible and weigh. Transfer the platinum sponge to a porcelain dish, add about four times its weight of concentrated hydrochloric acid heat on a water bath, and add concentrated nitric acid in small portions until the platinum is completely dissolved. Evaporate two or three times with hydrochloric acid to expel the nitric acid, then evaporate to a syrupy consistence, take up with water, and filter. Dilute the filtrate to the volume which will yield a platinum solution of the standard strength, viz., 1 gram in 10 ml.

It is important to use zinc or aluminum of high purity (commercial grades are not suitable) and to make sure, by testing the filtrate with more zinc or aluminum, that the platinum has been completely precipitated.

17. SEA SAND

For moisture determinations use clean sea sand, free from any great amount of dust. Screen it through a 40 mesh sieve and discard the portion retained by the sieve. Digest the remainder with hot, commercial hydrochloric acid, and wash the sand thoroughly in a current of water, then decant the excess of water, and dry on a hot plate.

The dried residues from moisture determinations may conveniently be loosened by soaking in water and then transferred to a jar, or suitable container. After washing the sand in a current of water and drying, as before, it may then be used again for the same purpose.

18. SODIUM CARBONATE

Dissolve 1 part of the anhydrous salt, or 2.7 parts of the crystals ($Na_2CO_3.10H_2O$) in 5 parts of water.

19. SODIUM AMMONIUM PHOSPHATE.

Dissolve 1 part of the crystals (microcosmic salt) in 17 parts of water.

20. SODIUM HYDROGEN PHOSPHATE

Dissolve 1 part of the crystals of disodium hydrogen phosphate in 10 parts of water.

21. STANDARD ACID AND ALKALI SOLUTIONS

(a) PRIMARY STANDARDS

A standard sodium carbonate solution will probably prove the most serviceable for general use. In case of doubt as to the purity of the sodium carbonate, or as an additional check, verify the strength of the finally prepared solution by one of the other methods given.

(1) *Sodium Carbonate:* Ignite sodium carbonate or bicarbonate of the *highest purity obtainable to constant weight in a †platinum dish or crucible at a *dull red* heat, being careful not to allow any of the material to fuse. From the freshly ignited material, cooled and kept in a desiccator over sulphuric acid, standard solutions may be made up in accordance with the table given below. 1.8906 parts of Na_2CO_3 are equivalent to 1 part of CaO. In titrating, use methyl orange as indicator.

Strength of Solution	Grams of Na_2CO_3 per Liter
Normal	53.0025
1 ml = .05 g CaO	94.5292
1 ml = .001 g CaO	1.8906

(2) *Benzoic Acid:* A sodium hydroxide solution may be standardized by titrating against weighed amounts of benzoic acid of the Bureau of Standards. A sulphuric acid solution is then standardized against the sodium hydroxide solution. Prepare the benzoic acid by heating in a covered platinum dish in an oven to about 130° (not over 140°). As soon as fusion is complete, pour

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*Use the grade "C. P. Special for Standardizing" and not the ordinary "C. P."

†A convenient arrangement for igniting sodium carbonate is shown in W. W. Scott's "Standard Methods of Chemical Analysis," p. 501.

it into a test tube or into glass tubes sealed at one end which have been thoroughly cleaned and dried. After the material has solidified, break away the glass and preserve the sticks in a glass-stoppered bottle. The material is not hygroscopic except after long standing. Dissolve the benzoic acid in 95% alcohol (20 ml for a 1 gram sample) and make a blank test on the same volume of alcohol, applying any correction thus found necessary. Use phenolphthalein as indicator. 4.3547 parts of pure benzoic acid ($C_6H_5CO_2H$) are equivalent to 1 part of CaO.

(3) *Gravimetric Method:* The strength of a sulphuric acid solution may be determined by diluting with water, precipitating with barium chloride, and weighing as barium sulphate in the regular manner. Sulphates, if present, will vitiate the result, but should not be present in any ordinary C. P. sulphuric acid. Serious error will be caused if any marked excess of barium chloride is used, owing to the occlusion of barium chloride in the precipitate; the best plan is perhaps to determine the theoretical amount of barium chloride needed and to add about 2 or 3% more than this amount. After weighing the ignited barium sulphate, add a drop or two of sulphuric acid, evaporate the acid on a radiator, and reignite and reweigh to determine if any reduced barium sulphide was present after the first ignition. As the barium sulphate precipitations must stand over night, this method is slow for adjusting a sulphuric acid solution to a definite strength, and is chiefly useful for standardizing a solution which is not made up to a definite strength, or for verifying the value of a solution already standardized by another method.

(b) N/28 SULPHURIC ACID

As large quantities of this acid (1 ml = .001 g CaO) are required, it should be made up in carboys or large bottles of about 40 liters capacity. Prepare a solution slightly over strength by slowly pouring *75 grams (40.8 ml) of sulphuric acid of 1.84 sp. gr. into 40 liters of water in a carboy, and mix thoroughly by a current of air.

Prepare a standard sodium carbonate solution (1 ml = .001 g CaO) as in "(a), (1)," by dissolving 1.8906 grams of freshly ignited sodium carbonate in neutral water and making up to 1

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*It may be more convenient to make up first an approximately normal solution and then dilute this in the proportion of 1 part of the normal solution to 27 parts of water. Then titrate the diluted solution in the manner described.

liter. Titrate 25—50 ml of the standard sodium carbonate solution to neutrality with the sulphuric acid solution, adding several drops of methyl orange as indicator. Calculate the additional amount of water which must be added, as in the following example: If 40 ml of the sodium carbonate requires 39.2 ml of the acid, then $\frac{40}{39.2} - 1 = .0204$ ml of water to be added per ml of original solution, or, to the original volume of 40,000 ml, $.0204 \times 40{,}000 = 816$ ml of water must be added. Add this amount of water, mix well with air, and titrate again. Repeat the above procedure, viz., dilution and titration, until the strength of the acid is exactly equal to that of the sodium carbonate. As a check against possible error in weighing or in volumetric apparatus, the final solution may then be titrated against a suitable weighed amount of the ignited sodium carbonate.

(c) N/28 SODIUM HYDROXIDE

As N/28 sodium hydroxide is not required in large quantities, and is unstable due to absorption of carbon dioxide from the air and its solvent action on glass, it is best to prepare this solution in small amounts and check it frequently against the N/28 sulphuric acid. Use about *1.6 grams of sodium hydroxide per liter of water. Titrate against the N/28 acid and dilute with water, etc., until its strength is exactly equal to that of the standard acid.

(d) STEFFEN NITRIC ACID (1 ml = .05 g CaO)

As large quantities of this acid are required, it should be made up in carboys. Make up 170 grams (120 ml) of nitric acid of 1.42 sp. gr. to 1 liter, or mix 6800 grams (4800 ml) of the acid with 35200 ml of water. After mixing, titrate against a sodium carbonate solution (1 ml = .05 g CaO) made by dissolving 23.632 grams of freshly ignited sodium carbonate, prepared as in "(a), (1)," in water and making up to a volume of 250 ml. Adjust the acid to the proper strength by titration and dilution as described under (b).

(e) STEFFEN SODIUM HYDROXIDE (1 ml = .05 g CaO)

Large amounts of this solution are required, but it should not be made up in carboy lots owing to its liability to change in strength. Dissolve about 80 grams of sodium hydroxide in 1 liter of water and standardize against the Steffen nitric acid. If desired, a solution slightly over strength may be made up in carboy

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*See footnote on previous page.

lots to serve as the source of supply for the preparation of smaller quantities of the standard solution.

22. STANDARD SOAP SOLUTION

As soap solution is subject to some alteration in strength on long standing, the standard solution should be made up in quantities which will last for not more than 3 or 4 weeks, or should be restandardized at the end of this time.

(a) PREPARATION

(1) *Method I:* Dissolve 20 grams of pure potassium hydroxide in 25 ml of water and add 200 ml of 95% ethyl alcohol. Add 100 ml of best, genuine olive oil and heat on a water bath in a flask provided with a reflux condenser until saponification is complete, recognizable by the fact that several drops of the clear solution, when mixed with water, cause no turbidity. Pour the solution into 3 liters of water, mix well, and add a calcium chloride solution as long as a precipitate is formed. Filter off the precipitate through a fine cloth, and press to remove the mother liquor as completely as possible. Mix the precipitate intimately with 40% of its weight of potassium carbonate in a large mortar, and extract with several portions of 95% ethyl alcohol, using a water bath and reflux condenser as before. Mix the various portions, filter, and preserve in a stoppered bottle. Use this strong solution of potassium soap as a source of supply for the preparation of the standard solution, which is made by diluting to the approximate strength with 60% alcohol and standardizing as described below.

(2) *Method II:* Dissolve sodium oleate, or shavings of the best Castile soap obtainable, in 60% alcohol.

(b) STANDARDIZATION

Prepare a barium chloride solution, as described in "8," containing 4.3574 grams of the C. P. crystallized salt ($BaCl_2.2H_2O$) in 1 liter, using the same kind of water which is employed for dilution in the standardization test described below. Transfer 10 ml with a pipette to an 8 oz. glass bottle provided with a ground stopper and marked at the point at which it holds 50 ml, and fill to the 50 ml mark with water. Add a drop of phenolphthalein and then add N/28 sodium hydroxide a drop at a time until a permanent pink color is produced; unless the water is of very poor quality one drop should be sufficient. Then add the soap solution in small quantities from a burette; after each addition stopper the bottle and shake vigorously. Take as the end point the *formation of a fine foam 5 mm in depth which will last five minutes. Make a blank test on 50 ml of the water used for dilution, adding a drop of phenolphthalein and then N/28 sodium hydroxide a drop at a time until a permanent pink color is produced. Subtract from the number of milliliters of soap solution used in the standardization test the number of milliliters of soap solution required by 50 ml of the water in the blank test.

Calculate from the above the †dilution necessary to reduce the solution to such a strength that it is exactly equal to the barium chloride solution, i. e., so that 10 ml of the barium chloride will be exactly neutralized by 10 ml (corrected) of the soap solution. After diluting, restandardize and continue in this manner until the strength is accurately adjusted.

One ml of the standard soap solution is equivalent to .001 gram of CaO.

23. WATER, DISTILLED

Distilled water produced from raw water of poor quality in the usual laboratory still is not always what it should be. One should occasionally test the reaction by titrating a measured amount with phenolphthalein as indicator, and determine the amount of solids present by evaporating a measured amount and drying at 100—105°; from these data one can determine the suitability of the water for the purpose in question. When the raw water contains large amounts of bicarbonates, the distilled water is frequently quite acid from the presence of dissolved carbon dioxide and is quite unsuitable for acidimetric titrations. In this case boiling the water after distillation until the carbon dioxide is all expelled will generally yield a water of neutral reaction.

24. ZINC NITRATE SOLUTION

This solution is used to decompose calcium saccharate in the analysis of lime cake. Dissolve 1 part of commercial zinc nitrate in 10 parts of water.

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*See Chap. I, 12.

†If a = no. of ml of the soap solution required by 10 ml of the standard barium chloride solution, and x = volume in ml to which each liter must be diluted, then $x = 10000 \div a$. E. g., if $a = 9.25$, $x = 1081$, i. e., 81 ml of water, or 60% alcohol, must be added to each 1000 ml of the original soap solution.

XXVI. MISCELLANEOUS

A few subjects of not great length which cannot well be classified elsewhere are treated in this chapter.

1. MOISTURE TESTS OF SUGAR IN STORAGE

The sugar in storage in the warehouses should be sampled and analyzed as described below during the entire intercampaign, or up to the time when all sugar has been shipped.

Sampling

Sample on the 15th and the last day of every month; if a sampling day falls on Sunday or a holiday, take the samples on the next succeeding working day. Take the first set of samples on the first sampling day after the sugar end has finished, provided that a week has elapsed since that time; if the elapsed period is less than a week, the sampling may be deferred until a half-month later.

Take separate samples from the outside bag at 3 points of each location, as follows:

(a) At a point 3 tiers from the top of the pile.

(b) At the middle of the pile.

(c) At a point 3 tiers from the bottom of the pile.

The selection of the locations for sampling is largely governed by the accessibility. The aisles and cross passages will usually afford opportunity to distribute the sampling locations suitably throughout the warehouses. It is desirable to draw a diagram, keeping this for reference and furnishing a copy with the first report.

Sample one bag only at each point, and mark this bag in order that the same bag may be sampled throughout the storage period. There should be one location (3 samples) for at least every 25,000 bags in storage, and at least five locations in every warehouse. Continue the sampling at every location until the sugar at the location has been shipped. In addition take samples at the point of shipment of "Standard," "Table" sugar, etc.

Take all samples with a small trier from the interior of the bag, avoiding the sugar immediatly next to the sack. Use 1 x 3 in. rubber stoppered test tubes as containers. Before use, clean them carefully, heat them in a drying oven together with the stoppers, and cool in a desiccator.

ANALYSIS

Allow the samples to stand in the containers long enough so that the sugar will attain the temperature of the laboratory, then weigh out 10 grams in each case and determine the moisture as in Chap. II, 23.

2. SODA ASH AND CAUSTIC SODA

Sample each carload or lot received and analyze according to the methods of the Solvay Process Company (Technical Bulletins Nos. 1 and 2).

3. MURIATIC ACID

If the acid is received in tank cars, sample each carload lot. If it is received in carboys, sample a number of carboys and test the individual samples to determine if there is any variation, also calculate the average of the individual tests.

Determine the density in degrees Baumé. Muriatic acid is usually sold on a specification of 18° Be. The scale employed is the *American Baumé scale, which is based on a modulus of 145 and sp. gr. at 60°/60° F. The determination may be made *at 20° C.* with a Brix hydrometer and the reading tranposed directly to degrees Baumé by the use of Table 1 without appreciable error.

4. BARIUM OXIDE

Sample each lot of barium oxide received. Grind rapidly, protecting the material from exposure to the air as it absorbs carbon dioxide rapidly.

Determine the total water-soluble barium as follows: Weigh out 3—4 grams, transfer to a 200 ml volumetric flask, add at least

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*Bureau of Standards, Circ. 19, 5th ed., pp 34-36.

150 ml of distilled water free from carbon dioxide, and boil until all soluble matter has been dissolved. Cool, make up to the mark, and filter through a dry filter, keeping the funnel covered to prevent absorption of carbon dioxide from the air. Transfer 50 ml of the filtrate to a beaker, dilute to a volume of about 200 ml, make slightly acid with hydrochloric acid, and precipitate with hot dilute sulphuric acid in the regular manner, proceeding as in Chap. XIII, 8. Multiply the weight of $BaSO_4$ by .6570 to obtain the BaO equivalent of the water-soluble barium present.

The weights and volumes prescribed above must be adhered to, in order that the limit of solubility of barium hydroxide may not be exceeded.

5. INSECTICIDES

The determination of total and water-soluble arsenic in Paris Green and other arsenicals should be made according to the ''Methods of Analysis of the Association of Official Agricultural Chemists.''

6. MISCELLANEOUS SUPPLIES

No methods are given or prescribed in this book for other miscellaneous supplies such as lubricating oils, paints, rubber goods, etc., because chemical analyses in such cases are mostly only of value when correlated with service tests. Methods may be found in the standard textbooks, among which may be particularly mentioned ''Some Technical Methods of Testing Miscellaneous Supplies,'' by Percy H. Walker, a miscellaneous publication of the Bureau of Standards.

TABLE 1

BRIX, BAUME, AND SPECIFIC GRAVITY OF SUGAR SOLUTIONS

Table showing equivalent degrees Brix, degrees Baumé, specific gravity at 20°/20° C., pounds per cubic foot, and pounds of dry substance per cubic foot, from *values of the U. S. Bureau of Standards.

Explanation

The Baumé scale is based on a modulus of 145 and is derived from specific gravities at 20°/20°C. (Bureau of Standards Baumé scale for sugar solutions.) That is, if d = degrees Baumé and s = specific gravity at 20°/20°C.,

Then $d = 145 - 145/s$

The values for †specific gravity at 20°/20°C. represent true specific gravity, i. e. the ratio of the weights *in vacuo* of equal volumes of the sugar solution and of water, based on the determinations of Plato.

The values for "pounds per cubic foot" represent weights at 20°C. in air against brass weights.

The values for "pounds of dry substance per cubic foot" are calculated by multiplying the "pounds per cubic foot" by the percentage of dry substance represented by the "degrees Brix." For impure sugar solutions these values are only approximate.

Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.	Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.
0.0	0.00	1.00000	62.25	0.00	2.0	1.12	1.00779	62.73	1.25
0.1	0.06	1.00039	62.27	0.06	2.1	1.18	1.00818	62.76	1.32
0.2	0.11	1.00078	62.30	0.12	2.2	1.23	1.00858	62.78	1.38
0.3	0.17	1.00117	62.32	0.19	2.3	1.29	1.00897	62.81	1.45
0.4	0.22	1.00155	62.35	0.25	2.4	1.34	1.00936	62.83	1.51
0.5	0.28	1.00194	62.37	0.31	2.5	1.40	1.00976	62.86	1.57
0.6	0.34	1.00233	62.40	0.37	2.6	1.46	1.01015	62.88	1.64
0.7	0.39	1.00272	62.42	0.44	2.7	1.51	1.01054	62.91	1.70
0.8	0.45	1.00311	62.44	0.50	2.8	1.57	1.01093	62.93	1.76
0.9	0.51	1.00350	62.47	0.56	2.9	1.62	1.01133	62.96	1.83
1.0	0.56	1.00389	62.49	0.62	3.0	1.68	1.01172	62.98	1.89
1.1	0.62	1.00428	62.52	0.69	3.1	1.74	1.01211	63.00	1.96
1.2	0.67	1.00467	62.54	0.75	3.2	1.79	1.01251	63.03	2.02
1.3	0.73	1.00506	62.56	0.81	3.3	1.85	1.01290	63.05	2.08
1.4	0.79	1.00545	62.59	0.88	3.4	1.90	1.01330	63.08	2.14
1.5	0.84	1.00584	62.61	0.94	3.5	1.96	1.01369	63.10	2.21
1.6	0.90	1.00623	62.64	1.00	3.6	2.02	1.01409	63.13	2.27
1.7	0.95	1.00662	62.66	1.07	3.7	2.07	1.01448	63.16	2.34
1.8	1.01	1.00701	62.69	1.13	3.8	2.13	1.01488	63.18	2.40
1.9	1.07	1.00740	62.71	1.19	3.9	2.18	1.01528	63.20	2.46

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*Circulars 19 and 44.

†The volume in milliliters, of a given weight of liquid in grams in air, is obtained from the table as follows: Let D = true sp. gr. at 20°/20° as given in the table, D′ = apparent sp gr. at 20°/20° (ratio of weights in air), W = weight in grams of liquid in air, and V = volume of liquid at 20° in milliliters.

Then $D' = D + .001\ (D-1)$
And $V = W \div .9972\ D'$

Conversely, to find W if V is known

$W = .9972\ V\ D'$

The constant .9972 is the weight in grams of 1 ml of water at 20° in air. The formula for D′ gives results which are accurate within four units in the fifth decimal place. See Chapter XXIV, 3, for instructions for use of the table in standardizing hydrometers.

TABLE 1—Continued

Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.	Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.
4.0	2.24	1.01567	63.23	2.53	8.0	4.46	1.03176	64.23	5.14
4.1	2.29	1.01607	63.25	2.59	8.1	4.52	1.03217	64.25	5.20
4.2	2.35	1.01647	63.28	2.66	8.2	4.58	1.03258	64.28	5.27
4.3	2.40	1.01687	63.30	2.72	8.3	4.63	1.03299	64.30	5.33
4.4	2.46	1.01726	63.33	2.79	8.4	4.69	1.03340	64.33	5.40
4.5	2.52	1.01766	63.36	2.85	8.5	4.74	1.03381	64.36	5.47
4.6	2.57	1.01806	63.38	2.92	8.6	4.80	1.03422	64.38	5.54
4.7	2.63	1.01846	63.40	2.98	8.7	4.85	1.03463	64.40	5.60
4.8	2.68	1.01886	63.43	3.04	8.8	4.91	1.03504	64.43	5.67
4.9	2.74	1.01926	63.45	3.11	8.9	4.96	1.03545	64.46	5.74
5.0	2.79	1.01965	63.47	3.17	9.0	5.02	1.03586	64.48	5.80
5.1	2.85	1.02005	63.50	3.24	9.1	5.07	1.03627	64.50	5.87
5.2	2.91	1.02045	63.52	3.30	9.2	5.13	1.03668	64.53	5.94
5.3	2.96	1.02085	63.55	3.37	9.3	5.19	1.03709	64.56	6.00
5.4	3.02	1.02125	63.57	3.43	9.4	5.24	1.03750	64.58	6.07
5.5	3.07	1.02165	63.60	3.50	9.5	5.30	1.03792	64.61	6.14
5.6	3.13	1.02206	63.62	3.56	9.6	5.35	1.03833	64.63	6.20
5.7	3.18	1.02246	63.65	3.63	9.7	5.41	1.03874	64.66	6.27
5.8	3.24	1.02286	63.67	3.69	9.8	5.46	1.03915	64.69	6.34
5.9	3.30	1.02321	63.70	3.76	9.9	5.52	1.03957	64.72	6.41
6.0	3.35	1.02366	63.72	3.82	10.0	5.57	1.03998	64.74	6.47
6.1	3.41	1.02407	63.75	3.89	10.1	5.63	1.04039	64.77	6.54
6.2	3.46	1.02447	63.77	3.95	10.2	5.68	1.04081	64.79	6.61
6.3	3.52	1.02487	63.80	4.02	10.3	5.74	1.04122	64.82	6.68
6.4	3.57	1.02527	63.82	4.08	10.4	5.80	1.04164	64.84	6.74
6.5	3.63	1.02568	63.85	4.15	10.5	5.85	1.04205	64.87	6.81
6.6	3.69	1.02608	63.87	4.21	10.6	5.91	1.04247	64.90	6.88
6.7	3.74	1.02648	63.90	4.28	10.7	5.96	1.04288	64.92	6.95
6.8	3.80	1.02689	63.92	4.34	10.8	6.02	1.04330	64.95	7.01
6.9	3.85	1.02729	63.95	4.41	10.9	6.07	1.04371	64.97	7.08
7.0	3.91	1.02770	63.97	4.47	11.0	6.13	1.04413	65.00	7.15
7.1	3.96	1.02810	64.00	4.54	11.1	6.18	1.04455	65.03	7.22
7.2	4.02	1.02851	64.03	4.60	11.2	6.24	1.04497	65.05	7.29
7.3	4.08	1.02892	64.05	4.67	11.3	6.30	1.04538	65.08	7.35
7.4	4.13	1.02932	64.08	4.74	11.4	6.35	1.04580	65.11	7.42
7.5	4.19	1.02973	64.10	4.80	11.5	6.41	1.04622	65.13	7.49
7.6	4.24	1.03013	64.13	4.87	11.6	6.46	1.04664	65.16	7.56
7.7	4.30	1.03054	64.15	4.94	11.7	6.52	1.04706	65.18	7.63
7.8	4.35	1.03095	64.18	5.01	11.8	6.57	1.04747	65.21	7.69
7.9	4.41	1.03136	64.20	5.07	11.9	6.63	1.04789	65.23	7.76

