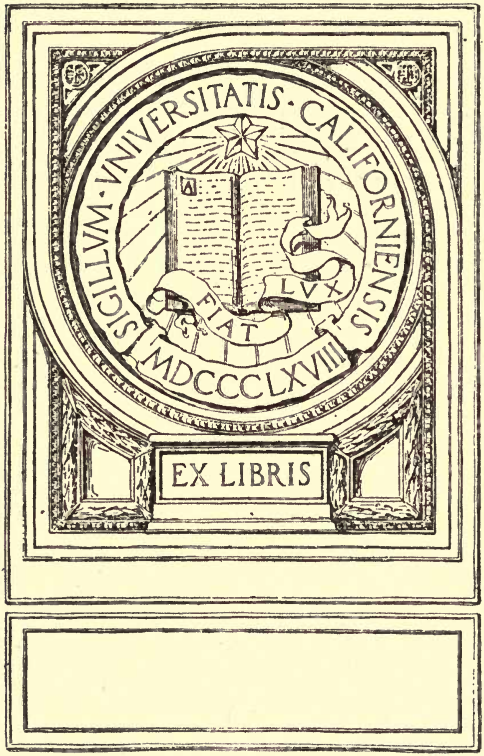
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SULPHURIC ACID HANDBOOK

SULPHURIC ACID HANDBOOK

BY

THOMAS J. SULLIVAN

WITH THE MINERAL POINT ZINC COMPANY, A SUBSIDIARY OF THE NEW JERSEY ZINC COMPANY

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PREFACE

As sulphuric acid is one of the most important of chemicals, being an intermediate raw product, essential in most manufacturing processes, I think the appearance of this handbook dealing solely with sulphuric acid is well justified. In fact, in almost every industry some sulphuric acid is used and it has been asserted that the consumption of sulphuric acid by any nation is a measure of its degree of industrial progress. This is certainly not strictly correct, but sulphuric acid forms the starting point of, and is used in so many industries that there is considerable element of truth in this statement. A few examples showing some of its important uses follows:

(*a*) For decomposing salts with the production of nitric acid, hydrochloric acid and sodium sulphate, thus indirectly in the manufacture of soda ash, soap, glass, bleaching powder, etc.

(*b*) For the purification of most kinds of oil, including petroleum and tar oils.

(*c*) For pickling (*i.e.*, cleaning) iron goods previous to tinning or galvanizing.

(*d*) As a drying agent in the production of organic dyes, on which the textile industry depends to a large extent.

(*e*) For rendering soluble mineral and animal phosphate (superphosphate) for manures; thus agriculture absorbs large amounts, and consequently food stuffs are affected by fluctuations in the supply of this important chemical.

(*f*) For the manufacture of nitric acid from Chile saltpetre: nitric acid and sulphuric acid together are used in the nitration of organic substances such as glycerine and cellulose forming nitro-glycerine and nitro-cellulose mainly used in the manufacture of explosives now in great demand. So, a copious supply of sulphuric acid is an absolute necessity for the explosive industry and any shortage in this supply would mean a shortage of explosives.

Without multiplying examples of this nature, enough has been said to indicate the complexity of modern industrial conditions, the interaction of one industry on the other, and finally the often obscure, but highly important, part played by sulphuric acid as an ultimate and absolutely essential raw material of these industries.

Owing to the enormous amount of literature containing data on sulphuric acid, it has become more and more difficult for the busy worker to gather from this mass of literature, the facts which are of practical interest and use to him. Much valuable material is of little use because it is scattered through the literature and is therefore inaccessible.

The publication of this handbook was undertaken as an attempt to overcome this difficulty, at least in part. The scope has been limited almost entirely to numerical data, inasmuch as such data cannot generally be carried in mind, but must be readily accessible for use. The special investigator would probably always prefer to go to the original source for the information he wishes, so, to republish all matter of this kind would be unnecessary and impracticable. The attempt has been made to select and tabulate only that which is of fairly general interest and utility and produce a convenient reference book of numerical data.

In collecting the tables only those generally adapted to American practice have been selected. When specific gravity is given in terms of the Baumé degrees, the so-called American Standard has been adhered to. Where a different Baumé scale has been used in a table, the figures have been recalculated to conform to the American Standard. Almost all of the tables of Bineau, Kolb, Otto, Winkler, Messel, Knietsch, Pickering, Lunge, Isler, Naef, etc., have been omitted as they have long since become obsolete as far as being of practical value for use in general American practice. All molecular weights as well as the factors for the calculation of analytical results have been calculated from the International Atomic Weights of 1917 (1918). The molecular weights and other figures have been carried out further beyond the decimal point than is necessary for most calculations.

Great care and pains have been taken to secure accuracy and completeness of data. All figures have been calculated several times, and it is hoped that the errors have been reduced to the minimum. However, errors have undoubtedly crept in, and the author would greatly appreciate notations of any of these which may come to the reader's attention, with a view to their correction in later reprints or editions of the book.

A large amount of time and labor was involved in the preparation of these tables, inasmuch as it was necessary to collect data from many widely scattered sources. The scope of the first issue, therefore, is rather more limited than originally planned, but if the demand for the publication justifies it, the scope will be extended in future issues.

The author wishes to express his appreciation to the many friends who assisted in checking problems, reading the manuscript and proof, and giving much valuable criticism and advice.

THOMAS J. SULLIVAN.

DE PUE, ILL.
March 1, 1918.

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International Atomic Weights, 1917[1]

	Symbol	Atomic weight		Symbol	Atomic weight
Aluminum	Al	27.1	Neodymium	Nd	144.3
Antimony	Sb	120.2	Neon	Ne	20.2
Argon	A	39.88	Nickel	Ni	58.68
Arsenic	As	74.96	Niton (radium emanation)	Nt	222.4
Barium	Ba	137.37	Nitrogen	N	14.01
Bismuth	Bi	208.0	Osmium	Os	190.9
Boron	B	11.0	Oxygen	O	16.00
Bromine	Br	79.92	Palladium	Pd	106.7
Cadmium	Cd	112.40	Phosphorus	P	31.04
Cæsium	Cs	132.81	Platinum	Pt	195.2
Calcium	Ca	40.07	Potassium	K	39.10
Carbon	C	12.005	Praseodymium	Pr	140.9
Cerium	Ce	140.25	Radium	Ra	226.0
Chlorine	Cl	35.46	Rhodium	Rh	102.9
Chromium	Cr	52.0	Rubidium	Rb	85.45
Cobalt	Co	58.97	Ruthenium	Ru	101.7
Columbium	Cb	93.1	Samarium	Sa	150.4
Copper	Cu	63.57	Scandium	Sc	44.1
Dysprosium	Dy	162.5	Selenium	Se	79.2
Erbium	Er	167.7	Silicon	Si	28.3
Europium	Eu	152.0	Silver	Ag	107.88
Fluorine	F	19.0	Sodium	Na	23.00
Gadolinium	Gd	157.3	Strontium	Sr	87.63
Gallium	Ga	69.9	Sulphur	S	32.06
Germanium	Ge	72.5	Tantalum	Ta	181.5
Glucinum	Gl	9.1	Tellurium	Te	127.5
Gold	Au	197.2	Terbium	Tb	159.2
Helium	He	4.00	Thallium	Tl	204.0
Holmium	Ho	163.5	Thorium	Th	232.4
Hydrogen	H	1.008	Thulium	Tm	168.5
Indium	In	114.8	Tin	Sn	118.7
Iodine	I	126.92	Titanium	Ti	48.1
Iridium	Ir	193.1	Tungsten	W	184.0
Iron	Fe	55.84	Uranium	U	238.2
Krypton	Kr	82.92	Vanadium	V	51.0
Lanthanum	La	139.0	Xenon	Xe	130.2
Lead	Pb	207.20	Ytterbium (Neoytterbium)	Yb	173.5
Lithium	Li	6.94	Yttrium	Yt	88.7
Lutecium	Lu	175.0	Zinc	Zn	65.37
Magnesium	Mg	24.32	Zirconium	Zr	90.6
Manganese	Mn	54.93			
Mercury	Hg	200.6			
Molybdenum	Mo	96.0			

[1] On account of the difficulties of correspondence between its members due to the war, the International Committee on Atomic Weights has decided to make no full report for 1918. Although a good number of new determinations have been published during the past year, none of them seem to demand any immediate change in the table for 1917. That table, therefore, may stand as official during the year 1918.—F. W. Clark, *Chairman.*

SULPHURIC ACID HANDBOOK

SPECIFIC GRAVITY

Definition of the Term "Specific Gravity of a Liquid"

The density of a liquid is defined as the weight of a unit volume.

The specific gravity, or the synonymous term, relative density, is the ratio of the density of the liquid in question, referred to the density of some substance which is taken as unity. The standard substance employed is water at its maximum density (4°C. or 39.2°F.).

More Common Methods of Determining the Specific Gravity of Liquids

1. Pycnometer.—Here we have vessels of unknown volume, but either having a mark on the neck, or having glass stopper with a capillary hole. Thus the pycnometers are made to hold constant volumes. Constant temperature is obtained by the aid of a bath of constant temperature. For use in a determination the pycnometer is weighed empty, filled with water, and filled with the liquid under consideration. The weight of the pycnometer full of water minus the weight of the empty pycnometer is equal to the weight of the water it will hold. This weight, compared to the weight of the liquid that the pycnometer will hold, gives us the specific gravity of the liquid.

2. Mohr, Westphal, Sartorius, Specific-gravity Balances.—In the balances the right-hand half of the beam is divided into ten equal parts from the fulcrum to the point of suspension at the end of the beam. Suspended from this end of the beam is the plummet while a weight at the other end acts as a counterbalance. When the plummet is immersed in water at 4°C., the equilibrium of the balance is destroyed by the buoyancy of the water. To adjust the equilibrium, a weight equal to this force and in grams equal to the weight of the volume of water displaced (which is equal to the volume of the plummet) is hung from the point of suspension. This weight is known as the unit weight and is called a rider. Other riders weighing respectively 0.1, 0.01, 0.001 of the weight of this rider constitute the set of weights used with these balances. With their aid the density of a liquid can be directly read off from the balance beam.

3. Hydrometers.—These instruments consist of a spindle-shaped float, with a cylindrical neck containing a scale. They are weighted at their lower end, thus bringing the center of gravity very far down, and insuring an upright position when floating. They depend upon the principle that a body will sink in a liquid until enough liquid has been displaced, so that the weight of the displaced liquid equals the weight of the body.

The weight and volume are so adjusted, that the instrument sinks to the lower mark on its neck in the heaviest liquid to be tested by it, and to the highest mark on its neck in the lightest liquid to be tested by it. As the density of a liquid changes with the temperature, the liquid should always be at the temperature at which the hydrometer was calibrated or proper correction made.

Corrections to be Applied in Specific Gravity Determinations

To obtain the true specific gravity of substances, their densities at 4°C., and *in vacuo*, must be compared with the density of water at 4°C., *in vacuo*.

For technical use, specific gravity is frequently determined at any convenient temperature, and referred to water, of either that same temperature, or to water at 4°C., the weight in air being taken as a basis.

In purely scientific calculations, water is taken as standard at 4°C., while in commercial laboratories the standard is often in the neighborhood of 15.56°C., consequently specific gravities determined by these standards do not agree. As the temperature of water increases from 4°C., it expands. The weight being constant, with increase of volume, the density is lowered. In the case of water this increase of volume with rise of temperature is not uniform, but has been determined with great care. Knowing the relative density of water at various temperatures, the volume of a gram is obtained by taking the reciprocal of the density. The expansion of liquids being appreciable, conditions should always be given with the specific gravities.

Thus $\frac{15°}{15°}$C. after the specific gravity figure, means that the temperature of the substance was 15°C. at the time of the determination and that the unit volume of it was compared with the weight of a unit volume of water at 15°C. Similarly $\frac{15°}{4°}$C. after the specific-gravity figure, means that here the comparison is made with the weight of a unit volume of substance at 15°C. compared with the weight of a unit volume of water at 4°C.

Conversion of Density Basis[1]

Prepared for use in reducing readings of a hydrometer graduated to indicate density or specific gravity at a specified standard temperature, T, referred to water at a specified temperature, T', as unity, to the basis of another standard temperature, t, and reference temperature, t'.

The factor Δ (given in units of the sixth decimal place), multiplied by the density or specific-gravity reading, gives the correction to be applied to the reading to reduce it to the required basis.

Suppose a hydrometer indicates specific gravity at $\frac{20°}{4°}$C., and it is required to know the correction in order that it shall indicate specific gravity at $\frac{15.56°}{15.56°}$C., then,

$$D\frac{15.56°}{15.56°} = D\frac{20°}{4°} + \Delta D\frac{20°}{4°}$$

That is, if the hydrometer indicates correctly a specific gravity of 1.5760 at $\frac{20°}{4°}$, then at $\frac{15.56°}{15.56°}$ the reading of the instrument will be too low by $1.5760 \times 0.001062 = 0.0017$. A correction of 0.0017 must, therefore, be added to the indication of the hydrometer.

Or, if a maker using standards indicating $D\frac{15.56°}{15.56°}$C. wishes to graduate a hydrometer to indicate density at 20°C. referred to water at 4°C. ($D\frac{20}{4}$), the readings of the standard must be corrected by use of the factor +0.001062.

Suppose the standard reads........................	1.5760
The corresponding correction is 1.6×0.001062 =...	+0.0017
Corrected reading..................................	1.5777

The table is calculated for Jena 16III glass.

[1] United States Bureau of Standards, *Circular* No. 19, 5th edition, March 30, 1916, p. 40.

Note: The Bureau of Standards for the sake of uniformity, use the same abbreviation, *D*, with proper temperature basis, for both density and specific gravity.

Given basis of density	Required basis of density $\frac{t}{t'}$									
	$D\frac{25°}{4°}$C.	$D\frac{20}{4}$	$D\frac{17.5}{4}$	$D\frac{15.56}{4}$	$D\frac{15}{4}$	$D\frac{15}{15}$	$D\frac{15.56}{15.56}$	$D\frac{17.5}{17.5}$	$D\frac{20}{20}$	$D\frac{25}{25}$
$\frac{T}{T'}$	Δ (in units of the sixth decimal place)									
$D\frac{25°}{4°}$C.	0	+115	+172	+217	+230	+1104	+1177	+1459	+1884	+2931
$D\frac{20}{4}$	−115	0	+58	+102	+115	+989	+1062	+1345	+1769	+2816
$D\frac{17.5}{4}$	−172	−58	0	+45	+58	+932	+1005	+1287	+1711	+2758
$D\frac{15.56}{4}$	−217	−102	−45	0	+13	+887	+960	+1242	+1667	+2713
$D\frac{15}{4}$	−230	−115	−58	−13	0	+874	+947	+1229	+1654	+2700
$D\frac{15}{15}$	−1103	−988	−931	−886	−873	0	+73	+354	+779	+1826
$D\frac{15.56}{15.56}$	−1176	−1061	−1004	−960	−947	−73	0	+281	+706	+1752
$D\frac{17.5}{17.5}$	−1457	−1343	−1285	−1240	−1227	−354	−281	0	+424	+1471
$D\frac{20}{20}$	−1881	−1766	−1708	−1664	−1651	−778	−705	−423	0	+1046
$D\frac{25}{25}$	−2923	−2808	−2751	−2707	−2694	−1821	−1748	−1468	−1044	0

HYDROMETERS

There are two types of hydrometers, namely, hydrometers proper, and hydrometers which are combined with thermometers, called thermo-hydrometers.

There are four classes of hydrometers:

1. Density hydrometers, indicating density of a specified liquid, at a specified temperature, in specified units.

2. Specific-gravity hydrometers, indicating the specific gravity or relative density of a specified liquid, at a specified temperature, in terms of water at a specified temperature as unity.

3. Per cent. hydrometers, indicating, at a specified temperature, the percentage of a substance in a mixture or solution.

4. Arbitrary scale hydrometers, concentration or strength of a specified liquid referred to an arbitrarily defined scale at a specified temperature (Baumé hydrometer, Twaddle hydrometer, etc.).

Manipulation of Hydrometers[1]

Hydrometers are seldom used for the greatest accuracy, as the usual conditions under which they are used preclude such special manipulation and exact observation as are necessary to obtain high precision. It is, nevertheless, important that they be accurately graduated to avoid as far as possible, the use of instrumental corrections, and to obtain this result it is necessary to employ certain precautions and methods in standardizing these instruments.

The methods of manipulation described below are, in general, the ones employed at this Bureau in testing hydrometers and should be followed by the maker or user to a degree depending on the accuracy required.

Observing.—The hydrometer should be clean, dry, and at the temperature of the liquid before immersing to make a reading.

The liquid in which the observation is made should be contained in a clear, smooth glass vessel of suitable size and shape.

[1] U. S. Bureau of Standards, *Circular* No. 16, 4th edition, Feb. 23, 1916.

By means of the stirrer which reaches to the bottom of the vessel, the liquid should be thoroughly mixed.

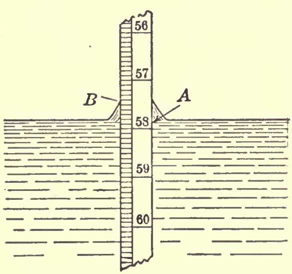
The hydrometer is slowly immersed in the liquid slightly beyond the point where it floats naturally and then allowed to float freely.

The scale reading should not be made until the liquid and hydrometer are free from air bubbles and at rest.

In reading the hydrometer scale the eye is placed slightly below the plane of the surface of the test liquid; it is raised slowly until the surface, seen as an ellipse, becomes a straight line. The point where this line cuts the hydrometer scale should be taken as the reading of the hydrometer.

In reading the thermometer scale, errors of parallax are avoided by so placing the eye that near the end of the mercury column the portions on either side of the stem and that seen through the capillary appear to lie in a straight line. The line of sight is then normal to the stem.

NOTE: According to the Bureau of Standards, then, the point *A* (see figure below) not the point *B* is the one to be noted as the reading.



Influence of Temperature.—In order that a hydrometer may correctly indicate the density or strength of a specified liquid, it is essential that the liquid be uniform throughout and at the standard temperature.

To insure uniformity in the liquid, stirring is required shortly before making the observation. This stirring should be complete and may be well accomplished by a perforated disk or spiral at the end of a rod long enough to reach the bottom of the vessel. Motion of this stirrer from top to bottom serves to disperse layers of the liquid of different density.

The liquid should be at nearly the temperature of the surrounding atmosphere, as otherwise its temperature will be changing during the observation, causing not only differences in density but also doubt as to the actual temperature. When the temperature at which the hydrometer is observed differs from the standard temperature of the instrument, the reading is not truly the density according to the basis of the instrument or the quality of the liquid according to per cent. or arbitrary scale, but a figure which differs from the normal reading by an amount depending on the difference in temperature and on the relative thermal expansions of the instrument and the particular liquid.

If the latter properties are known, tables of corrections for temperature may be prepared for use with hydrometers at various temperatures. Such tables 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.

Influence of Surface Tension.—Surface-tension effects on hydrometer observations are a consequence of the downward force exerted on the stem by the curved surface or meniscus, which rises about the stem, and affects the depth of immersion and consequent scale reading.

Because a hydrometer will indicate differently in two liquids having the same density but different surface tension, and since surface tension is a specific property of liquids, it is necessary to specify the liquid for which a hydrometer is intended.

Although hydrometers of equivalent dimensions may be compared, without error, in a liquid differing in surface tension from the specified liquid, comparisons of dissimilar instruments in such a liquid must be corrected for the effect of the surface tension.

In many liquids spontaneous changes in surface tension occur due to the formation of surface films of impurities, which may come from the apparatus, the liquid, or the air.

Errors from this cause are avoided either by the use of liquids not subject to such changes, which, however, require correction of the results by calculation, or by the purification of the surface by overflowing immediately before making the observation.

This latter method is employed at this Bureau for testing hydrometers in sulphuric-acid solutions and alcohol solutions, and is accomplished by causing the liquid to overflow from the part of the apparatus in which the hydrometer is immersed by a small rapidly rotating propeller which serves also to stir the liquid.

Cleanliness.—The accuracy of hydrometer observations depends, in many cases, upon the cleanliness of the instruments and of the liquids in which the observations are made.

