TABLE I—VALUES OBTAINED BY EXPERIMENT

No.	Specific gravity before distillation	Temperature during gravity determination	Per cent alcohol before distillation	Specific gravity of residue	Temperature during gravity determination	Per cent alcohol in residue	Average per cent alcohol in liquid	Specific gravity of distillate	Temperature during gravity determination	Per cent alcohol in distillate	Observed temperature of distillation	Barometer reading mm.	Barometer correction in boiling point	Room temperature	Correction for exposed mercury column	Corrected boiling point
1.....	0.815	20	91.1	0.812	23	91.1	91.1	0.811	22	91.8	77.2	750	0.4	23	0.6	78.2
2.....	0.822	22	87.7	0.821	23	87.7	87.7	0.815	23	90.0	77.2	750	0.4	22	0.6	78.2
3.....	0.829	23	84.6	0.829	23	84.6	84.6	0.819	22	89.6	77.4	750	0.4	22	0.6	78.4
4.....	0.836	24	81.5	0.838	22	81.5	81.5	0.823	22	88.0	77.6	748	0.5	22	0.6	78.7
5.....	0.845	22	78.7	0.843	25	78.8	78.8	0.825	22	86.5	77.7	743	0.7	22	0.6	79.0
6.....	0.852	22	75.8	0.851	23	75.8	75.8	0.827	22	85.8	77.8	740	0.8	22	0.6	79.2
7.....	0.857	24	72.9	0.860	21	72.9	72.9	0.829	23	84.6	78.1	741	0.8	22	0.6	79.5
8.....	0.864	23	70.4	0.866	23	69.6	70.0	0.832	22	83.8	78.4	741	0.8	23	0.6	79.8
9.....	0.873	21	67.5	0.873	21	67.5	67.5	0.833	20	84.2	78.6	743	0.7	21	0.6	79.9
10.....	0.879	21	65.0	0.880	21	64.6	64.8	0.835	20	83.5	78.9	743	0.7	21	0.6	80.2
11.....	0.884	21	62.7	0.885	23	61.4	62.0	0.838	19	82.7	79.1	743	0.7	21	0.6	80.4
12.....	0.891	22	59.2	0.893	20	59.2	59.2	0.839	20	81.9	79.5	750	0.4	21	0.6	80.5
13.....	0.898	20	57.1	0.899	21	57.5	57.3	0.839	21	81.5	79.6	750	0.4	21	0.6	80.6
14.....	0.904	21	54.1	0.904	23	53.2	53.6	0.839	23	80.8	80.2	757	0.1	23	0.6	80.9
15.....	0.908	23	51.4	0.910	22	51.0	51.2	0.840	21	81.2	80.3	756	0.2	22	0.6	81.1
16.....	0.915	22	48.6	0.916	22	48.2	48.4	0.842	21	80.4	80.5	756	0.2	22	0.6	81.4
17.....	0.920	22	46.4	0.923	22	45.0	45.7	0.843	20	80.4	80.8	756	0.2	22	0.6	81.7
18.....	0.926	23	43.8	0.928	22	42.5	43.1	0.844	21	79.6	81.0	756	0.2	22	0.6	81.8
19.....	0.933	22	40.5	0.932	25	40.0	40.2	0.845	20	79.6	81.2	755	0.2	19	0.6	82.0
20.....	0.936	24	38.0	0.938	23	37.5	37.7	0.848	19	78.8	81.5	755	0.2	20	0.6	82.3
21.....	0.940	24	36.0	0.942	23	35.5	35.7	0.846	20	79.2	81.6	755	0.2	20	0.7	82.5
22.....	0.945	23	33.9	0.947	22	33.3	33.6	0.849	19	78.3	82.0	755	0.2	20	0.7	82.9
23.....	0.949	23	31.7	0.950	23	31.1	31.4	0.851	20	77.1	82.4	755	0.2	21	0.7	83.3
24.....	0.952	24	30.0	0.955	23	28.1	29.0	0.853	20	76.2	82.7	756	0.2	21	0.7	83.6
25.....	0.956	23	27.5	0.956	25	26.9	27.2	0.853	21	75.8	82.5	748	0.5	20	0.7	84.0
26.....	0.958	24	26.2	0.961	22	24.7	25.4	0.856	22	74.2	83.4	748	0.5	22	0.8	84.7
27.....	0.962	23	23.7	0.964	23	22.3	23.0	0.858	19	73.7	83.7	750	0.4	21	0.8	84.9
28.....	0.965	23	21.7	0.966	23	21.0	21.3	0.859	20	73.7	84.3	750	0.4	21	0.8	85.7
29.....	0.966	23	21.0	0.969	23	18.9	19.9	0.860	22	72.5	84.8	747	0.5	22	0.8	86.1
30.....	0.970	23	17.9	0.972	22	16.7	17.3	0.866	22	70.0	85.5	745	0.6	23	0.8	86.9
31.....	0.973	22	15.8	0.974	24	14.4	15.1	0.865	23	70.0	86.2	747	0.5	23	0.8	87.5
32.....	0.975	24	13.3	0.977	25	12.3	12.8	0.873	23	66.7	86.9	756	0.6	24	0.9	88.4
33.....	0.977	25	12.3	0.979	25	11.0	11.6	0.882	24	62.5	88.1	748	0.5	25	0.9	89.5
34.....	0.980	22	11.0	0.982	23	9.3	10.1	0.891	21	60.0	89.1	750	0.4	22	0.9	90.3
35.....	0.982	23	11.0	0.984	24	7.9	9.4	0.901	20	55.8	90.1	750	0.4	22	0.9	91.4
36.....	0.985	22	7.9	0.987	22	6.4	7.1	0.910	22	51.4	91.1	750	0.4	22	0.9	92.4
37.....	0.987	22	6.4	0.989	20	5.0	5.7	0.919	22	46.8	92.2	750	0.4	23	0.9	93.5
38.....	0.990	21	4.4	0.991	23	3.9	4.1	0.927	22	43.7	93.1	747	0.5	21	0.9	94.7
39.....	0.991	23	3.9	0.992	24	2.8	3.3	0.947	21	33.5	94.3	747	0.5	22	0.9	95.7
40.....	0.992	24	2.8	0.994	22	2.2	2.5	0.953	21	30.6	95.2	747	0.5	22	0.9	96.6
41.....	0.995	22	1.7	0.996	21	1.1	1.4	0.964	21	23.6	96.0	747	0.5	22	0.9	97.4
42.....	0.996	22	1.1	0.996	23	0.9	1.0	0.972	22	16.7	96.8	751	0.4	22	0.9	98.1
43(a).....	0.998	25	—0.5	0.999	22	—0.3	—0.4	0.999	21	—0.1	98.7	753	0.3	22	0.9	99.9