TABLE 1—Continued

Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.	Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.
12.0	6.68	1.04831	65.26	7.83	16.0	8.89	1.06534	66.32	10.61
12.1	6.74	1.04873	65.29	7.90	16.1	8.95	1.06577	66.35	10.68
12.2	6.79	1.04915	65.31	7.97	16.2	9.00	1.06621	66.38	10.75
12.3	6.85	1.04957	65.34	8.04	16.3	9.06	1.06664	66.40	10.82
12.4	6.90	1.04999	65.36	8.10	16.4	9.11	1.06707	66.43	10.89
12.5	6.96	1.05041	65.39	8.17	16.5	9.17	1.06751	66.46	10.97
12.6	7.02	1.05084	65.42	8.24	16.6	9.22	1.06794	66.48	11.04
12.7	7.07	1.05126	65.44	8.31	16.7	9.28	1.06837	66.51	11.11
12.8	7.13	1.05168	65.47	8.38	16.8	9.33	1.06881	66.54	11.18
12.9	7.18	1.05210	65.50	8.45	16.9	9.39	1.06924	66.56	11.25
13.0	7.24	1.05252	65.52	8.52	17.0	9.45	1.06968	66.59	11.32
13.1	7.29	1.05295	65.55	8.59	17.1	9.50	1.07011	66.62	11.39
13.2	7.35	1.05337	65.58	8.66	17.2	9.56	1.07055	66.65	11.46
13.3	7.40	1.05379	65.60	8.72	17.3	9.61	1.07098	66.67	11.53
13.4	7.46	1.05422	65.63	8.79	17.4	9.67	1.07142	66.70	11.61
13.5	7.51	1.05464	65.65	8.86	17.5	9.72	1.07186	66.73	11.68
13.6	7.57	1.05506	65.68	8.93	17.6	9.78	1.07229	66.75	11.74
13.7	7.62	1.05549	65.71	9.00	17.7	9.83	1.07273	66.78	11.82
13.8	7.68	1.05591	65.73	9.07	17.8	9.89	1.07317	66.81	11.89
13.9	7.73	1.05634	65.76	9.14	17.9	9.94	1.07361	66.84	11.96
14.0	7.79	1.05677	65.79	9.21	18.0	10.00	1.07404	66.86	12.03
14.1	7.84	1.05719	65.81	9.28	18.1	10.05	1.07448	66.89	12.11
14.2	7.90	1.05762	65.84	9.35	18.2	10.11	1.07492	66.92	12.18
14.3	7.96	1.05804	65.87	9.42	18.3	10.16	1.07536	66.95	12.25
14.4	8.01	1.05847	65.89	9.49	18.4	10.22	1.07580	66.97	12.32
14.5	8.07	1.05890	65.92	9.56	18.5	10.27	1.07624	67.00	12.40
14.6	8.12	1.05933	65.95	9.63	18.6	10.33	1.07668	67.03	12.47
14.7	8.18	1.05975	65.97	9.70	18.7	10.38	1.07712	67.06	12.54
14.8	8.23	1.06018	66.00	9.77	18.8	10.44	1.07756	67.08	12.61
14.9	8.29	1.06061	66.03	9.84	18.9	10.49	1.07800	67.11	12.68
15.0	8.34	1.06104	66.05	9.91	19.0	10.55	1.07844	67.14	12.76
15.1	8.40	1.06147	66.08	9.98	19.1	10.60	1.07888	67.17	12.83
15.2	8.45	1.06190	66.11	10.05	19.2	10.66	1.07932	67.19	12.90
15.3	8.51	1.06233	66.13	10.12	19.3	10.71	1.07977	67.22	12.97
15.4	8.56	1.06276	66.16	10.19	19.4	10.77	1.08021	67.25	13.05
15.5	8.62	1.06319	66.19	10.26	19.5	10.82	1.08065	67.28	13.12
15.6	8.67	1.06362	66.21	10.33	19.6	10.88	1.08110	67.30	13.19
15.7	8.73	1.06405	66.24	10.40	19.7	10.93	1.08154	67.33	13.26
15.8	8.78	1.06448	66.27	10.47	19.8	10.99	1.08198	67.36	13.34
15.9	8.84	1.06491	66.29	10.54	19.9	11.04	1.08243	67.39	13.41

TABLE 1—Continued

Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.	Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.
20.0	11.10	1.08287	67.41	13.48	24.0	13.29	1.10092	68.54	16.45
20.1	11.15	1.08332	67.44	13.56	24.1	13.35	1.10137	68.57	16.52
20.2	11.21	1.08376	67.47	13.63	24.2	13.40	1.10183	68.60	16.60
20.3	11.26	1.08421	67.50	13.70	24.3	13.46	1.10229	68.63	16.67
20.4	11.32	1.08465	67.52	13.77	24.4	13.51	1.10275	68.66	16.75
20.5	11.37	1.08510	67.55	13.85	24.5	13.57	1.10321	68.69	16.83
20.6	11.43	1.08554	67.58	13.92	24.6	13.62	1.10367	68.72	16.90
20.7	11.48	1.08599	67.60	13.99	24.7	13.67	1.10413	68.75	16.98
20.8	11.54	1.08644	67.64	14.07	24.8	13.73	1.10459	68.78	17.05
20.9	11.59	1.08689	67.66	14.14	24.9	13.78	1.10505	68.80	17.13
21.0	11.65	1.08733	67.69	14.21	25.0	13.84	1.10551	68.82	17.21
21.1	11.70	1.08778	67.72	14.29	25.1	13.89	1.10597	68.85	17.28
21.2	11.76	1.08823	67.75	14.36	25.2	13.95	1.10643	68.88	17.36
21.3	11.81	1.08868	67.78	14.43	25.3	14.00	1.10689	68.91	17.43
21.4	11.87	1.08913	67.80	14.51	25.4	14.06	1.10736	68.94	17.51
21.5	11.92	1.08958	67.83	14.58	25.5	14.11	1.10782	68.97	17.59
21.6	11.98	1.09003	67.86	14.66	25.6	14.17	1.10828	69.00	17.66
21.7	12.03	1.09048	67.89	14.73	25.7	14.22	1.10874	69.03	17.74
21.8	12.09	1.09093	67.92	14.81	25.8	14.28	1.10921	69.06	17.82
21.9	12.14	1.09138	67.94	14.88	25.9	14.33	1.10967	69.08	17.89
22.0	12.20	1.09183	67.97	14.95	26.0	14.39	1.11014	69.11	17.97
22.1	12.25	1.09228	68.00	15.03	26.1	14.44	1.11060	69.14	18.05
22.2	12.31	1.09273	68.03	15.10	26.2	14.49	1.11106	69.17	18.12
22.3	12.36	1.09318	68.06	15.18	26.3	14.55	1.11153	69.20	18.20
22.4	12.42	1.09364	68.08	15.25	26.4	14.60	1.11200	69.23	18.28
22.5	12.47	1.09409	68.11	15.32	26.5	14.66	1.11246	69.26	18.35
22.6	12.52	1.09454	68.14	15.40	26.6	14.71	1.11293	69.29	18.43
22.7	12.58	1.09499	68.17	15.47	26.7	14.77	1.11339	69.32	18.51
22.8	12.63	1.09545	68.20	15.55	26.8	14.82	1.11386	69.34	18.58
22.9	12.69	1.09590	68.23	15.62	26.9	14.88	1.11433	69.37	18.66
23.0	12.74	1.09636	68.26	15.70	27.0	14.93	1.11480	69.40	18.74
23.1	12.80	1.09681	68.28	15.77	27.1	14.99	1.11526	69.43	18.82
23.2	12.85	1.09727	68.31	15.84	27.2	15.04	1.11573	69.46	18.89
23.3	12.91	1.09772	68.34	15.92	27.3	15.09	1.11620	69.49	18.97
23.4	12.96	1.09818	68.37	16.00	27.4	15.15	1.11667	69.52	19.05
23.5	13.02	1.09863	68.40	16.07	27.5	15.20	1.11714	69.55	19.13
23.6	13.07	1.09909	68.43	16.14	27.6	15.26	1.11761	69.58	19.20
23.7	13.13	1.09954	68.46	16.22	27.7	15.31	1.11808	69.61	19.29
23.8	13.18	1.10000	68.49	16.30	27.8	15.37	1.11855	69.64	19.36
23.9	13.24	1.10046	68.52	16.38	27.9	15.42	1.11902	69.67	19.44

TABLE 1—Continued

Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.	Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.
28.0	15.48	1.11949	69.70	19.52	32.0	17.65	1.13861	70.89	22.68
28.1	15.53	1.11996	69.72	19.59	32.1	17.70	1.13909	70.92	22.77
28.2	15.59	1.12043	69.75	19.67	32.2	17.76	1.13958	70.95	22.85
28.3	15.64	1.12090	69.78	19.75	32.3	17.81	1.14006	70.98	22.93
28.4	15.69	1.12138	69.81	19.82	32.4	17.87	1.14055	71.01	23.01
28.5	15.75	1.12185	69.84	19.90	32.5	17.92	1.14103	71.04	23.09
28.6	15.80	1.12232	69.87	19.98	32.6	17.98	1.14152	71.07	23.17
28.7	15.86	1.12280	69.90	20.06	32.7	18.03	1.14201	71.10	23.25
28.8	15.91	1.12327	69.93	20.14	32.8	18.08	1.14250	71.13	23.33
28.9	15.97	1.12374	69.96	20.22	32.9	18.14	1.14298	71.16	23.41
29.0	16.02	1.12422	69.99	20.30	33.0	18.19	1.14347	71.19	23.49
29.1	16.08	1.12469	70.02	20.38	33.1	18.25	1.14396	71.22	23.57
29.2	16.13	1.12517	70.05	20.45	33.2	18.30	1.14445	71.25	23.66
29.3	16.18	1.12564	70.08	20.53	33.3	18.36	1.14494	71.28	23.74
29.4	16.24	1.12612	70.11	20.61	33.4	18.41	1.14543	71.31	23.82
29.5	16.29	1.12659	70.14	20.69	33.5	18.46	1.14592	71.34	23.90
29.6	16.35	1.12707	70.17	20.77	33.6	18.52	1.14641	71.37	23.98
29.7	16.40	1.12755	70.20	20.85	33.7	18.57	1.14690	71.40	24.06
29.8	16.46	1.12802	70.23	20.93	33.8	18.63	1.14739	71.43	24.14
29.9	16.51	1.12850	70.26	21.01	33.9	18.68	1.14788	71.46	24.22
30.0	16.57	1.12898	70.29	21.08	34.0	18.73	1.14837	71.50	24.31
30.1	16.62	1.12946	70.32	21.17	34.1	18.79	1.14886	71.53	24.39
30.2	16.67	1.12993	70.35	21.25	34.2	18.84	1.14936	71.56	24.47
30.3	16.73	1.13041	70.38	21.32	34.3	18.90	1.14985	71.59	24.56
30.4	16.78	1.13089	70.41	21.40	34.4	18.95	1.15034	71.62	24.64
30.5	16.84	1.13137	70.44	21.48	34.5	19.00	1.15084	71.65	24.72
30.6	16.89	1.13185	70.47	21.56	34.6	19.06	1.15133	71.68	24.80
30.7	16.95	1.13233	70.50	21.64	34.7	19.11	1.15183	71.71	24.88
30.8	17.00	1.13281	70.53	21.72	34.8	19.17	1.15232	71.74	24.97
30.9	17.05	1.13329	70.56	21.80	34.9	19.22	1.15282	71.77	25.05
31.0	17.11	1.13378	70.59	21.88	35.0	19.28	1.15331	71.80	25.13
31.1	17.16	1.13426	70.62	21.96	35.1	19.33	1.15381	71.83	25.21
31.2	17.22	1.13474	70.65	22.04	35.2	19.38	1.15430	71.86	25.29
31.3	17.27	1.13522	70.68	22.12	35.3	19.44	1.15480	71.89	25.38
31.4	17.33	1.13570	70.71	22.20	35.4	19.49	1.15530	71.93	25.46
31.5	17.38	1.13619	70.74	22.28	35.5	19.55	1.15579	71.96	25.55
31.6	17.43	1.13667	70.77	22.36	35.6	19.60	1.15629	71.99	25.63
31.7	17.49	1.13715	70.80	22.44	35.7	19.65	1.15679	72.02	25.71
31.8	17.54	1.13764	70.83	22.52	35.8	19.71	1.15729	72.05	25.79
31.9	17.60	1.13812	70.86	22.60	35.9	19.76	1.15778	72.08	25.88

TABLE 1—Continued

Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.	Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.
36.0	19.81	1.15828	72.11	25.96	40.0	21.97	1.17853	73.37	29.35
36.1	19.87	1.15878	72.14	26.04	40.1	22.02	1.17904	73.41	29.44
36.2	19.92	1.15928	72.18	26.13	40.2	22.07	1.17956	73.44	29.52
36.3	19.98	1.15978	72.21	26.21	40.3	22.13	1.18007	73.47	29.61
36.4	20.03	1.16028	72.24	26.30	40.4	22.18	1.18058	73.50	29.69
36.5	20.08	1.16078	72.27	26.38	40.5	22.23	1.18110	73.53	29.78
36.6	20.14	1.16128	72.30	26.46	40.6	22.29	1.18162	73.57	29.87
36.7	20.19	1.16178	72.33	26.55	40.7	22.34	1.18213	73.60	29.96
36.8	20.25	1.16228	72.36	26.63	40.8	22.39	1.18265	73.63	30.04
36.9	20.30	1.16279	72.39	26.71	40.9	22.45	1.18316	73.66	30.13
37.0	20.35	1.16329	72.42	26.80	41.0	22.50	1.18368	73.70	30.22
37.1	20.41	1.16379	72.46	26.88	41.1	22.55	1.18420	73.73	30.30
37.2	20.46	1.16430	72.49	26.97	41.2	22.61	1.18472	73.76	30.39
37.3	20.52	1.16480	72.52	27.05	41.3	22.66	1.18524	73.79	30.48
37.4	20.57	1.16530	72.55	27.13	41.4	22.72	1.18575	73.82	30.56
37.5	20.62	1.16581	72.58	27.22	41.5	22.77	1.18627	73.86	30.65
37.6	20.68	1.16631	72.61	27.30	41.6	22.82	1.18679	73.89	30.74
37.7	20.73	1.16682	72.65	27.39	41.7	22.88	1.18731	73.92	30.82
37.8	20.78	1.16732	72.68	27.47	41.8	22.93	1.18783	73.95	30.91
37.9	20.84	1.16783	72.71	27.56	41.9	22.98	1.18835	73.99	31.00
38.0	20.89	1.16833	72.74	27.64	42.0	23.04	1.18887	74.02	31.09
38.1	20.94	1.16884	72.77	27.73	42.1	23.09	1.18939	74.05	31.18
38.2	21.00	1.16934	72.80	27.81	42.2	23.14	1.18992	74.08	31.26
38.3	21.05	1.16985	72.83	27.89	42.3	23.20	1.19044	74.12	31.35
38.4	21.11	1.17036	72.87	27.98	42.4	23.25	1.19096	74.15	31.44
38.5	21.16	1.17087	72.90	28.07	42.5	23.30	1.19148	74.18	31.53
38.6	21.21	1.17138	72.93	28.15	42.6	23.36	1.19201	74.21	31.61
38.7	21.27	1.17188	72.96	28.24	42.7	23.41	1.19253	74.24	31.70
38.8	21.32	1.17239	72.99	28.32	42.8	23.46	1.19305	74.28	31.79
38.9	21.38	1.17290	73.02	28.40	42.9	23.52	1.19358	74.31	31.88
39.0	21.43	1.17341	73.06	28.49	43.0	23.57	1.19410	74.34	31.97
39.1	21.48	1.17392	73.09	28.58	43.1	23.62	1.19463	74.38	32.06
39.2	21.54	1.17443	73.12	28.66	43.2	23.68	1.19515	74.41	32.15
39.3	21.59	1.17494	73.15	28.75	43.3	23.73	1.19568	74.44	32.23
39.4	21.64	1.17545	73.18	28.83	43.4	23.78	1.19620	74.48	32.32
39.5	21.70	1.17596	73.21	28.92	43.5	23.84	1.19673	74.51	32.41
39.6	21.75	1.17648	73.25	29.01	43.6	23.89	1.19726	74.54	32.50
39.7	21.80	1.17699	73.28	29.09	43.7	23.94	1.19778	74.57	32.59
39.8	21.86	1.17750	73.31	29.18	43.8	24.00	1.19831	74.61	32.68
39.9	21.91	1.17802	73.34	29.26	43.9	24.05	1.19884	74.64	32.77

TABLE 1—Continued

Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.	Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.
44.0	24.10	1.19936	74.67	32.86	48.0	26.23	1.22080	76.01	36.48
44.1	24.16	1.19989	74.71	32.95	48.1	26.28	1.22134	76.04	36.58
44.2	24.21	1.20042	74.74	33.04	48.2	26.33	1.22189	76.08	36.67
44.3	24.26	1.20095	74.77	33.12	48.3	26.38	1.22243	76.11	36.76
44.4	24.32	1.20148	74.80	33.21	48.4	26.44	1.22298	76.14	36.85
44.5	24.37	1.20201	74.84	33.30	48.5	26.49	1.22352	76.18	36.95
44.6	24.42	1.20254	74.87	33.39	48.6	26.54	1.22406	76.21	37.04
44.7	24.48	1.20307	74.90	33.48	48.7	26.59	1.22461	76.24	37.13
44.8	24.53	1.20360	74.94	33.57	48.8	26.65	1.22516	76.28	37.22
44.9	24.58	1.20414	74.97	33.66	48.9	26.70	1.22570	76.31	37.32
45.0	24.63	1.20467	75.00	33.75	49.0	26.75	1.22625	76.35	37.41
45.1	24.69	1.20520	75.04	33.84	49.1	28.81	1.22680	76.38	37.50
45.2	24.74	1.20573	75.07	33.93	49.2	26.86	1.22735	76.41	37.59
45.3	24.79	1.20627	75.11	34.02	49.3	26.91	1.22789	76.45	37.68
45.4	24.85	1.20680	75.14	34.11	49.4	26.96	1.22844	76.48	37.78
45.5	24.90	1.20733	75.17	34.20	49.5	27.02	1.22899	76.52	37.87
45.6	24.95	1.20787	75.20	34.29	49.6	27.07	1.22954	76.55	37.97
45.7	25.01	1.20840	75.24	34.38	49.7	27.12	1.23009	76.59	38.07
45.8	25.06	1.20894	75.27	34.47	49.8	27.18	1.23064	76.62	38.16
45.9	25.11	1.20947	75.30	34.56	49.9	27.23	1.23119	76.66	38.25
46.0	25.17	1.21001	75.33	34.65	50.0	27.28	1.23174	76.69	38.35
46.1	25.22	1.21054	75.37	34.74	50.1	27.33	1.23229	76.72	38.43
46.2	25.27	1.21108	75.40	34.83	50.2	27.39	1.23284	76.76	38.53
46.3	25.32	1.21162	75.43	34.92	50.3	27.44	1.23340	76.79	38.63
46.4	25.38	1.21215	75.47	35.02	50.4	27.49	1.23395	76.83	38.72
46.5	25.43	1.21269	75.50	35.11	50.5	27.54	1.23450	76.86	38.81
46.6	25.48	1.21323	75.53	35.20	50.6	27.60	1.23506	76.90	38.91
46.7	25.54	1.21377	75.57	35.29	50.7	27.65	1.23561	76.93	39.00
46.8	25.59	1.21431	75.60	35.38	50.8	27.70	1.23616	76.97	39.09
46.9	25.64	1.21484	75.63	35.47	50.9	27.75	1.23672	77.00	39.19
47.0	25.70	1.21538	75.67	35.56	51.0	27.81	1.23727	77.03	39.29
47.1	25.75	1.21592	75.70	35.65	51.1	27.86	1.23782	77.07	39.38
47.2	25.80	1.21646	75.73	35.74	51.2	27.91	1.23838	77.10	39.47
47.3	25.86	1.21700	75.77	35.84	51.3	27.96	1.23894	77.13	39.57
47.4	25.91	1.21755	75.80	35.93	51.4	28.02	1.23949	77.17	39.67
47.5	25.96	1.21809	75.84	36.02	51.5	28.07	1.24005	77.21	39.76
47.6	26.01	1.21863	75.87	36.11	51.6	28.12	1.24060	77.24	39.86
47.7	26.07	1.21917	75.91	36.21	51.7	28.17	1.24116	77.28	39.95
48.7	26.12	1.21971	75.94	36.30	51.8	28.23	1.24172	77.31	40.05
47.9	26.17	1.22026	75.97	36.39	51.9	28.28	1.24228	77.35	40.14

TABLE 1—Continued

Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.	Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.
52.0	28.33	1.24284	77.38	40.24	56.0	30.42	1.26548	78.79	44.12
52.1	28.38	1.24339	77.42	40.34	56.1	30.47	1.26605	78.83	44.22
52.2	28.44	1.24395	77.45	40.43	56.2	30.52	1.26663	78.86	44.32
52.3	28.49	1.24451	77.49	40.53	56.3	30.57	1.26720	78.90	44.42
52.4	28.54	1.24507	77.52	40.62	56.4	30.63	1.26778	78.93	44.52
52.5	28.59	1.24563	77.56	40.72	56.5	30.68	1.26835	78.97	44.62
52.6	28.65	1.24619	77.59	40.81	56.6	30.73	1.26893	79.01	44.72
52.7	28.70	1.24675	77.63	40.91	56.7	30.78	1.26950	79.04	44.82
52.8	28.75	1.24731	77.66	41.00	56.8	30.83	1.27008	79.08	44.92
52.9	28.80	1.24788	77.70	41.10	56.9	30.89	1.27066	79.11	45.01
53.0	28.86	1.24844	77.73	41.20	57.0	30.94	1.27123	79.15	45.11
53.1	28.91	1.24900	77.77	41.29	57.1	30.99	1.27181	79.19	45.21
53.2	28.96	1.24956	77.80	41.39	57.2	31.04	1.27239	79.22	45.31
53.3	29.01	1.25013	77.84	41.49	57.3	31.09	1.27297	79.26	45.42
53.4	29.06	1.25069	77.87	41.58	57.4	31.15	1.27355	79.29	45.51
53.5	29.12	1.25126	77.91	41.68	57.5	31.20	1.27413	79.33	45.61
53.6	29.17	1.25182	77.94	41.78	57.6	31.25	1.27471	79.37	45.71
53.7	29.22	1.25238	77.98	41.87	57.7	31.30	1.27529	79.40	45.81
53.8	29.27	1.25295	78.01	41.97	57.8	31.35	1.27587	79.44	45.92
53.9	29.32	1.25351	78.05	42.07	57.9	31.40	1.27645	79.48	46.02
54.0	29.38	1.25408	78.08	42.16	58.0	31.46	1.27703	79.51	46.12
54.1	29.43	1.25465	78.12	42.26	58.1	31.51	1.27761	79.55	46.22
54.2	29.48	1.25521	78.15	42.36	58.2	31.56	1.27819	79.58	46.32
54.3	29.53	1.25578	78.19	42.46	58.3	31.61	1.27878	79.62	46.42
54.4	29.59	1.25635	78.22	42.55	58.4	31.66	1.27936	79.66	46.52
54.5	29.64	1.25692	78.26	42.65	58.5	31.71	1.27994	79.69	46.62
54.6	29.69	1.25748	78.29	42.75	58.6	31.76	1.28052	79.73	46.72
54.7	29.74	1.25805	78.33	42.85	58.7	31.82	1.28111	79.77	46.82
54.8	29.80	1.25862	78.36	42.94	58.8	31.87	1.28169	79.80	46.92
54.9	29.85	1.25919	78.40	43.04	58.9	31.92	1.28228	79.84	47.03
55.0	29.90	1.25976	78.44	43.14	59.0	31.97	1.28286	79.88	47.13
55.1	29.95	1.26033	78.47	43.24	59.1	32.02	1.28345	79.91	47.23
55.2	30.00	1.26090	78.51	43.34	59.2	32.07	1.28404	79.95	47.33
55.3	30.06	1.26147	78.54	43.43	59.3	32.13	1.28462	79.99	47.43
55.4	30.11	1.26204	78.58	43.53	59.4	32.18	1.28520	80.02	47.53
55.5	30.16	1.26261	78.61	43.63	59.5	32.23	1.28579	80.06	47.64
55.6	30.21	1.26319	78.65	43.73	59.6	32.28	1.28638	80.10	47.74
55.7	30.26	1.26376	78.69	43.83	59.7	32.33	1.28697	80.13	47.84
55.8	30.32	1.26433	78.72	43.93	59.8	32.38	1.28755	80.17	47.94
55.9	30.37	1.26490	78.76	44.03	59.9	32.43	1.28814	80.20	48.04

TABLE 1—Continued

Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.	Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.
60.0	32.49	1.28873	80.24	48.14	64.0	34.53	1.31260	81.73	52.31
60.1	32.54	1.28932	80.28	48.25	64.1	34.58	1.31320	81.77	52.41
60.2	32.59	1.28991	80.31	48.35	64.2	34.63	1.31381	81.80	52.52
60.3	32.64	1.29050	80.35	48.45	64.3	34.68	1.31441	81.84	52.62
60.4	32.69	1.29109	80.39	48.56	64.4	34.74	1.31502	81.88	52.73
60.5	32.74	1.29168	80.43	48.66	64.5	34.79	1.31563	81.92	52.84
60.6	32.79	1.29227	80.46	48.76	64.6	34.84	1.31623	81.96	52.94
60.7	32.85	1.29286	80.50	48.86	64.7	34.89	1.31684	81.99	53.05
60.8	32.90	1.29346	80.54	48.96	64.8	34.94	1.31745	82.03	53.16
60.9	32.95	1.29405	80.57	49.07	64.9	34.99	1.31806	82.07	53.26
61.0	33.00	1.29464	80.61	49.17	65.0	35.04	1.31866	82.11	53.37
61.1	33.05	1.29523	80.65	49.28	65.1	35.09	1.31927	82.14	53.47
61.2	33.10	1.29583	80.68	49.38	65.2	35.14	1.31988	82.18	53.58
61.3	33.15	1.29642	80.72	49.48	65.3	35.19	1.32049	82.22	53.69
61.4	33.20	1.29701	80.76	49.59	65.4	35.24	1.32110	82.26	53.80
61.5	33.26	1.29761	80.79	49.69	65.5	35.29	1.32171	82.30	53.91
61.6	33.31	1.29820	80.83	49.79	65.6	35.34	1.32232	82.33	54.01
61.7	33.36	1.29880	80.87	49.90	65.7	35.39	1.32293	82.37	54.12
61.8	33.41	1.29940	80.91	50.00	65.8	35.45	1.32354	82.41	54.23
61.9	33.46	1.29999	80.94	50.10	65.9	35.50	1.32415	82.45	54.33
62.0	33.51	1.30059	80.98	50.21	66.0	35.55	1.32476	82.49	54.44
62.1	33.56	1.30118	81.02	50.31	66.1	35.60	1.32538	82.53	54.55
62.2	33.61	1.30178	81.05	50.41	66.2	35.65	1.32599	82.56	54.65
62.3	33.67	1.30238	81.09	50.52	66.3	35.70	1.32660	82.60	54.76
62.4	33.72	1.30298	81.13	50.63	66.4	35.75	1.32722	82.64	54.87
62.5	33.77	1.30358	81.16	50.73	66.5	35.80	1.32783	82.68	54.98
62.6	33.82	1.30418	81.20	50.83	66.6	35.85	1.32844	82.72	55.09
62.7	33.87	1.30477	81.24	50.94	66.7	35.90	1.32906	82.75	55.19
62.8	33.92	1.30537	81.28	51.04	66.8	35.95	1.32967	82.79	55.30
62.9	33.97	1.30597	81.32	51.15	66.9	36.00	1.33029	82.83	55.41
63.0	34.02	1.30657	81.35	51.25	67.0	36.05	1.33090	82.87	55.52
63.1	34.07	1.30718	81.39	51.36	67.1	36.10	1.33152	82.91	55.63
63.2	34.12	1.30778	81.43	51.46	67.2	36.15	1.33214	82.95	55.74
63.3	34.18	1.30838	81.47	51.57	67.3	36.20	1.33275	82.98	55.85
63.4	34.23	1.30898	81.50	51.67	67.4	36.25	1.33337	83.02	55.96
63.5	34.28	1.30958	81.54	51.78	67.5	36.30	1.33399	83.06	56.07
63.6	34.33	1.31019	81.58	51.88	67.6	36.35	1.33460	83.10	56.18
63.7	34.38	1.31079	81.62	51.99	67.7	36.40	1.33523	83.14	56.29
63.8	34.43	1.31139	81.65	52.09	67.8	36.45	1.33584	83.18	56.40
63.9	34.48	1.31200	81.69	52.20	67.9	36.50	1.33646	83.22	56.51