In order that readings shall be uniform and reproducible, the surface of the hydrometers, and especially of the stem, must be clean, so that the liquid will rise uniformly and merge into an imperceptible film on the stem.

The readiness with which this condition is fulfilled depends somewhat upon the character of the liquid, certain liquids, such as mineral oils and strong alcoholic mixture, adhere to the stem very readily, while with weak aqueous solutions of sugar, salts, acids, and alcohol, scrupulous cleaning of the stem is required in order to secure the normal condition.

Before being tested, hydrometers are thoroughly washed in soap and water, rinsed, and dried by wiping with a clean linen cloth.

If to be used in aqueous solutions which do not adhere readily, the stems are dipped into strong alcohol and immediately wiped dry with a soft, clean, linen cloth.

AMERICAN STANDARD BAUMÉ HYDROMETER

(Liquids Heavier than Water)

The Manufacturing Chemists' Association of the United States and the United States Bureau of Standards have adopted a Baumé scale based on the following relation to specific gravity:

$$\text{Degrees Baumé} = 145 - \frac{145}{\text{Specific gravity at } \frac{60°}{60°}\text{F.}}$$

or

$$\text{Specific gravity at } \frac{60°}{60°}\text{F.} = \frac{145}{145 - \text{degrees Baumé}}$$

The following history of the Baumé scale is taken from *Circular* No. 59 issued by the United States Bureau of Standards, April 5, 1916:

"The relation between specific gravity and Baumé degrees represented by the formulas given was adopted by this Bureau in 1904, when it first took up the question of testing hydrometers. At that time every important manufacturer of Baumé hydrometers in the United States was using this relation as the basis of these instruments, or at least such was their claim.

"The origin and early history of the Baumé scales has been admirably treated by Prof. C. F. Chandler in a paper read before the National Academy of Sciences at Philadelphia in 1881. As this paper may not be readily available to some who are interested in the matter, it may be well to include here a part of the material prepared by Prof. Chandler.

"The Baumé scale was first proposed and used by Antoine Baumé, a French chemist, in 1768, and from this beginning have come different Baumé scales that have been prepared since that time. The directions given by Baumé for reproducing his scale were first published in *L'Avant* in 1768, and though simple, are not specific, and the conditions assumed are not easily reproducible. It is not strange, therefore, that differences soon appeared between the Baumé scales as set up by different observers. That this divergence did actually occur is well shown by the large number of Baumé scales that have been used. Prof. Chandler found 23 different scales for liquids heavier than water.

"Baumé's directions for setting up his scale state that for the hydrometer scale for liquids heavier than water he used a solution of sodium chloride (common table salt) containing 15 parts of salt by weight in 85 parts of water by weight. He described the salt as being 'very pure' and 'very dry' and states that the experiments were carried out in a cellar in which the temperature was 10° Reaumur, equivalent to 12.5°C. or 54.5°F.

"The point to which the hydrometer sank in the 15 per cent. salt solution was marked 15°, and the point to which it sank in distilled water at the same temperature was marked 0°. The space between these two points was divided into 15 equal parts or degrees, and divisions of the same length were extended beyond the 15° point.

"Other makers of Baumé hydrometers soon began to deviate from the procedure outlined by Baumé, the deviations being, no doubt, partly accidental and partly intentional, and in course of time, as already pointed out, many different Baumé scales were in use.

"This condition of affairs led to great confusion in the use of the Baumé scale.

"From a consideration of the variations that occurred it was soon evident that some means of defining and reproducing the scale more exactly than could be done by the simple rules given by Baumé should, if possible, be found. This means was readily provided by assuming that a fixed relation should exist between the Baumé scale and the specific-gravity scale at some definite temperature, and in terms of some definite unit. When this relation is expressed in mathematical terms in the form of an equation, then the Baumé scale is fixed beyond all questions of doubt. At the present time all Baumé scales in use are based on such an assumed relation, and the differences existing between them arise from differences in the assumed relation or 'modulus' on which the various scales are based, and the standard temperature at which the instruments are intended to be correct.

"If a definite modulus is adopted, then the degrees Baumé corresponding to any given specific gravity, or the specific gravity corresponding to any given degree Baumé may be calculated; or if the specific gravity and corresponding degree Baumé at any point of the scale are known, then the modulus can be determined and the complete Baumé scale calculated from this single point.

Let s = specific gravity.
d = degrees Baumé.
m = modulus.

Then for liquids heavier than water:

$$s = \frac{m}{m - d}$$

$$d = m - \frac{m}{s}$$

$$m = \frac{ds}{s - 1}$$

"At the time the Bureau of Standards was contemplating taking up the work of standardizing hydrometers (1904), diligent inquiry was made of the more important American manufacturers of hydrometers as to the Baumé scales used by them. Without exception they replied that they were using the modulus 145 for liquids heavier than water. This scale, the "American Standard," was therefore adopted by the Bureau of Standards and has been in use ever since.

"There having been no objection or protest from any manufacturer or user of Baumé hydrometers at the time the scale was adopted by the Bureau, it was assumed that they were entirely satisfactory to the American trade and were in universal use."

Specific Gravities at $\frac{60°}{60°}$F. $\left(\frac{15.56°}{15.56°}\text{C.}\right)$ Corresponding to Degrees Baumé

(American Standard)

$$\text{Degrees Baumé} = 145 - \frac{145}{\text{Specific gravity}}$$ for Liquids Heavier than Water

Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity
0.0	1.0000	.1	1.0218	.2	1.0447	.3	1.0685
.1	1.0007	.2	1.0226	.3	1.0454	.4	1.0693
.2	1.0014	.3	1.0233	.4	1.0462	.5	1.0701
.3	1.0021	.4	1.0240	.5	1.0469	.6	1.0709
.4	1.0028	.5	1.0247	.6	1.0477	.7	1.0717
.5	1.0035	.6	1.0255	.7	1.0484	.8	1.0725
.6	1.0042	.7	1.0262	.8	1.0492	.9	1.0733
.7	1.0049	.8	1.0269	.9	1.0500	10.0	1.0741
.8	1.0055	.9	1.0276	7.0	1.0507	.1	1.0749
.9	1.0062	4.0	1.0284	.1	1.0515	.2	1.0757
1.0	1.0069	.1	1.0291	.2	1.0522	.3	1.0765
.1	1.0076	.2	1.0298	.3	1.0530	.4	1.0773
.2	1.0083	.3	1.0306	.4	1.0538	.5	1.0781
.3	1.0090	.4	1.0313	.5	1.0545	.6	1.0789
.4	1.0097	.5	1.0320	.6	1.0553	.7	1.0797
.5	1.0105	.6	1.0328	.7	1.0561	.8	1.0805
.6	1.0112	.7	1.0335	.8	1.0569	.9	1.0813
.7	1.0119	.8	1.0342	.9	1.0576	11.0	1.0821
.8	1.0126	.9	1.0350	8.0	1.0584	.1	1.0829
.9	1.0133	5.0	1.0357	.1	1.0592	.2	1.0837
2.0	1.0140	.1	1.0365	.2	1.0599	.3	1.0845
.1	1.0147	.2	1.0372	.3	1.0607	.4	1.0853
.2	1.0154	.3	1.0379	.4	1.0615	.5	1.0861
.3	1.0161	.4	1.0387	.5	1.0623	.6	1.0870
.4	1.0168	.5	1.0394	.6	1.0630	.7	1.0878
.5	1.0175	.6	1.0402	.7	1.0638	.8	1.0886
.6	1.0183	.7	1.0409	.8	1.0646	.9	1.0894
.7	1.0190	.8	1.0417	.9	1.0654	12.0	1.0902
.8	1.0197	.9	1.0424	9.0	1.0662	.1	1.0910
.9	1.0204	6.0	1.0432	.1	1.0670	.2	1.0919
3.0	1.0211	.1	1.0439	.2	1.0677	.3	1.0927

SPECIFIC GRAVITIES AT $\frac{60°}{60°}$F. $\left(\frac{15.56°}{15.56°}\text{C.}\right)$ CORRESPONDING TO DEGREES BAUMÉ—(*Continued*)

Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity
.4	1.0935	16.0	1.1240	.6	1.1563	.2	1.1905
.5	1.0943	.1	1.1249	.7	1.1572	.3	1.1915
.6	1.0952	.2	1.1258	.8	1.1581	.4	1.1924
.7	1.0960	.3	1.1267	.9	1.1591	.5	1.1934
.8	1.0968	.4	1.1275	20.0	1.1600	.6	1.1944
.9	1.0977	.5	1.1284	.1	1.1609	.7	1.1954
13.0	1.0985	.6	1.1293	.2	1.1619	.8	1.1964
.1	1.0993	.7	1.1302	.3	1.1628	.9	1.1974
.2	1.1002	.8	1.1310	.4	1.1637	24.0	1.1983
.3	1.1010	.9	1.1319	.5	1.1647	.1	1.1993
.4	1.1018	17.0	1.1328	.6	1.1656	.2	1.2003
.5	1.1027	.1	1.1337	.7	1.1665	.3	1.2013
.6	1.1035	.2	1.1346	.8	1.1675	.4	1.2023
.7	1.1043	.3	1.1355	.9	1.1684	.5	1.2033
.8	1.1052	.4	1.1364	21.0	1.1694	.6	1.2043
.9	1.1060	.5	1.1373	.1	1.1703	.7	1.2053
14.0	1.1069	.6	1.1381	.2	1.1712	.8	1.2063
.1	1.1077	.7	1.1390	.3	1.1722	.9	1.2073
.2	1.1086	.8	1.1399	.4	1.1731	25.0	1.2083
.3	1.1094	.9	1.1408	.5	1.1741	.1	1.2093
.4	1.1103	18.0	1.1417	.6	1.1750	.2	1.2104
.5	1.1111	.1	1.1426	.7	1.1760	.3	1.2114
.6	1.1120	.2	1.1435	.8	1.1769	.4	1.2124
.7	1.1128	.3	1.1444	.9	1.1779	.5	1.2134
.8	1.1137	.4	1.1453	22.0	1.1789	.6	1.2144
.9	1.1145	.5	1.1462	.1	1.1798	.7	1.2154
15.0	1.1154	.6	1.1472	.2	1.1808	.8	1.2164
.1	1.1162	.7	1.1481	.3	1.1817	.9	1.2175
.2	1.1171	.8	1.1490	.4	1.1827	26.0	1.2185
.3	1.1180	.9	1.1499	.5	1.1837	.1	1.2195
.4	1.1188	19.0	1.1508	.6	1.1846	.2	1.2205
.5	1.1197	.1	1.1517	.7	1.1856	.3	1.2216
.6	1.1206	.2	1.1526	.8	1.1866	.4	1.2226
.7	1.1214	.3	1.1535	.9	1.1876	.5	1.2236
.8	1.1223	.4	1.1545	23.0	1.1885	.6	1.2247
.9	1.1232	.5	1.1554	.1	1.1895	.7	1.2257

SPECIFIC GRAVITIES AT $\frac{60°}{60°}$F. $\left(\frac{15.56°}{15.56°}\text{C.}\right)$ CORRESPONDING TO DEGREES BAUMÉ—(*Continued*)

Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity
.8	1.2267	.4	1.2653	34.0	1.3063	.6	1.3501
.9	1.2278	.5	1.2664	.1	1.3075	.7	1.3514
27.0	1.2288	.6	1.2675	.2	1.3087	.8	1.3526
.1	1.2299	.7	1.2686	.3	1.3098	.9	1.3539
.2	1.2309	.8	1.2697	.4	1.3110	38.0	1.3551
.3	1.2319	.9	1.2708	.5	1.3122	.1	1.3564
.4	1.2330	31.0	1.2719	.6	1.3134	.2	1.3577
.5	1.2340	.1	1.2730	.7	1.3146	.3	1.3590
.6	1.2351	.2	1.2742	.8	1.3158	.4	1.3602
.7	1.2361	.3	1.2753	.9	1.3170	.5	1.3615
.8	1.2372	.4	1.2764	35.0	1.3182	.6	1.3628
.9	1.2383	.5	1.2775	.1	1.3194	.7	1.3641
28.0	1.2393	.6	1.2787	.2	1.3206	.8	1.3653
.1	1.2404	.7	1.2798	.3	1.3218	.9	1.3666
.2	1.2414	.8	1.2809	.4	1.3230	39.0	1.3679
.3	1.2425	.9	1.2821	.5	1.3242	.1	1.3692
.4	1.2436	32.0	1.2832	.6	1.3254	.2	1.3705
.5	1.2446	.1	1.2843	.7	1.3266	.3	1.3718
.6	1.2457	.2	1.2855	.8	1.3278	.4	1.3731
.7	1.2468	.3	1.2866	.9	1.3291	.5	1.3744
.8	1.2478	.4	1.2877	36.0	1.3303	.6	1.3757
.9	1.2489	.5	1.2889	.1	1.3315	.7	1.3770
29.0	1.2500	.6	1.2900	.2	1.3327	.8	1.3783
.1	1.2511	.7	1.2912	.3	1.3329	.9	1.3796
.2	1.2522	.8	1.2923	.4	1.3352	40.0	1.3810
.3	1.2532	.9	1.2935	.5	1.3364	.1	1.3823
.4	1.2543	33.0	1.2946	.6	1.3376	.2	1.3836
.5	1.2554	.1	1.2958	.7	1.3389	.3	1.3849
.6	1.2565	.2	1.2970	.8	1.3401	.4	1.3862
.7	1.2576	.3	1.2981	.9	1.3414	.5	1.3876
.8	1.2587	.4	1.2993	37.0	1.3426	.6	1.3889
.9	1.2598	.5	1.3004	.1	1.3438	.7	1.3902
30.0	1.2609	.6	1.3016	.2	1.3451	.8	1.3916
.1	1.2620	.7	1.3028	.3	1.3463	.9	1.3929
.2	1.2631	.8	1.3040	.4	1.3476	41.0	1.3942
.3	1.2642	.9	1.3051	.5	1.3488	.1	1.3956

Specific Gravities at $\frac{60°}{60°}$F. $\left(\frac{15.56°}{15.56°}C.\right)$ Corresponding to Degrees Baumé—(*Continued*)

Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity
.2	1.3969	.8	1.4471	.4	1.5010	52.0	1.5591
.3	1.3983	.9	1.4486	.5	1.5026	.1	1.5608
.4	1.3996	45.0	1.4500	.6	1.5041	.2	1.5625
.5	1.4010	.1	1.4515	.7	1.5057	.3	1.5642
.6	1.4023	.2	1.4529	.8	1.5073	.4	1.5659
.7	1.4037	.3	1.4544	.9	1.5088	.5	1.5676
.8	1.4050	.4	1.4558	49.0	1.5104	.6	1.5693
.9	1.4064	.5	1.4573	.1	1.5120	.7	1.5710
42.0	1.4078	.6	1.4588	.2	1.5136	.8	1.5727
.1	1.4091	.7	1.4602	.3	1.5152	.9	1.5744
.2	1.4105	.8	1.4617	.4	1.5167	53.0	1.5761
.3	1.4119	.9	1.4632	.5	1.5183	.1	1.5778
.4	1.4133	46.0	1.4646	.6	1.5199	.2	1.5795
.5	1.4146	.1	1.4661	.7	1.5215	.3	1.5812
.6	1.4160	.2	1.4676	.8	1.5231	.4	1.5830
.7	1.4174	.3	1.4691	.9	1.5247	.5	1.5847
.8	1.4188	.4	1.4706	50.0	1.5263	.6	1.5864
.9	1.4202	.5	1.4721	.1	1.5279	.7	1.5882
43.0	1.4216	.6	1.4736	.2	1.5295	.8	1.5899
.1	1.4230	.7	1.4751	.3	1.5312	.9	1.5917
.2	1.4244	.8	1.4766	.4	1.5328	54.0	1.5934
.3	1.4258	.9	1.4781	.5	1.5344	.1	1.5952
.4	1.4272	47.0	1.4796	.6	1.5360	.2	1.5969
.5	1.4286	.1	1.4811	.7	1.5376	.3	1.5987
.6	1.4300	.2	1.4826	.8	1.5393	.4	1.6004
.7	1.4314	.3	1.4841	.9	1.5409	.5	1.6022
.8	1.4328	.4	1.4857	51.0	1.5426	.6	1.6040
.9	1.4342	.5	1.4872	.1	1.5442	.7	1.6058
44.0	1.4356	.6	1.4887	.2	1.5458	.8	1.6075
.1	1.4371	.7	1.4902	.3	1.5475	.9	1.6093
.2	1.4385	.8	1.4918	.4	1.5491	55.0	1.6111
.3	1.4399	.9	1.4933	.5	1.5508	.1	1.6129
.4	1.4414	48.0	1.4948	.6	1.5525	.2	1.6147
.5	1.4428	.1	1.4964	.7	1.5541	.3	1.6165
.6	1.4442	.2	1.4979	.8	1.5558	.4	1.6183
.7	1.4457	.3	1.4995	.9	1.5575	.5	1.6201

Specific Gravities at $\frac{60°}{60°}$F. $\left(\frac{15.56°}{15.56°}\text{C.}\right)$ Corresponding to Degrees Baumé—(*Concluded*)

Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity	Degrees Baumé	Specific gravity
.6	1.6219	.3	1.6724	.9	1.7241	.5	1.7791
.7	1.6237	.4	1.6744	61.0	1.7262	.6	1.7813
.8	1.6256	.5	1.6763	.1	1.7282	.7	1.7835
.9	1.6274	.6	1.6782	.2	1.7303	.8	1.7857
56.0	1.6292	.7	1.6802	.3	1.7324	.9	1.7879
.1	1.6310	.8	1.6821	.4	1.7344	64.0	1.7901
.2	1.6329	.9	1.6841	.5	1.7365	.1	1.7923
.3	1.6347	59.0	1.6860	.6	1.7386	.2	1.7946
.4	1.6366	.1	1.6880	.7	1.7407	.3	1.7968
.5	1.6384	.2	1.6900	.8	1.7428	.4	1.7990
.6	1.6403	.3	1.6919	.9	1.7449	.5	1.8012
.7	1.6421	.4	1.6939	62.0	1.7470	.6	1.8035
.8	1.6440	.5	1.6959	.1	1.7491	.7	1.8057
.9	1.6459	.6	1.6979	.2	1.7512	.8	1.8080
57.0	1.6477	.7	1.6999	.3	1.7533	.9	1.8102
.1	1.6496	.8	1.7019	.4	1.7554	65.0	1.8125
.2	1.6515	.9	1.7039	.5	1.7576	.1	1.8148
.3	1.6534	60.0	1.7059	.6	1.7597	.2	1.8170
.4	1.6553	.1	1.7079	.7	1.7618	.3	1.8193
.5	1.6571	.2	1.7099	.8	1.7640	.4	1.8216
.6	1.6590	.3	1.7119	.9	1.7661	.5	1.8239
.7	1.6609	.4	1.7139	63.0	1.7683	.6	1.8262
.8	1.6628	.5	1.7160	.1	1.7705	.7	1.8285
.9	1.6648	.6	1.7180	.2	1.7726	.8	1.8308
58.0	1.6667	.7	1.7200	.3	1.7748	.9	1.8331
.1	1.6686	.8	1.7221	.4	1.7770	66.0	1.8354
.2	1.6705						

Degrees Baumé Corresponding to Specific Gravities at $\frac{60°}{60°}$F. $\left(\frac{15.56°}{15.56°}\text{C.}\right)$ for Liquids Heavier than Water

(Calculated from the Formula Degrees Baumé $= 145 - \frac{145}{\text{Sp. Gr.}\frac{60°}{60°}\text{F.}}$ which Defines the Baumé Scale, in General Use in the United States, for Liquids Heavier than Water)