(a) This experiment was with water only.

densing point and the composition of the liquid and vapor phases are shown clearly by the plot in Fig. I. A convenient table of results estimated from the curves appears in Table II, which enables one to determine quickly the approximate concentration of any alcohol-water mixture by observation of its boiling point, with corrections for barometric pressure and exposed mercury column. It is also possible to tell the approximate composition of both liquid and vapor (or distillate) at any moment during the distillation of a

TABLE II—VALUES ESTIMATED FROM CURVES IN FIG. I

Boiling point °C.	Weight per cent alcohol in liquid vapor	Boiling point °C.	Weight per cent alcohol in liquid vapor	Boiling point °C.	Weight per cent alcohol in liquid vapor
78.2	91	82.0	41	91.5	8
78.4	85	82.5	36	92.0	8
78.6	82	83.0	33	92.5	7
78.8	80	83.5	30	93.0	6
79.0	78	84.0	27	93.5	6
79.2	76	84.5	25	94.0	5
79.4	74	85.0	23	94.5	5
79.6	72	85.5	21	95.0	4
79.8	69	86.0	20	95.5	4
80.0	67	86.5	18	96.0	3
80.2	64	87.0	17	96.5	3
80.4	62	87.5	16	97.0	2
80.6	59	88.0	15	97.5	2
80.8	56	88.5	13	98.0	1
81.0	53	89.0	12	98.5	1
81.2	50	89.5	11	99.0	0
81.4	47	90.0	10	99.5	0
81.6	45	90.5	10	100.0	0
81.8	43	91.0	9		

mixture. The accuracy is, of course, less than by the usual and more difficult analytical method of distillation and the determination of the gravity of the distillate with a pycnometer.