TABLE 1—Continued

Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.	Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.
68.0	36.55	1.33708	83.25	56.61	72.0	38.55	1.36218	84.82	61.07
68.1	36.61	1.33770	83.29	56.72	72.1	38.60	1.36282	84.85	61.18
68.2	36.66	1.33832	83.33	56.83	72.2	38.65	1.36346	84.89	61.29
68.3	36.71	1.33894	83.37	56.94	72.3	38.70	1.36409	84.93	61.40
68.4	36.76	1.33957	83.41	57.05	72.4	38.75	1.36473	84.97	61.52
68.5	36.81	1.34019	83.45	57.16	72.5	38.80	1.36536	85.02	61.64
68.6	36.86	1.34081	83.49	57.27	72.6	38.85	1.36600	85.06	61.75
68.7	36.91	1.34143	83.52	57.38	72.7	38.90	1.36664	85.10	61.87
68.8	36.96	1.34205	83.56	57.49	72.8	38.95	1.36728	85.14	61.98
68.9	37.01	1.34268	83.60	57.60	72.9	39.00	1.36792	85.18	62.10
69.0	37.06	1.34330	83.64	57.71	73.0	39.05	1.36856	85.22	62.21
69.1	37.11	1.34392	83.68	57.82	73.1	39.10	1.36919	85.26	62.33
69.2	37.16	1.34455	83.72	57.93	73.2	39.15	1.36983	85.29	62.43
69.3	37.21	1.34517	83.76	58.05	73.3	39.20	1.37047	85.33	62.55
69.4	37.26	1.34580	83.80	58.16	73.4	39.25	1.37111	85.37	62.66
69.5	37.31	1.34642	83.84	58.27	73.5	39.30	1.37176	85.42	62.78
69.6	37.36	1.34705	83.88	58.38	73.6	39.35	1.37240	85.45	62.89
69.7	37.41	1.34768	83.91	58.49	73.7	39.39	1.37304	85.49	63.01
69.8	37.46	1.34830	83.95	58.60	73.8	39.44	1.37368	85.53	63.12
69.9	37.51	1.34893	83.99	58.71	73.9	39.49	1.37432	86.57	63.24
70.0	37.56	1.34956	84.03	58.82	74.0	39.54	1.37496	85.61	63.35
70.1	37.61	1.35019	84.07	58.93	74.1	39.59	1.37561	85.66	63.47
70.2	37.66	1.35081	84.11	59.05	74.2	39.64	1.37625	85.70	63.59
70.3	37.71	1.35144	84.15	59.16	74.3	39.69	1.37689	85.74	63.70
70.4	37.76	1.35207	84.19	59.27	74.4	39.74	1.37754	85.78	63.82
70.5	37.81	1.35270	84.23	59.38	74.5	39.79	1.37818	85.82	63.94
70.6	37.86	1.35333	84.26	59.49	74.6	39.84	1.37883	85.86	64.05
70.7	37.91	1.35396	84.30	59.60	74.7	39.89	1.37947	85.90	64.17
70.8	37.96	1.35459	84.34	59.71	74.8	39.94	1.38012	85.94	64.28
70.9	38.01	1.35522	84.38	59.83	74.9	39.99	1.38076	85.98	64.40
71.0	38.06	1.35585	84.42	59.94	75.0	40.03	1.38141	86.02	64.52
71.1	38.11	1.35648	84.46	60.05	75.1	40.08	1.38206	86.06	64.63
71.2	38.16	1.35711	84.50	60.16	75.2	40.13	1.38270	86.10	64.75
71.3	38.21	1.35775	84.54	60.28	75.3	40.18	1.38335	86.14	64.86
71.4	38.26	1.35838	84.58	60.39	75.4	40.23	1.38400	86.18	64.98
71.5	38.30	1.35901	84.62	60.50	75.5	40.28	1.38465	86.22	65.10
71.6	38.35	1.35964	84.66	60.62	75.6	40.33	1.38530	86.26	65.21
71.7	38.40	1.36028	84.70	60.73	75.7	40.38	1.38595	86.30	65.33
71.8	38.45	1.36091	84.74	60.84	75.8	40.43	1.38660	86.34	65.45
71.9	38.50	1.36155	84.78	60.96	75.9	40.48	1.38725	86.38	65.56

TABLE 1—Continued

Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.	Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.
76.0	40.53	1.38790	86.42	65.68	80.0	42.47	1.41421	88.06	70.45
76.1	40.57	1.38855	86.46	65.80	80.1	42.52	1.41488	88.10	70.57
76.2	40.62	1.38920	86.50	65.91	80.2	42.57	1.41554	88.14	70.69
76.3	40.67	1.38985	86.54	66.03	80.3	42.61	1.41621	88.19	70.82
76.4	40.72	1.39050	86.58	66.15	80.4	42.66	1.41688	88.23	70.94
76.5	40.77	1.39115	86.62	66.26	80.5	42.71	1.41754	88.27	71.06
76.6	40.82	1.39180	86.66	66.38	80.6	42.76	1.41821	88.31	71.18
76.7	40.87	1.39246	86.70	66.50	80.7	42.81	1.41888	88.35	71.30
76.8	40.92	1.39311	86.75	66.62	80.8	42.85	1.41955	88.39	71.42
76.9	40.97	1.39376	86.79	66.74	80.9	42.90	1.42022	88.43	71.54
77.0	41.01	1.39442	86.83	66.86	81.0	42.95	1.42088	88.48	71.67
77.1	41.06	1.39507	86.87	66.98	81.1	43.00	1.42155	88.52	71.79
77.2	41.11	1.39573	86.91	67.09	81.2	43.05	1.42222	88.56	71.91
77.3	41.16	1.39638	86.95	67.21	81.3	43.10	1.42289	88.60	72.03
77.4	41.21	1.39704	86.99	67.33	81.4	43.14	1.42356	88.64	72.15
77.5	41.26	1.39769	87.03	67.45	81.5	43.19	1.42423	88.68	72.27
77.6	41.31	1.39835	87.07	67.57	81.6	43.24	1.42490	88.73	72.40
77.7	41.36	1.39901	87.11	67.68	81.7	43.29	1.42558	88.77	72.53
77.8	41.40	1.39966	87.15	67.80	81.8	43.33	1.42625	88.81	72.65
77.9	41.45	1.40032	87.19	67.92	81.9	43.38	1.42692	88.85	72.77
78.0	41.50	1.40098	87.24	68.05	82.0	43.43	1.42759	88.89	72.89
78.1	41.55	1.40164	87.28	68.17	82.1	43.48	1.42827	88.94	73.02
78.2	41.60	1.40230	87.32	68.28	82.2	43.53	1.42894	88.98	73.14
78.3	41.65	1.40295	87.36	68.40	82.3	43.57	1.42961	89.02	73.26
78.4	41.70	1.40361	87.40	68.52	82.4	43.62	1.43029	89.06	73.39
78.5	41.74	1.40427	87.44	68.64	82.5	43.67	1.43096	89.10	73.51
78.6	41.79	1.40493	87.48	68.76	82.6	43.72	1.43164	89.15	73.64
78.7	41.84	1.40559	87.52	68.89	82.7	43.77	1.43231	89.19	73.76
78.8	41.89	1.40625	87.56	69.00	82.8	43.81	1.43298	89.23	73.88
78.9	41.94	1.40691	87.61	69.12	82.9	43.86	1.43366	89.27	74.00
79.0	41.99	1.40758	87.65	69.24	83.0	43.91	1.43434	89.31	74.13
79.1	42.03	1.40824	87.69	69.36	83.1	43.96	1.43502	89.36	74.26
79.2	42.08	1.40890	87.73	69.48	83.2	44.00	1.43569	89.40	74.38
79.3	42.13	1.40956	87.77	69.60	83.3	44.05	1.43637	89.44	74.50
79.4	42.18	1.41023	87.81	69.72	83.4	44.10	1.43705	89.48	74.63
79.5	42.23	1.41089	87.85	69.84	83.5	44.15	1.43773	89.53	74.76
79.6	42.28	1.41155	87.89	69.96	83.6	44.19	1.43841	89.57	74.88
79.7	42.32	1.41222	87.93	70.08	83.7	44.24	1.43908	89.61	75.00
79.8	42.37	1.41288	87.98	70.21	83.8	44.29	1.43976	89.65	75.13
79.9	42.42	1.41355	88.02	70.33	83.9	44.34	1.44044	89.69	75.25

TABLE 1—Continued

Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.	Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.
84.0	44.38	1.44112	89.74	75.38	88.0	46.27	1.46862	91.45	80.48
84.1	44.43	1.44180	89.78	75.50	88.1	46.31	1.46932	91.49	80.60
84.2	44.48	1.44249	89.82	75.63	88.2	46.36	1.47002	91.54	80.74
84.3	44.53	1.44317	89.86	75.75	88.3	46.41	1.47071	91.58	80.87
84.4	44.57	1.44385	89.91	75.88	88.4	46.45	1.47141	91.62	80.99
84.5	44.62	1.44453	89.95	76.01	88.5	46.50	1.47210	91.67	81.13
84.6	44.67	1.44521	89.99	76.13	88.6	46.55	1.47280	91.71	81.26
84.7	44.72	1.44590	90.04	76.26	88.7	46.59	1.47350	91.75	81.38
84.8	44.76	1.44658	90.08	76.39	88.8	46.64	1.47420	91.80	81.52
84.9	44.81	1.44726	90.12	76.51	88.9	46.69	1.47489	91.84	81.65
85.0	44.86	1.44794	90.16	76.64	89.0	46.73	1.47559	91.89	81.78
85.1	44.91	1.44863	90.21	76.77	89.1	46.78	1.47629	91.92	81.90
85.2	44.95	1.44931	90.25	76.89	89.2	46.83	1.47699	91.97	82.04
85.3	45.00	1.45000	90.29	77.02	89.3	46.87	1.47769	92.02	82.17
85.4	45.05	1.45068	90.33	77.14	89.4	46.92	1.47839	92.06	82.30
85.5	45.09	1.45137	90.38	77.27	89.5	46.97	1.47909	92.10	82.43
85.6	45.14	1.45205	90.42	77.40	89.6	47.01	1.47979	92.15	82.57
85.7	45.19	1.45274	90.46	77.52	89.7	47.06	1.48049	92.19	82.69
85.8	45.24	1.45343	90.50	77.65	89.8	47.11	1.48119	92.23	82.82
85.9	45.28	1.45411	90.55	77.78	89.9	47.15	1.48189	92.28	82.96
86.0	45.33	1.45480	90.59	77.91	90.0	47.20	1.48259	92.32	83.09
86.1	45.38	1.45549	90.63	78.03	90.1	47.24	1.48330	92.37	83.23
86.2	45.42	1.45618	90.68	78.17	90.2	47.29	1.48400	92.41	83.35
86.3	45.47	1.45686	90.72	78.29	90.3	47.34	1.48470	92.45	83.48
86.4	45.52	1.45755	90.76	78.42	90.4	47.38	1.48540	92.49	83.61
86.5	45.57	1.45824	90.80	78.54	90.5	47.43	1.48611	92.54	83.74
86.6	45.61	1.45893	90.85	78.68	90.6	47.48	1.48681	92.58	83.88
86.7	45.66	1.45962	90.89	78.80	90.7	47.52	1.48752	92.63	84.01
86.8	45.71	1.46031	90.93	78.93	90.8	47.57	1.48822	92.67	84.14
86.9	45.75	1.46100	90.97	79.05	90.9	47.61	1.48893	92.72	84.28
87.0	45.80	1.46170	91.02	79.19	91.0	47.66	1.48963	92.76	84.41
87.1	45.85	1.46239	91.06	79.31	91.1	47.71	1.49034	92.81	84.55
87.2	45.89	1.46308	91.11	79.45	91.2	47.75	1.49104	92.85	84.68
87.3	45.94	1.46377	91.15	79.57	91.3	47.80	1.49175	92.89	84.82
87.4	45.99	1.46446	91.19	79.70	91.4	47.84	1.49246	92.94	84.95
87.5	46.03	1.46516	91.24	79.84	91.5	47.89	1.49316	92.98	85.09
87.6	46.08	1.46585	91.28	79.96	91.6	47.94	1.49387	93.02	85.22
87.7	46.13	1.46654	91.32	80.09	91.7	47.98	1.49458	93.07	85.35
87.8	46.17	1.46724	91.36	80.21	91.8	48.03	1.49529	93.11	85.47
87.9	46.22	1.46793	91.41	80.35	91.9	48.08	1.49600	93.15	85.60

TABLE 1—Continued

Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.	Degrees Brix or % Sugar by Wt.	Degrees Baumé, Modulus 145	Specific Gravity at 20°/20°C	Pounds per Cubic Foot	Pounds Dry Sub. per Cu. Ft.
92.0	48.12	1.49671	93.20	85.74	96.0	49.94	1.52535	94.99	91.19
92.1	48.17	1.49741	93.24	85.87	96.1	49.98	1.52607	95.03	91.32
92.2	48.21	1.49812	93.29	86.01	96.2	50.03	1.52680	95.08	91.46
92.3	48.26	1.49883	93.33	86.14	96.3	50.08	1.52752	95.12	91.60
92.4	48.30	1.49954	93.37	86.27	96.4	50.12	1.52824	95.17	91.74
92.5	48.35	1.50026	93.42	86.41	96.5	50.16	1.52897	95.21	91.88
92.6	48.40	1.50097	93.47	86.55	96.6	50.21	1.52969	95.26	92.02
92.7	48.44	1.50168	93.51	86.68	96.7	50.25	1.53042	95.30	92.16
92.8	48.49	1.50239	93.55	86.82	96.8	50.30	1.53114	95.35	92.30
92.9	48.53	1.50310	93.60	86.95	96.9	50.34	1.53187	95.39	92.43
93.0	48.58	1.50381	93.64	87.09	97.0	50.39	1.53260	95.44	92.57
93.1	48.62	1.50453	93.69	87.23	97.1	50.43	1.53332	95.48	92.71
93.2	48.67	1.50524	93.73	87.36	97.2	50.48	1.53405	95.53	92.86
93.3	48.72	1.50595	93.77	87.49	97.3	50.52	1.53478	95.57	93.00
93.4	48.76	1.50667	93.82	87.63	97.4	50.57	1.53551	95.62	93.13
93.5	48.81	1.50738	93.87	87.77	97.5	50.61	1.53623	95.66	93.27
93.6	48.85	1.50810	93.91	87.90	97.6	50.66	1.53696	95.71	93.41
93.7	48.90	1.50881	93.96	88.04	97.7	50.70	1.53769	95.75	93.55
93.8	48.94	1.50952	94.00	88.17	97.8	50.75	1.53842	95.80	93.69
93.9	48.99	1.51024	94.04	88.30	97.9	50.79	1.53915	95.85	93.83
94.0	49.03	1.51096	94.09	88.44	98.0	50.84	1.53988	95.89	93.97
94.1	49.08	1.51167	94.13	88.58	98.1	50.88	1.54061	95.94	94.12
94.2	49.12	1.51239	94.18	88.72	98.2	50.93	1.54134	95.98	94.26
94.3	49.17	1.51311	94.22	88.85	98.3	50.97	1.54207	96.03	94.40
94.4	49.22	1.51382	94.27	88.99	98.4	51.02	1.54280	96.08	94.54
94.5	49.26	1.51454	94.31	89.12	98.5	51.06	1.54353	96.12	94.68
94.6	49.31	1.51526	94.36	89.26	98.6	51.10	1.54426	96.17	94.82
94.7	49.35	1.51598	94.40	89.40	98.7	51.15	1.54499	96.22	94.97
94.8	49.40	1.51670	95.45	89.53	98.8	51.19	1.54573	96.26	95.11
94.9	49.44	1.51742	94.49	89.67	98.9	51.24	1.54646	96.30	95.25
95.0	49.49	1.51814	94.54	89.81	99.0	51.28	1.54719	96.35	95.39
95.1	49.53	1.51886	94.58	89.95	99.1	51.33	1.54793	96.40	95.53
95.2	49.58	1.51958	94.63	90.09	99.2	51.37	1.54866	96.44	95.67
95.3	49.62	1.52030	94.67	90.22	99.3	51.42	1.54939	96.48	95.81
95.4	49.67	1.52102	94.72	90.36	99.4	51.46	1.55013	96.53	95.95
95.5	49.71	1.52174	94.76	90.50	99.5	51.50	1.55087	96.58	96.10
95.6	49.76	1.52246	94.81	90.64	99.6	51.55	1.55160	96.62	96.24
95.7	49.80	1.52318	94.85	90.77	99.7	51.59	1.55234	96.66	96.38
95.8	49.85	1.52390	94.90	90.91	99.8	51.64	1.55307	96.71	96.52
95.9	49.90	1.52463	94.94	91.04	99.9	51.68	1.55381	96.76	96.66
					100.0	51.73	1.55454	96.80	96.80

TABLE 2

FACTORS FOR CALCULATION OF APPARENT PURITY

One-tenth Dilution Method

DEGR. BRIX	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	DEGR. BRIX
0	00.00	286.7	143.3	95.49	71.59	57.25	47.69	40.86	35.74	31.76	0
1	28.57	25.96	23.79	21.95	20.37	19.01	17.81	16.76	15.82	14.98	1
2	14.23	13.55	12.93	12.36	11.84	11.36	10.92	10.51	10.13	9.779	2
3	9.449	9.141	8.852	8.580	8.324	8.084	7.856	7.641	7.437	7.243	3
4	7.059	6.884	6.718	6.559	6.407	6.263	6.124	5.991	5.864	5.742	4
5	5.625	5.513	5.405	5.301	5.200	5.104	5.011	4.921	4.834	4.751	5
6	4.669	4.591	4.515	4.442	4.370	4.302	4.235	4.170	4.107	4.046	6
7	3.987	3.929	3.873	3.818	3.765	3.713	3.663	3.614	3.566	3.520	7
8	3.475	3.430	3.387	3.345	3.304	3.264	3.224	3.186	3.149	3.112	8
9	3.076	3.041	3.007	2.973	2.941	2.909	2.877	2.846	2.816	2.787	9
10	2.758	2.729	2.701	2.674	2.647	2.621	2.595	2.570	2.545	2.521	10
11	2.497	2.473	2.450	2.428	2.406	2.384	2.362	2.341	2.320	2.300	11
12	2.280	2.260	2.241	2.221	2.203	2.184	2.166	2.148	2.130	2.113	12
13	2.096	2.079	2.063	2.046	2.030	2.014	1.999	1.983	1.968	1.953	13
14	1.938	1.924	1.910	1.895	1.882	1.868	1.854	1.841	1.828	1.815	14
15	1.802	1.789	1.777	1.764	1.752	1.740	1.728	1.717	1.705	1.694	15
16	1.682	1.671	1.660	1.649	1.639	1.628	1.618	1.607	1.597	1.587	16
17	1.577	1.567	1.557	1.548	1.538	1.529	1.520	1.510	1.501	1.492	17
18	1.483	1.475	1.466	1.457	1.449	1.440	1.432	1.424	1.416	1.408	18
19	1.400	1.392	1.384	1.376	1.368	1.361	1.353	1.346	1.339	1.331	19
20	1.324	1.317	1.310	1.303	1.296	1.289	1.282	1.276	1.269	1.262	20
21	1.256	1.249	1.243	1.237	1.230	1.224	1.218	1.212	1.206	1.200	21
22	1.194	1.188	1.182	1.176	1.171	1.165	1.159	1.154	1.148	1.143	22
23	1.137	1.132	1.127	1.121	1.116	1.111	1.106	1.100	1.095	1.090	23
24	1.085	1.080	1.076	1.071	1.066	1.061	1.056	1.052	1.047	1.042	24
25	1.038	1.033	1.029	1.024	1.020	1.015	1.011	1.006	1.002	.998	25
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	

Derivation

Let D = true sp. gr. of solution at $\frac{20°}{20°}$ (as in Table 1)

D′ = apparent sp. gr. of solution at $\frac{20°}{20°}$ (ratio of weights in air)

B = degrees Brix of solution

Then $D' = D + .001\,(D - 1)$

$$\text{“Factor”} = \frac{26 \times 100 \times 1.1}{99.72\ BD'} = \frac{28.680}{BD'}$$

TABLE 3

TEMPERATURE CORRECTIONS FOR BRIX HYDROMETERS STANDARD TEMPERATURE 20° C

From Bureau of Standards, Circ. 44, table 11, based on the determinations of Plato. 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.

TEMP. °C.	DEGREES BRIX											TEMP. °C.
	0	5	10	15	20	25	30	40	50	60	70	
	SUBTRACT FROM THE OBSERVED READING											
0	.30	.49	.65	.77	.89	.99	1.08	1.24	1.37	1.44	1.49	0
5	.36	.47	.56	.65	.73	.80	.86	.97	1.05	1.10	1.14	5
10	.32	.38	.43	.48	.52	.57	.60	.67	.72	.75	.77	10
11	.31	.35	.40	.44	.48	.51	.55	.60	.65	.68	.70	11
12	.29	.32	.36	.40	.43	.46	.50	.54	.58	.60	.62	12
13	.26	.29	.32	.35	.38	.41	.44	.48	.51	.53	.55	13
14	.24	.26	.29	.31	.34	.36	.38	.41	.44	.46	.47	14
15	.20	.22	.24	.26	.28	.30	.32	.34	.36	.38	.39	15
16	.17	.18	.20	.22	.23	.25	.26	.28	.29	.31	.32	16
17	.13	.14	.15	.16	.18	.19	.20	.21	.22	.23	.24	17
17.5	.11	.12	.12	.14	.15	.16	.16	.17	.18	.19	.20	17.5
18	.09	.10	.10	.11	.12	.13	.13	.14	.15	.15	.16	18
19	.05	.05	.05	.06	.06	.06	.07	.07	.08	.08	.08	19
	ADD TO THE OBSERVED READING											
21	.04	.05	.06	.06	.06	.07	.07	.07	.08	.08	.09	21
22	.10	.10	.11	.12	.12	.13	.14	.15	.16	.16	.16	22
23	.16	.16	.17	.17	.19	.20	.21	.22	.24	.24	.24	23
24	.21	.22	.23	.24	.26	.27	.28	.30	.32	.32	.32	24
25	.27	.28	.30	.31	.32	.34	.35	.38	.39	.40	.39	25
26	.33	.34	.36	.37	.40	.40	.42	.46	.47	.48	.48	26
27	.40	.41	.42	.44	.46	.48	.50	.54	.55	.56	.56	27
28	.46	.47	.49	.51	.54	.56	.58	.61	.63	.64	.64	28
29	.54	.55	.56	.59	.61	.62	.65	.70	.71	.72	.72	29
30	.61	.62	.63	.66	.68	.71	.73	.78	.79	.80	.81	30
35	.99	1.01	1.02	1.06	1.10	1.13	1.16	1.20	1.22	1.23	1.22	35
40	1.42	1.45	1.47	1.51	1.54	1.57	1.60	1.64	1.65	1.66	1.65	40
45	1.91	1.94	1.96	2.00	2.03	2.05	2.07	2.10	2.10	2.10	2.08	45
50	2.46	2.48	2.50	2.53	2.56	2.57	2.58	2.59	2.58	2.56	2.52	50
55	3.05	3.07	3.09	3.12	3.12	3.12	3.12	3.10	3.07	3.03	2.97	55
60	3.69	3.72	3.73	3.73	3.72	3.70	3.67	3.62	3.57	3.50	3.43	60
65	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.2	4.1	4.0	3.9	65
70	5.1	5.1	5.1	5.0	5.0	5.0	4.9	4.8	4.7	4.6	4.4	70
75	6.1	6.0	6.0	5.9	5.8	5.8	5.7	5.5	5.4	5.2	5.0	75
80	7.1	7.0	7.0	6.9	6.8	6.7	6.6	6.3	6.1	5.9	5.6	80
	0	5	10	15	20	25	30	40	50	60	70	

TABLE 3-A

TEMPERATURE CORRECTIONS FOR BRIX HYDROMETERS STANDARD TEMPERATURE 20° C.