Specific gravity $\frac{15.56°}{15.56°}$ C.	0	1	2	3	4	5	6	7	8	9	Difference
1.00	0.000	0.145	0.289	0.434	0.578	0.721	0.865	1.008	1.151	1.293	143
1.01	1.436	1.578	1.719	1.861	2.002	2.143	2.283	2.424	2.564	2.704	141
1.02	2.843	2.982	3.121	3.260	3.399	3.537	3.675	3.812	3.950	4.087	138
1.03	4.223	4.360	4.496	4.632	4.768	4.903	5.038	5.174	5.308	5.443	136
1.04	5.577	5.711	5.845	5.978	6.111	6.244	6.377	6.509	6.641	6.773	133
1.05	6.905	7.036	7.167	7.298	7.429	7.559	7.689	7.819	7.949	8.078	130
1.06	8.208	8.336	8.465	8.594	8.722	8.850	8.978	9.105	9.232	9.359	128
1.07	9.486	9.613	9.739	9.865	9.991	10.116	10.242	10.367	10.492	10.616	126
1.08	10.741	10.865	10.989	11.113	11.236	11.359	11.483	11.605	11.728	11.850	124
1.09	11.972	12.094	12.216	12.338	12.459	12.580	12.701	12.821	12.942	13.062	121
1.10	13.182	13.302	13.421	13.540	13.659	13.778	13.897	14.015	14.134	14.252	119
1.11	14.370	14.487	14.604	14.721	14.838	14.955	15.072	15.188	15.304	15.420	117
1.12	15.536	15.651	15.767	15.882	15.997	16.111	16.226	16.340	16.454	16.568	115
1.13	16.682	16.795	16.908	17.021	17.134	17.247	17.359	17.471	17.583	17.695	113
1.14	17.807	17.919	18.030	18.141	18.252	18.363	18.473	18.583	18.693	18.803	111
1.15	18.913	19.023	19.132	19.241	19.350	19.459	19.568	19.676	19.784	19.892	109
1.16	20.000	20.108	20.215	20.322	20.430	20.536	20.643	20.750	20.856	20.962	107
1.17	21.068	21.174	21.280	21.385	21.491	21.596	21.701	21.806	21.910	22.014	105

Degrees Baumé Corresponding to Specific Gravities at $\frac{60°}{60°}$F. $\left(\frac{15.56°}{15.56°}\text{C.}\right)$ for Liquids Heavier than Water—(*Continued*)

Specific gravity $\frac{15.56°}{15.56°}$C.	0	1	2	3	4	5	6	7	8	9	Difference
1.18	22.119	22.223	22.327	22.430	22.534	22.637	22.740	22.843	22.946	23.049	103
1.19	23.151	23.254	23.356	23.458	23.560	23.661	23.763	23.864	23.965	24.066	101
1.20	24.167	24.267	24.368	24.468	24.568	24.668	24.768	24.868	24.967	25.066	100
1.21	25.165	25.264	25.363	25.462	25.560	25.658	25.755	25.855	25.952	26.050	98
1.22	26.148	26.245	26.342	26.439	26.536	26.633	26.729	26.826	26.922	27.018	97
1.23	27.114	27.210	27.305	27.401	27.496	27.591	27.686	27.781	27.876	27.970	95
1.24	28.065	28.159	28.253	28.347	28.441	28.534	28.628	28.721	28.814	28.907	94
1.25	29.000	29.093	29.185	29.278	29.370	29.462	29.554	29.646	29.738	29.829	92
1.26	29.921	30.012	30.103	30.194	30.285	30.376	30.466	30.556	30.647	30.737	91
1.27	30.827	30.917	31.006	31.096	31.185	31.275	31.364	31.453	31.542	31.630	89
1.28	31.719	31.807	31.896	31.984	32.072	32.160	32.247	32.335	32.422	32.510	88
1.29	32.597	32.684	32.771	32.858	32.944	33.031	33.117	33.204	33.290	33.376	87
1.30	33.462	33.547	33.633	33.718	33.804	33.889	33.974	34.059	34.144	34.229	85
1.31	34.313	34.397	34.482	34.566	34.650	34.734	34.818	34.901	34.985	35.068	84
1.32	35.152	35.235	35.318	35.401	35.483	35.566	35.649	35.731	35.813	35.895	83
1.33	35.977	36.059	36.141	36.223	36.304	36.386	36.467	36.548	36.629	36.710	81
1.34	36.791	36.872	36.952	37.033	37.113	37.193	37.273	37.353	37.433	37.513	80
1.35	37.593	37.672	37.751	37.831	37.910	37.989	38.068	38.147	38.225	38.304	79
1.36	38.382	38.461	38.539	38.617	38.695	38.773	38.851	38.928	39.006	39.803	78
1.37	39.161	39.238	39.315	39.392	39.469	39.546	39.622	39.609	39.775	39.851	77
1.38	39.928	40.004	40.080	40.156	40.231	40.307	40.382	40.458	40.533	40.608	76
1.39	40.683	40.758	40.833	40.908	40.983	41.057	41.132	41.206	41.280	41.355	75
1.40	41.429	41.503	41.576	41.650	41.724	41.797	41.871	41.944	42.017	42.090	74

Degrees Baumé Corresponding to Specific Gravities at $\frac{60°}{60°}$ F. $\left(\frac{15.56°}{15.56°}\text{C.}\right)$ for Liquids Heavier than Water—(*Continued*)

Specific gravity $\frac{15.56°}{15.56°}$ C.	0	1	2	3	4	5	6	7	8	9	Difference
1.41	42.163	42.236	42.309	42.381	42.454	42.527	42.599	42.671	42.743	42.815	73
1.42	42.887	42.959	43.031	43.103	43.174	43.246	43.317	43.388	43.459	43.530	72
1.43	43.601	43.672	43.743	43.814	43.884	43.955	44.025	44.095	44.166	44.236	71
1.44	44.306	44.376	44.445	44.515	44.585	44.654	44.724	44.793	44.862	44.931	70
1.45	45.000	45.069	45.138	45.207	45.275	45.344	45.412	45.481	45.549	45.617	69
1.46	45.685	45.753	45.821	45.889	45.956	46.024	46.091	46.159	46.226	46.293	67
1.47	46.361	46.428	46.495	46.562	46.628	46.695	46.762	46.828	46.894	46.961	67
1.48	47.027	47.093	47.159	47.225	47.291	47.357	47.423	47.488	47.554	47.619	66
1.49	47.685	47.750	47.815	47.880	47.945	48.010	48.075	48.140	48.204	48.269	65
1.50	48.333	48.398	48.462	48.526	48.591	48.655	48.719	48.782	48.846	48.910	64
1.51	48.974	49.037	49.101	49.164	49.227	49.290	49.354	49.417	49.480	49.543	63
1.52	49.605	49.668	49.731	49.793	49.856	49.918	49.980	50.043	50.105	50.167	62
1.53	50.229	50.291	50.353	50.414	50.476	50.538	50.599	50.660	50.722	50.783	61
1.54	50.844	50.905	50.966	51.027	51.088	51.149	51.210	51.270	51.331	51.391	61
1.55	51.452	51.512	51.572	51.632	51.692	51.752	51.812	51.872	51.932	51.992	60
1.56	52.051	52.111	52.170	52.230	52.289	52.348	52.407	52.467	52.526	52.585	59
1.57	52.643	52.702	52.761	52.820	52.878	52.937	52.995	53.053	53.112	53.170	59
1.58	53.228	53.286	53.344	53.402	53.460	53.517	53.575	53.633	53.690	53.748	58
1.59	53.805	53.862	53.920	53.977	54.034	54.091	54.148	54.205	54.262	54.318	57
1.60	54.375	54.432	54.488	54.545	54.601	54.657	54.714	54.770	54.826	54.882	56
1.61	54.938	54.994	55.050	55.106	55.161	55.217	55.272	55.328	55.383	55.439	56
1.62	55.494	55.549	55.604	55.659	55.714	55.769	55.824	55.879	55.934	55.988	55

DEGREES BAUMÉ CORRESPONDING TO SPECIFIC GRAVITIES AT $\frac{60°}{60°}$F. $\left(\frac{15.56°}{15.56°}\text{C.}\right)$ FOR LIQUIDS HEAVIER THAN WATER—(*Concluded*)

Specific gravity $\frac{15.56°}{15.66°}$ C.	0	1	2	3	4	5	6	7	8	9	Difference
1.63	56.043	56.098	56.152	56.206	56.261	56.315	56.369	56.423	56.478	56.531	54
1.64	56.585	56.639	56.693	56.747	56.801	56.854	56.908	56.961	57.015	57.068	54
1.65	57.121	57.175	57.228	57.281	57.334	57.387	57.440	57.493	57.545	57.598	53
1.66	57.651	57.703	57.756	57.808	57.861	57.913	57.965	58.017	58.070	58.122	52
1.67	58.174	58.226	58.278	58.329	58.381	58.433	58.485	58.536	58.588	58.639	52
1.68	58.690	58.742	58.793	58.844	58.896	58.947	58.998	59.049	59.100	59.150	51
1.69	59.201	59.252	59.303	59.353	59.404	59.454	59.505	59.555	59.605	59.656	50
1.70	59.706	59.756	59.806	59.856	59.906	59.956	60.006	60.056	60.105	60.155	50
1.71	60.205	60.254	60.304	60.353	60.403	60.452	60.501	60.550	60.600	60.649	49
1.72	60.698	60.747	60.796	60.844	60.893	60.942	60.991	61.039	61.088	61.136	49
1.73	61.185	61.234	61.282	61.330	61.378	61.427	61.475	61.523	61.571	61.619	48
1.74	61.667	61.715	61.762	61.810	61.858	61.906	61.953	62.001	62.048	62.096	48
1.75	62.143	62.190	62.237	62.285	62.332	62.379	62.426	62.473	62.520	62.567	47
1.76	62.614	62.660	62.707	62.754	62.801	62.847	62.894	62.940	62.987	63.033	46
1.77	63.079	63.125	63.172	63.218	63.264	63.310	63.356	63.402	63.448	63.494	46
1.78	63.539	63.585	63.631	63.676	63.722	63.768	63.813	63.858	63.904	63.949	46
1.79	63.994	64.040	64.085	64.130	64.175	64.220	64.265	64.310	64.355	64.400	45
1.80	64.445	64.489	64.534	64.579	64.623	64.668	64.712	64.757	64.801	64.845	45
1.81	64.890	64.934	64.978	65.022	65.066	65.110	65.154	65.198	65.242	65.286	44
1.82	65.330	65.374	65.417	65.461	65.504	65.548	65.591	65.635	65.678	65.722	43
1.83	65.765	65.808	65.852	65.895	65.938	65.981	66.024	66.067	66.110	66.153	43

TWADDLE HYDROMETER

(Generally used in England)

Methods of Converting Specific Gravity to Degrees Twaddle

1. Let x = degrees Twaddle.
   y = specific gravity.
   $$x = \frac{1000y - 1000}{5}$$
2. Or $x = 200\,(y - 1)$.

3. This method may be used for any value below 2.000. Move the decimal point two figures to the right, striking off the first figure and multiplying the remainder by 2.

Methods of Converting Degrees Twaddle to Specific Gravity

1. Let x = specific gravity.
   y = degrees Twaddle.
   $$x = \frac{5y + 1000}{1000}$$
2. Or $x = \frac{y}{200} + 1$

The degrees in Twaddle's hydrometer bear a direct relationship to the specific gravity, the basis of the system being plain and unmistakable, since every degree is equal to a difference in specific gravity of 0.005.

SPECIFIC GRAVITIES CORRESPONDING TO DEGREES TWADDLE

Degrees Twaddle	Specific gravity	Degrees Twaddle	Specific gravity	Degrees Twaddle	Specific gravity	Degrees Twaddle	Specific gravity	Degrees Twaddle	Specific gravity
1	1.005	35	1.175	69	1.345	103	1.515	137	1.685
2	1.010	36	1.180	70	1.350	104	1.520	138	1.690
3	1.015	37	1.185	71	1.355	105	1.525	139	1.695
4	1.020	38	1.190	72	1.360	106	1.530	140	1.700
5	1.025	39	1.195	73	1.365	107	1.535	141	1.705
6	1.030	40	1.200	74	1.370	108	1.540	142	1.710
7	1.035	41	1.205	75	1.375	109	1.545	143	1.715
8	1.040	42	1.210	76	1.380	110	1.550	144	1.720
9	1.045	43	1.215	77	1.385	111	1.555	145	1.725
10	1.050	44	1.220	78	1.390	112	1.560	146	1.730
11	1.055	45	1.225	79	1.395	113	1.565	147	1.735
12	1.060	46	1.230	80	1.400	114	1.570	148	1.740
13	1.065	47	1.235	81	1.405	115	1.575	149	1.745
14	1.070	48	1.240	82	1.410	116	1.580	150	1.750
15	1.075	49	1.245	83	1.415	117	1.585	151	1.755
16	1.080	50	1.250	84	1.420	118	1.590	152	1.760
17	1.085	51	1.255	85	1.425	119	1.595	153	1.765
18	1.090	52	1.260	86	1.430	120	1.600	154	1.770
19	1.095	53	1.265	87	1.435	121	1.605	155	1.775
20	1.100	54	1.270	88	1.440	122	1.610	156	1.780
21	1.105	55	1.275	89	1.445	123	1.615	157	1.785
22	1.110	56	1.280	90	1.450	124	1.620	158	1.790
23	1.115	57	1.285	91	1.455	125	1.625	159	1.795
24	1.120	58	1.290	92	1.460	126	1.630	160	1.800
25	1.125	59	1.295	93	1.465	127	1.635	161	1.805
26	1.130	60	1.300	94	1.470	128	1.640	162	1.810
27	1.135	61	1.305	95	1.475	129	1.645	163	1.815
28	1.140	62	1.310	96	1.480	130	1.650	164	1.820
29	1.145	63	1.315	97	1.485	131	1.655	165	1.825
30	1.150	64	1.320	98	1.490	132	1.660	166	1.830
31	1.155	65	1.325	99	1.495	133	1.665	167	1.835
32	1.160	66	1.330	100	1.500	134	1.670	168	1.840
33	1.165	67	1.335	101	1.505	135	1.675	169	1.845
34	1.170	68	1.340	102	1.510	136	1.680	170	1.850

NOMENCLATURE OF SULPHURIC ACID

Sulphuric acid shows a definite relation between the specific gravity and strength up to 93.19 per cent. H_2SO_4. As it is much easier to determine the specific gravity than the strength, acids weaker than 93.19 per cent. are nearly always spoken of and sold as being of so many degrees Baumé, the Baumé hydrometer being the instrument generally used for determining the specific gravity. The principal strengths of such acids are:

Degrees Baumé	Specific gravity	Per cent. SO_3	Per cent. H_2SO_4
50	1.5263	50.76	62.18
60	1.7059	63.40	77.67
66	1.8354	76.07	93.19

In 1882 the Manufacturing Chemists' Association of the United States agreed on a set of values for Baumé degrees and their H_2SO_4 equivalents. In 1904 the Association adopted the table of Ferguson and Talbot. The H_2SO_4 equivalents show a slight change from the table of 1882 and those values have been used in this country ever since. In Germany especially, and quite generally on the continent, a different set of values for Baumé degrees is used in which all have higher values in specific gravity and H_2SO_4 than those used here. For instance 66°Bé. here corresponds to 93.19 per cent. H_2SO_4 and in Germany to 98 per cent.

The 66° acid is also known as oil of vitriol (O. V.) and strengths of weaker acids are sometimes spoken of as so many per cent. O. V., a 60°Bé. acid containing 77.67 per cent. H_2SO_4 being called 83.35 per cent. O. V.

$$\frac{77.67 \times 100}{93.19} = 83.35$$

This, however, is not very common. In reporting total production or uses of sulphuric acid it is frequently stated as being equivalent to a certain quantity of acid of 50° or 60° or some other standard strength, the total amount of H_2SO_4 being the same as that contained in the stated quantity of the stated strength. Productions are also often reported as tons of SO_3.

When an acid becomes stronger than 93.19 per cent. H_2SO_4, to speak of it in terms of specific gravity or degrees Baumé would be fallacious as 94.5 per cent. acid has practically the same specific gravity as 100 per cent. Acids between 93.19 and 100 per cent. are spoken of as so many per cent. sulphuric acid; 100 per cent. acid being commonly called the mono-hydrate. This contains 100 per cent. H_2SO_4 (81.63 per cent. SO_3).

SO_3 dissolves in the mono-hydrate giving fuming acid or oleum. It is called fuming acid because the SO_3 escapes, forming white fumes, when exposed to the air. Oleum is the German name which has been used extensively in this country, since the first practical methods of making it were German and the German nomenclature was frequently adopted here. It is also known in Germany as Nordhausen Oil of Vitriol.

There are three ways of stating the strength of fuming acid:

1. The per cent. of free (dissolved) SO_3.
2. The per cent. of total SO_3.
3. The equivalent per cent. 100 per cent. H_2SO_4. That is the per cent. of 100 per cent. H_2SO_4 it would make if sufficient water were added to combine with all the free SO_3.

For instance an acid containing 20 per cent. free SO_3 would contain a total of 85.30 per cent. SO_3, and actual H_2SO_4 content of 80 per cent. and would make 104.49 per cent. H_2SO_4 if sufficient water were added to combine with all the free SO_3. It might, therefore, be called 20 per cent., 85.30 per cent. or 104.49 per cent.

Mixed acid is the technical term for a mixture of strong sulphuric acid and nitric acid.

FORMULAS FOR USE IN SULPHURIC-ACID CALCULATIONS

(By non-fuming acid is meant all strengths under 81.63 per cent. SO_3)
(By fuming acid is meant all strengths over 81.63 per cent. SO_3)

The following factors were calculated from molecular weights:

$$\frac{SO_3}{H_2SO_4} = \frac{80.06}{98.076} = 0.8163$$

$$\frac{H_2SO_4}{SO_3} = \frac{98.076}{80.06} = 1.2250$$

$$\frac{H_2O}{H_2SO_4} = \frac{18.016}{98.076} = 0.1837$$

$$\frac{H_2SO_4}{H_2O} = \frac{98.076}{18.016} = 5.4438$$

$$\frac{SO_3}{H_2O} = \frac{80.06}{18.016} = 4.4438$$

$$\frac{H_2O}{SO_3} = \frac{18.016}{80.06} = 0.2250$$

To Calculate Per Cent. SO_3—*Non-fuming Acid*—

Per cent. $H_2SO_4 \times 0.8163$
or Per cent. $H_2SO_4 \div 1.2250$

To Calculate Per Cent. H_2SO_4—*Non-fuming Acid*—

Per cent. $SO_3 \div 0.8163$
or Per cent. $SO_3 \times 1.2250$

To Calculate Per Cent. Free H_2O—*Non-fuming Acid*—

100 − per cent. H_2SO_4

To Calculate Per Cent. Combined H_2O—*Non-fuming Acid*—

Per cent. H_2SO_4 − per cent. SO_3
or Per cent. $H_2SO_4 \times 0.1837$
or Per cent. $SO_3 \times 0.2250$

To Calculate Per Cent. Combined H_2O—*Fuming Acid*—

Per cent. $H_2SO_4 \times 0.1837$

or 100 − per cent. total SO_3

or Per cent. combined $SO_3 \times 0.2250$

To Calculate Per Cent. H_2SO_4—*Fuming Acid*—

$$\frac{98.076\ (100 - \text{per cent. total } SO_3)}{18.016}$$

or 100 − per cent. free SO_3

or Per cent. combined $H_2O \times 5.4438$

or

Per cent. combined H_2O + (4.4438 × per cent. combined H_2O)

To Calculate Equivalent 100 *Per Cent.* H_2SO_4—*Fuming Acid*—

Per cent. total $SO_3 \div 0.8163$

or Per cent. total $SO_3 \times 1.2250$

To Calculate Per Cent. Combined SO_3—*Fuming Acid*—

$$\frac{80.06\ (100 - \text{per cent. free } SO_3)}{98.076}$$

or Per cent. $H_2SO_4 \times 0.8163$

or Per cent. combined $H_2O \times 4.4438$

or Per cent. total SO_3 − per cent. free SO_3

To Calculate Per Cent. Free SO_3—*Fuming Acid*—

$$\frac{(\text{Per cent. total } SO_3 \times 98.076) - 8006}{18.016}$$

or (Per cent. total $SO_3 \times 5.4438$) − 444.38

or (Per cent. total SO_3 − 81.63) 5.4438

or Per cent. total SO_3 − (per cent. combined $H_2O \times 4.4438$)

or Per cent. total SO_3 − per cent. combined SO_3

or 100 − Per cent. H_2SO_4

To Calculate Per Cent. Total SO_3—*Fuming Acid*—

$$\frac{(\text{Per cent. free } SO_3 \times 18.016) + 8006}{98.076}$$

or (Per cent. free SO_3 × 0.1837) + 81.63
or 0.8163 (100 − per cent. free SO_3) + per cent. free SO_3
or Equivalent per cent. 100 per cent. H_2SO_4 × 0.8163
or Per cent. free SO_3 + per cent. combined SO_3

To Calculate Weight per Cubic Foot Acid—

Specific gravity at $\frac{60°}{60°}$F. $\left(\frac{15.56°}{15.56°}\text{C.}\right)$ × weight per cubic foot water at 60°F. (62.37 lb.)