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A RAPID PYCNOMETRIC METHOD FOR "GRAVITY SOLIDS" IN CANE-SUGAR FACTORIES

By HERBERT S. WALKER

Received September 13, 1915

Since the introduction into sugar factory control by Deerr¹ of the terms "gravity purity" and "gravity solids," and his demonstration that the determination of total solids by the Brix spindle, while not absolutely accurate except in pure sucrose solutions, when applied to juices, sugars, and molasses at approximately the same dilution (about 15° Brix) yielded, in consequence of consistent error, results fully as valuable for factory control work as the more tedious process of drying to more or less constant weight, this latter method has been entirely abandoned in many factories.

The principal objection to the substitution of densimetric for direct drying methods has been the lack of even relative accuracy in Brix spindle readings; this, as regards accuracy of reading the graduations on the stem of the spindle, has been somewhat improved by several devices suggested in recent years, but there still remain certain inherent errors in the method, due to variable viscosity and surface tension of liquids, which are very difficult to eliminate.

The pycnometer is generally conceded to be an exceedingly accurate means of determining specific gravities, but has thus far found little favor in cane-

¹ Bull. 41, Agr. and Chem. Series, H. S. P. A. Expt. Station.

sugar factories, owing probably to real or fancied difficulty of manipulation and to the extra calculation involved. By means of a few simple modifications, however, a pycnometer determination may be made almost as easily as an ordinary Brix test, and with no calculation other than looking up the Brix in a specific gravity table.

A 100 cc. pycnometer with ground-in thermometer and capillary side arm is used; since all determinations are made at room temperature, the cap of the side arm is thrown away and the arm itself cut off two or three millimeters above the graduation mark, thus facilitating rapid filling to a definite volume.

All calculations could be eliminated by making a pycnometer to contain exactly 100 g. water at a given standard temperature, such as 17.5°, 20°, 27.5° (weighed in air), or 4° (weighed in vacuum), according to the tables one intends to use. The weight of the liquid in the pycnometer would then be 100 times its density as compared with water at that temperature, and if a tare were made to just balance the empty pycnometer, then the weights required to balance the pycnometer filled with sugar solution would indicate the density of that solution without calculation; Brix could then be obtained from the tables, applying the same correction used for Brix spindles in case the determination were not made at exactly standard temperature.

It is, unfortunately, difficult to obtain a pycnometer of exactly a desired capacity; one a little too large may be reduced by grinding in the thermometer with emery powder, a rather tedious though not difficult process; but a bottle of too small capacity is difficult to enlarge with accuracy.

In such cases it is easiest so to regulate the tare that the additional weights required to balance the pycnometer full of water at standard temperature shall be exactly 100 g., irrespective of the true volume of the pycnometer, *i. e.*, if pycnometer contains 101 g. water at standard temperature and weight of tare equals weight of pycnometer, then

$$\text{Pycnometer} + \text{water} = \text{tare} + 101 \text{ g.}$$

Increasing weight of tare by 1 g.,

$$\text{Pycnometer} + \text{water} = \text{tare} + 100 \text{ g.,}$$

and with pure water this pycnometer and tare will always indicate a density by direct weighing of 1.0000.

With dilute sugar solutions, a pycnometer as much as 1 cc. "off" in capacity will give densities with very little error, but when working with more concentrated solutions a small correction must be made to the observed weights, since the 1 cc. excess capacity which, in the case of pure water, was compensated for by the 1 g. heavier tare, will now weigh more than 1 g. In the above case of a 101 cc. pycnometer with tare adjusted for pure water, if it be used with a solution of 1.3000 density, the extra 1 cc. weighs of course 1.30 grams, while only 1 g. has been compensated for by the excess weight of tare.

Knowing the capacity of a pycnometer, it is a simple matter to make a table of corrections to be applied at different densities. Such a table for a pycnometer

containing 101 cc. (a cc. here being considered to be the volume occupied by 1 g. of water at the temperature taken as a standard for the density tables it is desired to use) would be as follows:

Weights used—grams....	100	101	105	110	120	130
Cor. to wts. (subtract)....	0.00	0.01	0.05	0.10	0.20	0.30 g.