(Condensed Table)

This table covers only the temperature range permissible in laboratory control work and is figured to the nearest .05° Brix.

TEMP. °C.	DEGREES BRIX											TEMP. °C.
	0	5	10	15	20	25	30	40	50	60	70	
	SUBTRACT FROM THE OBSERVED READING											
15	.2	.2	.25	.25	.3	.3	.3	.35	.35	.4	.4	15
16	.15	.2	.2	.2	.25	.25	.25	.3	.3	.3	.3	16
17	.15	.15	.15	.15	.2	.2	.2	.2	.2	.25	.25	17
18	.1	.1	.1	.1	.1	.15	.15	.15	.15	.15	.15	18
19	.05	.05	.05	.05	.05	.05	.05	.05	.1	.1	.1	19
	ADD TO THE OBSERVED READING											
21	.05	.05	.05	.05	.05	.05	.05	.05	.1	.1	.1	21
22	.1	.1	.1	.1	.1	.15	.15	.15	.15	.15	.15	22
23	.15	.15	.15	.15	.2	.2	.2	.2	.25	.25	.25	23
24	.2	.2	.25	.25	.25	.25	.3	.3	.3	.3	.3	24
25	.25	.3	.3	.3	.3	.35	.35	.4	.4	.4	.4	25
	0	5	10	15	20	25	30	40	50	60	70	

TABLE 4

TEMPERATURE CORRECTIONS FOR THE ABBÉ SUGAR REFRACTOMETER STANDARD TEMPERATURE 20° C.

From Stanek's temperature correction table.

TEMP. °C.	REFRACTOMETER READING										TEMP. °C.
	5	10	15	20	30	40	50	60	70	75	
	SUBTRACT FROM THE OBSERVED READING										
15	.25	.27	.31	.31	.34	.35	.36	.37	.36	.36	15
16	.21	.23	.26	.27	.29	.31	.31	.32	.31	.29	16
17	.16	.18	.20	.20	.22	.23	.23	.23	.20	.17	17
18	.11	.12	.14	.14	.15	.16	.16	.15	.12	.09	18
19	.06	.07	.08	.08	.08	.09	.09	.08	.07	.05	19
	ADD TO THE OBSERVED READING										
21	.06	.07	.07	.07	.07	.07	.07	.07	.07	.07	21
22	.12	.14	.14	.14	.14	.14	.15	.14	.14	.14	22
23	.18	.20	.20	.21	.21	.21	.23	.21	.22	.22	23
24	.24	.26	.26	.27	.28	.28	.30	.28	.29	.29	24
25	.30	.32	.32	.34	.36	.36	.38	.36	.36	.37	25
	5	10	15	20	30	40	50	60	70	75	

TABLE 5

APPROXIMATE AMOUNTS OF BASIC LEAD ACETATE SOLUTION (55° BRIX) FOR VARIOUS PRODUCTS

In clarifying sugar factory juices, etc., with basic lead acetate, it is important to add a sufficient amount but at the same time to avoid the influence which a large excess of the reagent has on the polarization. This table is intended as a general guide for the amounts of the standard basic lead acetate solution of 55° Brix to be used in clarifying the various products analyzed. The figures should be regarded as only approximate, since variations in the density or composition of the juices may require the use of different amounts of lead acetate, but they will hold for the most part under ordinary working conditions.

KIND OF MATERIAL	AMT. OF MATERIAL	ml OF LEAD ACETATE
Cossettes (sugar detn.)	26 g	6
Cossette Juice (purity detn.)	100 ml	*10
Diffusion Juice	100 ml	8–10
Pulp	100 ml	2–4
Pulp Water	100 ml	1–2
Lime Cake, 1st	54 g	†3 (exactly)
Lime Cake, 2d	54 g	†3 (exactly)
Lime Sewer	54 g	†3 (exactly)
Lime Sewer	100 ml	1–3
Excess Water	100 ml	1–3
Sweet Water	100 ml	2–4
Filter Cloth Wash Water	100 ml	3 (or more)
Main Sewer	100 ml	3
Thin Juice	100 ml	2
Thick Juice	100 ml at 23° Brix	3
White Massecuite	100 ml at 23° Brix	3
High Wash Syrup	100 ml at 23° Brix	3
High Green Syrup	100 ml at 23° Brix	5
Remelt Massecuite	100 ml at 23° Brix	6
Remelt Sugar	100 ml at 23° Brix	1–2
Sugar Melter	100 ml at 23° Brix	2
Low Wash Syrup	100 ml at 23° Brix	8–10
Low Green Syrup (Molasses)	13 g, or 100 ml at 23° Brix	10
Solution for Cooler	50 ml	3–6
Steffen Waste & Wash Waters	50 ml	2–4
Saccharate Milk and Cake (carbonated)	100 ml at 23° Brix	3–5
Saccharate Cake (sugar detn.)	13 g	3–5
Dried Pulp	12.6 g	12–15

*Use a stronger lead solution if 10 ml of the regular solution is insufficient.

†No lead acetate is added if the zinc nitrate method is used.

TABLE 6

POLARIZATION TABLE—200mm TUBE, 1/10 DILUTION
For Pulp and Pulp Water

POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml
.0	.00	1.0	.29	2.0	.57	3.0	.86	4.0	1.14
.1	.03	1.1	.31	2.1	.60	3.1	.89	4.1	1.17
.2	.06	1.2	.34	2.2	.63	3.2	.92	4.2	1.20
.3	.09	1.3	.37	2.3	.66	3.3	.94	4.3	1.23
.4	.11	1.4	.40	2.4	.69	3.4	.97	4.4	1.26
.5	.14	1.5	.43	2.5	.72	3.5	1.00	4.5	1.29
.6	.17	1.6	.46	2.6	.74	3.6	1.03	4.6	1.32
.7	.20	1.7	.49	2.7	.77	3.7	1.06	4.7	1.34
.8	.23	1.8	.51	2.8	.80	3.8	1.09	4.8	1.37
.9	.26	1.9	.54	2.9	.83	3.9	1.12	4.9	1.40

Formula:—Grams Sugar in 100 ml = Pol. Reading × .286

TABLE 7

POLARIZATION TABLE—400mm TUBE, 1/10 DILUTION
For Sewer Water

POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml
.0	.00	2.0	.29	4.0	.57	6.0	.86	8.0	1.14
.1	.01	2.1	.30	4.1	.59	6.1	.87	8.1	1.16
.2	.03	2.2	.31	4.2	.60	6.2	.89	8.2	1.17
.3	.04	2.3	.33	4.3	.61	6.3	.90	8.3	1.19
.4	.06	2.4	.34	4.4	.63	6.4	.92	8.4	1.20
.5	.07	2.5	.36	4.5	.64	6.5	.93	8.5	1.22
.6	.09	2.6	.37	4.6	.66	6.6	.94	8.6	1.23
.7	.10	2.7	.39	4.7	.67	6.7	.96	8.7	1.24
.8	.11	2.8	.40	4.8	.69	6.8	.97	8.8	1.26
.9	.13	2.9	.41	4.9	.70	6.9	.99	8.9	1.27
1.0	.14	3.0	.43	5.0	.72	7.0	1.00	9.0	1.29
1.1	.16	3.1	.44	5.1	.73	7.1	1.02	9.1	1.30
1.2	.17	3.2	.46	5.2	.74	7.2	1.03	9.2	1.32
1.3	.19	3.3	.47	5.3	.76	7.3	1.04	9.3	1.33
1.4	.20	3.4	.49	5.4	.77	7.4	1.06	9.4	1.34
1.5	.21	3.5	.50	5.5	.79	7.5	1.07	9.5	1.36
1.6	.23	3.6	.51	5.6	.80	7.6	1.09	9.6	1.37
1.7	.24	3.7	.53	5.7	.82	7.7	1.10	9.7	1.39
1.8	.26	3.8	.54	5.8	.83	7.8	1.12	9.8	1.40
1.9	.27	3.9	.56	5.9	.84	7.9	1.13	9.9	1.42

Formula:—Grams Sugar in 100 ml = Polariscope Reading × .143

TABLE 8

POLARIZATION TABLE—400mm TUBE, READ DIRECT
For Condensed Waters

POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml
.0	.00	2.0	.26	4.0	.52	6.0	.78	8.0	1.04
.1	.01	2.1	.27	4.1	.53	6.1	.79	8.1	1.05
.2	.03	2.2	.29	4.2	.55	6.2	.81	8.2	1.07
.3	.04	2.3	.30	4.3	.56	6.3	.82	8.3	1.08
.4	.05	2.4	.31	4.4	.57	6.4	.83	8.4	1.09
.5	.07	2.5	.33	4.5	.59	6.5	.85	8.5	1.11
.6	.08	2.6	.34	4.6	.60	6.6	.86	8.6	1.12
.7	.09	2.7	.35	4.7	.61	6.7	.87	8.7	1.13
.8	.10	2.8	.36	4.8	.62	6.8	.88	8.8	1.14
.9	.12	2.9	.38	4.9	.64	6.9	.90	8.9	1.16
1.0	.13	3.0	.39	5.0	.65	7.0	.91	9.0	1.17
1.1	.14	3.1	.40	5.1	.66	7.1	.92	9.1	1.18
1.2	.16	3.2	.42	5.2	.68	7.2	.94	9.2	1.20
1.3	.17	3.3	.43	5.3	.69	7.3	.95	9.3	1.21
1.4	.18	3.4	.44	5.4	.70	7.4	.96	9.4	1.22
1.5	.20	3.5	.46	5.5	.72	7.5	.98	9.5	1.24
1.6	.21	3.6	.47	5.6	.73	7.6	.99	9.6	1.25
1.7	.22	3.7	.48	5.7	.74	7.7	1.00	9.7	1.26
1.8	.23	3.8	.49	5.8	.75	7.8	1.01	9.8	1.27
1.9	.25	3.9	.51	5.9	.77	7.9	1.03	9.9	1.29

Formula:—Grams Sugar in 100 ml = Polariscope Reading × .13

TABLE 9

STEFFEN POLARIZATION TABLE

POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml	POL. READING	GRAMS SUGAR IN 100 ml
.0	.00	3.5	1.82	7.0	3.64	10.5	5.46	14.0	7.28
.1	.05	3.6	1.87	7.1	3.69	10.6	5.51	14.1	7.33
.2	.10	3.7	1.92	7.2	3.74	10.7	5.56	14.2	7.38
.3	.16	3.8	1.98	7.3	3.80	10.8	5.62	14.3	7.44
.4	.21	3.9	2.03	7.4	3.85	10.9	5.67	14.4	7.49
.5	.26	4.0	2.08	7.5	3.90	11.0	5.72	14.5	7.54
.6	.31	4.1	2.13	7.6	3.95	11.1	5.77	14.6	7.59
.7	.36	4.2	2.18	7.7	4.00	11.2	5.82	14.7	7.64
.8	.42	4.3	2.24	7.8	4.06	11.3	5.88	14.8	7.70
.9	.47	4.4	2.29	7.9	4.11	11.4	5.93	14.9	7.75
1.0	.52	4.5	2.34	8.0	4.16	11.5	5.98	15.0	7.80
1.1	.57	4.6	2.39	8.1	4.21	11.6	6.03	15.1	7.85
1.2	.62	4.7	2.44	8.2	4.26	11.7	6.08	15.2	7.90
1.3	.68	4.8	2.50	8.3	4.32	11.8	6.14	15.3	7.96
1.4	.73	4.9	2.55	8.4	4.37	11.9	6.19	15.4	8.01
1.5	.78	5.0	2.60	8.5	4.42	12.0	6.24	15.5	8.06
1.6	.83	5.1	2.65	8.6	4.47	12.1	6.29	15.6	8.11
1.7	.88	5.2	2.70	8.7	4.52	12.2	6.34	15.7	8.16
1.8	.94	5.3	2.76	8.8	4.58	12.3	6.40	15.8	8.22
1.9	.99	5.4	2.81	8.9	4.63	12.4	6.45	15.9	8.27
2.0	1.04	5.5	2.86	9.0	4.68	12.5	6.50	16.0	8.32
2.1	1.09	5.6	2.91	9.1	4.73	12.6	6.55	16.1	8.37
2.2	1.14	5.7	2.96	9.2	4.78	12.7	6.60	16.2	8.42
2.3	1.20	5.8	3.02	9.3	4.84	12.8	6.66	16.3	8.48
2.4	1.25	5.9	3.07	9.4	4.89	12.9	6.71	16.4	8.53
2.5	1.30	6.0	3.12	9.5	4.94	13.0	6.76	16.5	8.58
2.6	1.35	6.1	3.17	9.6	4.99	13.1	6.81	16.6	8.63
2.7	1.40	6.2	3.22	9.7	5.04	13.2	6.86	16.7	8.68
2.8	1.46	6.3	3.28	9.8	5.10	13.3	6.92	16.8	8.74
2.9	1.51	6.4	3.33	9.9	5.15	13.4	6.97	16.9	8.79
3.0	1.56	6.5	3.38	10.0	5.20	13.5	7.02	17.0	8.84
3.1	1.61	6.6	3.43	10.1	5.25	13.6	7.07	17.1	8.89
3.2	1.66	6.7	3.48	10.2	5.30	13.7	7.12	17.2	8.94
3.3	1.72	6.8	3.54	10.3	5.36	13.8	7.18	17.3	9.00
3.4	1.77	6.9	3.59	10.4	5.41	13.9	7.23	17.4	9.05

Formula:—Grams Sugar in 100 ml = Polariscope Reading × .52

TABLE 10

INVERT SUGAR IN THICK JUICES, SYRUPS, AND SOLID PRODUCTS

This table shows the weight of material to be used for the determination of invert sugar according to the method described in Chapter I, 6 (a).

Brix or Dry Sub.	Grams	Brix or Dry Sub.	Grams	Brix or Dry Sub.	Grams	Brix or Dry Sub.	Grams
40.0	110.0	55.0	80.0	70.0	62.9	85.0	51.8
.5	108.6	.5	79.3	.5	62.4	.5	51.5
41.0	107.3	56.0	78.6	71.0	62.0	86.0	51.2
.5	106.0	.5	77.9	.5	61.5	.5	50.9
42.0	104.8	57.0	77.2	72.0	61.1	87.0	50.6
.5	103.5	.5	76.5	.5	60.7	.5	50.3
43.0	102.3	58.0	75.9	73.0	60.3	88.0	50.0
.5	101.1	.5	75.2	.5	59.9	.5	49.7
44.0	100.0	59.0	74.6	74.0	59.5	89.0	49.4
.5	98.9	.5	73.9	.5	59.1	.5	49.2
45.0	97.8	60.0	73.3	75.0	58.7	90.0	48.9
.5	96.7	.5	72.7	.5	58.3	.5	48.6
46.0	95.7	61.0	72.1	76.0	57.9	91.0	48.4
.5	94.6	.5	71.5	.5	57.5	.5	48.1
47.0	93.6	62.0	71.0	77.0	57.1	92.0	47.8
.5	92.6	.5	70.4	.5	56.8	.5	47.6
48.0	91.7	63.0	69.8	78.0	56.4	93.0	47.3
.5	90.7	.5	69.3	.5	56.1	.5	47.1
49.0	89.8	64.0	68.7	79.0	55.7	94.0	46.8
.5	88.9	.5	68.2	.5	55.3	.5	46.6
50.0	88.0	65.0	67.7	80.0	55.0	95.0	46.3
.5	87.1	.5	67.2	.5	54.6	.5	46.1
51.0	86.3	66.0	66.7	81.0	54.3	96.0	45.8
.5	85.4	.5	66.2	.5	54.0	.5	45.6
52.0	84.6	67.0	65.7	82.0	53.7	97.0	45.4
.5	83.8	.5	65.2	.5	53.3	.5	45.1
53.0	83.0	68.0	64.7	83.0	53.0	98.0	44.9
.5	82.3	.5	64.2	.5	52.7	.5	44.7
54.0	81.5	69.0	63.8	84.0	52.4	99.0	44.4
.5	80.7	.5	63.3	.5	52.1	.5	44.2

FORMULA:—$\text{“Grams”} = \frac{4400}{\text{Brix}}$

TABLE 11

INVERT SUGAR IN THIN JUICES

This table shows the weight of material to be used for the determination of invert sugar according to the method described in Chapter I, 6 (b).

Brix or Dry Sub.	Grams	Brix or Dry Sub.	Grams	Brix or Dry Sub.	Grams	Brix or Dry Sub.	Grams
12.0	183.3	15.0	146.7	18.0	122.2	21.0	104.8
.1	181.8	.1	145.7	.1	121.5	.1	104.3
.2	180.3	.2	144.7	.2	120.9	.2	103.8
.3	178.9	.3	143.8	.3	120.2	.3	103.3
.4	177.4	.4	142.9	.4	119.6	.4	102.8
12.5	176.0	15.5	141.9	18.5	118.9	21.5	102.3
.6	174.6	.6	141.0	.6	118.3	.6	101.9
.7	173.2	.7	140.1	.7	117.6	.7	101.4
.8	171.9	.8	139.2	.8	117.0	.8	100.9
.9	170.5	.9	138.4	.9	116.4	.9	100.5
13.0	169.2	16.0	137.5	19.0	115.8	22.0	100.0
.1	167.9	.1	136.6	.1	115.2	.1	99.5
.2	166.7	.2	135.8	.2	114.6	.2	99.1
.3	165.4	.3	134.9	.3	114.0	.3	98.7
.4	164.2	.4	134.1	.4	113.4	.4	98.2
13.5	163.0	16.5	133.3	19.5	112.8	22.5	97.8
.6	161.8	.6	132.5	.6	112.2	.6	97.3
.7	160.6	.7	131.7	.7	111.7	.7	96.9
.8	159.4	.8	131.0	.8	111.1	.8	96.5
.9	158.3	.9	130.2	.9	110.6	.9	96.1
14.0	157.1	17.0	129.4	20.0	110.0	23.0	95.7
.1	156.0	.1	128.7	.1	109.5	.1	95.2
.2	154.9	.2	127.9	.2	108.9	.2	94.8
.3	153.8	.3	127.2	.3	108.4	.3	94.4
.4	152.8	.4	126.4	.4	107.8	.4	94.0
14.5	151.7	17.5	125.7	20.5	107.3	23.5	93.6
.6	150.7	.6	125.0	.6	106.8	.6	93.2
.7	149.7	.7	124.3	.7	106.3	.7	92.8
.8	148.6	.8	123.6	.8	105.8	.8	92.4
.9	147.7	.9	122.9	.9	105.3	.9	91.9

$$\text{FORMULA:—“Grams”} = \frac{2200}{\text{Brix}}$$

TABLE 12

CUPRIC OXIDE TABLE FOR OBTAINING THE PERCENTAGE OF INVERT SUGAR

(10 Grams of Material)

Calculated from Herzfeld's Table

CuO mg	Invert Sugar %	CuO mg	Invert Sugar %	CuO mg	Invert Sugar %	CuO mg	Invert Sugar %
63	.05	150	.40	238	.79	319	1.16
69	.07	156	.43	244	.82	325	1.19
75	.09	163	.45	250	.85	331	1.21
81	.11	169	.48	256	.88	338	1.24
88	.14	175	.51	263	.90	344	1.27
94	.16	181	.53	269	.93	350	1.30
100	.19	188	.56	275	.96	356	1.33
106	.21	194	.59	281	.99	363	1.36
113	.24	200	.62	288	1.02	369	1.38
119	.27	206	.65	294	1.05	375	1.41
125	.30	213	.68	300	1.07	381	1.44
131	.32	219	.71	306	1.10	388	1.47
138	.35	225	.74	313	1.13	394	1.50
144	.38	231	.76				

TABLE 13

CUPRIC OXIDE TABLE FOR OBTAINING THE PERCENTAGE OF INVERT SUGAR

(5 Grams of Material)

Calculated from Baumann's Table

CuO mg	Invert Sugar %	CuO mg	Invert Sugar %	CuO mg	Invert Sugar %	CuO mg	Invert Sugar %
(44)	(.04)	138	.83	231	1.65	319	2.44
50	.09	144	.88	238	1.70	325	2.50
56	.14	150	.93	244	1.76	331	2.56
63	.19	156	.99	250	1.82	338	2.62
69	.25	163	1.04	256	1.87	344	2.68
75	.30	169	1.10	263	1.93	350	2.74
81	.35	175	1.15	269	1.98	356	2.79
88	.40	181	1.21	275	2.04	363	2.85
94	.45	188	1.26	281	2.10	369	2.91
100	.51	194	1.31	288	2.16	375	2.97
106	.56	200	1.37	294	2.21	381	3.03
113	.61	206	1.42	300	2.27	388	3.09
119	.66	213	1.48	306	2.33	394	3.15
125	.72	219	1.54	313	2.39	400	3.21
131	.77	225	1.59				

TABLE 14

CaO BY SOAP SOLUTION IN THIN JUICES

Calculated for the employment of 20 ml of thin juice, and soap solution of the strength, 1 ml = .001 g CaO.

An example will make clear the use of the table:—20 ml of thin juice of 11.8° Brix required 1.2 ml of soap solution. From the table, on the line opposite 11.8 in the Brix column, .041 + (.081 × .1) = .041 + .008 = .049, which is the "CaO to 100 Brix."

BRIX	NUMBER OF MILLILITERS OF SOAP SOLUTION										BRIX
	1	2	3	4	5	6	7	8	9	10	
8.0	.061	.121	.182	.243	.304	.364	.425	.486	.547	.607	8.0
.2	.059	.118	.178	.237	.296	.355	.415	.474	.533	.592	.2
.4	.058	.116	.173	.231	.289	.347	.404	.462	.520	.578	.4
.6	.056	.113	.169	.225	.282	.338	.395	.451	.507	.564	.6
.8	.055	.110	.165	.220	.275	.330	.385	.440	.495	.550	.8
9.0	.054	.108	.161	.215	.269	.323	.376	.430	.484	.538	9.0
.2	.053	.105	.158	.210	.263	.315	.368	.421	.473	.526	.2
.4	.051	.103	.154	.206	.257	.308	.360	.411	.463	.514	.4
.6	.050	.101	.151	.201	.251	.302	.352	.402	.453	.503	.6
.8	.049	.098	.148	.197	.246	.295	.345	.394	.443	.492	.8
10.0	.048	.096	.145	.193	.241	.289	.337	.386	.434	.482	10.0
.2	.047	.094	.142	.189	.236	.283	.331	.378	.425	.472	.2
.4	.046	.093	.139	.185	.231	.278	.324	.370	.417	.463	.4
.6	.045	.091	.136	.181	.227	.272	.318	.363	.408	.454	.6
.8	.044	.089	.133	.178	.222	.267	.311	.356	.400	.445	.8
11.0	.044	.087	.131	.175	.218	.262	.306	.349	.393	.437	11.0
.2	.043	.086	.129	.171	.214	.257	.300	.343	.386	.428	.2
.4	.042	.084	.126	.168	.210	.252	.294	.336	.378	.421	.4
.6	.041	.083	.124	.165	.206	.248	.289	.330	.372	.413	.6
.8	.041	.081	.122	.162	.203	.243	.284	.325	.365	.406	.8
12.0	.040	.080	.120	.159	.199	.239	.279	.319	.359	.399	12.0
.2	.039	.078	.118	.157	.196	.235	.274	.313	.353	.392	.2
.4	.039	.077	.116	.154	.193	.231	.270	.308	.347	.385	.4
.6	.038	.076	.114	.151	.189	.227	.265	.303	.341	.379	.6
.8	.037	.074	.112	.149	.186	.223	.261	.298	.335	.372	.8
13.0	.037	.073	.110	.147	.183	.220	.256	.293	.330	.366	13.0
.2	.036	.072	.108	.144	.180	.216	.252	.288	.325	.361	.2
.4	.035	.071	.106	.142	.177	.213	.248	.284	.319	.355	.4
.6	.035	.070	.105	.140	.175	.210	.245	.280	.314	.349	.6
.8	.034	.069	.103	.138	.172	.206	.241	.275	.310	.344	.8
14.0	.034	.068	.102	.136	.169	.203	.237	.271	.305	.339	14.0
.2	.033	.067	.100	.134	.167	.200	.234	.267	.300	.334	.2
.4	.033	.066	.099	.132	.164	.197	.230	.263	.296	.329	.4
.6	.032	.065	.097	.130	.162	.195	.227	.259	.292	.324	.6
.8	.032	.064	.096	.128	.160	.192	.224	.256	.288	.320	.8
	1	2	3	4	5	6	7	8	9	10	

TABLE 14—Continued

BRIX	NUMBER OF MILLILITERS OF SOAP SOLUTION										BRIX
	1	2	3	4	5	6	7	8	9	10	
15.0	.032	.063	.095	.126	.158	.189	.221	.252	.284	.315	15.0
.2	.031	.062	.093	.124	.155	.186	.217	.248	.280	.311	.2
.4	.031	.061	.092	.123	.153	.184	.214	.245	.276	.306	.4
.6	.030	.060	.091	.121	.151	.181	.212	.242	.272	.302	.6
.8	.030	.060	.089	.119	.149	.179	.209	.238	.268	.298	.8
16.0	.029	.059	.088	.118	.147	.176	.206	.235	.265	.294	16.0
.2	.029	.058	.087	.116	.145	.174	.203	.232	.261	.290	.2
.4	.029	.057	.086	.115	.143	.172	.201	.229	.258	.286	.4
.6	.028	.057	.085	.113	.141	.170	.198	.226	.255	.283	.6
.8	.028	.056	.084	.112	.140	.168	.195	.223	.251	.279	.8
17.0	.028	.055	.083	.110	.138	.165	.193	.221	.248	.276	17.0
.2	.027	.054	.082	.109	.136	.163	.191	.218	.245	.272	.2
.4	.027	.054	.081	.108	.134	.161	.188	.215	.242	.269	.4
.6	.027	.053	.080	.106	.133	.159	.186	.213	.239	.266	.6
.8	.026	.052	.079	.105	.131	.157	.184	.210	.236	.262	.8
18.0	.026	.052	.078	.104	.130	.156	.182	.207	.233	.259	18.0
.2	.026	.051	.077	.103	.128	.154	.179	.205	.231	.256	.2
.4	.025	.051	.076	.101	.127	.152	.177	.203	.228	.253	.4
.6	.025	.050	.075	.100	.125	.150	.175	.200	.225	.250	.6
.8	.025	.049	.074	.099	.124	.148	.173	.198	.223	.247	.8
19.0	.024	.049	.073	.098	.122	.147	.171	.196	.220	.245	19.0
.2	.024	.048	.073	.097	.121	.145	.169	.194	.218	.242	.2
.4	.024	.048	.072	.096	.120	.144	.167	.191	.215	.239	.4
.6	.024	.047	.071	.095	.118	.142	.166	.189	.213	.237	.6
.8	.023	.047	.070	.094	.117	.140	.164	.187	.211	.234	.8
	1	2	3	4	5	6	7	8	9	10	

Formula: $\text{“CaO to 100 Brix”} = \dfrac{\text{No. of ml of soap soln.}}{2 \times .9972 \times \text{Brix} \times D'}$

Where D' is the apparent sp. gr. at $\frac{20°}{20°}$ (ratio of weights in air).