To Calculate Weight SO_3 *per Cubic Foot*

(Weight of acid per cubic foot × per cent. SO_3) ÷ 100)

To Calculate the Equivalent Per Cent. and Weight of One Strength Acid af Compared to Another

The equivalent per cent. in 66°Bé. (93.19 per cent. H_2SO_4) of an acid of 60°Bé. (77.67 per cent. H_2SO_4) is:

$$\frac{77.67}{93.19} \times 100 = 83.35 \text{ per cent. } 66°\text{Bé.}$$

and as 60°Bé. corresponds to 1.7059 specific gravity, the pounds of 66°Bé. equivalent to 1 cu. ft. of 60°Bé. is:

$$\frac{77.67}{93.19} \times 1.7059 \times 62.37 = 88.68 \text{ lb. } 66°\text{Bé.}$$

Note.—While ascertaining equivalents of non-fuming acid, strengths used for the calculations can either be taken as per cent. SO_3 or of per cent. H_2SO_4.

If calculating fuming-acid equivalents, strengths should be used in terms of total per cent. SO_3 unless expressed in the equivalent per cent. of 100 per cent. H_2SO_4.

Description of Methods Employed in Preparing the Tables of Specific Gravity of Sulphuric Acid, Nitric Acid, and Hydrochloric Acid, Adopted by the Manufacturing Chemists' Association of the United States[1]

By W. C. Ferguson

INTRODUCTORY

The General Chemical Company, finding that many different methods of analysis were being used in their various works, and realizing the advantages of uniform methods, submitted the task of unification to the writer. After careful investigation, the methods best adapted were selected, and by the constant examination of new methods described in the literature as well as by original research, these methods are from time to time substituted or modified. The need soon became apparent for uniform specific-gravity tables, no two authorities agreeing; not only was there disagreement between specific gravities and corresponding percentage composition when reduced to the same standard, but different moduli, temperatures, etc., were used as standards.

The preparation of standard tables of the specific gravity and corresponding composition, with other useful data, was undertaken for nitric acid, hydrochloric acid, ammonia and sulphuric acid. The Manufacturing Chemists' Association of the United States, hearing of our efforts while the work was in progress, after investigation, accepted the tables as they were completed as standard tables of the association. In the case of the sulphuric acid table, they employed Prof. H. P. Talbot of the Massachusetts Institute of Technology of Boston, as expert, whose name appears with that of the writer as authority.

These tables are designed primarily as a basis for sales which are largely governed by the degree Baumé; they are also useful for controlling processes, taking account of stock, etc.

[1] *Jour. Soc. Chem. Ind.*, July 31, 1905, pp. 781–790.

The acids and ammonia used were the purest obtainable c.p., and were carefully examined for impurities and purified when necessary. The impurities in commercial products are such a variable quantity and, as their purity is becoming more pronounced as manufacturing processes improve, many substances made on a large scale being nearly c.p., it was deemed that the tables would have more practical value if they were based upon c.p. compounds. As to any scientific merit they may possess, it is needless to say that such a positive basis to which they can always be referred is an essential.

All of the analytical and specific-gravity determinations, determinations of the coefficient of expansion (or allowance for temperature), determination of boiling points, as well as all calculations and clerical work, were performed by two experienced men working independently.

SPECIFIC-GRAVITY DETERMINATIONS

All specific-gravity determinations were taken at 60°F., compared with water at 60°F. The work was done in winter and no account was taken of differences of atmospheric pressure or temperature, which averaged about 760 mm. and 65°F.

The apparatus used in this work was a 50-c.c. Geissler picnometer having a capillary side-arm tube fitted with a glass cap, in the top of which was a small hole which allowed the liquid to expand without loosening the thermometer or cap, at the same time preventing loss while weighing. The thermometer, which was ground to fit the neck of the bottle, was graduated to $\frac{1}{9}$°F. and readable to $\frac{1}{18}$°F., and was frequently checked against a standard thermometer.

Before making a determination the water content of the bottle was first accurately determined and checked from time to time during a series of determinations. To obtain the water content, the bottle together with the thermometer and glass cap were carefully cleaned, dried and weighed. (The accuracy of the balance and weights were systematically checked against a standard set of weights.) The bottle was then filled with freshly distilled water at 55°–57°F., and the thermometer tightly inserted. As the temperature slowly rose, the water expanded through the capillary side arm. When the thermometer registered 60°F., the last drop was removed from the top of the capillary, the tube capped and the whole weighed. This weight, less the tare obtained above, was taken as the water content of the bottle at 60°F. Check determinations agreed within 0.002 gram, or less than 0.00005 specific gravity. Distilled water freed from carbon dioxide by boiling, and cooling in a closed vessel, gave the same water content as the ordinary distilled water which was used throughout the work. This water was free from chloride and residue upon evaporation.

In determining the specific gravity of liquids, the weight of the liquid contained by the bottle at 60°F. was obtained as above. This weight, divided by the water content, equals the specific gravity.

It was thought that the temperature of the liquid in the bottle might vary in different parts and the whole not have the same temperature as registered by the thermometer in the center of the bottle. To ascertain the facts in the case a beaker was filled with water below the temperature of the room, and a thermometer placed in the center of the beaker showed the same temperature as those placed near the sides, the temperature rising uniformly throughout the liquid.

COEFFICIENT OF EXPANSION

The correction for temperature was found by allowing the liquid to slowly expand, and when the temperature had risen 8°–10°F., the tube was wiped off and capped, and the apparatus again weighed. Another weight was taken at a still higher temperature, and from these results the difference in specific gravity for 1°F. and the number of degrees corresponding to 1°Bé. were calculated. To determine how much the expansion of the picnometer affected the specific-gravity determinations at different temperature, the bottle was filled with distilled water and weighed at 50°, 60°, 70° and 80°F. From Kopp's table of the volume of water at different temperatures, the increase in volume of 50 c.c. for each 10°F. was calculated. If the bottle had not expanded, the successive differences in weight should have corresponded with the differences in volume, but in each case the differences in weight were less than the calculated expansion of water, the amount less being due to the expansion of the glass bottle. The results showed that 1°F. = 0.00062 gram = effect of expansion of 50-c.c. bottle. 100 c.c. = 0.0012 gram which would make a difference of 0.000012 specific gravity, which is less than the accuracy of our determinations, and no correction has been made for it.

Analytical Determinations.—All calculations are based upon F. W. Clarke's "Table of Atomic Weights," 1901—0 = 16.

Preparation of Standards.—The following standards were prepared by the methods to be described: Sodium carbonate (*a*) ignited at low red heat to constant weight; sodium carbonate (*b*) heated at 572°F. to constant weight; ammonium sulphate; 100 per cent. sulphuric acid; sulphuric anhydride; sulphanilic acid.

Sodium Carbonate (*a*).—This standard was prepared from the purest obtainable sodium bicarbonate made by the ammonia process and specially selected for us by a prominent manufacturer. Our analysis showed it to contain in addition to some sodium chloride—

	Per cent.		Per cent.
SiO_2......	0.001	equivalent Na_2CO_3 =	0.00
$Fe_2O_3.Al_2O_3$	0.002	equivalent Na_2CO_3 =	0.00
$CaCO_3$....	0.010	equivalent Na_2CO_3 =	0.0106
$MgCO_3$....	0.009	equivalent Na_2CO_3 =	0.0113
	0.022		0.0219

The impurities that are titratable by an acid, calcium and magnesium carbonates, are exactly equivalent to the sodium carbonate displaced.

About 200 grams of sodium bicarbonate were washed in a funnel having a porcelain plate until entirely free from chloride. It was then dried at 100°C., protected from acid gases, finely ground, and kept in a sealed bottle until used. About 20 grams of bicarbonate thus prepared was heated in a platinum dish at a moderate red heat, until the weight was constant, and then 5 grams was quickly and accurately weighed for analysis. Our attention was directed to the method of heating sodium carbonate, for, in standardizing, various results were obtained depending on the temperature of ignition, the highest temperature giving the greatest alkalinity, or about 0.09 per cent. greater than the lowest. It remained to be proved whether the high or low result was correct, and whether in heating to the higher temperature (red heat over a Bunsen flame) water was given off, or whether the loss in weight was due to a decomposition of sodium carbonate into sodium oxide and carbon dioxide.

In referring to the literature several references were found upon the ignition of sodium carbonate. Mendeleeff, vol. I, p. 525, in quoting the work of Pickering, says: "When sodium carbonate is fused about 1 per cent. of carbon dioxide is disengaged." In Lunge's "Untersuchungs Methoden," vol. I, p. 83, reference is made to an article in *Zeitschr. f. Angew. Chem.*, 1897, p. 522, by Lunge, in which he says that soda intended for the standardization of acids must not be heated higher than 300°C. (572°F.), and if the heating is carried on at this temperature for a sufficient length of time, one may be sure that neither bicarbonate nor water is left behind, and yet no sodium oxide has been formed as may happen if the heating is carried to a low red heat.

Sodium Carbonate (*b*).—A portion of the washed and dried bicarbonate was carefully heated in a platinum crucible with occasional stirring at 572°F. to constant weight, and immediately analyzed.

Ammonium Sulphate.—Ten grams of the standard acid (to be hereinafter described) were quickly and accurately weighed in a small glass weighing tube, avoiding absorption of moisture from the atmosphere. After rinsing the sample into a large platinum dish, it was made slightly ammoniacal with ammonia that had been freshly distilled to free it from silica. During evaporation on the steam bath, the dish was kept covered by a large funnel and protected from acid fumes. Ammonia was added from time to time, as it was found that the salt became acid on evaporation. After evaporation the dish was dried in an air bath to constant weight at 230°F.

Sulphuric Acid (100 Per Cent. H_2SO_4).—In reviewing the work of Pickering (*Jour. Chem. Soc.*, 1890) it occurred to us that it would be possible to make some pure 100 per cent. sulphuric acid, and that the analysis of this would serve as a suitable check on our other methods. Pickering has shown that the curve of the melting point of sulphuric acid near 100 per cent. reaches a maximum at 100 per cent. Therefore, by starting with an acid slightly less than 100 per cent. and another slightly more than 100 per cent., a point should be reached in recrystallizing when the successive crops of crystals obtained from both acids should show the same per cent. sulphuric acid. This was actually the case.

Starting with 2 liters of chemically pure sulphuric acid, pure redistilled sulphuric anhydride was added until, on analysis, the strength was 99.8 per cent. The bottle was shaken during crystallization so as to obtain small crystals, and when the bottle was half full of crystals the mother liquor was drained off through a porcelain plate fitted over the mouth of the bottle and having a glass tube passing through its center to the bottom of the bottle through which air dried with strong sulphuric acid was admitted, when the bottle was inverted. By draining the crystals for several hours at a temperature slightly above the melting point, the mother liquor was entirely removed. These crystals were then melted and recrystallized, and drained as described above. The crystals thus contained were melted, recrystallized and drained, the final crystals being melted and kept in a sealed bottle until analyzed. Two liters of acid were prepared, analyzing 100.1 per cent. sulphuric acid. From this the standard was prepared in exactly the same manner as in the case of acid analyzing 99.8 per cent. sulphuric acid.

Sulphuric Anhydride.—Another method used as a check on our standard was the titration of sulphuric acid formed by the addition of water to 100 per cent. sulphuric anhydride. To do this required especial care—first, to obtain a sample of sulphuric anhydride free from water, and, after obtaining it, to mix it with water without loss of anhydride. The plan adopted was as follows:

Fuming sulphuric acid containing 40 per cent. free SO_3 was distilled at a low temperature into a long-necked flask fitting tightly over the delivery tube of the retort. A few crystals of potassium permanganate were added to oxidize any sulphur dioxide present. The first 25 c.c. of the distillate were rejected. About 200 c.c. were distilled over. Then this 200 c.c. was redistilled, rejecting the first few cubic centimeters and collecting about 100 c.c. in an ordinary distilling flask, to the delivery tube of which was sealed the open end of a test-tube, which had been drawn out in the center, and bent at the constricted part, almost to a right angle, thus forming a receiver. As soon as the distillation into the flask was completed the neck was sealed, thus making the whole apparatus air-tight. By warming the flask to 140°F. and cooling the receiver, about 20 grams of sulphuric anhydride were distilled over into the latter, which was then sealed at the constricted part having a slight vacuum.

Sulphanilic Acid.—In looking through the list of organic acids for one that would be suitable, sulphanilic acid was decided upon on account of its being a monobasic acid with a high molecular weight, crystallizing without water and drying without decomposition. The so-called c.p. acid was recrystallized three times, finely ground, and dried in an air bath at 230°F. to constant weight.

ANALYSIS OF STANDARDS

For the comparison of the above carefully prepared compounds as standards 2 liters of c.p. sulphuric acid were used. This acid was tested for impurities, found to be practically free, and was kept sealed when not in use, its percentage composition being determined as follows:

Sodium Carbonate (*a*).—Five grams of freshly ignited sodium carbonate, prepared as above, were quickly weighed out, and an amount of standard acid, slightly in excess of the amount required for neutralization was weighed in a small weighing tube and washed into a flask containing the sodium carbonate. After boiling for 15 min. to expel carbon dioxide, the excess of sulphuric acid was titrated with N/2 sodium hydroxide, using phenolphthalein as indicator. A short stem funnel was placed in the neck of the flask to prevent loss while boiling. Duplicate analyses of the standard acid by this method gave 97.33–97.35 per cent. of sulphuric acid.

Sodium Carbonate (*b*).—Five grams sodium carbonate, prepared as above by heating at 572°F. to constant weight, were used in determining the strength of our standard acid. Observing exactly the same conditions described above, we obtained 97.41–97.42 per cent. sulphuric acid.

Ammonium Sulphate.—The ammonium sulphate dried to constant weight at 230°F., as described above, was cooled in a desiccator and quickly weighed.

The salt was then dissolved in water and the small amount of free acid present, as indicated by methyl orange, was titrated with N/3 sodium hydroxide. Adding an equivalent weight of ammonia to the weight above, gave 97.41 per cent. as the strength of the sulphuric acid. The amount of acid titrated was less than 0.10 per cent. (with methyl orange a sharp end point is obtained). A duplicate analysis gave 97.41 per cent. of sulphuric acid.

Sulphuric Acid (100 Per Cent. H_2SO_4).—About 6 grams of acid, crystallized from 99.8 per cent. sulphuric acid, as described above, were introduced into the bottom of a small weighed tube by means of a long-stemmed dropping tube manipulated with a rubber bulb. The glass stopper was then inserted in the tube, the whole weighed, after which the acid was carefully washed into a casserole containing cold water, and titrated with sodium hydroxide solution, using phenolphthalein as indicator, according to the method to be described.

Assuming this acid to be 100 per cent. sulphuric acid, and using the NaOH solution standardized on this basis to determine the composition of the standard acid, duplicate determinations gave 97.39–97.41 per cent. sulphuric acid. Acid crystallized from 100.1 per cent. sulphuric acid. Using this standard exactly as in the preceding our standard acid analyzed 97.40 per cent. sulphuric acid.

Sulphuric Anhydride.—The tube containing the sulphuric anhydride was weighed and placed in a glass-stoppered bottle containing about 100 c.c. of water. The tip was broken off above the level of the water and the bottle sealed. After standing in a warm place for 3 days, the sulphuric anhydride had distilled out of the tube and was absorbed by the water, thus mixing without any loss of sulphuric anhydride. The glass tube was dried and weighed, and, deducting this weight from the weight above, we have the weight of sulphuric anhydride. The resulting acid was diluted to 1 liter and 300 c.c. measured with the dividing burette were titrated with sodium hydroxide solution, using phenolphthalein as indicator, boiling out carbon dioxide and observing the same conditions as in standardizing.

Assuming the sulphuric anhydride to be absolute, and using the sodium hydroxide solution, standardized on this basis, to determine the strength of the standard acid, it was found to be 97.40 and 97.43 per cent. of sulphuric acid.

Sulphanilic Acid.—Twenty grams of this acid, prepared as described above, were titrated, using about 95 c.c. of sodium hydroxide solution, phenolphthalein as indicator, and observing all conditions as in standardizing with sulphuric acid. Assuming the acid to be 100 per cent. pure, and using the sodium hydroxide solution standardized on this basis to determine the strength of our standard acid, it was found to be 97.41 per cent. of sulphuric acid.

Recapitulation of composition of standard sulphuric acid referred to all the standards employed:

	Per cent.	Average
Sodium carbonate—		
(A) Ignited at low red heat to constant weight	97.33 97.35	97.34
(B) Heated at 572°F. to constant weight	97.41 97.42	97.415
Ammonium sulphate method	97.41 97.41	97.41
100 per cent. sulphuric acid prepared from acid slightly under 100 per cent.	97.39 97.41	97.40
100 per cent. sulphuric acid prepared from acid slightly over 100 per cent.	97.40	97.40
Sulphuric anhydride	97.40 97.43	97.415
Sulphanilic acid	97.41	97.41

The close agreement between the above standards, with one exception, is only what the writer and his assistants expected, provided the standards themselves were pure. The analytical methods employed and to be described yield results in experienced hands that are entirely in accordance with the above figures.

The abnormal result in the case of sodium carbonate ignited at a low red heat was investigated as follows:

About 20 grams of sodium carbonate were heated to constant weight at 572°F., and 10 grams used for analysis of the standard acid showed it to contain 97.416 per cent. sulphuric acid. Ten grams were placed in a platinum boat in a combustion tube, where it was heated to moderate red heat in a combustion furnace. A slow stream of dry air, free from carbon dioxide, was aspirated through the tube, and the carbon dioxide, disengaged by heating the sodium carbonate, was absorbed in a saturated solution of barium hydroxide, contained in a bottle. A Mohr bulb containing barium hydroxide was connected with the bottle and proved the complete absorption of carbon dioxide therein. After aspirating for several hours, the bulb was connected directly to the tube and the aspiration continued, which showed that no more carbon dioxide was evolved, no precipitate being formed.

The excess of barium hydroxide was neutralized with strong HCl, and finally carefully titrated with N/300 hydrochloric acid, using phenolphthalein as indicator; the barium carbonate was then titrated with N/300 hydrochloric acid, using methyl orange as indicator.

A blank titration was made using the same reagents, and the difference between the two methyl orange titrations represented the alkalinity due to barium carbonate. In this way 0.0060 gram carbon dioxide were determined by a titration of about 35 c.c. of hydrochloric acid, thus making a simple and accurate determination.[1] The carbonate of soda that had been heated in the combustion tube was removed, accurately weighed, and used to analyze the standard acid. About 10 grams were used, and the result obtained was 97.358 per cent., which is 0.058 per cent. lower than the result obtained above.

0.0060 gram of carbon dioxide formed by decomposition of sodium carbonate would leave 0.0084 gram Na_2O, which, when weighed and calculated as Na_2CO_3, would make a difference in the per cent. of sulphuric acid of 0.056 per cent., which agrees within 0.002 per cent. with the result found.

[1] This method was subsequently published in the *Analyst*, May, 1904, vol. 29, pp. 152–153, Thos. Macara.

After heating to redness:

9.9916 grams Na_2CO_3 are equivalent to	9.2369 grams H_2SO_4
0.0084 gram Na_2CO_3 are equivalent to	0.0134 gram H_2SO_4
	9.2503 grams H_2SO_4
Before heating to redness:	
10.0000 grams Na_2CO_3 are equivalent to	9.2447 grams H_2SO_4
Increased alkalinity due to Na_2O formed	0.0056 gram H_2SO_4
Equivalent to................	0.056 per cent. of H_2SO_4

If the CO_2 found had been the result of decomposition of sodium bicarbonate, the increased alkalinity would have been 0.078 per cent. instead of 0.058 per cent. as found.

By heat:

$$\underset{168.116}{2NaHCO_3} = \underset{106.1}{Na_2CO_3} + \underset{44}{CO_2} + \underset{18.016}{H_2O}.$$

0.0060 gram CO_2 found are equivalent to 0.0228 gram $NaHCO_3$.