According to the amount of change in tare needed to give a weight of 100 g. with pure water, a table such as the above can be easily constructed for any pycnometer; thus, if it contain 100.30 g. water at standard temperature, make tare equal weight of pycnometer + 0.30 g., and the correction table for different densities is the one given above multiplied by 0.30. The following is an example of pycnometer calibration:

Weight of Pycnometer.....	47.40 grams
Weight of Pycnometer + water at 29° C.....	146.93
Weight of water.....	99.53 grams

Assuming that this pycnometer is to be used with 17.5°/17.5° tables, and that the average temperature at which it is to be used approximates that of calibration, the change of volume due to expansion of glass may be neglected and the weight of water contained at 17.5° (or its volume in terms of "17.5° cc.") may be considered to be $99.53 \times (\text{density aq. } 17.5^\circ \div \text{density aq. } 29^\circ)$ or $99.53 \times (0.99872/0.99598) = 99.80$. If a tare is then made to equal weight of pycnometer *minus* 0.20 g., or 47.20 g., the weights needed to balance pycnometer full of water at 17.5° will be 100 g., thus giving density direct. The correction for densities greater than 1.0000 will be:

Weights used....	100	101	105	110	115	120	125	130 g.
Correction (add)....	0.00	0.002	0.01	0.02	0.03	0.04	0.05	0.06 g.

After looking up the Brix corresponding to any density, the customary Brix correction for temperature of observation must of course be made.

In case the laboratory temperature prevailing were as high as that just noted, it would perhaps be more convenient to use tables calculated for 17.5°/27.5°, in which case the calculation of tare and correction table would be the following:

Weight water content at 27.5° = $99.53 \times (0.99641/0.99598) = 99.57 \text{ g.}$								
Weight tare should be $47.40 - 0.43 = 46.97 \text{ g.}$								
Wts. used....	100	101	102	105	110	115	120	125 130 g.
Cor. (add)....	0.00	0.004	0.009	0.02	0.04	0.06	0.09	0.11 0.13 g.

Where it is desired to use a pycnometer for juices or solutions of always the same approximate density, the correction for this density may be incorporated in the tare. In case the above pycnometer were to be used solely with solutions of about 15° Brix or 1.06 density, the correction could be added automatically by making tare 0.02 g. *lighter* than for pure water, *i. e.*, 46.95 g. instead of 46.97 g. Densities around 15° Brix would then be obtained by direct weighing, with absolutely no correction other than that for temperature subsequently applied to the Brix reading.

The calibration of a new pycnometer, including adjustment of a tare (best made from a small bottle weighted with shot) and construction of a correction table, can easily be done in less than an hour; the calibration of a new Brix spindle at three points on the stem, which is just as necessary, takes considerably more time than this.

An ordinary determination of density of a juice or diluted molasses consists simply of filling the pycnometer to the mark and weighing the centigrams on any ordinary sugar balance, which requires from 3 to 5 minutes, hardly more time than is needed for an accurate determination by means of the Brix spindle.

As regards accuracy, an error of more than 0.01 gram in weighing is unusual; this, at 15° Brix, corresponds to 0.023° Brix, or about one-fourth the average error in reading a Brix spindle.

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SEED ANALYSIS

By NAHUM E. KATZ

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The chemical analysis of cotton seed is of interest and value to oil mill operators only when accompanied by a table showing the available yield of products that may be expected from each ton of seed.

The following formulae are offered as a method for calculating the theoretical yield of products per ton of seed, based on the results of a chemical analysis of the seed. As the derivation of the formulae is rather lengthy, it is omitted.

Let a = per cent kernels in whole seed
 b = lbs. in whole seed
 f = per cent oil in whole seed
 g = per cent ammonia in whole seed
 l = per cent oil lost in the hulls, as made in the mill, due to imperfect separation
 p = lbs. of oil left in cake
 L = lbs. of lint removed in delinting
 V = lbs. of waste due to mott, dirt, loss in moisture, etc.
 A = per cent ammonia desired in the cake
 0.2 per cent be assumed to be the average per cent of oil naturally found in the hulls as made in the mill
 0.3 per cent be assumed to be the average per cent of ammonia naturally found in the hulls as made in the mill
 r = lbs. of hulls, which are necessary to mix with the kernels in order to dilute the cake to the desired per cent of ammonia
 z = per cent of r in the uncooked and unextracted meats.