TABLE 15

CaO BY SOAP SOLUTION IN THICK JUICE, MASSECUITE, MOLASSES, ETC.

Calculated for the employment of 10 ml of approximately 23° Brix material, and soap solution of the strength, 1 ml = .001 g CaO.

An example will make clear the use of the table:—10 ml of diluted molasses of 23.7° Brix required 8.4 ml of soap solution. From the table, on the line opposite 23.7 in the Brix column, .308 + (.154 × .1) = .308 + .015 = .323, which is the "CaO to 100 Brix."

BRIX	NUMBER OF MILLILITERS OF SOAP SOLUTION										BRIX
	1	2	3	4	5	6	7	8	9	10	
20.0	.046	.093	.139	.185	.231	.278	.324	.370	.417	.463	20.0
.1	.046	.092	.138	.184	.230	.276	.322	.368	.414	.461	.1
.2	.046	.092	.137	.183	.229	.275	.321	.366	.412	.458	.2
.3	.046	.091	.137	.182	.228	.273	.319	.364	.410	.456	.3
.4	.045	.091	.136	.181	.227	.272	.317	.363	.408	.453	.4
20.5	.045	.090	.135	.180	.225	.270	.316	.361	.406	.451	20.5
.6	.045	.090	.135	.179	.224	.269	.314	.359	.404	.448	.6
.7	.045	.089	.134	.178	.223	.268	.312	.357	.401	.446	.7
.8	.044	.089	.133	.177	.222	.266	.311	.355	.399	.444	.8
.9	.044	.088	.132	.177	.221	.265	.309	.353	.397	.441	.9
21.0	.044	.088	.132	.176	.220	.263	.307	.351	.395	.439	21.0
.1	.044	.087	.131	.175	.218	.262	.306	.349	.393	.437	.1
.2	.043	.087	.130	.174	.217	.261	.304	.348	.391	.435	.2
.3	.043	.086	.130	.173	.216	.259	.303	.346	.389	.432	.3
.4	.043	.086	.129	.172	.215	.258	.301	.344	.387	.430	.4
21.5	.043	.086	.128	.171	.214	.257	.300	.342	.385	.428	21.5
.6	.043	.085	.128	.170	.213	.256	.298	.341	.383	.426	.6
.7	.042	.085	.127	.169	.212	.254	.297	.339	.381	.424	.7
.8	.042	.084	.126	.169	.211	.253	.295	.337	.379	.422	.8
.9	.042	.084	.126	.168	.210	.252	.294	.336	.378	.420	.9
22.0	.042	.083	.125	.167	.209	.250	.292	.334	.376	.417	22.0
.1	.042	.083	.125	.166	.208	.249	.291	.332	.374	.415	.1
.2	.041	.083	.124	.165	.207	.248	.289	.331	.372	.413	.2
.3	.041	.082	.123	.165	.206	.247	.288	.329	.370	.411	.3
.4	.041	.082	.123	.164	.205	.246	.287	.327	.368	.409	.4
22.5	.041	.081	.122	.163	.204	.244	.285	.326	.367	.407	22.5
.6	.041	.081	.122	.162	.203	.243	.284	.324	.365	.405	.6
.7	.040	.081	.121	.161	.202	.242	.282	.323	.363	.403	.7
.8	.040	.080	.120	.161	.201	.241	.281	.321	.361	.401	.8
.9	.040	.080	.120	.160	.200	.240	.280	.320	.360	.400	.9
23.0	.040	.080	.119	.159	.199	.239	.278	.318	.358	.398	23.0
.1	.040	.079	.119	.158	.198	.237	.277	.317	.356	.396	.1
.2	.039	.079	.118	.158	.197	.236	.276	.315	.355	.394	.2
.3	.039	.078	.118	.157	.196	.235	.274	.314	.353	.392	.3
.4	.039	.078	.117	.156	.195	.234	.273	.312	.351	.390	.4
	1	2	3	4	5	6	7	8	9	10	

TABLE 15—Continued

BRIX	NUMBER OF MILLILITERS OF SOAP SOLUTION									BRIX
	1	2	3	4	5	6	7	8	9	10	
23.5	.039	.078	.117	.155	.194	.233	.272	.311	.350	.388	23.5
.6	.039	.077	.116	.155	.193	.232	.271	.309	.348	.387	.6
.7	.038	.077	.115	.154	.192	.231	.269	.308	.346	.385	.7
.8	.038	.077	.115	.153	.192	.230	.268	.306	.345	.383	.8
.9	.038	.076	.114	.152	.191	.229	.267	.305	.343	.381	.9
24.0	.038	.076	.114	.152	.190	.228	.266	.304	.342	.379	24.0
.1	.038	.076	.113	.151	.189	.227	.264	.302	.340	.378	.1
.2	.038	.075	.113	.150	.188	.226	.263	.301	.339	.376	.2
.3	.037	.075	.112	.150	.187	.225	.262	.299	.337	.374	.3
.4	.037	.075	.112	.149	.186	.224	.261	.298	.335	.373	.4
24.5	.037	.074	.111	.148	.185	.223	.260	.297	.334	.371	24.5
.6	.037	.074	.111	.148	.185	.222	.259	.295	.332	.369	.6
.7	.037	.074	.110	.147	.184	.221	.257	.294	.331	.368	.7
.8	.037	.073	.110	.146	.183	.220	.256	.293	.329	.366	.8
.9	.036	.073	.109	.146	.182	.219	.255	.292	.328	.364	.9
25.0	.036	.073	.109	.145	.181	.218	.254	.290	.327	.363	25.0
.1	.036	.072	.108	.144	.181	.217	.253	.289	.325	.361	.1
.2	.036	.072	.108	.144	.180	.216	.252	.288	.324	.360	.2
.3	.036	.072	.107	.143	.179	.215	.251	.286	.322	.358	.3
.4	.036	.071	.107	.143	.178	.214	.250	.285	.321	.356	.4
25.5	.035	.071	.106	.142	.177	.213	.248	.284	.319	.355	25.5
.6	.035	.071	.106	.141	.177	.212	.247	.283	.318	.353	.6
.7	.035	.070	.106	.141	.176	.211	.246	.282	.317	.352	.7
.8	.035	.070	.105	.140	.175	.210	.245	.280	.315	.350	.8
.9	.035	.070	.105	.140	.174	.209	.244	.279	.314	.349	.9
	1	2	3	4	5	6	7	8	9	10	

Formula: $\text{“CaO to 100 Brix”} = \frac{\text{No. of ml of soap soln.}}{2 \times .9972 \times \text{Brix} \times D'}$

Where D' is the apparent sp. gr. at $\frac{20^\circ}{20^\circ}$ (ratio of weights in air).

TABLE 16
TABLE FOR USE IN DRY SUBSTANCE DETERMINATIONS ON PULP SOLD

See Chap. VI, 3 (b) for the derivation and use of this table.

Acidity of Pulp	Grams Lime to be Added	Weight to be Subtracted	Acidity of Pulp	Grams Lime to be Added	Weight to be Subtracted
.100	.0100	.0068	.600	.0600	.0407
.110	.0110	.0075	.610	.0610	.0414
.120	.0120	.0081	.620	.0620	.0420
.130	.0130	.0088	.630	.0630	.0427
.140	.0140	.0095	.640	.0640	.0434
.150	.0150	.0102	.650	.0650	.0441
.160	.0160	.0109	.660	.0660	.0448
.170	.0170	.0116	.670	.0670	.0454
.180	.0180	.0122	.680	.0680	.0461
.190	.0190	.0129	.690	.0690	.0468
.200	.0200	.0136	.700	.0700	.0475
.210	.0210	.0143	.710	.0710	.0482
.220	.0220	.0149	.720	.0720	.0488
.230	.0230	.0156	.730	.0730	.0495
.240	.0240	.0162	.740	.0740	.0502
.250	.0250	.0169	.750	.0750	.0509
.260	.0260	.0176	.760	.0760	.0516
.270	.0270	.0183	.770	.0770	.0522
.280	.0280	.0190	.780	.0780	.0529
.290	.0290	.0196	.790	.0790	.0536
.300	.0300	.0203	.800	.0800	.0543
.310	.0310	.0210	.810	.0810	.0550
.320	.0320	.0217	.820	.0820	.0557
.330	.0330	.0224	.830	.0830	.0564
.340	.0340	.0230	.840	.0840	.0571
.350	.0350	.0237	.850	.0850	.0578
.360	.0360	.0244	.860	.0860	.0585
.370	.0370	.0251	.870	.0870	.0592
.380	.0380	.0258	.880	.0880	.0598
.390	.0390	.0264	.890	.0890	.0605
.400	.0400	.0271	.900	.0900	.0612
.410	.0410	.0278	.910	.0910	.0619
.420	.0420	.0285	.920	.0920	.0626
.430	.0430	.0291	.930	.0930	.0632
.440	.0440	.0298	.940	.0940	.0639
.450	.0450	.0305	.950	.0950	.0646
.460	.0460	.0312	.960	.0960	.0653
.470	.0470	.0319	.970	.0970	.0660
.480	.0480	.0325	.980	.0980	.0666
.490	.0490	.0332	.990	.0990	.0673
.500	.0500	.0339	1.000	.1000	.0680
.510	.0510	.0346	1.010	.1010	.0687
.520	.0520	.0353	1.020	.1020	.0694
.530	.0530	.0359	1.030	.1030	.0700
.540	.0540	.0366	1.040	.1040	.0707
.550	.0550	.0373	1.050	.1050	.0714
.560	.0560	.0380	1.060	.1060	.0721
.570	.0570	.0387	1.070	.1070	.0728
.580	.0580	.0393	1.080	.1080	.0734
.590	.0590	.0400	1.090	.1090	.0741

TABLE 17

B. T. U. LOST IN DRY FLUE GAS PER POUND OF COAL CONTAINING 57% CARBON

Based on percentage of CO_2 in the flue gas, temperature, °F., of flue gas (T), and temperature, °F., of boiler room (t).

% CO_2	T—t									
	250	255	260	265	270	275	280	285	290	295
6.0	1401	1429	1457	1485	1513	1541	1569	1597	1625	1653
6.1	1379	1406	1434	1462	1489	1517	1544	1572	1599	1627
6.2	1357	1384	1411	1438	1466	1493	1520	1547	1574	1601
6.3	1336	1363	1389	1416	1443	1470	1496	1523	1550	1577
6.4	1316	1342	1369	1395	1421	1448	1474	1500	1527	1553
6.5	1296	1322	1348	1374	1400	1426	1452	1478	1503	1529
6.6	1277	1303	1328	1354	1379	1405	1430	1456	1481	1507
6.7	1259	1284	1309	1335	1360	1385	1410	1435	1460	1486
6.8	1241	1266	1291	1315	1340	1365	1390	1415	1439	1464
6.9	1223	1247	1272	1296	1321	1345	1370	1394	1419	1443
7.0	1206	1230	1254	1278	1302	1326	1350	1375	1399	1423
7.1	1189	1213	1237	1261	1285	1308	1332	1356	1380	1404
7.2	1173	1197	1220	1244	1267	1291	1314	1338	1362	1386
7.3	1158	1181	1204	1227	1250	1273	1297	1320	1343	1366
7.4	1143	1165	1188	1211	1234	1257	1280	1302	1325	1348
7.5	1128	1150	1173	1195	1218	1241	1263	1286	1308	1331
7.6	1114	1136	1158	1180	1203	1225	1247	1269	1292	1314
7.7	1100	1121	1143	1165	1187	1209	1231	1253	1275	1297
7.8	1086	1108	1129	1151	1173	1194	1216	1238	1260	1281
7.9	1073	1094	1115	1137	1158	1180	1201	1223	1244	1266
8.0	1060	1081	1102	1123	1144	1165	1187	1208	1229	1250
8.1	1047	1068	1089	1110	1131	1152	1172	1193	1214	1235
8.2	1034	1055	1076	1097	1117	1138	1159	1179	1200	1221
8.3	1022	1043	1063	1084	1104	1125	1145	1166	1186	1206
8.4	1011	1031	1051	1071	1092	1112	1132	1152	1172	1193
8.5	1001	1021	1041	1061	1081	1101	1121	1141	1161	1181
8.6	988	1008	1027	1047	1067	1087	1107	1126	1146	1166
8.7	977	997	1016	1036	1055	1075	1094	1114	1133	1153
8.8	966	986	1005	1024	1044	1063	1082	1102	1121	1140
8.9	956	975	994	1013	1032	1051	1070	1090	1109	1128
9.0	946	965	984	1003	1022	1041	1059	1078	1097	1116
9.1	936	955	973	992	1011	1030	1048	1067	1086	1104
9.2	926	945	963	982	1000	1019	1037	1056	1074	1093
9.3	918	936	955	973	991	1010	1028	1047	1065	1083
9.4	908	926	944	962	981	999	1017	1035	1053	1071
9.5	898	915	933	951	969	987	1005	1023	1041	1059
9.6	889	906	924	942	960	977	995	1013	1031	1048
9.7	880	897	915	932	950	968	985	1003	1020	1038
9.8	871	889	906	924	941	958	976	993	1011	1028
9.9	863	880	897	915	932	949	966	984	1001	1018
10.0	854	871	888	905	922	939	956	974	991	1001
10.1	846	863	880	897	914	931	948	965	981	998
10.2	838	855	872	888	905	922	939	955	972	989
10.3	831	848	864	881	897	914	931	947	964	980
10.4	823	839	856	872	889	905	922	938	955	971

TABLE 17—Continued

% CO_2	T—t									
	300	305	310	315	320	325	330	335	340	345
6.0	1681	1709	1737	1765	1793	1821	1849	1877	1905	1933
6.1	1655	1682	1710	1737	1764	1793	1820	1847	1875	1903
6.2	1628	1655	1683	1710	1737	1764	1791	1818	1846	1873
6.3	1603	1630	1657	1683	1710	1737	1764	1790	1817	1844
6.4	1579	1606	1632	1658	1684	1711	1737	1763	1790	1816
6.5	1555	1581	1607	1633	1659	1685	1711	1737	1763	1789
6.6	1532	1558	1583	1609	1635	1660	1686	1711	1737	1762
6.7	1511	1536	1561	1586	1611	1637	1662	1687	1712	1737
6.8	1489	1514	1539	1564	1588	1613	1638	1663	1688	1712
6.9	1468	1492	1517	1541	1565	1590	1614	1639	1663	1688
7.0	1447	1471	1495	1519	1543	1567	1591	1616	1640	1664
7.1	1427	1451	1475	1499	1523	1546	1570	1594	1618	1641
7.2	1409	1432	1455	1478	1502	1525	1549	1572	1596	1619
7.3	1389	1412	1435	1458	1482	1505	1528	1551	1574	1598
7.4	1371	1394	1417	1440	1462	1485	1508	1531	1554	1577
7.5	1353	1376	1398	1421	1444	1466	1489	1511	1534	1556
7.6	1336	1358	1381	1403	1425	1448	1470	1492	1514	1537
7.7	1319	1341	1363	1385	1407	1429	1451	1473	1495	1517
7.8	1303	1325	1347	1368	1390	1412	1433	1455	1477	1499
7.9	1287	1308	1330	1351	1373	1394	1416	1437	1459	1480
8.0	1272	1293	1314	1335	1356	1378	1399	1420	1441	1462
8.1	1256	1277	1298	1319	1340	1361	1382	1403	1424	1445
8.2	1241	1262	1283	1303	1324	1345	1366	1386	1407	1428
8.3	1227	1247	1268	1288	1309	1329	1350	1370	1391	1411
8.4	1213	1233	1253	1273	1294	1314	1334	1354	1374	1395
8.5	1201	1221	1241	1261	1281	1301	1321	1341	1361	1381
8.6	1186	1205	1225	1245	1265	1284	1304	1324	1344	1363
8.7	1172	1192	1211	1231	1251	1270	1290	1309	1329	1348
8.8	1160	1179	1198	1218	1237	1256	1275	1295	1314	1334
8.9	1147	1166	1185	1204	1223	1242	1262	1281	1300	1319
9.0	1135	1154	1173	1192	1211	1230	1249	1267	1286	1305
9.1	1123	1142	1161	1179	1198	1217	1235	1254	1273	1291
9.2	1111	1130	1148	1167	1185	1204	1222	1241	1259	1278
9.3	1102	1120	1138	1157	1175	1194	1212	1230	1249	1267
9.4	1089	1108	1126	1144	1162	1180	1198	1216	1235	1253
9.5	1077	1095	1113	1131	1149	1167	1185	1203	1221	1239
9.6	1066	1083	1102	1120	1137	1155	1173	1191	1208	1226
9.7	1055	1073	1090	1108	1125	1143	1160	1178	1196	1213
9.8	1045	1063	1080	1098	1115	1133	1150	1168	1185	1202
9.9	1035	1053	1070	1087	1104	1122	1139	1156	1173	1191
10.0	1025	1042	1059	1076	1093	1110	1127	1144	1161	1179
10.1	1015	1032	1049	1066	1083	1100	1117	1134	1151	1168
10.2	1006	1022	1039	1056	1073	1089	1106	1123	1140	1156
10.3	997	1014	1030	1047	1064	1080	1097	1113	1130	1147
10.4	988	1004	1021	1037	1053	1070	1086	1103	1119	1136

TABLE 17—Continued

% CO_2	T—t									
	350	355	360	365	370	375	380	385	390	395
6.0	1961	1989	2107	2045	2073	2102	2136	2158	2186	2214
6.1	1931	1958	1986	2013	2041	2068	2096	2124	2151	2179
6.2	1900	1927	1954	1981	2008	2036	2063	2089	2117	2144
6.3	1871	1897	1924	1951	1978	2004	2031	2058	2084	2111
6.4	1842	1869	1895	1921	1948	1974	2000	2027	2053	2079
6.5	1815	1841	1866	1892	1918	1944	1970	1996	2022	2048
6.6	1788	1814	1839	1865	1890	1916	1941	1967	1992	2018
6.7	1762	1788	1813	1838	1863	1888	1913	1939	1964	1989
6.8	1737	1762	1787	1812	1836	1861	1886	1911	1936	1960
6.9	1712	1737	1761	1786	1810	1835	1859	1883	1908	1932
7.0	1688	1712	1736	1760	1785	1809	1833	1857	1881	1905
7.1	1665	1689	1713	1737	1760	1784	1808	1832	1855	1879
7.2	1643	1666	1690	1713	1737	1760	1784	1807	1831	1854
7.3	1621	1644	1667	1690	1713	1737	1760	1783	1806	1829
7.4	1600	1622	1645	1668	1691	1714	1737	1759	1782	1805
7.5	1579	1602	1624	1647	1669	1692	1714	1737	1759	1782
7.6	1559	1581	1603	1626	1648	1670	1692	1715	1737	1759
7.7	1539	1561	1583	1605	1627	1649	1671	1693	1715	1737
7.8	1520	1542	1564	1585	1607	1629	1651	1672	1694	1716
7.9	1502	1523	1544	1566	1587	1609	1630	1652	1673	1695
8.0	1483	1505	1526	1547	1568	1589	1610	1632	1653	1674
8.1	1466	1487	1507	1528	1549	1570	1591	1612	1633	1654
8.2	1448	1469	1490	1510	1531	1552	1572	1593	1614	1634
8.3	1431	1452	1472	1493	1513	1534	1554	1575	1595	1615
8.4	1415	1435	1455	1476	1496	1516	1536	1556	1577	1597
8.5	1401	1421	1441	1461	1481	1501	1521	1541	1561	1581
8.6	1383	1403	1423	1442	1462	1482	1502	1521	1541	1561
8.7	1368	1387	1407	1426	1446	1466	1485	1505	1524	1544
8.8	1353	1372	1392	1411	1431	1450	1469	1488	1508	1527
8.9	1338	1357	1376	1395	1414	1434	1456	1472	1490	1510
9.0	1324	1343	1362	1381	1400	1419	1438	1457	1475	1494
9.1	1310	1329	1348	1366	1385	1404	1422	1441	1460	1479
9.2	1296	1315	1333	1352	1370	1389	1408	1426	1445	1463
9.3	1285	1304	1322	1341	1359	1377	1396	1414	1432	1451
9.4	1271	1289	1307	1325	1343	1362	1380	1398	1416	1434
9.5	1257	1274	1291	1310	1328	1346	1364	1382	1400	1418
9.6	1244	1262	1279	1297	1315	1333	1351	1368	1386	1404
9.7	1231	1248	1264	1282	1299	1317	1334	1352	1369	1387
9.8	1220	1237	1255	1272	1289	1307	1324	1342	1359	1377
9.9	1208	1225	1242	1260	1277	1294	1311	1329	1346	1363
10.0	1196	1213	1230	1247	1264	1281	1298	1315	1332	1349
10.1	1185	1202	1218	1235	1252	1269	1286	1303	1320	1337
10.2	1173	1190	1207	1223	1240	1257	1274	1291	1307	1324
10.3	1163	1180	1196	1213	1230	1246	1263	1279	1296	1313
10.4	1152	1169	1185	1202	1218	1235	1251	1267	1284	1300