After heating to redness:

10.0 grams Na_2CO_3 are equivalent to....... 9.2447 grams H_2SO_4

Before heating to redness:

9.9772 grams Na_2CO_3 are equivalent to............ 9.2236 grams

0.0228 gram $NaHCO_3$ are equivalent to............ 0.0133 gram

9.2369 grams 9.2369 grams H_2SO_4

Increased alkalinity due to formation.......... 0.0078 gram H_2SO_4

or of Na_2CO_3 from $NaHCO_3$ equivalent to 0.078 per cent. of H_2SO_4

It is thus indicated by this experiment that the carbon dioxide formed is the result of decomposition of Na_2CO_3 into Na_2O+CO_2.

A sample of sodium carbonate, prepared by drying to constant weight at 572°F., was heated until it had completely fused, and analysis showed an increased alkalinity equivalent to 0.30 per cent. of carbon dioxide disengaged.

If the calcium and magnesium carbonates present in the purified carbonate were entirely converted into oxides when ignited at low red heat only 0.018 per cent. increased alkalinity would be accounted for.

These results, considered together with the close agreement between the other standards and sodium carbonate ignited at 572°F., are very convincing arguments in favor of preparing standard sodium carbonate in this manner.

Standard Acid.—Averaging the results obtained from the different standards enumerated above, excepting sodium carbonate ignited to redness, its percentage composition was found to be 97.41 per cent. sulphuric acid.

This acid or its equivalent was used for standardizing the caustic soda that was employed for all analytical determinations embraced in these tables.

The burette used was a 100-c.c. chamber burette graduated from 95–100 c.c. in $\frac{1}{10}$ c.c., and readable to $\frac{1}{100}$ c.c. The burette was standardized between 95 and 100 by weighing mercury delivered every $\frac{1}{2}$ c.c., and for 1 c.c. the mercury was weighed every $\frac{1}{10}$ c.c.; the readings and graduations were found to be accurate to $\frac{1}{100}$ c.c. The burette was frequently cleaned with strong sulphuric acid, so that it drained perfectly for each determination.

Standard Sodium Hydroxide Solution.—This solution was prepared from c.p. caustic soda, purified by baryta, and was made of such strength that 6 grams of standard acid required 95–98 c.c. Caustic soda purified by alcohol is not suitable for this purpose, as it does not drain properly in the burette, but produces an oily appearance. To standardize this solution, using methyl orange as indicator, about 6 grams of the standard acid were quickly and accurately weighed out, diluted with about 400 c.c. cold distilled water and 1 c.c. of a $\frac{1}{10}$ per cent. solution of methyl orange added. The caustic soda solution was then run in from the 100-c.c. chamber burette until a few tenths of a cubic centimeter excess had been added, and after 3-min. draining the burette was read. Standard sulphuric acid of strength about equivalent to the soda solution was added from a burette until a trace changed the color of the solution from yellow to orange. The end point is sharper in titrating from alkaline to acid than *vice versa.*

$$\frac{H_2SO_4 \text{ taken} - H_2SO_4 \text{ 2d titration}}{\text{c.c. NaOH}} = \text{grams of sulphuric acid}$$
equivalent to 1 c.c. sodium hydroxide solution.

A thermometer was kept in the standard solution, and the temperature at which the solution was standardized was recorded, and in making a subsequent titration at any other temperature the necessary correction was applied to the reading. The correction for temperature was determined with the picnometer, as described above, and for 100 c.c. of solution was found to be 0.015 c.c. = 1°F., to be subtracted when the temperature was above the temperature of standardizing, and added when below.

Duplicate titrations agreed within 0.03 c.c. Methyl orange was used in titrating nitric acid, hydrochloric acid and ammonia.

To standardize with phenolphthalein, about 6 grams of the standard acid were accurately weighed out and poured into a casserole containing about 25 c.c. of cold water, all acid being rinsed from a small weighing beaker into the casserole. One cubic centimeter of phenolphthalein solution (1 gram per liter) was added, and the sodium hydroxide solution run in from the 100-c.c. chamber burette until within about 0.5 c.c. of the end point. The solution was then boiled for 5 min. to remove carbon dioxide, and the titration finished by cutting the drops from the tip of the burette until a fraction of a drop produced a faint pink color. This tint was carefully noted, and all analyses run to the same end point. By boiling for exactly 5 min., provision was made for uniform draining of the burette. Duplicate titrations agreed within 0.02 c.c.

While the limits of burette reading were placed at 0.03 c.c. when methyl orange was used, and 0.02 c.c. for phenolphthalein, yet, as will be shown, the actual duplicates obtained by two men working independently averaged much closer.

Dividing Burette.—The dividing burette referred to under standardizing with sulphuric anhydride is designed for accurately dividing a solution. It consists of a burette the top of which is drawn to a capillary and bent downward; the stop-cock of the burette is a three-way cock, the third passage being connected to a vertical tube at the top of which is a funnel for filling the burette. One and 2-liter flasks with small necks were graduated by running from the burette a sufficient number of times to fill the flask to a point in the neck. This point was carefully checked, and in subsequent use, it was always filled to this mark.

The amount of water delivered by the burette was weighed, and the weights checked within 0.004 gram, or $\frac{1}{25,000}$ of the weight of one burette full. In measuring out an equivalent of 5 grams of a liquid made up to volume, the error would be 0.0002 gram.

The tables are described in the order in which they were prepared during a period of nearly 3 years.

NITRIC-ACID TABLE

The c.p. nitric acid employed was free from nitrous and hydrochloric acids, and the residue upon evaporation at 212°F. was too small to affect the determinations. This acid was used for all samples up to 43°Bé., and for the stronger samples this acid was concentrated by distilling with pure glacial phosphoric acid and potassium permanganate, the latter to prevent the formation of nitrous acid. 95.80 per cent. nitric acid was the strongest sample obtainable, for above this point the acid contained large amounts of nitrous acid.

The specific-gravity determinations were made as described above, and at the same time the picnometer was filled, a 6 to 8-gram sample was weighed in a small weighing tube having a ground-glass stopper, which prevented loss while weighing and diluting. The sample was diluted with water by removing the stopper of the tube with a glass fork while immersed in a casserole containing approximately 400 c.c. of water. The titration was then made, using methyl orange as indicator, observing the conditions described in standardizing.

Allowance for Temperature.—After determining the specific gravity of the different strengths employed at 60°F., the temperature was raised to 70°F., and the picnometer weighed; likewise at 80°F. from this data the allowance for temperature was calculated, and was found to be uniform for a given strength of acid. At 43°Bé. the determinations were made from 50° to 90°F.

The following determinations were made, and from these the table was calculated by interpolation, the specific gravity and corresponding percentage composition being calculated to correspond with each 0.25°Bé.

From the Baumé the corresponding specific gravity was calculated by the formula:

$$\text{Degrees Baumé} = 145 - \frac{145}{\text{Specific gravity}}$$

The instability of 96 per cent. nitric acid is so great that agreeing determinations were difficult to obtain, and those selected corresponded with the differential of the table at this point.

Specific gravity	Per cent. HNO_3	Specific gravity	Per cent. HNO_3
1.0844[1]	14.49	1.4506	77.15
		1.4507	77.16
1.1095[1]	18.45		
		1.4563	78.78
1.1659[1]	27.15	1.4563	78.80
1.2109[1]	33.80	1.4707	82.88
		1.4707	82.91
1.2641	41.77		
1.2643	41.81	1.4873	88.33
		1.4871	88.31
1.3144	49.69		
1.3144	49.70	1.4951	91.42
		1.4950	91.39
1.3761	60.45		
1.3760	60.44	1.4963	91.92
		1.4961	91.91
1.4469	76.57		
1.4471	76.57	1.5014	94.59
		1.5014	94.58
1.4405	74.84		
1.4404	74.80	1.5037	95 64
		1.5044	95.80

[1] These determinations are the average of results that checked within 0.0001 specific gravity and 0.02 per cent., the record of which has been lost.

The following will show the comparative sensitiveness of the analytical determinations, specific-gravity determinations and reading of a delicate Baumé hydrometer and thermometer graduated to 1°F., in terms of specific gravity:

Bé.	Anal. det.	Sp.-gr. det.	Bé. reading 1/20°
15°	0.00013 sp. gr.	0.0001 sp. gr.	0.00044 sp. gr.
30°	0.00013 sp. gr.	0.0001 sp. gr.	0.00056 sp. gr.
45°	0.00008 sp. gr.	0.0001 sp. gr.	0.00072 sp. gr.

HYDROCHLORIC-ACID TABLE

The purest c.p. hydrochloric acid obtainable was tested for free chlorine, sulphuric acid and residue upon evaporation at 212°F. There were only traces of impurities, which would affect the determinations less than the errors of manipulation.

For the samples above 22°Bé. this acid was concentrated by distilling it into a portion cooled in ice water. 42.61 per cent. hydrochloric acid was the strongest sample upon which a specific-gravity determination could be obtained at 60°F. Above this point bubbles of gas were formed in the picnometer when warmed to 60°F.

The specific gravity and allowance for temperature were determined as in the case of nitric acid. The allowance for temperature was found to be uniform for each strength of acid; 22°Bé. deteminations were made from 50° to 90°F.

After making the above determinations the thermometer of the picnometer was withdrawn while the bottle was immersed in about 700 c.c. of water in a large casserole, thus avoiding loss while diluting. The bottle was carefully washed out and the dilute acid made up to 2 liters in a flask standardized against the 100 c.c., dividing burette and portions of this solution were taken with the burette for titration with sodium hydroxide. Methyl orange was used as indicator, the same conditions used in standardizing being closely followed, about 98 c.c. of sodium hydroxide solution being used for each determination. A sample of hydrochloric acid was analyzed by precipitating with silver nitrate and the silver chloride calculated to hydrochloric acid checked the results obtained by titration.

By silver chloride	By titration
29.97 per cent. HCl	29.97 per cent. HCl
29.98 per cent. HCl	30.00 per cent. HCl

The following determinations were made, and from these the table was calculated by interpolation, the specific gravity and corresponding percentage composition being calculated for each 1°Bé. from 1°–5°, 0.25°Bé., from 5°–16° and for the rest of the table for each 0.1°Bé.

Specific gravity	Per cent. HCl	Specific gravity	Per cent. HCl
1.02813	5.73	1.13926	27.44
1.02815	5.73	1.13928	27.47
1.05353	10.74	1.15277	30.07
1.05359	10.73	1.15273	30.04
1.07676	15.37	1.16642	32.70
1.07678	15.37	1.16652	32.72
1.09670	19.29	1.19918	39.61
1.09664	19.28	1.19902	39.56
1.11440	22.73	1.20586	41.16
1.11442	22.76	1.20584	41.13
1.12300	24.35	1.21140	42.65
1.12300	24.37	1.21120	42.57

The following will show the comparative sensitiveness of the analytical determinations, specific gravity determination and reading of a delicate Baumé hydrometer and thermometer graduated to 1°F. in terms of specific gravity:

Specific gravity	Anal. det.	Sp.-gr. det.	Bé. $\frac{1}{10}$°
10°	0.00004 sp. gr.	0.00005 sp. gr.	0.00027 sp. gr.
18°	0.00015 sp. gr.	0.00005 sp. gr.	0.00031 sp. gr.
24°	0.00012 sp. gr.	0.00010 sp. gr.	0.00033 sp. gr.

SULPHURIC-ACID TABLE

The c.p. sulphuric acid used was 1.84 specific gravity, was free from hydrochloric and nitric acids and ammonia and gave a trace of residue upon evaporation. The impurities were less than enough to affect either the specific gravity or analytical determinations.

The specific-gravity determinations were made as described above, except that in bringing the temperature to 60°F., the picnometer was immersed to the neck in a beaker of water a few degrees below 60°F., so that the temperature rose slowly, being the same inside and outside when capped.

The allowance for temperature for every 10°F. between 50° and 90°F. was determined at the following degrees Baumé: 66, 63, 57, 51, 44, 36, 29, 21, 12. It was found to be practically uniform for a given strength of acid, and the results are based on a range of 40°F., the table giving the corrections at even degrees Baumé, being calculated from these results by interpolation. Samples were taken from the picnometer for analysis, and an amount of acid was weighed out each time which would require between 95 and 100 c.c. of soda solution. With the weakest samples a more dilute standard soda solution was used, but the same conditions as used in standardizing with phenolphthalein were closely observed in all cases.

The boiling-point determinations were made in a 200 c.c. long-necked flask, using about 100 c.c. of acid in each case. A certified thermometer accurate to 1°F. was suspended in the acid. A small piece of porcelain was placed in the bottom of the flask to facilitate boiling. The flask was gradually heated with a free flame and the temperature recorded when boiling was first perceptible.

The following determinations were made, and from these the table was calculated by interpolation, the specific gravity and the corresponding percentage composition being calculated for each degree Baumé from 0°–64° and for each ¼°Bé. from 64°–66°Bé.

From the Baumé the corresponding specific gravity was calculated by the formula: Degrees Baumé $= 145 - \frac{145}{\text{specific gravity}}$. The degree Twaddle was calculated by dividing the decimal part of the specific gravity by 0.005.

Specific gravity	Per cent. H_2SO_4	Specific gravity	Per cent. H_2SO_4
1.00488	0.713	1.52814	62.342
1.00468	0.701	1.52803	62.334
1.03471	5.145	1.54403	63.792
1.03470	5.142	1.54399	63.776
1.06488	9.473	1.57481	66.518
1.06472	9.469	1.57482	66.515
1.09918	14.221	1.62722	70.990
1.09912	14.217	1.62723	71.000
1.13532	19.042	1.66807	74.480
1.13532	19.041	1.66773	74.438
1.17362	23.936	1.70438	77.546
1.17344	23.929	1.70449	77.555
1.21051	28.549	1.72577	79.377
1.21045	28.543	1.72576	79.398
1.25129	33.488	1.74733	81.322
1.25132	33.484	1.74714	81.324
1.29513	38.651	1.77002	83.482
1.29507	38.631	1.76987	83.467
1.34415	44.149	1.79590	86.364
1.34403	44.140	1.79603	86.363
1.39469	49.521	1.81185	88.534
1.39460	49.519	1.81163	88.527
1.43084	53.193	1.81939	89.752
1.43072	53.175	1.81929	89.732
1.46673	56.674	1.82756	91.337
1.46678	56.675	1.82750	91.308
1.48219	58.143	1.83557	93.219
1.48225	58.128	1.83555	93.226

The following will show the comparative sensitiveness of the analytical determinations, the specific-gravity determinations, and the reading of a delicate Baumé hydrometer and thermometer graduated to 1°F., in terms of a specific gravity:

Bé.	Anal. det.	Sp.-gr. det.	Bé. 1/10°
20°	0.00007 sp. gr.	0.00005 sp. gr.	0.00024 sp. gr.
50°	0.00005 sp. gr.	0.00005 sp. gr.	0.00040 sp. gr.
66°	0.00004 sp. gr.	0.00006 sp. gr.	0.00057 sp. gr.

The following chemists, my assistants, aided in the preparation of the tables:

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T. Lynton Briggs, F. I. C., F. C. S.

Such merit as these tables possess is largely due to these gentlemen, but more especially to Mr. Bishop who had immediate charge of, and participated in most of the determinations, and who shared with the writer the preparation of this paper.

Nitric Acid
By W. C. Ferguson

Degrees Baumé	Specific gravity $\frac{60^\circ}{60^\circ}$F.	Degrees Twaddle	Per cent. HNO_3	Degrees Baumé	Specific gravity $\frac{60^\circ}{60^\circ}$F.	Degrees Twaddle	Per cent. HNO_3
10.00	1.0741	14.82	12.86	20.75	1.1671	33.42	27.33
10.25	1.0761	15.22	13.18	21.00	1.1694	33.88	27.67
10.50	1.0781	15.62	13.49	21.25	1.1718	34.36	28.02
10.75	1.0801	16.02	13.81	21.50	1.1741	34.82	28.36
11.00	1.0821	16.42	14.13	21.75	1.1765	35.30	28.72
11.25	1.0841	16.82	14.44	22.00	1.1789	35.78	29.07
11.50	1.0861	17.22	14.76	22.25	1.1813	36.26	29.43
11.75	1.0881	17.62	15.07	22.50	1.1837	36.74	29.78
12.00	1.0902	18.04	15.41	22.75	1.1861	37.22	30.14
12.25	1.0922	18.44	15.72	23.00	1.1885	37.70	30.49
12.50	1.0943	18.86	16.05	23.25	1.1910	38.20	30.86
12.75	1.0964	19.28	16.39	23.50	1.1934	38.68	31.21
13.00	1.0985	19.70	16.72	23.75	1.1959	39.18	31.58
13.25	1.1006	20.12	17.05	24.00	1.1983	39.66	31.94
13.50	1.1027	20.54	17.38	24.25	1.2008	40.16	32.31
13.75	1.1048	20.96	17.71	24.50	1.2033	40.66	32.68
14.00	1.1069	21.38	18.04	24.75	1.2058	41.16	33.05
14.25	1.1090	21.80	18.37	25.00	1.2083	41.66	33.42
14.50	1.1111	22.22	18.70	25.25	1.2109	42.18	33.80
14.75	1.1132	22.64	19.02	25.50	1.2134	42.68	34.17
15.00	1.1154	23.08	19.36	25.75	1.2160	43.20	34.56
15.25	1.1176	23.52	19.70	26.00	1.2185	43.70	34.94
15.50	1.1197	23.94	20.02	26.25	1.2211	44.22	35.33
15.75	1.1219	24.38	20.36	26.50	1.2236	44.72	35.70
16.00	1.1240	24.80	20.69	26.75	1.2262	45.24	36.09
16.25	1.1262	25.24	21.03	27.00	1.2288	45.76	36.48
16.50	1.1284	25.68	21.36	27.25	1.2314	46.28	36.87
16.75	1.1306	26.12	21.70	27.50	1.2340	46.80	37.26
17.00	1.1328	26.56	22.04	27.75	1.2367	47.34	37.67
17.25	1.1350	27.00	22.38	28.00	1.2393	47.86	38.06
17.50	1.1373	27.46	22.74	28.25	1.2420	48.40	38.46
17.75	1.1395	27.90	23.08	28.50	1.2446	48.92	38.85
18.00	1.1417	28.34	23.42	28.75	1.2473	49.46	39.25
18.25	1.1440	28.80	23.77	29.00	1.2500	50.00	39.66
18.50	1.1462	29.24	24.11	29.25	1.2527	50.54	40.06
18.75	1.1485	29.70	24.47	29.50	1.2554	51.08	40.47
19.00	1.1508	30.16	24.82	29.75	1.2582	51.64	40.89
19.25	1.1531	30.62	25.18	30.00	1.2609	52.18	41.30
19.50	1.1554	31.08	25.53	30.25	1.2637	52.74	41.72
19.75	1.1577	31.54	25.88	30.50	1.2664	53.28	42.14
20.00	1.1600	32.00	26.24	30.75	1.2692	53.84	42.58
20.25	1.1624	32.48	26.61	31.00	1.2719	54.38	43.00
20.50	1.1647	32.94	26.96	31.25	1.2747	54.94	43.44

NITRIC ACID—(*Concluded*)

Degrees Baumé	Specific gravity $\frac{60°}{60°}$ F.	Degrees Twaddle	Per cent. HNO_3	Degrees Baumé	Specific gravity $\frac{60°}{60°}$ F.	Degrees Twaddle	Per cent. HNO_3
31.50	1.2775	55.50	43.89	40.25	1.3843	76.86	62.07
31.75	1.2804	56.08	44.34	40.50	1.3876	77.52	62.77
32.00	1.2832	56.64	44.78	40.75	1.3909	78.18	63.48
32.25	1.2861	57.22	45.24	41.00	1.3942	78.84	64.20
32.50	1.2889	57.78	45.68	41.25	1.3976	79.52	64.93
32.75	1.2918	58.36	46.14	41.50	1.4010	80.20	65.67
33.00	1.2946	58.92	46.58	41.75	1.4044	80.88	66.42
33.25	1.2975	59.50	47.04	42.00	1.4078	81.56	67.18
33.50	1.3004	60.08	47.49	42.25	1.4112	82.24	67.95
33.75	1.3034	60.68	47.95	42.50	1.4146	82.92	68.73
34.00	1.3063	61.26	48.42	42.75	1.4181	83.62	69.52
34.25	1.3093	61.86	48.90	43.00	1.4216	84.32	70.33
34.50	1.3122	62.44	49.35	43.25	1.4251	85.02	71.15
34.75	1.3152	63.04	49.83	43.50	1.4286	85.72	71.98
35.00	1.3182	63.64	50.32	43.75	1.4321	86.42	72.82
35.25	1.3212	64.24	50.81	44.00	1.4356	87.12	73.67
35.50	1.3242	64.84	51.30	44.25	1.4392	87.84	74.53
35.75	1.3273	65.46	51.80	44.50	1.4428	88.56	75.40
36.00	1.3303	66.06	52.30	44.75	1.4464	89.28	76.28
36.25	1.3334	66.68	52.81	45.00	1.4500	90.00	77.17
36.50	1.3364	67.28	53.32	45.25	1.4536	90.72	78.07
36.75	1.3395	67.90	53.84	45.50	1.4573	91.46	79.03
37.00	1.3426	68.52	54.36	45.75	1.4610	92.20	80.04
37.25	1.3457	69.14	54.89	46.00	1.4646	92.92	81.08
37.50	1.3488	69.76	55.43	46.25	1.4684	93.68	82.18
37.75	1.3520	70.40	55.97	46.50	1.4721	94.42	83.33
38.00	1.3551	71.02	56.52	46.75	1.4758	95.16	84.48
38.25	1.3583	71.66	57.08	47.00	1.4796	95.92	85.70
38.50	1.3615	72.30	57.65	47.25	1.4834	96.68	86.98
38.75	1.3647	72.94	58.23	47.50	1.4872	97.44	88.32
39.00	1.3679	73.58	58.82	47.75	1.4910	98.20	89.76
39.25	1.3712	74.24	59.43	48.00	1.4948	98.96	91.35
39.50	1.3744	74.88	60.06	48.25	1.4987	99.74	93.13
39.75	1.3777	75.54	60.71	48.50	1.5026	100.52	95.11
40.00	1.3810	76.20	61.38				

Specific gravity determinations were made at 60°F., compared with water at 60°F.