H = lbs. of hulls to be made to the ton of seed
 O = lbs. of oil to be pressed out per ton of seed
 C = lbs. of cake to be made to the ton of seed

Then:

$$H = \frac{A(2000 - 20f + p + 0.04b - 1.002L) - 2000g}{1.002A - l(0.01A - 0.01) - g/a(3.33l - 0.67) - 0.3} \left(1 - \frac{V}{2000 - L}\right)$$

$$O = \left[(20f - 0.04b - p + 0.002L) \left(1 - \frac{V}{2000 - L}\right)\right] - H(0.01l - 0.002)$$

$$C = 2000 - (H + O + L + V)$$

$$r = b \left(20 - \frac{V}{100}\right) - L - H(1.0067 - 0.0333l)$$

$$z = \frac{100r}{2000 - V - L - H}$$

C may also be calculated by the formula

$$C = \left[(2000 - 20f + p + 0.04b - 1.002L) \left(1 - \frac{V}{2000 - L}\right)\right] - H(1.002 - 0.01l)$$

If it be agreed to consider the numerical values 0.7 per cent for l , 75 lbs. for L , and 57 lbs. for p , as standard values, then the above given formulae may be considerably simplified. They then appear as follows:

$$H = \frac{A(1981.85 - 20f + 0.04b) - 2000g}{0.995A - 1.66g/a - 0.3} \left(1 - \frac{V}{1925}\right)$$

$$O = \left[(20f - 0.04b - 56.85) \left(1 - \frac{V}{1925}\right)\right] - 0.005H$$

$$C = 1925 - (H + O + V)$$

or $C = \left[(1981.85 - 20f + 0.04b) \left(1 - \frac{V}{1925}\right)\right] - 0.995H$

$$r = b \left(20 - \frac{V}{100}\right) - 75 - 0.983H$$

$$z = \frac{100r}{1925 - H - V}$$

The formulae for r and z are especially valuable to the superintendent. Knowing the percentage of hulls which should be mixed with the kernels, and comparing it with the percentage obtained by an actual test on the meats, he is enabled to tell whether the proportions of kernels and hulls in the meats are correct or not, before the meats are carried to the crushing rolls.

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ADDRESSES

THE USE OF DIAGRAMS IN CHEMICAL CALCULATIONS

By HORACE G. DEMING

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The use of charts or diagrams for the solution of arithmetical problems is well known to the engineering profession, and several books have been written on the subject.¹ Thus we have the graphical representation of forces and moments, Kutter's formula for the flow of water, indicator diagrams for steam engines, and vector diagrams for the diagrammatic representation or graphical solution of problems in alternating current theory. In metallurgy we have diagrams for the representation of the composition of slags; in chemistry the familiar rectangular and triangular diagrams for the representation of the phase relations between the members of two-component and three-component systems; and, in chemical technology, diagrams for the calculation of mixtures for the manufacture of cement.

In spite of such scattering instances of the use of graphical

methods in industrial chemistry, it appears that chemists do not in general take advantage of the really remarkable opportunities that the use of diagrams presents for the quick solution of chemical problems met in every-day work; and but little systematic study of the possibilities of the graphical method in chemistry has ever been published.¹ The diagrams that are here presented are selected from among a large number devised by the writer with a view to illustrating some of the principal computations that may be solved by graphical means; they indicate at the same time what a great variety of problems are susceptible to such treatment, and what diverse types of diagrams may be used. It is hoped that those presented may suggest others better adapted to the individual needs of the readers of THIS JOURNAL; for this reason it will be necessary to mention the mathematical principles on which the construction of the different types of charts is based; but, since we are concerned rather with general principles than with details of execution, we can do no more than refer to many interesting charts that differ from those here given in but a few particulars.

¹ d'Ocagne, "Traité de Nomographie," Paris: Gauthier-Villars; Peddle, "The Construction of Graphical Charts," New York: The McGraw-Hill Book Co.; Turner, "Graphical Methods in Applied Mathematics," London: Macmillan and Co.

¹ But see a series of articles by Nickel, *Z. physik. Chem.*, Vols. 10 to 14. Of somewhat different scope is Kremann, "Leitfaden der graphischen Chemie," Berlin: Geb. Borntraeger, 1910.