TABLE 17—Continued

% CO₂	T—t									
	400	405	410	415	420	425	430	435	440	445
6.0	2242	2270	2298	2326	2354	2382	2410	2438	2466	2494
6.1	2206	2234	2262	2289	2317	2344	2372	2399	2427	2455
6.2	2171	2198	2225	2253	2280	2307	2334	2361	2388	2415
6.3	2138	2165	2191	2218	2245	2272	2298	2325	2352	2378
6.4	2106	2132	2158	2185	2211	2237	2264	2290	2316	2342
6.5	2074	2100	2126	2152	2178	2204	2230	2256	2281	2307
6.6	2043	2069	2094	2120	2146	2171	2197	2222	2248	2273
6.7	2014	2039	2064	2090	2115	2140	2165	2190	2215	2241
6.8	1985	2010	2035	2060	2085	2109	2134	2159	2184	2209
6.9	1957	1981	2006	2030	2055	2079	2104	2128	2152	2177
7.0	1929	1953	1977	2002	2026	2050	2074	2098	2122	2146
7.1	1903	1927	1951	1974	1998	2022	2046	2069	2093	2117
7.2	1877	1901	1924	1948	1971	1995	2018	2042	2065	2089
7.3	1852	1875	1899	1922	1945	1968	1991	2014	2038	2061
7.4	1828	1851	1874	1897	1919	1942	1965	1988	2011	2034
7.5	1805	1827	1850	1872	1895	1917	1940	1962	1985	2068
7.6	1782	1804	1826	1848	1871	1893	1915	1937	1960	1982
7.7	1759	1781	1803	1825	1847	1869	1891	1913	1935	1957
7.8	1737	1759	1781	1803	1824	1846	1868	1890	1911	1933
7.9	1716	1737	1759	1780	1802	1823	1845	1866	1888	1909
8.0	1695	1716	1738	1759	1780	1801	1822	1844	1865	1886
8.1	1675	1696	1717	1738	1759	1780	1801	1821	1842	1863
8.2	1655	1676	1697	1717	1738	1759	1779	1800	1821	1841
8.3	1636	1656	1677	1697	1718	1738	1759	1779	1799	1820
8.4	1617	1637	1657	1678	1698	1718	1738	1758	1779	1799
8.5	1601	1621	1641	1661	1681	1701	1721	1741	1761	1781
8.6	1581	1601	1620	1640	1660	1680	1699	1719	1739	1759
8.7	1563	1583	1602	1622	1641	1661	1680	1700	1720	1739
8.8	1546	1566	1585	1604	1624	1643	1662	1682	1701	1720
8.9	1529	1548	1567	1586	1605	1625	1644	1663	1682	1701
9.0	1513	1532	1551	1570	1589	1608	1627	1646	1665	1683
9.1	1497	1516	1535	1553	1572	1591	1610	1628	1647	1666
9.2	1482	1500	1519	1537	1556	1574	1593	1611	1630	1648
9.3	1469	1487	1506	1524	1543	1561	1579	1598	1616	1634
9.4	1452	1470	1488	1507	1525	1543	1561	1579	1597	1615
9.5	1436	1454	1472	1490	1508	1526	1544	1562	1580	1598
9.6	1422	1439	1457	1475	1493	1510	1528	1546	1564	1582
9.7	1405	1422	1440	1457	1475	1492	1510	1528	1545	1563
9.8	1394	1411	1429	1446	1464	1481	1499	1516	1533	1551
9.9	1380	1398	1415	1432	1449	1467	1484	1501	1518	1536
10.0	1366	1383	1401	1418	1435	1452	1469	1486	1503	1520
10.1	1354	1371	1388	1405	1422	1439	1455	1472	1489	1506
10.2	1341	1358	1374	1391	1408	1425	1441	1458	1475	1492
10.3	1329	1346	1363	1379	1396	1412	1429	1446	1462	1479
10.4	1317	1333	1350	1366	1383	1399	1416	1432	1448	1465

TABLE 17—Continued

% CO₂	T—t									
	450	455	460	465	470	475	480	485	490	495
6.0	2522	2550	2578	2606	2634	2662	2690	2718	2746	2774
6.1	2482	2510	2537	2565	2593	2620	2648	2675	2703	2730
6.2	2443	2470	2497	2524	2551	2578	2605	2633	2660	2687
6.3	2305	2432	2459	2485	2512	2539	2566	2592	2619	2646
6.4	2369	2395	2421	2448	2474	2500	2527	2553	2579	2606
6.5	2333	2357	2385	2411	2437	2463	2489	2515	2541	2567
6.6	2299	2324	2356	2375	2401	2427	2452	2478	2508	2529
6.7	2266	2291	2316	2341	2366	2392	2417	2442	2467	2492
6.8	2233	2258	2283	2308	2333	2357	2382	2407	2432	2457
6.9	2201	2226	2250	2275	2299	2324	2348	2373	2397	2422
7.0	2170	2194	2219	2243	2267	2291	2315	2339	2363	2387
7.1	2141	2165	2188	2212	2236	2260	2284	2307	2331	2355
7.2	2112	2136	2159	2183	2206	2229	2253	2276	2300	2323
7.3	2084	2107	2130	2153	2176	2200	2223	2246	2269	2292
7.4	2057	2079	2102	2125	2148	2171	2194	2216	2239	2262
7.5	2030	2053	2075	2098	2120	2143	2165	2188	2211	2233
7.6	2004	2027	2049	2071	2093	2116	2138	2160	2182	2205
7.7	1979	2001	2023	2045	2067	2089	2111	2133	2155	2177
7.8	1955	1976	1998	2020	2042	2063	2085	2107	2128	2150
7.9	1931	1952	1973	1995	2016	2038	2059	2081	2102	2124
8.0	1907	1928	1950	1971	1992	2013	2034	2055	2077	2098
8.1	1884	1905	1926	1947	1968	1989	2010	2031	2052	2072
8.2	1862	1883	1903	1924	1945	1966	1986	2007	2028	2048
8.3	1840	1861	1881	1901	1922	1943	1963	1984	2004	2024
8.4	1819	1839	1860	1880	1900	1920	1940	1961	1981	2001
8.5	1801	1821	1841	1861	1881	1901	1921	1941	1961	1981
8.6	1778	1798	1818	1838	1857	1877	1897	1917	1936	1956
8.7	1759	1778	1797	1817	1837	1856	1876	1895	1915	1934
8.8	1740	1759	1778	1798	1817	1836	1856	1875	1894	1914
8.9	1720	1739	1758	1777	1797	1816	1835	1854	1873	1892
9.0	1702	1721	1740	1759	1778	1797	1816	1835	1854	1873
9.1	1684	1703	1722	1741	1759	1778	1797	1815	1834	1853
9.2	1667	1685	1704	1722	1741	1759	1778	1796	1815	1833
9.3	1653	1671	1690	1708	1726	1745	1763	1781	1800	1818
9.4	1634	1652	1670	1688	1707	1725	1743	1761	1779	1797
9.5	1616	1633	1651	1669	1687	1705	1723	1741	1759	1777
9.6	1599	1617	1635	1653	1670	1688	1706	1724	1741	1759
9.7	1580	1598	1615	1633	1650	1668	1685	1703	1720	1738
9.8	1568	1586	1603	1621	1638	1655	1673	1690	1708	1725
9.9	1553	1570	1587	1605	1622	1639	1657	1674	1691	1708
10.0	1537	1554	1571	1588	1606	1623	1640	1657	1674	1691
10.1	1523	1540	1557	1574	1591	1608	1625	1642	1659	1676
10.2	1508	1525	1542	1559	1575	1592	1609	1626	1642	1659
10.3	1495	1512	1529	1545	1562	1578	1595	1612	1628	1645
10.4	1481	1498	1514	1531	1547	1564	1580	1597	1613	1630

TABLE 17—Continued

% CO_2	T—t										
	500	505	510	515	520	525	530	535	540	545	550
6.0	2803	2830	2858	2886	2914	2942	2970	2998	3026	3054	3082
6.1	2758	2786	2813	2841	2868	2896	2923	2951	2979	3006	3034
6.2	2714	2741	2768	2795	2823	2850	2877	2904	2931	2958	2985
6.3	2673	2699	2726	2753	2779	2806	2833	2860	2886	2913	2940
6.4	2632	2658	2685	2711	2737	2764	2790	2816	2843	2869	2891
6.5	2593	2618	2644	2670	2696	2722	2748	2774	2800	2825	2850
6.6	2554	2580	2605	2631	2656	2682	2707	2733	2759	2784	2810
6.7	2517	2543	2568	2593	2618	2643	2669	2694	2719	2744	2769
8.8	2482	2506	2531	2556	2581	2606	2630	2655	2680	2705	2730
6.9	2446	2470	2495	2519	2544	2568	2593	2617	2642	2666	2691
7.0	2412	2436	2460	2484	2508	2532	2556	2580	2604	2629	2653
7.1	2379	2403	2426	2450	2474	2498	2521	2545	2569	2593	2617
7.2	2347	2370	2394	2417	2441	2464	2488	2511	2535	2558	2581
7.3	2315	2339	2362	2385	2408	2431	2454	2477	2501	2524	2547
7.4	2285	2208	2331	2354	2376	2399	2422	2445	2468	2491	2514
7.5	2256	2278	2301	2324	2346	2369	2391	2414	2436	2459	2481
7.6	2227	2249	2271	2294	2316	2338	2361	2383	2405	2427	2450
7.7	2199	2221	2243	2264	2287	2309	2331	2353	2375	2397	2419
7.8	2172	2194	2215	2237	2259	2280	2302	2324	2346	2367	2389
7.9	2145	2166	2188	2209	2231	2252	2274	2295	2317	2338	2360
8.0	2119	2140	2161	2183	2204	2225	2246	2267	2282	2310	2331
8.1	2094	2115	2136	2156	2177	2198	2119	2240	2261	2282	2303
8.2	2069	2089	2110	2131	2152	2172	2193	2114	2234	2255	2276
8.3	2045	2065	2086	2106	2127	2147	2168	2188	2209	2229	2249
8.4	2021	2041	2062	2082	2102	2122	2142	2163	2183	2203	2223
8.5	2001	2021	2041	2061	2081	2101	2121	2141	2161	2181	2201
8.6	1976	1996	2015	2035	2055	2075	2095	2114	2134	2154	2174
8.7	1953	1974	1993	2013	2032	2052	2071	2091	2110	2130	2149
8.8	1933	1952	1972	1991	2010	2030	2049	2068	2088	2107	2126
8.9	1911	1930	1950	1969	1988	2007	2026	2045	2064	2083	2103
9.0	1892	1910	1929	1948	1967	1986	2005	2024	2043	2081	2100
9.1	1872	1890	1909	1928	1946	1965	1984	2002	2021	2040	2059
9.2	1852	1871	1889	1908	1926	1945	1963	1982	2000	2019	2037
9.3	1837	1855	1873	1892	1910	1928	1947	1965	1983	2002	2020
9.4	1816	1834	1852	1870	1888	1906	1924	1942	1961	1979	1997
9.5	1795	1813	1831	1849	1867	1885	1903	1921	1939	1957	1974
9.6	1777	1795	1813	1830	1848	1866	1884	1901	1919	1937	1955
9.7	1756	1773	1791	1808	1826	1843	1861	1878	1896	1913	1931
9.8	1743	1760	1777	1795	1812	1830	1847	1864	1882	1899	1917
9.9	1726	1743	1760	1777	1795	1812	1821	1846	1863	1880	1898
10.0	1708	1725	1742	1759	1776	1793	1810	1828	1845	1862	1879
10.1	1693	1709	1726	1743	1760	1777	1794	1811	1828	1845	1862
10.2	1676	1693	1710	1726	1743	1760	1777	1793	1810	1827	1844
10.3	1662	1678	1695	1711	1728	1745	1761	1778	1795	1811	1828
10.4	1646	1662	1679	1695	1712	1728	1745	1761	1778	1794	1810

TABLE 17—Continued

% CO_2	T—t									
	250	255	260	265	270	275	280	285	290	295
10.5	815	832	848	864	881	891	913	930	946	962
10.6	808	824	840	856	873	889	905	921	937	953
10.7	801	817	833	849	865	881	897	913	929	945
10.8	794	810	826	842	857	873	889	905	921	937
10.9	787	803	818	834	850	866	881	897	913	929
11.0	780	796	811	827	842	858	874	889	905	920
11.1	773	788	804	819	835	859	866	881	897	912
11.2	766	782	797	812	828	843	858	874	889	904
11.3	760	775	790	806	821	836	851	866	882	897
11.4	754	709	785	800	815	830	846	861	876	891
11.5	748	763	778	793	808	823	838	853	868	883
11.6	742	757	772	787	801	816	831	846	861	876
11.7	736	751	765	780	795	810	824	839	854	868
11.8	730	745	759	774	788	803	818	832	847	861
11.9	724	738	753	767	782	796	810	825	839	854
12.0	719	733	748	762	776	791	805	820	834	848
12.1	713	727	742	756	770	784	799	813	827	841
12.2	707	721	735	749	764	778	792	806	820	834
12.3	702	716	730	744	758	772	786	800	814	828
12.4	696	710	724	738	757	766	780	794	807	821
12.5	691	705	719	732	746	760	774	788	802	815
12.6	686	700	713	727	741	755	768	782	796	809
12.7	680	694	707	721	734	748	762	775	789	802
12.8	675	689	702	716	729	743	756	770	783	797
12.9	670	683	697	710	724	737	750	764	777	791
13.0	665	678	692	705	718	732	745	758	771	786
13.1	660	673	686	700	713	726	739	752	766	779
13.2	656	669	682	695	708	722	735	748	761	774
13.3	651	664	677	690	703	716	729	742	755	768
13.4	646	659	672	685	698	711	724	737	749	762
13.5	642	655	668	681	693	706	719	732	745	758
13.6	637	650	663	675	688	701	714	726	739	752
13.7	633	646	658	671	684	696	709	722	734	747
13.8	628	641	653	666	678	691	703	716	729	741
13.9	624	636	649	661	674	686	699	711	724	736
14.0	620	632	645	657	670	682	694	707	719	732
14.1	616	628	641	653	665	678	690	702	715	727
14.2	612	624	636	649	661	673	685	698	710	722
14.3	608	620	632	644	657	669	681	693	705	717
14.4	604	616	628	640	652	664	676	689	701	713
14.5	600	612	624	636	648	660	672	684	696	708
14.6	596	608	620	632	644	656	668	679	691	703
14.7	592	604	616	628	639	651	663	675	687	699
14.8	588	600	612	623	635	647	659	670	682	694
14.9	585	597	508	620	632	643	655	667	679	690
15.0	581	593	604	616	627	639	651	662	674	686

TABLE 17—Continued

% CO_2	T–t									
	300	305	310	315	320	325	330	335	340	345
10.5	979	995	1011	1027	1044	1060	1076	1092	1109	1125
10.6	970	986	1002	1018	1034	1050	1067	1083	1099	1115
10.7	961	977	993	1009	1025	1041	1057	1073	1089	1105
10.8	953	969	984	1000	1016	1032	1048	1064	1080	1095
10.9	944	960	976	991	1007	1023	1039	1054	1070	1086
11.0	936	952	967	983	998	1014	1030	1045	1061	1076
11.1	928	943	959	974	989	1005	1020	1036	1051	1067
11.2	920	935	950	966	981	996	1012	1027	1042	1058
11.3	912	927	942	958	973	988	1003	1018	1034	1049
11.4	906	921	936	951	966	981	996	1012	1027	1042
11.5	898	913	928	943	958	973	988	1002	1017	1032
11.6	890	905	920	935	950	965	979	994	1009	1024
11.7	883	898	913	927	942	957	972	986	1001	1016
11.8	876	891	905	920	935	949	964	978	993	1008
11.9	868	882	897	911	926	940	954	969	983	998
12.0	863	887	891	906	920	935	949	963	978	992
12.1	856	870	884	898	913	927	941	955	970	984
12.2	849	863	877	891	905	919	933	948	962	976
12.3	842	856	870	884	898	913	927	941	955	969
12.4	835	849	863	877	891	905	919	933	947	961
12.5	829	843	857	871	884	898	912	926	940	954
12.6	823	837	851	864	878	892	906	919	933	947
12.7	816	830	843	857	870	884	898	911	925	938
12.8	810	824	837	851	864	878	891	905	918	932
12.9	804	817	831	844	858	871	884	898	911	925
13.0	798	811	825	838	851	865	878	891	904	918
13.1	792	805	819	832	845	858	871	885	898	911
13.2	787	800	813	826	840	853	866	879	892	905
13.3	781	794	807	820	833	846	859	872	885	898
13.4	775	788	801	814	827	840	853	866	879	892
13.5	770	783	796	809	822	835	847	860	873	886
13.6	765	777	790	803	816	828	841	854	867	879
13.7	760	772	785	797	810	823	835	848	861	873
13.8	754	766	779	791	804	817	829	842	854	867
13.9	749	761	774	786	799	811	824	836	849	861
14.0	744	756	769	781	794	806	818	831	843	856
14.1	739	752	764	776	788	801	813	825	838	850
14.2	734	747	759	771	783	796	808	820	832	845
14.3	730	742	754	766	778	790	803	815	827	839
14.4	725	737	749	761	773	785	797	809	821	834
14.5	720	732	744	756	768	780	792	804	816	828
14.6	715	727	739	751	763	775	787	799	811	822
14.7	711	722	734	746	758	770	782	793	805	817
14.8	706	717	729	741	753	764	776	788	800	811
14.9	702	714	725	737	749	760	772	784	795	807
15.0	697	709	720	732	744	755	767	779	790	802

TABLE 17—Continued

% CO_2	T—t									
	350	355	360	365	370	375	380	385	390	395
10.5	1142	1158	1174	1191	1207	1223	1239	1256	1272	1288
10.6	1131	1147	1164	1179	1196	1212	1228	1244	1260	1277
10.7	1121	1137	1153	1169	1185	1202	1217	1234	1249	1266
10.8	1111	1127	1143	1159	1175	1191	1207	1222	1238	1254
10.9	1102	1117	1133	1149	1165	1180	1196	1212	1226	1243
11.0	1092	1108	1123	1139	1154	1170	1186	1201	1217	1232
11.1	1082	1098	1113	1129	1144	1160	1175	1190	1206	1221
11.2	1073	1088	1104	1119	1134	1150	1165	1180	1196	1211
11.3	1064	1079	1094	1109	1125	1140	1155	1170	1186	1201
11.4	1057	1072	1087	1102	1117	1132	1147	1162	1178	1193
11.5	1047	1062	1077	1092	1107	1122	1137	1152	1167	1182
11.6	1039	1054	1068	1083	1098	1113	1128	1143	1158	1172
11.7	1030	1045	1060	1075	1089	1104	1119	1133	1148	1163
11.8	1022	1037	1051	1066	1081	1095	1110	1124	1139	1154
11.9	1012	1026	1041	1055	1070	1084	1099	1113	1127	1142
12.0	1006	1021	1035	1050	1064	1078	1093	1107	1121	1136
12.1	998	1012	1027	1041	1055	1070	1084	1098	1113	1127
12.2	990	1004	1018	1032	1047	1061	1075	1089	1103	1117
12.3	983	997	1011	1025	1039	1053	1067	1081	1095	1109
12.4	975	989	1002	1016	1030	1044	1058	1072	1086	1100
12.5	967	981	995	1009	1023	1037	1050	1064	1078	1092
12.6	960	974	988	1002	1015	1029	1043	1056	1070	1084
12.7	952	966	979	993	1006	1020	1034	1047	1061	1074
12.8	945	959	972	986	999	1013	1026	1046	1053	1067
12.9	938	951	965	978	992	1005	1018	1032	1045	1059
13.0	931	944	958	971	984	998	1011	1024	1037	1051
13.1	924	937	951	964	977	990	1003	1017	1030	1043
13.2	918	931	944	958	971	984	997	1010	1023	1036
13.3	911	924	937	950	963	977	990	1003	1016	1029
13.4	905	918	930	943	956	969	982	995	1008	1021
13.5	899	912	924	937	950	963	976	989	1002	1014
13.6	892	905	918	930	943	956	969	981	994	1007
13.7	886	899	911	924	937	949	962	975	987	1000
13.8	879	892	905	917	930	942	955	967	980	993
13.9	874	886	899	911	924	936	949	961	974	986
14.0	868	880	893	905	918	930	942	955	967	980
14.1	862	875	887	899	912	924	936	949	961	973
14.2	857	869	881	894	906	918	930	942	955	967
14.3	851	863	876	888	900	912	924	936	948	961
14.4	846	858	870	882	894	906	918	930	942	954
14.5	840	852	864	876	888	900	912	924	936	948
14.6	834	846	858	870	882	894	906	918	930	942
14.7	829	841	853	864	876	888	900	912	924	935
14.8	823	835	847	858	870	882	894	906	917	929
14.9	819	830	842	854	866	877	889	901	912	924
15.0	813	825	837	848	860	872	883	895	906	918

TABLE 17—Continued

% CO_2	T—t									
	400	405	410	415	420	425	430	435	440	445
10.5	1305	1321	1337	1354	1370	1386	1403	1419	1435	1451
10.6	1293	1309	1325	1341	1357	1374	1390	1406	1422	1438
10.7	1282	1298	1314	1330	1346	1362	1378	1394	1410	1426
10.8	1270	1286	1302	1318	1334	1349	1365	1381	1397	1413
10.9	1259	1275	1290	1306	1322	1338	1353	1369	1385	1400
11.0	1248	1264	1279	1295	1310	1326	1342	1357	1373	1385
11.1	1237	1252	1268	1283	1299	1314	1330	1345	1360	1376
11.2	1226	1242	1257	1272	1288	1303	1318	1334	1349	1364
11.3	1216	1231	1246	1262	1277	1292	1307	1322	1338	1353
11.4	1208	1223	1238	1253	1268	1283	1298	1313	1328	1344
11.5	1197	1212	1227	1242	1257	1272	1287	1302	1317	1332
11.6	1187	1202	1217	1232	1247	1261	1276	1291	1306	1321
11.7	1178	1192	1207	1222	1236	1251	1266	1281	1295	1310
11.8	1168	1183	1198	1212	1228	1241	1256	1271	1285	1300
11.9	1156	1171	1185	1199	1214	1228	1243	1257	1271	1286
12.0	1150	1164	1179	1193	1208	1222	1236	1251	1265	1279
12.1	1141	1155	1169	1184	1198	1212	1226	1241	1255	1269
12.2	1132	1146	1160	1174	1188	1202	1216	1231	1245	1259
12.3	1123	1137	1151	1165	1179	1193	1207	1221	1236	1250
12.4	1114	1128	1142	1156	1170	1184	1197	1211	1225	1239
12.5	1106	1119	1133	1147	1161	1175	1189	1202	1216	1230
12.6	1098	1111	1125	1139	1152	1166	1180	1194	1207	1221
12.7	1088	1102	1115	1129	1142	1156	1170	1183	1197	1210
12.8	1080	1094	1107	1121	1134	1148	1161	1175	1188	1202
12.9	1072	1085	1099	1112	1126	1139	1152	1166	1179	1193
13.0	1064	1077	1091	1104	1117	1131	1144	1157	1170	1184
13.1	1056	1070	1083	1096	1109	1122	1136	1149	1162	1175
13.2	1049	1062	1076	1089	1102	1115	1128	1141	1154	1167
13.3	1042	1055	1068	1081	1094	1107	1120	1133	1146	1159
13.4	1034	1047	1060	1073	1086	1099	1111	1124	1137	1150
13.5	1027	1040	1053	1066	1079	1091	1109	1117	1130	1143
13.6	1020	1032	1045	1058	1071	1083	1096	1109	1122	1134
13.7	1013	1025	1038	1050	1063	1076	1088	1101	1114	1126
13.8	1005	1018	1030	1043	1055	1068	1081	1093	1106	1118
13.9	999	1011	1023	1036	1049	1061	1074	1086	1099	1111
14.0	992	1004	1017	1029	1042	1054	1066	1079	1091	1104
14.1	986	998	1010	1023	1035	1047	1060	1072	1084	1096
14.2	979	991	1004	1016	1028	1040	1053	1065	1077	1089
14.3	973	985	997	1001	1029	1074	1046	1058	1070	1082
14.4	966	978	991	1003	1015	1027	1039	1051	1063	1075
14.5	960	972	984	996	1008	1020	1032	1044	1056	1068
14.6	954	966	977	989	1001	1013	1025	1037	1049	1061
14.7	947	959	971	983	995	1007	1018	1030	1042	1054
14.8	941	953	964	976	988	1000	1011	1023	1035	1047
14.9	936	947	959	971	982	994	1006	1018	1029	1041
15.0	930	941	953	964	976	988	999	1011	1023	1034

TABLE 17—Continued

% CO_2	T—t									
	450	455	460	465	470	475	480	485	490	495
10.5	1468	1484	1500	1517	1533	1549	1566	1582	1598	1615
10.6	1454	1471	1487	1503	1519	1535	1551	1568	1584	1600
10.7	1442	1458	1474	1490	1506	1522	1538	1554	1570	1586
10.8	1429	1445	1461	1476	1492	1508	1524	1540	1556	1572
10.9	1416	1432	1448	1463	1479	1495	1511	1526	1542	1558
11.0	1404	1420	1435	1451	1466	1482	1498	1513	1529	1544
11.1	1391	1407	1422	1438	1453	1469	1484	1500	1515	1531
11.2	1380	1395	1410	1426	1441	1456	1472	1487	1502	1518
11.3	1369	1383	1398	1414	1429	1444	1459	1474	1490	1505
11.4	1359	1374	1389	1404	1419	1434	1449	1464	1479	1494
11.5	1347	1362	1377	1392	1407	1422	1437	1452	1467	1482
11.6	1336	1350	1365	1380	1395	1410	1425	1439	1454	1469
11.7	1325	1340	1354	1369	1384	1398	1413	1428	1443	1457
11.8	1314	1329	1344	1358	1373	1387	1402	1417	1431	1446
11.9	1300	1315	1329	1343	1358	1372	1387	1401	1416	1430
12.0	1294	1308	1323	1337	1351	1366	1380	1394	1409	1423
12.1	1283	1298	1312	1326	1340	1355	1369	1383	1397	1412
12.2	1273	1287	1301	1315	1330	1344	1358	1372	1386	1400
12.3	1264	1278	1292	1306	1320	1334	1348	1362	1376	1390
12.4	1253	1267	1281	1295	1309	1323	1337	1351	1365	1379
12.5	1244	1258	1271	1285	1299	1313	1327	1341	1354	1368
12.6	1235	1249	1262	1276	1290	1303	1317	1331	1345	1358
12.7	1224	1238	1251	1265	1278	1292	1306	1319	1333	1346
12.8	1215	1229	1242	1256	1269	1283	1296	1310	1323	1337
12.9	1206	1219	1233	1246	1260	1273	1286	1300	1313	1327
13.0	1197	1210	1224	1237	1250	1264	1277	1290	1303	1317
13.1	1188	1202	1215	1228	1241	1254	1268	1281	1294	1307
13.2	1180	1194	1207	1220	1233	1246	1259	1272	1285	1298
13.3	1172	1185	1198	1211	1224	1237	1250	1263	1276	1289
13.4	1163	1176	1189	1202	1215	1228	1241	1254	1267	1280
13.5	1156	1168	1181	1194	1207	1220	1233	1245	1258	1271
13.6	1147	1160	1173	1185	1198	1211	1224	1236	1249	1262
13.7	1139	1152	1164	1177	1190	1202	1215	1228	1240	1253
13.8	1131	1143	1156	1169	1181	1194	1206	1219	1231	1244
13.9	1124	1136	1149	1161	1174	1186	1199	1211	1224	1236
14.0	1116	1128	1141	1153	1166	1178	1190	1203	1215	1228
14.1	1109	1121	1133	1146	1158	1170	1183	1195	1207	1220
14.2	1102	1114	1126	1138	1151	1163	1175	1187	1200	1212
14.3	1094	1107	1119	1131	1143	1155	1167	1179	1192	1204
14.4	1087	1099	1111	1123	1136	1148	1160	1172	1184	1196
14.5	1080	1092	1104	1116	1128	1140	1152	1164	1176	1188
14.6	1073	1085	1097	1109	1120	1132	1144	1156	1168	1180
14.7	1066	1078	1089	1101	1113	1125	1137	1149	1160	1172
14.8	1058	1070	1082	1094	1105	1117	1129	1141	1152	1164
14.9	1053	1064	1076	1088	1099	1111	1123	1134	1146	1158
15.0	1046	1057	1069	1081	1092	1104	1116	1127	1139	1150