From the specific gravities, the corresponding degrees Baumé were calculated by the following formula:

$$\text{Degrees Baumé} = 145 - \frac{145}{\text{specific gravity}}$$

Baumé hydrometers for use with this table must be graduated by the above formula, which formula should always be printed on the scale.

Atomic weights from F. W. Clarke's table of 1901. O = 16.

ALLOWANCE FOR TEMPERATURE

At 10°–20° Bé.—$\frac{1}{30}$°Bé. or .00029 specific gravity = 1°F.
20°–30° Bé.—$\frac{1}{23}$°Bé. or .00044 specific gravity = 1°F.
30°–40° Bé.—$\frac{1}{20}$°Bé. or .00060 specific gravity = 1°F.
40°–48.5°Bé.—$\frac{1}{17}$°Bé. or .00084 specific gravity = 1°F.

AUTHORITY—W. C. FERGUSON

This table has been approved and adopted as a Standard by the Manufacturing Chemists' Association of the United States.

W. H. BOWER, JAS. L. MORGAN,
HENRY HOWARD, ARTHUR WYMAN.
A. G. ROSENGARTEN,

New York, May 14, 1903. *Executive Committee.*

HYDROCHLORIC ACID
BY W. C. FERGUSON

Degrees Baumé	Specific gravity $\frac{60°}{60°}$F.	Degrees Twaddle	Per cent. HCl	Degrees Baumé	Specific gravity $\frac{60°}{60°}$F.	Degrees Twaddle	Per cent. HCl
1.00	1.0069	1.38	1.40	15.00	1.1154	23.08	22.92
2.00	1.0140	2.80	2.82	15.25	1.1176	23.52	23.33
3.00	1.0211	4.22	4.25	15.50	1.1197	23.94	23.75
4.00	1.0284	5.68	5.69	15.75	1.1219	24.38	24.16
5.00	1.0357	7.14	7.15	16.0	1.1240	24.80	24.57
5.25	1.0375	7.50	7.52	16.1	1.1248	24.96	24.73
5.50	1.0394	7.88	7.89	16.2	1.1256	25.12	24.90
5.75	1.0413	8.26	8.26	16.3	1.1265	25.30	25.06
6.00	1.0432	8.64	8.64	16.4	1.1274	25.48	25.23
6.25	1.0450	9.00	9.02	16.5	1.1283	25.66	25.39
6.50	1.0469	9.38	9.40	16.6	1.1292	25.84	25.56
6.75	1.0488	9.76	9.78	16.7	1.1301	26.02	25.72
7.00	1.0507	10.14	10.17	16.8	1.1310	26.20	25.89
7.25	1.0526	10.52	10.55	16.9	1.1319	26.38	26.05
7.50	1.0545	10.90	10.94	17.0	1.1328	26.56	26.22
7.75	1.0564	11.28	11.32	17.1	1.1336	26.72	26.39
8.00	1.0584	11.68	11.71	17.2	1.1345	26.90	26.56
8.25	1.0603	12.06	12.09	17.3	1.1354	27.08	26.73
8.50	1.0623	12.46	12.48	17.4	1.1363	27.26	26.90
8.75	1.0642	12.84	12.87	17.5	1.1372	27.44	27.07
9.00	1.0662	13.24	13.26	17.6	1.1381	27.62	27.24
9.25	1.0681	13.62	13.65	17.7	1.1390	27.80	27.41
9.50	1.0701	14.02	14.04	17.8	1.1399	27.98	27.58
9.75	1.0721	14.42	14.43	17.9	1.1408	28.16	27.75
10.00	1.0741	14.82	14.83	18.0	1.1417	28.34	27.92
10.25	1.0761	15.22	15.22	18.1	1.1426	28.52	28.09
10.50	1.0781	15.62	15.62	18.2	1.1435	28.70	28.26
10.75	1.0801	16.02	16.01	18.3	1.1444	28.88	28.44
11.00	1.0821	16.42	16.41	18.4	1.1453	29.06	28.61
11.25	1.0841	16.82	16.81	18.5	1.1462	29.24	28.78
11.50	1.0861	17.22	17.21	18.6	1.1471	29.42	28.95
11.75	1.0881	17.62	17.61	18.7	1.1480	29.60	29.13
12.00	1.0902	18.04	18.01	18.8	1.1489	29.78	29.30
12.25	1.0922	18.44	18.41	18.9	1.1498	29.96	29.48
12.50	1.0943	18.86	18.82	19.0	1.1508	30.16	29.65
12.75	1.0964	19.28	19.22	19.1	1.1517	30.34	29.83
13.00	1.0985	19.70	19.63	19.2	1.1526	30.52	30.00
13.25	1.1006	20.12	20.04	19.3	1.1535	30.70	30.18
13.50	1.1027	20.54	20.45	19.4	1.1544	30.88	30.35
13.75	1.1048	20.96	20.86	19.5	1.1554	31.08	30.53
14.00	1.1069	21.38	21.27	19.6	1.1563	31.26	30.71
14.25	1.1090	21.80	21.68	19.7	1.1572	31.44	30.90
14.50	1.1111	22.22	22.09	19.8	1.1581	31.62	31.08
14.75	1.1132	22.64	22.50	19.9	1.1590	31.80	31.27

HYDROCHLORIC ACID—(*Concluded*)

Degrees Baumé	Specific gravity $\frac{60°}{60°}$F.	Degrees Twaddle	Per cent. HCl	Degrees Baumé	Specific gravity $\frac{60°}{60°}$F.	Degrees Twaddle	Per cent. HCl
20.0	1.1600	32.00	31.45	22.8	1.1866	37.32	36.73
20.1	1.1609	32.18	31.64	22.9	1.1875	37.50	36.93
20.2	1.1619	32.38	31.82	23.0	1.1885	37.70	37.14
20.3	1.1628	32.56	32.01	23.1	1.1895	37.90	37.36
20.4	1.1637	32.74	32.19	23.2	1.1904	38.08	37.58
20.5	1.1647	32.94	32.38	23.3	1.1914	38.28	37.80
20.6	1.1656	33.12	32.56	23.4	1.1924	38.48	38.03
20.7	1.1666	33.32	32.75	23.5	1.1934	38.68	38.26
20.8	1.1675	33.50	32.93	23.6	1.1944	38.88	38.49
20.9	1.1684	33.68	33.12	23.7	1.1953	39.06	38.72
21.0	1.1694	33.88	33.31	23.8	1.1963	39.26	38.95
21.1	1.1703	34.06	33.50	23.9	1.1973	39.46	39.18
21.2	1.1713	34.26	33.69	24.0	1.1983	39.66	39.41
21.3	1.1722	34.44	33.88	24.1	1.1993	39.86	39.64
21.4	1.1732	34.64	34.07	24.2	1.2003	40.06	39.86
21.5	1.1741	34.82	34.26	24.3	1.2013	40.26	40.09
21.6	1.1751	35.02	34.45	24.4	1.2023	40.46	40.32
21.7	1.1760	35.20	34.64	24.5	1.2033	40.66	40.55
21.8	1.1770	35.40	34.83	24.6	1.2043	40.86	40.78
21.9	1.1779	35.58	35.02	24.7	1.2053	41.06	41.01
22.0	1.1789	35.78	35.21	24.8	1.2063	41.26	41.24
22.1	1.1798	35.96	35.40	24.9	1.2073	41.46	41.48
22.2	1.1808	36.16	35.59	25.0	1.2083	41.66	41.72
22.3	1.1817	36.34	35.78	25.1	1.2093	41.86	41.99
22.4	1.1827	36.54	35.97	25.2	1.2103	42.06	42.30
22.5	1.1836	36.72	36.16	25.3	1.2114	42.28	42.64
22.6	1.1846	36.92	36.35	25.4	1.2124	42.48	43.01
22.7	1.1856	37.12	36.54	25.5	1.2134	42.68	43.40

Specific-gravity determinations were made at 60°F., compared with water at 60°F.

From the specific gravities, the corresponding degrees Baumé were calculated by the following formula:

$$\text{Degrees Baumé} = 145 - \frac{145}{\text{specific gravity}}$$

Atomic weights from F. W. Clarke's table of 1901. O = 16.

ALLOWANCE FOR TEMPERATURE

10–15°Bé.—$\frac{1}{40}$°Bé. or .0002 sp. gr. for 1°F.
15–22°Bé.—$\frac{1}{30}$°Bé. or .0003 sp. gr. for 1°F.
22–25°Bé.—$\frac{1}{28}$°Bé. or .00035 sp. gr. for 1°F.

AUTHORITY—W. C. FERGUSON

This table has been approved and adopted as a Standard by the Manufacturing Chemists' Association of the United States.

W. H. BOWER, JAS. L. MORGAN,
HENRY HOWARD, ARTHUR WYMAN.
A. G. ROSENGARTEN,

New York, May 14, 1903. *Executive Committee.*

TABLE OF SULPHURIC ACID

By W. C. Ferguson and H. P. Talbot

Sulphuric Acid

By W. C. Ferguson and H. P. Talbot

Degrees Baumé	Specific gravity $\frac{60°}{60°}$F.	Degrees Twaddle	Per cent. H_2SO_4	Weight of 1 cu. ft. in lb. av.	Per cent. O. V.	Pounds O. V. in 1 cu. ft.
0	1.0000	0.0	0.00	62.37	0.00	0.00
1	1.0069	1.4	1.02	62.80	1.09	0.68
2	1.0140	2.8	2.08	63.24	2.23	1.41
3	1.0211	4.2	3.13	63.69	3.36	2.14
4	1.0284	5.7	4.21	64.14	4.52	2.90
5	1.0357	7.1	5.28	64.60	5.67	3.66
6	1.0432	8.6	6.37	65.06	6.84	4.45
7	1.0507	10.1	7.45	65.53	7.99	5.24
8	1.0584	11.7	8.55	66.01	9.17	6.06
9	1.0662	13.2	9.66	66.50	10.37	6.89
10	1.0741	14.8	10.77	66.99	11.56	7.74
11	1.0821	16.4	11.89	67.49	12.76	8.61
12	1.0902	18.0	13.01	68.00	13.96	9.49
13	1.0985	19.7	14.13	68.51	15.16	10.39
14	1.1069	21.4	15.25	69.04	16.36	11.30
15	1.1154	23.1	16.38	69.57	17.58	12.23
16	1.1240	24.8	17.53	70.10	18.81	13.19
17	1.1328	26.6	18.71	70.65	20.08	14.18
18	1.1417	28.3	19.89	71.21	21.34	15.20
19	1.1508	30.2	21.07	71.78	22.61	16.23
20	1.1600	32.0	22.25	72.35	23.87	17.27
21	1.1694	33.9	23.43	72.94	25.14	18.34
22	1.1789	35.8	24.61	73.53	26.41	19.42
23	1.1885	37.7	25.81	74.13	27.69	20.53
24	1.1983	39.7	27.03	74.74	29.00	21.68

Specific Gravity determinations were made at 60°F., compared with water at 60°F.

From the Specific Gravities, the corresponding degrees Baumé were calculated by the following formula: Degrees Baumé $= 145 - \frac{145}{\text{Specific Gravity}}$.

Baumé hydrometers for use with this table must be graduated by the above formula, which formula should always be printed on the scale.

66°Bé. = specific gravity 1.8354 = Oil of Vitriol (O. V.).

1 cu. ft. water at 60°F. weighs 62.37 lb. av.

Atomic weights from F. W. Clarke's table of 1901. O = 16.

H_2SO_4 = 100 per cent.

	Per cent. H_2SO_4	Per cent O. V.	Per cent. 60°
O. V. =	93.19 =	100.00 =	119.98
60° =	77.67 =	83.35 =	100.00
50° =	62.18 =	66.72 =	80.06

SULPHURIC ACID

BY W. C. FERGUSON AND H. P. TALBOT

Degrees Baumé	Freezing[1] (melting) points, °F.
0	32.0
1	31.2
2	30.5
3	29.8
4	28.9
5	28.1
6	27.2
7	26.3
8	25.1
9	24.0
10	22.8
11	21.5
12	20.0
13	18.3
14	16.6
15	14.7
16	12.6
17	10.2
18	7.7
19	4.8
20	+ 1.6
21	− 1.8
22	− 6.0
23	−11.0
24	−16.0

APPROXIMATE BOILING POINTS

50°Bé., 295°F.
60°Bé., 386°F.
61°Bé., 400°F.
62°Bé., 415°F.
63°Bé., 432°F.
64°Bé., 451°F.
65°Bé., 485°F.
66°Bé., 538°F.

FIXED POINTS

Specific gravity	Per cent. H_2SO_4	Specific gravity	Per cent. H_2SO_4
1.0000	0.00	1.5281	62.34
1.0048	0.71	1.5440	63.79
1.0347	5.14	1.5748	66.51
1.0649	9.48	1.6272	71.00
1.0992	14.22	1.6679	74.46
1.1353	19.04	1.7044	77.54
1.1736	23.94	1.7258	79.40
1.2105	28.55	1.7472	81.32
1.2513	33.49	1.7700	83.47
1.2951	38.64	1.7959	86.36
1.3441	44.15	1.8117	88.53
1.3947	49.52	1.8194	89.75
1.4307	53.17	1.8275	91.32
1.4667	56.68	1.8354	93.19
1.4822	58.14		

Acids stronger than 66°Bé. should have their percentage compositions determined by chemical analysis.

AUTHORITIES—W. C. FERGUSON; H. P. TALBOT.

This table has been approved and adopted as a standard by the Manufacturing Chemists' Association of the United States.

W. H. BOWER,
HENRY HOWARD,
JAS. L. MORGAN,
ARTHUR WYMAN,
A. G. ROSENGARTEN,
Executive Committee.

New York, June 23, 1904.

[1] Calculated from Pickering's results, *Jour. Lon. Chem. Soc.*, vol. 57, p. 363.

Sulphuric Acid—(*Continued*)

Degrees Baumé	Specific gravity $\frac{60°}{60°}$F.	Degrees Twaddle	Per cent. H_2SO_4	Weight of 1 cu. ft. in lb av.	Per cent. O. V.	Pounds O. V. in 1 cu. ft.
25	1.2083	41.7	28.28	75.36	30.34	22.87
26	1.2185	43.7	29.53	76.00	31.69	24.08
27	1.2288	45.8	30.79	76.64	33.04	25.32
28	1.2393	47.9	32.05	77.30	34.39	26.58
29	1.2500	50.0	33.33	77.96	35.76	27.88
30	1.2609	52.2	34.63	78.64	37.16	29.22
31	1.2719	54.4	35.93	79.33	38.55	30.58
32	1.2832	56.6	37.26	80.03	39.98	32.00
33	1.2946	58.9	38.58	80.74	41.40	33.42
34	1.3063	61.3	39.92	81.47	42.83	34.90
35	1.3182	63.6	41.27	82.22	44.28	36.41
36	1.3303	66.1	42.63	82.97	45.74	37.95
37	1.3426	68.5	43.99	83.74	47.20	39.53
38	1.3551	71.0	45.35	84.52	48.66	41.13
39	1.3679	73.6	46.72	85.32	50.13	42.77
40	1.3810	76.2	48.10	86.13	51.61	44.45
41	1.3942	78.8	49.47	86.96	53.08	46.16
42	1.4078	81.6	50.87	87.80	54.58	47.92
43	1.4216	84.3	52.26	88.67	56.07	49.72
44	1.4356	87.1	53.66	89.54	57.58	51.56
45	1.4500	90.0	55.07	90.44	59.09	53.44
46	1.4646	92.9	56.48	91.35	60.60	55.36
47	1.4796	95.9	57.90	92.28	62.13	57.33
48	1.4948	99.0	59.32	93.23	63.65	59.34
49	1.5104	102.1	60.75	94.20	65.18	61.40
50	1.5263	105.3	62.18	95.20	66.72	63.52
51	1.5426	108.5	63.66	96.21	68.31	65.72
52	1.5591	111.8	65.13	97.24	69.89	67.96
53	1.5761	115.2	66.63	98.30	71.50	70.28
54	1.5934	118.7	68.13	99.38	73.11	72.66
55	1.6111	122.2	69.65	100.48	74.74	75.10
56	1.6292	125.8	71.17	101.61	76.37	77.60
57	1.6477	129.5	72.75	102.77	78.07	80.23
58	1.6667	133.3	74.36	103.95	79.79	82.95
59	1.6860	137.2	75.99	105.16	81.54	85.75

SULPHURIC ACID—(*Continued*)

ALLOWANCE FOR TEMPERATURE

At 10°Bé. .029° Bé. or .00023 sp. gr. = 1°F.
At 20°Bé. .036° Bé. or .00034 sp. gr. = 1°F.
At 30°Bé. .035° Bé. or .00039 sp. gr. = 1°F.
At 40°Bé. .031° Bé. or .00041 sp. gr. = 1°F.
At 50°Bé. .028° Bé. or .00045 sp. gr. = 1°F.
At 60°Bé. .026° Bé. or .00053 sp. gr. = 1°F.
At 63°Bé. .026° Bé. or .00057 sp. gr. = 1°F.
At 66°Bé. .0235°Bé. or .00054 sp. gr. = 1°F.

Degrees Baumé	Freezing[1] (melting) points °F.	Per cent. 60°Bé.	Pounds 60°Bé. in 1 cu. ft.	Per cent. 50°Bé.	Pounds 50°Bé. in 1 cu. ft.
25	−23				
26	−30				
27	−39				
28	−49				
29	−61				
30	−74				
31	−82				
32	−96				
33	−97				
34	−91				
35	−81				
36	−70				
37	−60				
38	−53				
39	−47				
40	−41	61.93	53.34	77.36	66.63
41	−35	63.69	55.39	79.56	69.19
42	−31	65.50	57.50	81.81	71.83
43	−27	67.28	59.66	84.05	74.53
44	−23	69.09	61.86	86.30	77.27
45	−20	70.90	64.12	88.56	80.10
46	−14	72.72	66.43	90.83	82.98
47	−15	74.55	68.79	93.12	85.93
48	−18	76.37	71.20	95.40	88.94
49	−22	78.22	73.68	97.70	92.03
50	−27	80.06	76.21	100.00	95.20
51	−33	81.96	78.85	102.38	98.50
52	−39	83.86	81.54	104.74	101.85
53	−49	85.79	84.33	107.15	105.33
54	−59	87.72	87.17	109.57	108.89
55	... Below 40	89.67	90.10	112.01	112.55
56	...	91.63	93.11	114.46	116.30
57	...	93.67	96.26	117.00	120.24
58	...	95.74	99.52	119.59	124.31
59	−7	97.84	102.89	122.21	128.52

[1]Calculated from Pickering's results, *Jour. Lon. Chem. Soc.*, vol. 57, p. 363.