TABLE 17—Continued

% CO_2	T—t										
	500	505	510	515	520	525	530	535	540	545	550
10.5	1631	1647	1664	1680	1696	1712	1729	1745	1761	1778	1794
10.6	1616	1632	1648	1664	1681	1697	1713	1729	1745	1761	1778
10.7	1602	1618	1634	1650	1666	1682	1698	1714	1730	1746	1762
10.8	1588	1603	1619	1635	1651	1667	1683	1699	1714	1730	1746
10.9	1574	1589	1605	1621	1636	1652	1668	1684	1699	1715	1731
11.0	1560	1576	1591	1607	1622	1638	1654	1669	1685	1700	1716
11.1	1546	1561	1577	1592	1608	1623	1639	1654	1670	1685	1701
11.2	1533	1548	1564	1579	1594	1610	1625	1640	1656	1671	1686
11.3	1520	1535	1550	1566	1581	1596	1611	1626	1642	1657	1672
11.4	1510	1525	1540	1555	1570	1585	1600	1615	1630	1645	1660
11.5	1497	1511	1526	1541	1556	1571	1586	1601	1616	1631	1646
11.6	1484	1499	1514	1529	1543	1558	1573	1588	1608	1618	1632
11.7	1472	1487	1501	1516	1531	1546	1560	1575	1590	1604	1619
11.8	1461	1475	1490	1504	1519	1534	1548	1563	1577	1592	1607
11.9	1444	1459	1473	1488	1502	1516	1531	1546	1560	1575	1589
12.0	1438	1452	1466	1481	1495	1509	1524	1538	1552	1567	1581
12.1	1426	1440	1455	1469	1483	1497	1512	1526	1540	1554	1569
12.2	1415	1429	1443	1457	1472	1485	1499	1514	1528	1542	1556
12.3	1404	1418	1432	1446	1460	1474	1488	1502	1516	1530	1544
12.4	1393	1406	1420	1434	1440	1462	1476	1490	1504	1518	1532
12.5	1382	1396	1410	1423	1437	1451	1465	1479	1493	1506	1520
12.6	1372	1386	1399	1413	1427	1441	1454	1468	1482	1495	1509
12.7	1360	1374	1387	1401	1414	1428	1442	1455	1469	1482	1496
12.8	1350	1364	1377	1389	1404	1417	1431	1445	1459	1472	1485
12.9	1340	1353	1367	1380	1394	1407	1420	1434	1447	1461	1474
13.0	1330	1343	1357	1370	1383	1397	1410	1423	1436	1450	1463
13.1	1321	1334	1347	1360	1373	1387	1400	1413	1426	1439	1453
13.2	1312	1325	1338	1351	1364	1377	1390	1403	1416	1429	1443
13.3	1302	1315	1328	1341	1354	1367	1380	1393	1406	1419	1432
13.4	1293	1305	1318	1331	1344	1357	1370	1383	1396	1409	1422
13.5	1284	1297	1310	1323	1335	1348	1361	1374	1387	1400	1412
13.6	1275	1287	1300	1313	1326	1338	1351	1364	1377	1389	1402
13.7	1266	1278	1291	1303	1316	1329	1341	1354	1367	1379	1392
13.8	1257	1269	1282	1294	1307	1319	1332	1344	1357	1370	1382
13.9	1249	1261	1273	1286	1298	1311	1323	1336	1348	1361	1373
14.0	1240	1252	1265	1277	1290	1302	1314	1327	1339	1352	1364
14.1	1232	1244	1257	1269	1281	1294	1306	1318	1331	1343	1355
14.2	1224	1236	1248	1261	1273	1285	1297	1310	1322	1334	1346
14.3	1216	1228	1240	1252	1264	1277	1289	1301	1313	1325	1338
14.4	1208	1220	1232	1244	1256	1268	1280	1293	1305	1317	1329
14.5	1200	1211	1223	1285	1247	1259	1271	1283	1295	1307	1319
14.6	1192	1204	1216	1228	1240	1252	1264	1275	1287	1299	1311
14.7	1184	1196	1208	1220	1231	1243	1255	1267	1279	1291	1303
14.8	1176	1188	1200	1211	1223	1235	1247	1258	1270	1282	1294
14.9	1170	1181	1193	1205	1216	1228	1240	1251	1263	1275	1286
15.0	1162	1176	1185	1197	1200	1220	1232	1243	1255	1267	1278

TABLE 17—Continued

Derivation

The flue gas is assumed to contain 80.5% nitrogen and no carbon monoxide. The specific heat is taken as 0.24.

Let a = % CO_2 in flue gas
b = % oxygen in flue gas
c = % nitrogen in flue gas (80.5)
W = lbs. of dry flue gas per lb. of carbon burned
L = B. T. U. lost in dry flue gas, per lb. of carbon burned
L′ = B. T. U. lost in dry flue gas, per lb. of coal burned

$$\text{Then } W = \frac{11a + 8b + 7c}{3a}$$

$$L = 0.24\, W\, (T - t)$$

$$L' = .57\, L$$

TABLE 18

"MOISTURE FACTOR" FOR COMPUTING LOSS OF HEAT IN FLUE GAS DUE TO MOISTURE

Based on Coal Containing 6% Hydrogen

If F = moisture factor as found in this table, F′ = temperature factor as found in Table 18-A, A = B. T. U. in coal as fired, and L_2 = total loss of heat due to moisture,

$$L_2 = \frac{F \times F'}{A}$$

% MOISTURE IN COAL	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
10	64.0	64.1	64.2	64.3	64.4	64.5	64.6	64.7	64.8	64.9
11	65.0	65.1	65.2	65.3	65.4	65.5	65.6	65.7	65.8	65.9
12	66.0	66.1	66.2	66.3	66.4	66.5	66.6	66.6	66.8	66.9
13	67.0	67.1	67.2	67.3	67.4	67.5	67.6	67.7	67.8	67.9
14	68.0	68.1	68.2	68.2	68.4	68.5	68.6	68.7	68.8	68.9
15	69.0	69.1	69.2	69.3	69.4	69.5	69.6	69.7	69.8	69.9
16	70.0	70.1	70.2	70.3	70.4	70.5	70.6	70.7	70.8	70.9
17	71.0	71.1	71.2	71.3	71.4	71.5	71.6	71.7	71.8	71.9
18	72.0	72.1	72.2	72.3	72.4	72.5	72.6	72.7	72.8	72.9
19	73.0	73.1	73.2	73.3	73.4	73.5	73.6	73.7	73.8	73.9
20	74.0	74.1	74.2	74.3	74.4	74.5	74.6	74.7	74.8	74.9
21	75.0	75.1	75.2	75.3	75.4	75.5	75.6	75.7	75.8	75.9
22	76.0	76.1	76.2	76.3	76.4	76.5	76.6	76.7	76.8	76.9
23	77.0	77.1	77.2	77.3	77.4	77.5	77.6	77.7	77.8	77.9
24	78.0	78.1	78.2	78.3	78.4	78.5	78.6	78.7	78.8	78.9
25	79.0	79.1	79.2	79.3	79.4	79.5	79.6	79.7	79.8	79.9

Derivation

Let M = moisture in coal
H = hydrogen in coal
F = moisture factor

$$\text{Then } F = M + 9\,H = M + 54$$

TABLE 18-A

"TEMPERATURE FACTOR" FOR COMPUTING LOSS OF HEAT IN FLUE GAS DUE TO MOISTURE,

Based on boiling point of water of 202° F. (at 5000 feet elevation)
The use of this factor is described in the explanation under Table 18.

TEMP. (°F.) OF FLUE GAS	TEMPERATURE (°F.) OF BOILER ROOM								TEMP. (°F.) OF FLUE GAS
	30	40	50	60	70	80	90	100	
330	1209	1199	1189	1179	1169	1159	1149	1139	330
340	1213	1203	1193	1183	1173	1163	1153	1143	340
350	1218	1208	1198	1188	1178	1168	1158	1148	350
360	1223	1213	1203	1193	1183	1173	1163	1153	360
370	1228	1218	1208	1198	1188	1178	1168	1158	370
380	1232	1222	1212	1202	1192	1182	1172	1162	380
390	1237	1227	1217	1207	1197	1187	1177	1167	390
400	1242	1232	1222	1212	1202	1192	1182	1172	400
410	1246	1236	1226	1216	1206	1196	1186	1176	410
420	1251	1241	1231	1221	1211	1201	1191	1181	420
430	1256	1246	1236	1226	1216	1206	1196	1186	430
440	1260	1250	1240	1230	1220	1210	1200	1190	440
450	1265	1255	1245	1235	1225	1215	1205	1195	450
460	1270	1260	1250	1240	1230	1220	1210	1200	460
470	1275	1265	1255	1245	1235	1225	1215	1205	470
480	1279	1269	1259	1249	1239	1229	1219	1209	480
490	1284	1274	1264	1254	1244	1234	1224	1214	490
500	1289	1279	1269	1259	1249	1239	1229	1219	500
510	1293	1283	1273	1263	1253	1243	1233	1223	510
520	1298	1288	1278	1268	1258	1248	1238	1228	520
530	1303	1293	1283	1273	1263	1253	1243	1233	530
540	1307	1297	1287	1277	1267	1257	1247	1237	540
550	1312	1302	1292	1282	1272	1262	1252	1242	550
560	1317	1307	1297	1287	1277	1267	1257	1247	560
570	1322	1312	1302	1292	1282	1272	1262	1252	570
580	1326	1316	1306	1296	1286	1276	1266	1256	580
590	1331	1321	1311	1301	1291	1281	1271	1261	590
600	1336	1326	1316	1306	1296	1286	1276	1266	600
610	1340	1330	1320	1310	1300	1290	1280	1270	610
620	1345	1335	1325	1315	1305	1295	1285	1275	620
630	1350	1340	1330	1320	1310	1300	1290	1280	630
640	1354	1344	1334	1324	1314	1304	1294	1284	640
650	1359	1349	1339	1329	1319	1309	1299	1289	650
	30	40	50	60	70	80	90	100	

Derivation

If T = temp. (°F.) of flue gas, t = temp. (°F.) of boiler room, w = boiling point of water (202° F. at 5000 feet elevation), and F′ = factor in table,

Then $F' = (w - t) + 976.6 + .47\ (T - w)$

TABLE 19

CaO IN MILK OF LIME OF VARIOUS DENSITIES (15°C.)

Blattner's Table

Milk of lime made up with sweet water will show only about 85 per cent. of the CaO given by this table.

Degrees Brix	Specific Gravity	Grams CaO per Liter	% CaO by Weight	Degrees Brix	Specific Gravity	Grams CaO per Liter	% CaO by Weight
25	1.107	135	12.2	36	1.160	203	17.5
26	1.111	141	12.6	37	1.165	209	17.9
27	1.116	147	13.2	38	1.170	215	18.4
28	1.120	153	13.7	39	1.175	221	18.8
29	1.125	159	14.1	40	1.180	228	19.3
30	1.130	165	14.6	41	1.185	235	19.8
31	1.135	171	15.1	42	1.190	242	20.3
32	1.140	177	15.5	43	1.195	248	20.8
33	1.145	183	16.0	44	1.200	255	21.3
34	1.150	189	16.4	45	1.205	262	21.7
35	1.155	195	16.9	46	1.210	269	22.2

TABLE 20

EQUIVALENTS OF NORMAL SOLUTIONS

SUBSTANCE	FORMULA	MOLECULAR OR ATOMIC WEIGHT	NORMAL COEFFICIENTS	
			g per Liter	1 ml = g
Ammonia	NH_3	17.032	17.032	.01703
Ammonium sulphocyanate	NH_4CNS	76.113	76.113	.07611
Arsenious oxide	As_2O_3	197.92	*49.48	*.04948
Barium hydroxide	$Ba(OH)_2.8H_2O$	315.514	157.757	.15776
Benzoic acid	$C_6H_5CO_2H$	122.083	122.083	.12208
Calcium	Ca	40.07	20.035	.02003
Calcium carbonate	$CaCO_3$	100.075	50.037	.05004
Calcium oxide	CaO	56.07	28.035	.02803
Chlorine	Cl	35.46	35.46	.03546
Copper	Cu	63.57	31.785	.03178
Hydrochloric acid	HCl	36.468	36.468	.03647
Iodine	I	126.92	126.92	.12692
Nitric acid	HNO_3	63.016	63.016	.06202
Potassium permanganate	$KMnO_4$	158.03	*31.606	*.03151
Potassium sulphocyanate	KCNS	97.173	97.173	.09717
Silver nitrate	$AgNO_3$	169.888	169.888	.16989
Sodium carbonate	Na_2CO_3	106.005	53.002	.05300
Sodium chloride	NaCl	58.46	58.46	.05846
Sodium hydroxide	NaOH	40.008	40.008	.04001
Sodium oxalate	$Na_2C_2O_4$	134.01	*67.005	*.06700
Sodium thiosulphate	$Na_2S_2O_3.5H_2O$	248.20	*248.20	*.24820
Sulphuric acid	H_2SO_4	98.076	49.038	.04904

*As oxidizing or reducing agent.

TABLE 21

PERCENTAGE OF AVAILABLE GRANULATED ON DRY SUBSTANCE OF SUGAR SOLUTIONS (MOLASSES PURITY OF 60)

Purity	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Purity
60	0.0	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	60
61	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75	61
62	5.0	5.25	5.5	5.75	6.0	6.25	6.5	6.75	7.0	7.25	62
63	7.5	7.75	8.0	8.25	8.5	8.75	9.0	9.25	9.5	9.75	63
64	10.0	10.25	10.5	10.75	11.0	11.25	11.5	11.75	12.0	12.25	64
65	12.5	12.75	13.0	13.25	13.5	13.75	14.0	14.25	14.5	14.75	65
66	15.0	15.25	15.5	15.75	16.0	16.25	16.5	16.75	17.0	17.25	66
67	17.5	17.75	18.0	18.25	18.5	18.75	19.0	19.25	19.5	19.75	67
68	20.0	20.25	20.5	20.75	21.0	21.25	21.5	21.75	22.0	22.25	68
69	22.5	22.75	23.0	23.25	23.5	23.75	24.0	24.25	24.5	24.75	69
70	25.0	25.25	25.5	25.75	26.0	26.25	26.5	26.75	27.0	27.25	70
71	27.5	27.75	28.0	28.25	28.5	28.75	29.0	29.25	29.5	29.75	71
72	30.0	30.25	30.5	30.75	31.0	31.25	31.5	31.75	32.0	32.25	72
73	32.5	32.75	33.0	33.25	33.5	33.75	34.0	34.25	34.5	34.75	73
74	35.0	35.25	35.5	35.75	36.0	36.25	36.5	36.75	37.0	37.25	74
75	37.5	37.75	38.0	38.25	38.5	38.75	39.0	39.25	39.5	39.75	75
76	40.0	40.25	40.5	40.75	41.0	41.25	41.5	41.75	42.0	42.25	76
77	42.5	42.75	43.0	43.25	43.5	43.75	44.0	44.25	44.5	44.75	77
78	45.0	45.25	45.5	45.75	46.0	46.25	46.5	46.75	47.0	47.25	78
79	47.5	47.75	48.0	48.25	48.5	48.75	49.0	49.25	49.5	49.75	79
80	50.0	50.25	50.5	50.75	51.0	51.25	51.5	51.75	52.0	52.25	80
81	52.5	52.75	53.0	53.25	53.5	53.75	54.0	54.25	54.5	54.75	81
82	55.0	55.25	55.5	55.75	56.0	56.25	56.5	56.75	57.0	57.25	82
83	57.5	57.75	58.0	58.25	58.5	58.75	59.0	59.25	59.5	59.75	83
84	60.0	60.25	60.5	60.75	61.0	61.25	61.5	61.75	62.0	62.25	84
85	62.5	62.75	63.0	63.25	63.5	63.75	64.0	64.25	64.5	64.75	85
86	65.0	65.25	65.5	65.75	66.0	66.25	66.5	66.75	67.0	67.25	86
87	67.5	67.75	68.0	68.25	68.5	68.75	69.0	69.25	69.5	69.75	87
88	70.0	70.25	70.5	70.75	71.0	71.25	71.5	71.75	72.0	72.25	88
89	72.5	72.75	73.0	73.25	73.5	73.75	74.0	74.25	74.5	74.75	89
90	75.0	75.25	75.5	75.75	76.0	76.25	76.5	76.75	77.0	77.25	90
91	77.5	77.75	78.0	78.25	78.5	78.75	79.0	79.25	79.5	79.75	91
92	80.0	80.25	80.5	80.75	81.0	81.25	81.5	81.75	82.0	82.25	92
93	82.5	82.75	83.0	83.25	83.5	83.75	84.0	84.25	84.5	84.75	93
94	85.0	85.25	85.5	85.75	86.0	86.25	86.5	86.75	87.0	87.25	94
95	87.5	87.75	88.0	88.25	88.5	88.75	89.0	89.25	89.5	89.75	95
96	90.0	90.25	90.5	90.75	91.0	91.25	91.5	91.75	92.0	92.25	96
97	92.5	92.75	93.0	93.25	93.5	93.75	94.0	94.25	94.5	94.75	97
98	95.0	95.25	95.5	95.75	96.0	96.25	96.5	96.75	97.0	97.25	98
99	97.5	97.75	98.0	98.25	98.5	98.75	99.0	99.25	99.5	99.75	99
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	

DERIVATION:—If P = purity and F = granulated factor, F = 2.5 (P − 60).

TABLE 22

PERCENTAGE OF AVAILABLE GRANULATED ON TOTAL SUGAR OF SUGAR SOLUTIONS (MOLASSES PURITY OF 60)

This table should not be confused with Table 21, which is the one mostly employed in taking stock. Table 22 is intended for use where the polarization and purity of a product are known. E. g., if a lot of 10,000 lbs. of raw sugar has a polarization of 96.7 and a purity of 97.1, the amount of sugar in the raw sugar is 10,000×96.7÷100=9670 lbs. The factor corresponding to 97.1 in Table 22 is 95.52. The "available granulated" is then, 9670×95.52÷100=9237 lbs.

Purity	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Purity
60	0.00	0.42	0.83	1.25	1.66	2.07	2.48	2.88	3.29	3.69	60
61	4.10	4.50	4.90	5.30	5.70	6.10	6.49	6.89	7.28	7.67	61
62	8.06	8.45	8.84	9.23	9.62	10.00	10.38	10.77	11.15	11.53	62
63	11.90	12.28	12.66	13.03	13.41	13.78	14.15	14.52	14.89	15.26	63
64	15.62	15.99	16.36	16.72	17.08	17.44	17.80	18.16	18.52	18.88	64
65	19.23	19.59	19.94	20.29	20.64	20.99	21.34	21.69	22.04	22.38	65
66	22.73	23.07	23.41	23.76	24.10	24.44	24.77	25.11	25.45	25.79	66
67	26.12	26.45	26.79	27.12	27.45	27.78	28.11	28.43	28.76	29.09	67
68	29.41	29.74	30.06	30.38	30.70	31.02	31.34	31.66	31.98	32.29	68
69	32.61	32.92	33.24	33.55	33.86	34.17	34.48	34.79	35.10	35.41	69
70	35.71	36.02	36.32	36.63	36.93	37.23	37.54	37.84	38.14	38.43	70
71	38.73	39.03	39.33	39.62	39.92	40.21	40.50	40.79	41.09	41.38	71
72	41.67	41.96	42.24	42.53	42.82	43.10	43.39	33.67	43.96	44.24	72
73	44.52	44.80	45.08	45.36	45.64	45.92	46.20	46.47	46.75	47.02	73
74	47.30	47.57	47.84	48.12	48.39	48.66	48.93	49.20	49.47	49.73	74
75	50.00	50.27	50.53	50.80	51.06	51.32	51.59	51.85	52.11	52.37	75
76	52.63	52.89	53.15	53.41	53.66	53.92	54.18	54.43	54.69	54.94	76
77	55.19	55.45	55.70	55.95	56.20	56.45	56.70	56.95	57.20	57.45	77
78	57.69	57.94	58.18	58.43	58.67	58.92	59.16	59.40	59.64	59.89	78
79	60.13	60.37	60.61	60.85	61.08	61.32	61.56	61.79	62.03	62.27	79
80	62.50	62.73	62.97	63.20	63.43	63.66	63.90	64.13	64.36	64.59	80
81	64.81	65.04	65.27	65.50	65.72	65.95	66.18	66.40	66.63	66.85	81
82	67.07	67.30	67.52	67.74	67.96	68.18	68.40	68.62	68.84	69.06	82
83	69.28	69.49	69.71	69.93	70.14	70.36	70.57	70.79	71.00	71.22	83
84	71.43	71.64	71.85	72.06	72.27	72.49	72.70	72.90	73.11	73.32	84
85	73.53	73.74	73.94	74.15	74.36	74.56	74.77	74.97	75.17	75.38	85
86	75.58	75.78	75.99	76.19	76.39	76.59	76.79	76.99	77.19	77.39	86
87	77.59	77.78	77.98	78.18	78.38	78.57	78.77	78.96	79.16	79.35	87
88	79.55	79.74	79.93	80.12	80.32	80.51	80.70	80.89	81.08	81.27	88
89	81.46	81.65	81.84	82.03	82.21	82.40	82.59	82.78	82.96	83.15	89
90	83.33	83.52	83.70	83.89	84.07	84.25	84.44	84.62	84.80	84.98	90
91	85.16	85.35	85.53	85.71	85.89	86.07	86.24	86.42	86.60	86.78	91
92	86.96	87.13	87.31	87.49	87.66	87.84	88.01	88.19	88.36	88.54	92
93	88.71	88.88	89.06	89.23	89.40	89.57	89.74	89.91	90.09	90.26	93
94	90.43	90.60	90.76	90.93	91.10	91.27	91.44	91.61	91.77	91.94	94
95	92.11	92.27	92.44	92.60	92.77	92.93	93.10	93.26	93.42	93.59	95
96	93.75	93.91	94.07	94.24	94.40	94.56	94.72	94.88	95.04	95.20	96
97	95.36	95.52	95.68	95.84	96.00	96.15	96.31	96.47	96.63	96.78	97
98	96.94	97.09	97.25	97.41	97.56	97.72	97.87	98.02	98.18	98.33	98
99	98.48	98.64	98.79	98.94	99.09	99.25	99.40	99.55	99.70	99.85	99
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	

DERIVATION:—If P = purity and F′ = granulated factor, $F' = \frac{250\ (P-60)}{P}$

TABLE 23

STANDARD BEET EXTRACTION

Based on 0.60% total losses on beets, 40% elimination, and 57 apparent purity of molasses.