SULPHURIC ACID—(*Concluded*)

Degrees Baumé	Specific gravity $\frac{60°}{60°}$F.	Degrees Twaddle	Per cent. H_2SO_4	Weight of 1 cu. ft. in lbs. av.	Per cent. O. V.	Pounds O. V. in 1 cu. ft.
60	1.7059	141.2	77.67	106.40	83.35	88.68
61	1.7262	145.2	79.43	107.66	85.23	91.76
62	1.7470	149.4	81.30	108.96	87.24	95.06
63	1.7683	153.7	83.34	110.29	89.43	98.63
64	1.7901	158.0	85.66	111.65	91.92	102.63
64¼	1.7957	159.1	86.33	112.00	92.64	103.75
64½	1.8012	160.2	87.04	112.34	93.40	104.93
64¾	1.8068	161.4	87.81	112.69	94.23	106.19
65	1.8125	162.5	88.65	113.05	95.13	107.54
65¼	1.8182	163.6	89.55	113.40	96.10	108.97
65½	1.8239	164.8	90.60	113.76	97.22	110.60
65¾	1.8297	165.9	91.80	114.12	98.51	112.42
66	1.8354	167.1	93.19	114.47	100.00	114.47

SULPHURIC ACID—(*Concluded*)

Degrees Baumé	Freezing[1] (melting) point	Per cent. 60°Bé.	Pounds 60°Bé. in cubic foot	Per cent. 50°Bé.	Pounds 50°Bé. in cubic foot
60	+12.6	100.00	106.40	124.91	132.91
61	27.3	102.27	110.10	127.74	137.52
62	39.1	104.67	114.05	130.75	142.47
63	46.1	107.30	118.34	134.03	147.82
64	46.4	110.29	123.14	137.76	153.81
64¼	43.6	111.15	124.49	138.84	155.50
64½	41.1	112.06	125.89	139.98	157.25
64¾	37.9	113.05	127.40	141.22	159.14
65	33.1	114.14	129.03	142.57	161.17
65¼	24.6	115.30	130.75	144.02	163.32
65½	13.4	116.65	132.70	145.71	165.76
65¾	− 1.0	118.19	134.88	147.63	168.48
66	−29.0	119.98	137.34	149.87	171.56

SULPHURIC ACID

94–100 per cent. H_2SO_4[1]

H. B. Bishop

The acid used in this table was prepared from c.p. 95 per cent. sulphuric acid, which was strengthened to 100 per cent. by the addition of fuming acid made by distilling fuming sulphuric acid (70 per cent. free SO_3) into a portion of 95 per cent. c.p. acid. The final acid was tested for impurities; residue upon evaporation, chlorine, niter and sulphur dioxide (0.001 per cent.) which was less than the sensitiveness of the determination.

The analytical and specific-gravity determinations, and the allowance for temperature were made in the same manner, and with the same accuracy as in the sulphuric-acid table adopted by the Manufacturing Chemists' Association, the specific gravity 1.8354 and 93.19 per cent. H_2SO_4 being taken as standard.

The actual determinations were made within a few hundredths of a per cent. of the points given in the table, the even percentage being calculated by interpolation.

Per cent. H_2SO_4	Specific gravity at $\frac{60°}{60°}$F.	Allowance for temperature
66°Bé. 93.19	1.8354	At 94 per cent. 0.00054 sp. gr. = 1°F.
94.00	1.8381	At 96 per cent. 0.00053 sp. gr. = 1°F.
95.00	1.8407	At 97.5 per cent. 0.00052 sp. gr. = 1°F.
96.00	1.8427	At 100 per cent. 0.00052 sp. gr. = 1°F.
97.00	1.8437	
97.50	1.8439	
98.00	1.8437	
99.00	1.8424	
100.00	1.8391	

[1] W. W. Scott: "Standard Methods of Chemical Analysis," 1917.

Author's Note.—Mr. Ferguson in his article describing the methods used in the preparation of the tables adopted by the Manufacturing Chemists' Association names several chemists who assisted him, among them Mr. Bishop. "Such merit as these tables possess is largely due to these gentlemen, but more especially to Mr. Bishop who had immediate charge of and participated in most of the determinations, and who shared with the writer the preparation of this paper."

SULPHURIC ACID

0°Bé.–100 per cent. H_2SO_4

From 0°–66°Bé. the table is from the one of Ferguson and Talbot with the following supplementals incorporated:

Per cent. SO_3

Pounds SO_3 per cubic foot

Pounds H_2SO_4 per cubic foot

Per cent. free water

Per cent. combined water

Freezing (melting) points calculated in degrees Centigrade from the given degrees Fahrenheit.

Approximate boiling points calculated in degrees Centigrade from the given degrees Fahrenheit.

Allowance for temperature calculated per degree Centigrade from the given, per degree Fahrenheit.

From 94–100 per cent. H_2SO_4 is from the table of H. B. Bishop. Mr. Bishop gives only the specific gravity and allowance for temperature per degree Fahrenheit. All other calculations are supplied.

Freezing (melting) points were calculated after Knietsch, *Ber.*, 1901.

It should be noted that the highest percentages show lower specific gravities than those just below, the maximum being at 97.5 per cent. H_2SO_4.

Sulphuric Acid
0°Bé.–100 per cent. H_2SO_4

Degrees Baumé	Degrees Twaddle	Specific gravity	Lb. av. per cu. ft.	Per cent. SO_3	Lb. SO_3 per cu. ft.	Per cent. H_2SO_4	Lb. H_2SO_4 per cu. ft.
1	1.38	1.0069	62.80	0.83	0.52	1.02	0.64
2	2.80	1.0140	63.24	1.70	1.08	2.08	1.32
3	4.22	1.0211	63.69	2.56	1.63	3.13	1.99
4	5.68	1.0284	64.14	3.44	2.21	4.21	2.70
5	7.14	1.0354	64.60	4.31	2.78	5.28	3.41
6	8.64	1.0432	65.06	5.20	3.38	6.37	4.14
7	10.14	1.0507	65.53	6.08	3.98	7.45	4.88
8	11.68	1.0584	66.01	6.98	4.61	8.55	5.64
9	13.24	1.0662	66.50	7.89	5.25	9.66	6.42
10	14.82	1.0741	66.99	8.79	5.89	10.77	7.21
11	16.42	1.0821	67.49	9.71	6.55	11.89	8.02
12	18.04	1.0902	68.00	10.62	7.22	13.01	8.85
13	19.70	1.0985	68.51	11.54	7.91	14.13	9.69
14	21.38	1.1069	69.04	12.45	8.60	15.25	10.53
15	23.08	1.1154	69.57	13.37	9.30	16.38	11.40
16	24.80	1.1240	70.10	14.31	10.03	17.53	12.29
17	26.56	1.1328	70.65	15.27	10.78	18.71	13.22
18	28.34	1.1417	71.21	16.24	11.56	19.89	14.16
19	30.16	1.1508	71.78	17.20	12.35	21.07	15.12
20	32.00	1.1600	72.35	18.16	13.14	22.25	16.10
21	33.88	1.1694	72.94	19.13	13.95	23.43	17.09
22	35.78	1.1789	73.53	20.09	14.77	24.61	18.10
23	37.70	1.1885	74.13	21.07	15.62	25.81	19.13
24	39.66	1.1983	74.74	22.07	16.50	27.03	20.20
25	41.66	1.2083	75.36	23.09	17.40	28.28	21.31
26	43.70	1.2185	76.00	24.11	18.32	29.53	22.44
27	45.76	1.2288	76.64	25.14	19.27	30.79	23.60
28	47.86	1.2393	77.30	26.16	20.22	32.05	24.77
29	50.00	1.2500	77.96	27.21	21.21	33.33	25.98
30	52.18	1.2609	78.64	28.27	22.23	34.63	27.23
31	54.38	1.2719	79.33	29.33	23.27	35.93	28.50
32	56.64	1.2832	80.03	30.42	24.35	37.26	29.82
33	58.92	1.2946	80.74	31.49	25.42	38.58	31.15
34	61.26	1.3063	81.47	32.59	26.55	39.92	32.52
35	63.64	1.3182	82.22	33.69	27.70	41.27	33.93
36	66.06	1.3303	82.97	34.80	28.87	42.63	35.37
37	68.52	1.3426	83.74	35.91	30.07	43.99	36.84
38	71.02	1.3551	84.52	37.02	31.31	45.35	38.33
39	73.58	1.3679	85.32	38.14	32.54	46.72	39.86

Sulphuric Acid

0°Bé.–100 per cent. H_2SO_4

Degrees Baumé	Per cent. free H_2O	Per cent. combined H_2O	Per cent. O. V.	Lb. O. V. in 1 cu. ft.	Freezing (melting) points	
					°F.	°C.
1	98.98	0.19	1.09	0.68	31.2	−0.4
2	97.92	0.38	2.23	1.41	30.5	−0.8
3	96.87	0.57	3.36	2.14	29.8	−1.2
4	95.79	0.77	4.52	2.90	28.9	−1.7
5	94.72	0.97	5.67	3.66	28.1	−2.2
6	93.63	1.17	6.84	4.45	27.2	−2.7
7	92.55	1.37	7.99	5.24	26.3	−3.3
8	91.45	1.57	9.17	6.06	25.1	−3.8
9	90.34	1.77	10.37	6.89	24.0	−4.4
10	89.23	1.98	11.56	7.74	22.8	−5.1
11	88.11	2.18	12.76	8.61	21.5	−5.8
12	86.99	2.39	13.96	9.49	20.0	−6.7
13	85.87	2.59	15.16	10.39	18.3	−7.6
14	84.75	2.80	16.36	11.30	16.6	−8.6
15	83.62	3.01	17.58	12.23	14.7	−9.6
16	82.47	3.22	18.81	13.19	12.6	−10.8
17	81.29	3.44	20.08	14.18	10.2	−12.1
18	80.11	3.65	21.34	15.20	7.7	−13.5
19	78.93	3.87	22.61	16.23	4.8	−15.1
20	77.75	4.09	23.87	17.27	1.6	−16.9
21	76.57	4.30	25.14	18.34	−1.8	−18.8
22	75.39	4.52	26.41	19.42	−6.0	−21.1
23	74.19	4.74	27.69	20.53	−11.0	−23.9
24	72.97	4.96	29.00	21.68	−16.0	−26.7
25	71.72	5.19	30.34	22.87	−23.0	−30.6
26	70.47	5.42	31.69	24.08	−30.0	−34.4
27	69.21	5.65	33.04	25.32	−39.0	−39.4
28	67.95	5.89	34.39	26.58	−49.0	−45.0
29	66.67	6.12	35.76	27.88	−61.0	−51.7
30	65.37	6.36	37.16	29.22	−74.0	−58.9
31	64.07	6.60	38.55	30.58	−82.0	−63.3
32	62.74	6.84	39.98	32.00	−96.0	−71.1
33	61.42	7.09	41.40	33.42	−97.0	−71.7
34	60.08	7.33	42.83	34.90	−91.0	−68.3
35	58.73	7.58	44.28	36.41	−81.0	−62.8
36	57.37	7.83	45.74	37.95	−70.0	−56.7
37	56.01	8.08	47.20	39.53	−60.0	−51.1
38	54.65	8.33	48.66	41.13	−53.0	−47.2
39	53.28	8.58	50.13	42.77	−47.0	−43.9

SULPHURIC ACID

0°Bé.–100 per cent. H_2SO_4—(*Continued*)

Degrees Baumé	Degrees Twaddle	Specific gravity	Lb. av. per cu. ft.	Per cent. SO_3	Lb. SO_3 per cu. ft.	Per cent. H_2SO_4	Lb. H_2SO_4 per cu. ft.
40	76.20	1.3810	86.13	39.27	33.82	48.10	41.43
41	78.84	1.3942	86.96	40.38	35.11	49.47	43.02
42	81.56	1.4078	87.80	41.53	36.46	50.87	44.66
43	84.32	1.4216	88.67	42.66	37.83	52.26	46.34
44	87.12	1.4356	89.54	43.80	39.22	53.66	48.05
45	90.00	1.4500	90.44	44.96	40.66	55.07	49.81
46	92.92	1.4646	91.35	46.11	42.12	56.48	51.59
47	95.92	1.4796	92.28	47.27	43.62	57.90	53.43
48	98.96	1.4948	93.23	48.43	45.10	59.32	55.30
49	102.08	1.5104	94.20	49.59	46.71	60.75	57.23
50	105.26	1.5263	95.20	50.76	48.32	62.18	59.20
51	108.52	1.5426	96.21	51.97	50.00	63.66	61.25
52	111.82	1.5591	97.24	53.17	51.70	65.13	63.33
53	115.22	1.5761	98.30	54.39	53.47	66.63	65.49
54	118.68	1.5934	99.38	55.62	55.28	68.13	67.71
55	122.22	1.6111	100.48	56.86	57.13	69.65	69.98
56	125.84	1.6292	101.61	58.10	59.04	71.17	72.32
57	129.54	1.6477	102.77	59.39	61.04	72.75	74.77
58	133.34	1.6667	103.95	60.70	63.10	74.36	77.30
59	137.20	1.6860	105.16	62.03	65.23	75.99	79.91
60	141.18	1.7059	106.40	63.40	67.46	77.67	82.64
61	145.24	1.7262	107.66	64.84	69.81	79.43	85.51
62	149.40	1.7470	108.96	66.37	72.31	81.30	88.58
63	153.66	1.7683	110.29	68.03	75.03	83.34	91.92
64	158.02	1.7901	111.65	69.92	78.07	85.66	95.64
64¼	159.14	1.7957	112.00	70.47	78.93	86.33	96.69
64½	160.24	1.8012	112.34	71.05	79.82	87.04	97.78
64¾	161.36	1.8068	112.69	71.68	80.78	87.81	98.95
65	162.50	1.8125	113.05	72.37	81.81	88.65	100.22
65¼	163.64	1.8182	113.40	73.10	82.90	89.55	101.55
65½	164.78	1.8239	113.76	73.96	84.14	90.60	103.07
65¾	165.94	1.8297	114.12	74.94	85.52	91.80	104.76
66	167.08	1.8354	114.47	76.07	87.08	93.19	106.67
		1.8381	114.64	76.73	87.97	94.00	107.76
		1.8407	114.80	77.55	89.03	95.00	109.06
		1.8427	114.93	78.37	90.07	96.00	110.33
		1.8437	114.99	79.18	91.05	97.00	111.54
		1.8439	115.00	79.59	91.53	97.50	112.13
		1.8437	114.99	80.00	91.99	98.00	112.69
		1.8424	114.91	80.82	92.87	99.00	113.76
		1.8391	114.70	81.63	93.63	100.00	114.70

Sulphuric Acid

0°Bé.–100 per cent. H_2SO_4—(*Continued*)

Degrees Baumé	Per cent. H_2SO_4	Per cent. free H_2O	Per cent. combin d H_2Oe	Per cent. O. V.	Lb. O. V. in 1 cu. ft.	Freezing (melting) points °F.	°C.
40	....	51.90	8.83	51.61	44.45	−41.0	−40.6
41	....	50.53	9.09	53.08	46.16	−35.0	−37.2
42	....	49.13	9.34	54.58	47.92	−31.0	−35.0
43	....	47.74	9.60	56.07	49.72	−27.0	−32.8
44	....	46.34	9.86	57.58	51.56	−23.0	−30.6
45	....	44.93	10.11	59.09	53.44	−20.0	−28.9
46	....	43.52	10.37	60.60	55.36	−14.0	−25.6
47	....	42.10	10.63	62.13	57.33	−15.0	−26.1
48	....	40.68	10.89	63.65	59.34	−18.0	−27.8
49	....	39.25	11.16	65.18	61.40	−22.0	−30.0
50	....	37.82	11.42	66.72	63.52	−27.0	−32.8
51	....	36.34	11.69	68.31	65.72	−33.0	−36.1
52	....	34.87	11.96	69.89	67.96	−39.0	−39.4
53	....	33.37	12.24	71.50	70.28	−49.0	−45.0
54	....	31.87	12.51	73.11	72.66	−59.0	−50.6
55	....	30.35	12.79	74.74	75.10		
56	....	28.83	13.07	76.37	77.60	Below −40	
57	....	27.25	13.36	78.07	80.23		
58	....	25.64	13.66	79.79	82.95		
59	....	24.01	13.96	81.54	85.75	− 7.0	−21.7
60	....	22.33	14.27	83.35	88.68	+12.6	−10.8
61	....	20.57	14.59	85.23	91.76	27.3	−2.6
62	....	18.70	14.93	87.24	95.06	39.1	+3.9
63	....	16.66	15.31	89.43	98.63	46.1	7.8
64	....	14.34	15.74	91.92	102.63	46.4	8.0
64¼	....	13.67	15.86	92.64	103.75	43.6	6.4
64½	....	12.96	15.99	93.40	104.93	41.1	5.1
64¾	....	12.19	16.13	94.23	106.19	37.9	3.3
65	....	11.35	16.28	95.13	107.54	33.1	0.6
65¼	....	10.45	16.45	96.10	108.97	24.6	−4.1
65½	....	9.40	16.64	97.22	110.60	13.4	−10.3
65¾	....	8.20	16.86	98.51	112.42	−1.0	−18.3
66	....	6.81	17.12	100.00	114.47	−29.0	−33.9
	94.00	6.00	17.26	100.87	115.64	−20.6	−29.2
	95.00	5.00	17.45	101.94	117.03	−7.2	−21.8
	96.00	4.00	17.63	103.01	118.39	+9.9	−12.3
	97.00	3.00	17.82	104.09	119.69	25.3	−3.7
	97.50	2.50	17.91	104.63	120.32	31.3	−0.4
	98.00	2.00	18.00	105.16	120.92	37.4	+3.0
	99.00	1.00	18.18	106.23	122.07	43.3	6.3
	100.00	0.00	18.37	107.31	123.08	50.0	10.0

SULPHURIC ACID

0°Bé–.100 per cent. H_2SO_4—(*Concluded*)

Degrees Baumé	Per cent. H_2SO_4	Per cent. 60°Bé.	Lb. 60° in 1 cu. ft.	Per cent. 50°Bé.	Lb. 50° in 1 cu. ft.
40	.....	61.93	53.34	77.36	66.63
41	.....	63.69	55.39	79.59	69.19
42	.....	65.50	57.50	81.81	71.83
43	.....	67.28	59.66	84.05	74.53
44	.....	69.09	61.86	86.30	77.27
45	.....	70.90	64.12	88.56	80.10
46	.....	72.72	66.43	90.83	82.98
47	.....	74.55	68.79	93.12	85.93
48	.....	76.37	71.20	95.40	88.94
49	.....	78.22	73.68	97.70	92.03
50	.....	80.06	76.21	100.00	95.20
51	.....	81.96	78.85	102.38	98.50
52	.....	83.86	81.54	104.74	101.85
53	.....	85.79	84.33	107.15	105.33
54	.....	87.72	87.17	109.57	108.89
55	.....	89.67	90.10	112.01	112.55
56	.....	91.63	93.11	114.46	116.30
57	.....	93.67	96.26	117.00	120.24
58	.....	95.74	99.52	119.59	124.31
59	.....	97.84	102.89	122.21	128.52
60	.....	100.00	106.40	124.91	132.91
61	.....	102.27	110.10	127.74	137.52
62	.....	104.67	114.05	130.75	142.47
63	.....	107.30	118.34	134.03	147.82
64	.....	110.29	123.14	137.76	153.81
64¼	.....	111.15	124.49	138.84	155.50
64½	.....	112.06	125.89	139.98	157.25
64¾	.....	113.05	127.40	141.22	159.14
65	.....	114.14	129.03	142.57	161.17
65¼	.....	115.30	130.75	144.02	163.32
65½	.....	116.65	132.70	145.71	165.76
65¾	.....	118.19	134.88	147.63	168.48
66	.....	119.98	137.34	149.87	171.56
	94.00	121.02	138.74	151.17	173.30
	95.00	122.31	140.41	152.78	175.39
	96.00	123.60	142.05	154.39	177.44
	97.00	124.89	143.61	156.00	179.38
	98.00	126.17	145.08	157.61	181.24
	99.00	126.46	145.32	159.22	182.96
	100.00	128.75	147.68	160.82	184.46

Approximate Boiling Points

Degrees Baumé	Boiling point	
	°F.	°C.
50	295	146.1
60	386	196.7
61	400	204.4
62	415	212.8
63	432	222.2
64	451	232.8
65	485	251.6
66	538	281.1

Allowance For Temperature

Strength	Per degree Fahrenheit		Per degree Centigrade	
10°Bé.	.029°Bé.	.00023 sp. gr.	.052°Bé.	.00041 sp. gr.
20°Bé.	.036°Bé.	.00034 sp. gr.	.065°Bé.	.00061 sp. gr.
30°Bé.	.035°Bé.	.00039 sp. gr.	.063°Bé.	.00070 sp. gr.
40°Bé.	.031°Bé.	.00041 sp. gr.	.056°Bé.	.00074 sp. gr.
50°Bé.	.028°Bé.	.00045 sp. gr.	.050°Bé.	.00081 sp. gr.
60°Bé.	.026°Bé.	.00053 sp. gr.	.047°Bé.	.00095 sp. gr.
63°Bé.	.026°Bé.	.00057 sp. gr.	.047°Bé.	.00103 sp. gr.
66°Bé.	.0235°Bé.	.00054 sp. gr.	.042°Bé.	.00097 sp. gr.
94 per cent. H_2SO_4	....	.00054 sp. gr.	....	.00097 sp. gr.
96 per cent. H_2SO_4	....	.00053 sp. gr.	....	.00095 sp. gr.
97.5 per cent. H_2SO_4	....	.00052 sp. gr.	....	.00094 sp. gr.
100 per cent. H_2SO_4	....	.00052 sp. gr.	....	.00094 sp. gr.