Cossette Pur.	% SUGAR IN COSSETTES										Cossette Pur.
	13.0	13.2	13.4	13.6	13.8	14.0	14.2	14.4	14.6	14.8	
79.0	75.22	75.27	75.32	75.38	75.42	75.48	75.52	75.57	75.62	75.67	79.0
79.1	75.35	75.41	75.45	75.52	75.56	75.61	75.66	75.71	75.76	75.80	79.1
79.2	75.47	75.52	75.57	75.63	75.68	75.73	75.77	75.82	75.88	75.92	79.2
79.3	75.59	75.64	75.69	75.76	75.80	75.85	75.91	75.95	76.00	76.04	79.3
79.4	75.71	75.76	75.80	75.87	75.92	75.97	76.02	76.06	76.12	76.16	79.4
79.5	75.84	75.89	75.94	76.00	76.05	76.10	76.16	76.19	76.25	76.29	79.5
79.6	75.95	76.00	76.04	76.11	76.16	76.21	76.26	76.30	76.35	76.40	79.6
79.7	76.06	76.11	76.16	76.22	76.27	76.32	76.37	76.41	76.47	76.51	79.7
79.8	76.18	76.24	76.28	76.35	76.40	76.45	76.50	76.54	76.60	76.64	79.8
79.9	76.32	76.37	76.42	76.48	76.53	76.58	76.64	76.67	76.73	76.77	79.9
80.0	76.43	76.48	76.53	76.60	76.64	76.70	76.75	76.79	76.85	76.88	80.0
80.1	76.55	76.60	76.64	76.71	76.76	76.81	76.87	76.90	76.96	77.00	80.1
80.2	76.66	76.71	76.76	76.83	76.88	76.93	76.98	77.02	77.08	77.12	80.2
80.3	76.78	76.84	76.88	76.95	77.00	77.05	77.09	77.13	77.20	77.24	80.3
80.4	76.90	76.95	77.01	77.07	77.12	77.17	77.22	77.25	77.32	77.36	80.4
80.5	77.01	77.07	77.12	77.18	77.24	77.28	77.33	77.38	77.43	77.48	80.5
80.6	77.13	77.18	77.25	77.29	77.35	77.39	77.45	77.50	77.54	77.59	80.6
80.7	77.24	77.30	77.36	77.41	77.46	77.51	77.56	77.61	77.66	77.71	80.7
80.8	77.37	77.42	77.47	77.52	77.58	77.63	77.68	77.72	77.77	77.82	80.8
80.9	77.48	77.53	77.59	77.64	77.69	77.74	77.79	77.84	77.89	77.94	80.9
81.0	77.60	77.65	77.70	77.75	77.81	77.86	77.91	77.96	78.00	78.05	81.0
81.1	77.71	77.76	77.82	77.87	77.92	77.97	78.02	78.07	78.12	78.17	81.1
81.2	77.82	77.88	77.93	77.98	78.04	78.09	78.14	78.19	78.23	78.28	81.2
81.3	77.95	78.00	78.06	78.11	78.16	78.21	78.26	78.31	78.36	78.41	81.3
81.4	78.05	78.11	78.16	78.21	78.27	78.32	78.37	78.42	78.46	78.51	81.4
81.5	78.17	78.22	78.28	78.33	78.38	78.43	78.48	78.53	78.58	78.63	81.5
81.6	78.28	78.34	78.39	78.44	78.50	78.55	78.60	78.65	78.69	78.75	81.6
81.7	78.40	78.45	78.51	78.55	78.61	78.66	78.71	78.76	78.81	78.86	81.7
81.8	78.51	78.56	78.62	78.67	78.73	78.78	78.83	78.88	78.93	78.98	81.8
81.9	78.63	78.68	78.74	78.78	78.84	78.89	78.94	78.99	79.04	79.09	81.9
82.0	78.74	78.79	78.85	78.90	78.96	79.01	79.06	79.01	79.16	79.20	82.0
82.1	78.85	78.91	78.96	79.01	79.07	79.12	79.17	79.22	79.27	79.32	82.1
82.2	78.97	79.02	79.08	79.13	79.19	79.24	79.28	79.34	79.39	79.44	82.2
82.3	79.08	79.14	79.19	79.24	79.30	79.35	79.40	79.45	79.50	79.55	82.3
82.4	79.20	79.25	79.31	79.36	79.42	79.47	79.52	79.57	79.62	79.67	82.4
82.5	79.30	79.36	79.41	79.46	79.52	79.57	79.62	79.67	79.72	79.77	82.5
82.6	79.42	79.47	79.53	79.59	79.64	79.69	79.74	79.79	79.84	79.89	82.6
82.7	79.52	79.58	79.64	79.68	79.77	79.82	79.87	79.92	79.97	80.02	82.7
82.8	79.65	79.70	79.76	79.81	79.87	79.92	79.97	80.02	80.07	80.12	82.8
82.9	79.75	79.81	79.86	79.91	79.97	80.02	80.07	80.12	80.17	80.22	82.9
	13.0	13.2	13.4	13.6	13.8	14.0	14.2	14.4	14.6	14.8	

TABLE 23—Continued

STANDARD BEET EXTRACTION

Cossette Pur	% SUGAR IN COSSETTES										Cossette Pur.
	15.0	15.2	15.4	15.6	15.8	16.0	16.2	16.4	16.6	16.8	
79.0	75.71	75.75	75.78	75.82	75.86	75.90	75.93	75.97	76.01	76.04	79.0
79.1	75.84	75.88	75.92	75.96	76.00	76.04	76.07	76.11	76.15	76.18	79.1
79.2	75.96	75.99	76.02	76.07	76.11	76.15	76.18	76.22	76.26	76.30	79.2
79.3	76.08	76.12	76.16	76.20	76.24	76.28	76.31	76.35	76.39	76.42	79.3
79.4	76.20	76.23	76.27	76.31	76.35	76.39	76.43	76.47	76.50	76.54	79.4
79.5	76.33	76.37	76.41	76.45	76.49	76.53	76.56	76.60	76.63	76.67	79.5
79.6	76.44	76.48	76.51	76.55	76.59	76.63	76.67	76.71	76.74	76.78	79.6
79.7	76.55	76.59	76.63	76.67	76.70	76.75	76.78	76.82	76.86	76.89	79.7
79.8	76.68	76.72	76.76	76.80	76.83	76.88	76.91	76.95	76.98	77.02	79.8
79.9	76.81	76.85	76.88	76.93	76.97	77.01	77.04	77.08	77.12	77.15	79.9
80.0	76.92	76.96	77.00	77.04	77.09	77.13	77.16	77.20	77.24	77.27	80.0
80.1	77.04	77.08	77.12	77.16	77.20	77.24	77.27	77.31	77.35	77.38	80.1
80.2	77.16	77.20	77.24	77.28	77.32	77.36	77.40	77.43	77.47	77.51	80.2
80.3	77.28	77.32	77.36	77.40	77.44	77.48	77.51	77.55	77.58	77.62	80.3
80.4	77.40	77.44	77.48	77.52	77.57	77.61	77.64	77.67	77.71	77.75	80.4
80.5	77.52	77.56	77.60	77.64	77.68	77.72	77.75	77.78	77.82	77.87	80.5
80.6	77.63	77.67	77.71	77.75	77.79	77.84	77.87	77.90	77.95	77.98	80.6
80.7	77.75	77.79	77.83	77.87	77.91	77.95	77.98	78.02	78.07	78.10	80.7
80.8	77.85	77.90	77.94	77.99	78.03	78.07	78.11	78.14	78.18	78.21	80.8
80.9	77.98	78.02	78.06	78.10	78.14	78.19	78.23	78.26	78.30	78.33	80.9
81.0	78.09	78.13	78.18	78.22	78.26	78.30	78.34	78.37	78.41	78.44	81.0
81.1	78.21	78.25	78.29	78.33	78.37	78.41	78.46	78.49	78.53	78.56	81.1
81.2	78.32	78.37	78.41	78.45	78.49	78.53	78.57	78.60	78.64	78.68	81.2
81.3	78.45	78.49	78.53	78.57	78.61	78.65	78.69	78.73	78.76	78.80	81.3
81.4	78.55	78.60	78.64	78.68	78.72	78.76	78.80	78.84	78.87	78.91	81.4
81.5	78.64	78.69	78.73	78.77	78.81	78.85	78.89	78.92	78.97	79.02	81.5
81.6	78.79	78.83	78.87	78.91	78.95	78.99	79.03	79.06	79.10	79.14	81.6
81.7	78.90	78.94	78.98	79.02	79.06	79.11	79.15	79.18	79.22	79.25	81.7
81.8	79.02	79.06	79.10	79.14	79.18	79.22	79.27	79.30	79.34	79.37	81.8
81.9	79.13	79.17	79.21	79.25	79.29	79.34	79.38	79.41	79.44	79.49	81.9
82.0	79.25	79.29	79.33	79.37	79.41	79.46	79.49	79.53	79.56	79.60	82.0
82.1	79.36	79.40	79.44	79.49	79.54	79.59	79.63	79.64	79.69	79.72	82.1
82.2	79.48	79.52	79.56	79.60	79.64	79.69	79.73	79.76	79.79	79.83	82.2
82.3	79.59	79.63	79.67	79.72	79.77	79.81	79.85	79.88	79.91	79.95	82.3
82.4	79.71	79.75	79.79	79.83	79.87	79.91	79.95	79.99	80.02	80.06	82.4
82.5	79.81	79.85	79.89	79.94	79.99	80.03	80.07	80.10	80.14	80.17	82.5
82.6	79.93	79.97	80.01	80.05	80.10	80.14	80.18	80.21	80.25	80.29	82.6
82.7	80.03	80.07	80.12	80.16	80.20	80.24	80.29	80.32	80.36	80.39	82.7
82.8	80.16	80.20	80.24	80.28	80.32	80.37	80.41	80.44	80.48	80.52	82.8
82.9	80.26	80.31	80.35	80.39	80.43	80.47	80.52	80.55	80.59	80.62	82.9
	15.0	15.2	15.4	15.6	15.8	16.0	16.2	16.4	16.6	16.8	

TABLE 23—Continued

STANDARD BEET EXTRACTION

Cos-sette Pur.	% SUGAR IN COSSETTES										Cos-sette Pur.
	13.0	13.2	13.4	13.6	13.8	14.0	14.2	14.4	14.6	14.8	
83.0	79.85	79.90	79.96	80.01	80.06	80.12	80.17	80.22	80.27	80.32	83.0
83.1	79.94	79.99	80.06	80.10	80.15	80.20	80.26	80.31	80.36	80.41	83.1
83.2	80.08	80.13	80.19	80.24	80.29	80.35	80.40	80.45	80.50	80.55	83.2
83.3	80.18	80.23	80.29	80.34	80.39	80.45	80.50	80.55	80.60	80.65	83.3
83.4	80.30	80.35	80.41	80.45	80.49	80.57	80.62	80.67	80.72	80.77	83.4
83.5	80.41	80.46	80.52	80.57	80.62	80.68	80.73	80.78	80.83	80.88	83.5
83.6	80.51	80.57	80.63	80.68	80.73	80.79	80.84	80.89	80.94	80.99	83.6
83.7	80.63	80.68	80.74	80.79	80.84	80.90	80.95	81.00	81.05	81.10	83.7
83.8	80.74	80.80	80.86	80.91	80.95	81.02	81.07	81.12	81.17	81.22	83.8
83.9	80.84	80.88	80.95	80.99	81.04	81.10	81.15	81.20	81.26	81.31	83.9
84.0	80.93	80.99	81.05	81.10	81.15	81.21	81.26	81.31	81.36	81.41	84.0
84.1	81.05	81.10	81.16	81.21	81.26	81.32	81.37	81.42	81.47	81.53	84.1
84.2	81.16	81.22	81.28	81.33	81.38	81.42	81.49	81.54	81.59	81.64	84.2
84.3	81.27	81.32	81.35	81.43	81.47	81.52	81.57	81.65	81.70	81.75	84.3
84.4	81.36	81.42	81.48	81.53	81.59	81.64	81.69	81.74	81.79	81.85	84.4
84.5	81.48	81.53	81.59	81.64	81.70	81.75	81.80	81.85	81.90	81.95	84.5
84.6	81.58	81.64	81.70	81.75	81.81	81.86	81.91	81.96	82.01	82.06	84.6
84.7	81.70	81.75	81.81	81.86	81.92	81.97	82.03	82.08	82.13	82.18	84.7
84.8	81.80	81.85	81.92	81.97	82.03	82.08	82.13	82.18	82.23	82.28	84.8
84.9	81.91	81.96	82.02	82.07	82.13	82.18	82.24	82.29	82.34	82.39	84.9
85.0	82.00	82.06	82.12	82.17	82.23	82.28	82.33	82.38	82.43	82.48	85.0
85.1	82.11	82.16	82.22	82.27	82.33	82.39	82.44	82.49	82.54	82.59	85.1
85.2	82.22	82.28	82.34	82.39	82.45	82.50	82.55	82.60	82.66	82.71	85.2
85.3	82.33	82.38	82.44	82.49	82.55	82.60	82.65	82.70	82.75	82.80	85.3
85.4	82.43	82.49	82.55	82.60	82.65	82.71	82.76	82.81	82.86	82.91	85.4
85.5	82.53	82.58	82.64	82.69	82.75	82.80	82.85	82.91	82.96	83.01	85.5
85.6	82.63	82.69	82.75	82.80	82.86	82.91	82.96	83.02	83.07	83.12	85.6
85.7	82.74	82.79	82.88	82.90	82.96	83.02	83.07	83.12	83.17	82.23	85.7
85.8	82.84	82.89	82.96	83.01	83.07	83.12	83.17	83.23	83.28	83.33	85.8
85.9	82.94	82.99	83.05	83.10	83.17	83.20	83.27	83.32	83.37	83.43	85.9
86.0	83.03	83.09	83.15	83.20	83.21	83.32	83.37	83.42	83.47	83.52	86.0
86.1	83.16	83.21	83.27	83.32	83.39	83.44	83.49	83.54	83.59	83.65	86.1
86.2	83.26	83.32	83.38	83.43	83.49	83.54	83.59	83.65	83.70	83.75	86.2
86.3	83.35	83.40	83.46	83.52	83.58	83.63	83.68	83.73	83.78	83.84	86.3
86.4	83.45	83.51	83.57	83.62	83.68	83.73	83.78	83.83	83.89	83.95	86.4
86.5	83.57	83.62	83.68	83.74	83.80	83.85	83.90	83.95	84.01	84.06	86.5
86.6	83.65	83.71	83.77	83.82	83.88	83.94	83.99	84.04	84.09	84.15	86.6
86.7	83.76	83.81	83.87	83.93	83.99	84.04	84.09	84.15	84.20	84.25	86.7
86.8	83.86	83.92	83.98	84.03	84.09	84.15	84.19	84.25	84.30	84.35	86.8
86.9	83.96	84.01	84.07	84.13	84.19	84.24	84.29	84.35	84.40	84.45	86.9
	13.0	13.2	13.4	13.6	13.8	14.0	14.2	14.4	14.6	14.8	

TABLE 23—Continued
STANDARD BEET EXTRACTION

Cos-sette Pur.	% SUGAR IN COSSETTES										Cos-sette Pur.
	15.0	15.2	15.4	15.6	15.8	16.0	16.2	16.4	16.6	16.8	
83.0	80.36	80.40	80.44	80.49	80.54	80.58	80.63	80.67	80.69	80.72	83.0
83.1	80.46	80.50	80.54	80.58	80.63	80.67	80.71	80.74	80.79	80.82	83.1
83.2	80.59	80.63	80.67	80.72	80.76	80.80	80.84	80.88	80.92	80.95	83.2
83.3	80.70	80.74	80.78	80.82	80.86	80.91	80.95	80.98	81.03	81.07	83.3
83.4	80.80	80.85	80.89	80.94	80.99	81.03	81.07	81.10	81.14	81.18	83.4
83.5	80.93	80.97	81.01	81.05	81.09	81.14	81.18	81.21	81.26	81.30	83.5
83.6	81.03	81.07	81.12	81.16	81.20	81.24	81.28	81.31	81.36	81.40	83.6
83.7	81.15	81.19	81.23	81.27	81.32	81.37	81.41	81.44	81.48	81.52	83.7
83.8	81.26	81.30	81.35	81.39	81.44	81.48	81.52	81.55	81.59	81.63	83.8
83.9	81.35	81.39	81.43	81.48	81.53	81.57	81.61	81.64	81.68	81.71	83.9
84.0	81.46	81.50	81.54	81.58	81.62	81.67	81.71	81.74	81.79	81.82	84.0
84.1	81.57	81.61	81.65	81.70	81.75	81.78	81.81	81.85	81.89	81.93	84.1
84.2	81.68	81.73	81.77	81.81	81.85	81.90	81.94	81.98	82.02	82.06	84.2
84.3	81.79	81.83	81.87	81.91	81.95	82.00	82.04	82.08	82.12	82.16	84.3
84.4	81.88	81.93	81.97	82.02	82.06	82.10	82.15	82.18	82.22	82.25	84.4
84.5	82.00	82.04	82.09	82.14	82.18	82.22	82.26	82.30	82.34	82.37	84.5
84.6	82.11	82.16	82.21	82.26	82.29	82.32	82.36	82.40	82.44	82.48	84.6
84.7	82.23	82.27	82.31	82.36	82.39	82.44	82.49	82.53	82.57	82.59	84.7
84.8	82.33	82.38	82.42	82.47	82.51	82.55	82.59	82.63	82.65	82.70	84.8
84.9	82.43	82.48	82.52	82.56	82.60	82.65	82.69	82.73	82.77	82.81	84.9
85.0	82.53	82.57	82.62	82.66	82.70	82.75	82.79	82.83	82.87	82.91	85.0
85.1	82.63	82.68	82.72	82.77	82.81	82.86	82.91	82.95	82.98	83.03	85.1
85.2	82.75	82.79	82.84	82.89	82.93	82.97	83.01	83.04	83.08	83.12	85.2
85.3	82.86	82.91	82.95	82.99	83.03	83.08	83.11	83.15	83.19	83.25	85.3
85.4	82.96	83.00	83.05	83.09	83.13	83.18	83.23	83.26	83.30	83.34	85.4
85.5	83.06	83.11	83.15	83.19	83.23	83.28	83.32	83.35	83.39	83.43	85.5
85.6	83.17	83.21	83.25	83.30	83.34	83.38	83.42	83.45	83.49	83.54	85.6
85.7	83.28	83.33	83.38	83.41	83.46	83.50	83.53	83.57	83.61	83.65	85.7
85.8	83.37	83.42	83.46	83.50	83.55	83.59	83.64	83.67	83.71	83.75	85.8
85.9	83.48	83.53	83.57	83.61	83.65	83.69	83.74	83.77	83.81	83.85	85.9
86.0	83.57	83.61	83.65	83.70	83.74	83.78	83.83	83.86	83.90	83.94	86.0
86.1	83.70	83.75	83.79	83.83	83.88	83.92	83.97	84.00	84.04	84.08	86.1
86.2	83.80	83.84	83.88	83.93	83.97	84.02	84.06	84.10	84.14	84.17	86.2
86.3	83.89	83.94	83.98	84.02	84.07	84.11	84.15	84.18	84.23	84.27	86.3
86.4	83.99	84.03	84.08	84.13	84.17	84.21	84.25	84.28	84.32	84.36	86.4
86.5	84.10	84.15	84.19	84.24	84.28	84.33	84.37	84.40	84.44	84.48	86.5
86.6	84.20	84.25	84.30	84.34	84.39	84.43	84.46	84.49	84.53	84.58	86.6
86.7	84.30	84.35	84.39	84.43	84.47	84.51	84.55	84.59	84.64	84.68	86.7
86.8	84.40	84.45	84.49	84.53	84.58	84.62	84.66	84.70	84.74	84.78	86.8
86.9	84.50	84.54	84.59	84.63	84.68	84.72	84.76	84.80	84.84	84.88	86.9
	15.0	15.2	15.4	15.6	15.8	16.0	16.2	16.4	16.6	16.8	

Derivation

Let S = % sugar in cossettes, P = apparent purity of cossettes, and X = standard extraction. Also let J = apparent purity of purified juice. and G = granulated factor, % on sugar.

$$\text{Then } J = \frac{100\,P}{.4P + 60} \qquad G = \frac{10{,}000\,(J - 57)}{43\,J} \qquad X = \frac{G\;(S - .60)}{S}$$

TABLE 24
STANDARD STEFFEN EXTRACTION

Based on 58 true purity of "molasses produced from Steffen," and a total loss of 5.25% of the original sugar in the molasses worked.

True Pur. of Perf. Washed Cake	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	True Pur. of Perf. Washed Cake
80	62.04	62.24	62.45	62.65	62.85	63.05	63.26	63.46	63.66	63.86	80
81	64.06	64.26	64.46	64.66	64.85	65.05	65.25	65.44	65.64	65.83	81
82	66.03	66.22	66.42	66.61	66.80	67.00	67.19	67.38	67.57	67.76	82
83	67.95	68.13	68.33	68.53	68.71	68.89	69.08	69.27	69.46	69.64	83
84	69.84	70.01	70.20	70.38	70.57	70.75	70.93	71.11	71.30	71.48	84
85	71.67	71.84	72.02	72.20	72.38	72.56	72.74	72.91	73.10	73.26	85
86	73.45	73.62	73.80	73.98	74.15	74.33	74.50	74.67	74.85	75.02	86
87	75.20	75.37	75.54	75.71	75.89	76.06	76.23	76.40	76.57	76.73	87
88	76.91	77.08	77.24	77.41	77.58	77.75	77.91	78.08	78.25	78.41	88
89	78.58	78.75	78.91	79.07	79.24	79.40	79.56	79.72	79.89	80.04	89
90	80.21	80.38	80.53	80.70	80.85	81.01	81.17	81.34	81.49	81.64	90
91	81.81	81.97	82.12	82.29	82.44	82.59	82.75	82.91	83.06	83.22	91
92	83.38	83.52	83.68	83.83	83.99	84.14	84.29	84.45	84.60	84.75	92
93	84.90	85.05	85.20	85.36	85.50	85.65	85.80	85.95	86.10	86.25	93
94	86.40	86.54	86.69	86.84	86.99	87.13	87.28	87.42	87.57	87.72	94
95	87.86	88.01	88.15	88.30	88.44	88.58	88.73	88.87	89.01	89.16	95
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	

Derivation

Let W = true purity of perfectly washed cake
Y = standard Steffen extraction

$$\text{Then } Y = \frac{9475\ (W-58)}{42\ W} = \frac{225.6\ (W-58)}{W}$$

TABLE 25
SPECIFIC GRAVITY OF VARIOUS MATERIALS

	WEIGHT IN POUNDS OF ONE CUBIC FT.
Beets	40–42
Beet pulp, fresh	37–40
Beet pulp, fermented	40–50
Coal (Colorado lignite)	50–52
Coke	27
Lime, burned	50–60
Limestone	90
Molasses	90
Sugar, raw	50–55
Sugar, white	55

	TRUE SP. GR.
Sugar	1.591
Lime, burned	2.30–4.20
Limestone, usually	2.65–2.70

TABLE 26

INTERNATIONAL ATOMIC WEIGHTS, 1920

	Symbol	Atomic Weight		Symbol	Atomic Weight
Aluminum	Al	27.1	Molybdenum	Mo	96.0
Antimony	Sb	120.2	Neodymium	Nd	144.3
Argon	A	39.9	Neon	Ne	20.2
Arsenic	As	74.96	Nickel	Ni	58.68
Barium	Ba	137.37	Niton (radium emanation)	Nt	222.4
Bismuth	Bi	208.0	Nitrogen	N	14.008
Boron	B	10.9	Osmium	Os	190.9
Bromine	Br	79.92	Oxygen	O	16.00
Cadmium	Cd	112.40	Palladium	Pd	106.7
Caesium	Cs	132.81	Phosphorus	P	31.04
Calcium	Ca	40.07	Platinum	Pt	195.2
Carbon	C	12.005	Potassium	K	39.10
Cerium	Ce	140.25	Praseodymium	Pr	140.9
Chlorine	Cl	35.46	Radium	Ra	226.0
Chromium	Cr	52.0	Rhodium	Rh	102.9
Cobalt	Co	58.97	Rubidium	Rb	85.45
Columbium	Cb	93.1	Ruthenium	Ru	101.7
Copper	Cu	63.57	Samarium	Sa	150.4
Dysprosium	Dy	162.5	Scandium	Sc	44.1
Erbium	Er	167.7	Selenium	Se	79.2
Europium	Eu	152.0	Silicon	Si	28.3
Fluorine	F	19.0	Silver	Ag	107.88
Gadolinium	Gd	157.3	Sodium	Na	23.00
Gallium	Ga	70.1	Strontium	Sr	87.63
Germanium	Ge	72.5	Sulfur	S	32.06
Glucinum	Gl	9.1	Tantalum	Ta	181.5
Gold	Au	197.2	Tellurium	Te	127.5
Helium	He	4.00	Terbium	Tb	159.2
Holmium	Ho	163.5	Thallium	Tl	204.0
Hydrogen	H	1.008	Thorium	Th	232.15
Indium	In	114.8	Thulium	Tm	168.5
Iodine	I	126.92	Tin	Sn	118.7
Iridium	Ir	193.1	Titanium	Ti	48.1
Iron	Fe	55.84	Tungsten	W	184.0
Krypton	Kr	82.92	Uranium	U	238.2
Lanthanum	La	139.0	Vanadium	V	51.0
Lead	Pb	207.20	Xenon	Xe	130.2
Lithium	Li	6.94	Ytterbium (Neoytterbium)	Yb	173.5
Lutecium	Lu	175.0	Yttrium	Yt	89.33
Magnesium	Mg	24.32	Zinc	Zn	65.37
Manganese	Mn	54.93	Zirconium	Zr	90.6
Mercury	Hg	200.6			

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