SULPHURIC ACID[1]
50°–62°Bé.

Degrees Baumé	Specific gravity $\frac{60°}{60°}$ F.	Lb. av. per cu. ft.	Per cent. H_2SO_4	Per cent. SO_3
50.0	1.5263	95.20	62.18	50.76
.1	1.5279	95.30	62.33	50.88
.2	1.5295	95.40	62.48	51.00
.3	1.5312	95.50	62.62	51.12
.4	1.5328	95.60	62.77	51.24
.5	1.5344	95.71	62.90	51.37
.6	1.5360	95.81	63.07	51.49
.7	1.5376	95.91	63.22	51.61
.8	1.5393	96.01	63.36	51.73
.9	1.5409	96.11	63.51	51.85
51.0	1.5426	96.21	63.66	51.97
.1	1.5442	96.31	63.81	52.09
.2	1.5458	96.42	63.95	52.21
.3	1.5475	96.52	64.10	52.33
.4	1.5491	96.62	64.25	52.45
.5	1.5508	96.73	64.40	52.57
.6	1.5525	96.83	64.52	52.69
.7	1.5541	96.93	64.69	52.81
.8	1.5558	97.03	64.84	52.93
.9	1.5575	97.14	64.98	53.05
52.0	1.5591	97.24	65.13	53.17
.1	1.5608	97.35	65.28	53.29
.2	1.5625	97.45	65.43	53.41
.3	1.5642	97.56	65.58	53.54
.4	1.5659	97.66	65.73	53.66
.5	1.5676	97.77	65.88	53.78
.6	1.5693	97.88	66.03	53.90
.7	1.5710	97.98	66.18	54.02
.8	1.5727	98.09	66.31	54.15
.9	1.5744	98.19	66.45	54.27
53.0	1.5761	98.30	66.63	54.39
.1	1.5778	98.41	66.78	54.51
.2	1.5795	98.52	66.93	54.64
.3	1.5812	98.62	67.08	54.76
.4	1.5830	98.73	67.23	54.88
.5	1.5847	98.84	67.38	55.01
.6	1.5864	98.95	67.53	55.13
.7	1.5882	99.06	67.68	55.25
.8	1.5899	99.16	67.83	55.37
.9	1.5917	99.27	67.98	55.50

[1] The values for the even degrees were taken from the preceding table and the values for the tenths of a degree calculated by interpolation.

Sulphuric Acid
50°–62°Bé.—(*Continued*)

Degrees Baumé	Specific gravity $\frac{60°}{60°}$F.	Lb. av. per cu. ft.	Per cent. H_2SO_4	Per cent. SO_3
54.0	1.5934	99.38	68.13	55.62
.1	1.5952	99.49	68.28	55.74
.2	1.5969	99.60	68.43	55.87
.3	1.5987	99.71	68.59	55.99
.4	1.6004	99.82	68.74	56.12
.5	1.6022	99.93	68.89	56.24
.6	1.6040	100.04	69.04	56.36
.7	1.6058	100.15	69.19	56.49
.8	1.6075	100.26	69.35	56.61
9	1.6093	100.37	69.50	56.74
55.0	1.6111	100.48	69.65	56.86
.1	1.6129	100.59	69.80	56.98
.2	1.6147	100.71	69.95	57.11
.3	1.6165	100.82	70.11	57.23
.4	1.6183	100.93	70.26	57.36
.5	1.6201	101.05	70.41	57.48
.6	1.6219	101.16	70.56	57.60
.7	1.6237	101.27	70.71	57.73
.8	1.6256	101.38	70.87	57.85
.9	1.6274	101.50	71.02	57.98
56.0	1.6292	101.61	71.17	58.10
.1	1.6310	101.73	71.33	58.23
.2	1.6329	101.84	71.49	58.36
.3	1.6347	101.96	71.64	58.49
.4	1.6366	102.08	71.80	58.62
.5	1.6384	102.19	71.96	58.75
.6	1.6403	102.31	72.12	58.87
.7	1.6421	102.42	72.28	59.00
.8	1.6440	102.54	72.43	59.13
.9	1.6459	102.65	72.59	59.26
57.0	1.6477	102.77	72.75	59.39
.1	1.6496	102.89	72.91	59.52
.2	1.6515	103.01	73.07	59.65
.3	1.6534	103.12	73.23	59.78
.4	1.6553	103.24	73.39	59.91
.5	1.6571	103.36	73.56	60.05
.6	1.6590	103.48	73.72	60.18
.7	1.6609	103.60	73.88	60.31
.8	1.6628	103.71	74.04	60.44
.9	1.6648	103.83	74.20	60.57

Sulphuric Acid
50°–62°Bé.—(*Concluded*)

Degrees Baumé	Specific gravity $\frac{60°}{60°}$F.	Lb. av. per cu. ft.	Per cent. H_2SO_4	Per cent. SO_3	Per cent. 60°Baumé.
58.0	1.6667	103.95	74.36	60.70	95.74
.1	1.6686	104.07	74.52	60.83	95.95
.2	1.6705	104.19	74.69	60.97	96.17
.3	1.6724	104.31	74.85	61.10	96.37
.4	1.6744	104.43	75.01	61.23	96.58
.5	1.6763	104.56	75.18	61.37	96.80
.6	1.6782	104.68	75.34	61.50	97.00
.7	1.6802	104.80	75.50	61.63	97.21
.8	1.6821	104.92	75.66	61.76	97.41
.9	1.6841	105.04	75.83	61.90	97.63
59.0	1.6860	105.16	75.99	62.03	97.84
.1	1.6880	105.28	76.16	62.17	98.06
.2	1.6900	105.41	76.33	62.30	98.27
.3	1.6919	105.53	76.49	62.44	98.49
.4	1.6939	105.66	76.66	62.58	98.71
.5	1.6959	105.78	76.83	62.72	98.93
.6	1.6979	105.90	77.00	62.85	99.13
.7	1.6999	106.03	77.17	62.99	99.35
.8	1.7019	106.15	77.33	63.13	99.57
.9	1.7039	106.28	77.50	63.26	99.78
60.0	1.7059	106.40	77.67	63.40	100.00
.1	1.7079	106.53	77.85	63.54	100.22
.2	1.7099	106.65	78.02	63.69	100.46
.3	1.7119	106.78	78.20	63.83	100.68
.4	1.7139	106.90	78.37	63.98	100.91
.5	1.7160	107.03	78.55	64.12	101.14
.6	1.7180	107.16	78.73	64.26	101.36
.7	1.7200	107.28	78.90	64.41	101.59
.8	1.7221	107.41	79.08	64.55	101.81
.9	1.7241	107.53	79.25	64.70	102.05
61.0	1.7262	107.66	79.43	64.84	102.27
.1	1.7282	107.79	79.62	64.99	102.51
.2	1.7303	107.92	79.80	65.15	102.76
.3	1.7324	108.05	79.99	65.30	103.00
.4	1.7344	108.18	80.18	65.45	103.23
.5	1.7365	108.31	80.37	65.61	103.49
.6	1.7386	108.44	80.55	65.76	103.72
.7	1.7407	108.57	80.74	65.91	103.96
.8	1.7428	108.70	80.93	66.06	104.20
.9	1.7449	108.83	81.11	66.22	104.45
62.0	1.7470	108.96	81.30	66.37	104.67

FUMING SULPHURIC ACID

T. J. Sullivan

Clear commercial acid was used in all analytical, specific gravity and coefficient of expansion (allowance for temperature) determinations.

Specific-gravity determinations were made at 15.56°C., compared with water at 15.56°C., a Sartorius hydrostatic specific-gravity balance being used for all determinations. Three separate samples at each given point agreed on all determinations. The specific gravity 1.8391 of 100 per cent. H_2SO_4 (H. B. Bishop) was taken as standard.

This table was constructed as a means of obtaining quick analysis for plant control and is very satisfactory as fuming acid may be checked within 0.1 per cent. SO_3 of the titration analysis. Slight deviations may be due to impurities always present in commercial acid.

Fixed Points

Per cent. SO_3	Specific gravity
81.63	1.8391
81.9	1.848
82.1	1.853
82.7	1.865
83.3	1.877
83.8	1.887
84.5	1.900
85.1	1.911
85.6	1.922
86.2	1.934
86.5	1.942
87.5	1.958
88.1	

Allowance for Temperature

At 82 per cent. SO_3 = 0.00100 per degree C.
83 per cent. SO_3 = 0.00105 per degree C.
84 per cent. SO_3 = 0.00110 per degree C.
85 per cent. SO_3 = 0.00110 per degree C.
86 per cent. SO_3 = 0.00115 per degree C.
87 per cent. SO_3 = 0.00120 per degree C.
88 per cent. SO_3 = 0.00125 per degree C.

FUMING SULPHURIC ACID

Per cent. total SO_3	Specific gravity $\frac{15.56°}{15.56°}$C.	Weight per cu. ft., lb. av.	Lb. SO_3 in cu. ft.	Per cent. total SO_3	Specific gravity $\frac{15.56°}{15.56°}$C.	Weight per cu. ft., lb. av.	Lb. SO_3 in cu. ft.
81.63	1.8391	114.70	93.63	84.4	1.899	118.44	99.96
81.7	1.842	114.89	93.87	84.5	1.900	118.50	100.13
81.8	1.845	115.07	94.13	84.6	1.902	118.63	100.36
81.9	1.848	115.26	94.40	84.7	1.904	118.75	100.58
82.0	1.851	115.45	94.67	84.8	1.906	118.88	100.81
82.1	1.853	115.57	94.88	84.9	1.908	119.00	101.03
82.2	1.855	115.70	95.11	85.0	1.910	119.13	101.26
82.3	1.857	115.82	95.32	85.1	1.912	119.25	101.48
82.4	1.859	115.95	95.54	85.2	1.914	119.38	101.71
82.5	1.861	116.07	95.76	85.3	1.916	119.50	101.93
82.6	1.863	116.20	95.98	85.4	1.918	119.63	102.16
82.7	1.865	116.32	96.20	85.5	1.920	119.75	102.39
82.8	1.867	116.44	96.41	85.6	1.922	119.88	102.62
82.9	1.869	116.57	96.63	85.7	1.924	120.00	102.84
83.0	1.871	116.69	96.85	85.8	1.926	120.12	103.06
83.1	1.873	116.82	97.08	85.9	1.928	120.25	103.29
83.2	1.875	116.94	97.29	86.0	1.930	120.37	103.52
83.3	1.877	117.07	97.52	86.1	1.932	120.50	103.75
83.4	1.879	117.19	97.74	86.2	1.934	120.62	103.97
83.5	1.881	117.32	97.96	86.3	1.936	120.75	104.21
83.6	1.883	117.44	98.18	86.4	1.939	120.94	104.49
83.7	1.885	117.57	98.41	86.5	1.942	121.12	104.77
83.8	1.887	117.69	98.63	87.0	1.950	121.62	105.81
83.9	1.889	117.82	98.85	87.5	1.958	122.12	106.81
84.0	1.891	117.94	99.07		Crystallized at 15.56°		
84.1	1.893	118.07	99.30	88.1[1]	1.966 at 18°C.		
84.2	1.895	118.19	99.52		1.944 at 35°C.		
84.3	1.897	118.32	99.75				

[1] Acid of this strength only remains in solution momentarily when cooled to 18°C. Crystallization starts and the acid solidifies with rise of temperature and remains constant at 26°C.

FUMING SULPHURIC ACID

Specific gravity at various temperatures—degrees C.

Per cent. total SO_3	$\frac{15.56°}{15.56°}$	20°	25°	30°	35°
82.0	1.851	1.846	1.841	1.836	1.831
82.2	1.855	1.850	1.845	1.840	1.835
82.4	1.859	1.854	1.849	1.844	1.839
82.6	1.863	1.858	1.853	1.848	1.843
82.8	1.867	1.862	1.857	1.852	1.847
83.0	1.871	1.866	1.860	1.855	1.850
83.2	1.875	1.870	1.864	1.859	1.854
83.4	1.879	1.874	1.868	1.863	1.858
83.6	1.883	1.878	1.872	1.867	1.862
83.8	1.887	1.882	1.876	1.871	1.866
84.0	1.891	1.886	1.880	1.874	1.869
84.2	1.895	1.890	1.884	1.878	1.873
84.4	1.899	1.894	1.888	1.882	1.877
84.6	1.902	1.897	1.891	1.885	1.880
84.8	1.906	1.901	1.895	1.889	1.884
85.0	1.910	1.905	1.899	1.893	1.888
85.2	1.914	1.909	1.903	1.897	1.892
85.4	1.918	1.913	1.907	1.901	1.896
85.6	1.922	1.917	1.911	1.905	1.900
85.8	1.926	1.921	1.915	1.909	1.904
86.0	1.930	1.924	1.918	1.912	1.907
86.2	1.934	1.928	1.922	1.916	1.911
86.4	1.939	1.933	1.927	1.921	1.916
86.5	1.942	1.936	1.930	1.924	1.919
87.0	1.950	1.944	1.938	1.932	1.926
87.5	1.958	1.952	1.946	1.940	1.934
88.1	Cryst.	1.963	1.956	1.950	1.944

FUMING SULPHURIC ACID

Per cent. free SO_3 as units

Per cent. free SO_3	Per cent. total SO_3	Per cent. combined SO_3	Per cent. combined H_2O	Per cent. H_2SO_4	Per cent. 100 H_2SO_4
0	81.63	81.63	18.37	100	100.00
1	81.81	80.81	18.19	99	100.22
2	82.00	80.00	18.00	98	100.45
3	82.18	79.18	17.82	97	100.67
4	82.36	78.36	17.64	96	100.89
5	82.55	77.55	17.45	95	101.13
6	82.73	76.73	17.27	94	101.35
7	82.92	75.92	17.08	93	101.58
8	83.10	75.10	16.90	92	101.80
9	83.28	74.28	16.72	91	102.02
10	83.47	73.43	16.57	90	102.25
11	83.65	72.65	16.35	89	102.47
12	83.83	71.83	16.17	88	102.71
13	84.02	71.02	15.98	87	102.92
14	84.20	70.20	15.80	86	103.15
15	84.39	69.39	15.61	85	103.38
16	84.57	68.57	15.43	84	103.60
17	84.75	67.75	15.25	83	103.82
18	84.94	66.94	15.06	82	104.05
19	85.12	66.12	14.88	81	104.28
20	85.30	65.30	14.70	80	104.49
21	85.49	64.49	14.51	79	104.73
22	85.67	63.67	14.33	78	104.95
23	85.86	62.86	14.14	77	105.18
24	86.04	62.04	13.96	76	105.40
25	86.22	61.22	13.78	75	105.62

FUMING SULPHURIC ACID

Per cent. free SO_3 as units—(*Concluded*)

Per cent. free SO_3	Per cent. total SO_3	Per cent. combined SO_3	Per cent. combined H_2O	Per cent. H_2SO_4	Per cent. 100 H_2SO_4
26	86.41	60.41	13.59	74	105.85
27	86.59	59.59	13.41	73	106.08
28	86.77	58.77	13.28	72	106.29
29	86.96	57.96	13.04	71	106.53
30	87.14	57.14	12.86	70	106.75
31	87.32	56.32	12.68	69	106.97
32	87.51	55.51	12.49	68	107.20
33	87.69	54.69	12.31	67	107.42
34	87.88	53.88	12.12	66	107.65
35	88.06	53.06	11.94	65	107.87
36	88.24	52.24	11.76	64	108.10
37	88.43	51.43	11.57	63	108.33
38	88.61	50.61	11.39	62	108.55
39	88.79	49.79	11.21	61	108.77
40	88.98	48.98	11.02	60	109.00
41	89.16	48.16	10.84	59	109.22
42	89.35	47.35	10.65	58	109.45
43	89.53	46.53	10.47	57	109.68
44	89.71	45.71	10.29	56	109.90
45	89.90	44.90	10.10	55	110.13
50	90.82	40.82	9.18	50	111.25
60	92.65	32.65	7.35	40	113.50
70	94.49	24.49	5.51	30	115.75
80	96.33	16.33	3.67	20	118.00
90	98.16	8.16	1.84	10	120.25
100	100.00	0.00	0.00	0	122.50

Fuming Sulphuric Acid

Per cent. total SO_3 as units

Per cent. total SO_3	Per cent. free SO_3	Per cent. combined SO_3	Per cent. combined H_2O	Per cent. H_2SO_4	Per cent. 100 % H_2SO_4
81.63	0.00	81.63	18.37	100.00	100.00
81.7	0.38	81.32	18.30	99.62	100.09
81.8	0.92	80.88	18.20	99.08	100.21
81.9	1.47	80.43	18.10	98.53	100.33
82.0	2.01	79.99	18.00	97.99	100.45
82.1	2.56	79.54	17.90	97.44	100.58
82.2	3.10	79.10	17.80	96.90	100.70
82.3	3.64	78.66	17.70	96.36	100.82
82.4	4.19	78.21	17.60	95.81	100.94
82.5	4.73	77.77	17.50	95.27	101.07
82.6	5.28	77.32	17.40	94.72	101.19
82.7	5.82	76.88	17.30	94.18	101.31
82.8	6.37	76.43	17.20	93.63	101.43
82.9	6.91	75.99	17.10	93.09	101.56
83.0	7.46	75.54	17.00	92.54	101.68
83.1	8.00	75.10	16.90	92.00	101.80
83.2	8.54	74.66	16.80	91.46	101.92
83.3	9.09	74.21	16.70	90.91	102.05
83.4	9.63	73.77	16.60	90.37	102.17
83.5	10.18	73.32	16.50	89.82	102.29
83.6	10.72	72.88	16.40	89.28	102.41
83.7	11.27	72.43	16.30	88.73	102.54
83.8	11.81	71.99	16.20	88.19	102.66
83.9	12.35	71.55	16.10	87.65	102.78
84.0	12.90	71.10	16.00	87.10	102.90
84.1	13.44	70.66	15.90	86.56	103.03
84.2	13.99	70.21	15.80	86.01	103.15
84.3	14.53	69.77	15.70	85.47	103.27
84.4	15.08	69.32	15.60	84.92	103.39
84.5	15.62	68.88	15.50	84.38	103.52
84.6	16.17	68.43	15.40	83.83	103.64

Fuming Sulphuric Acid

Per cent. total SO_3 as units—(*Continued*)

Per cent. total SO_3	Per cent. free SO_3	Per cent. combined SO_3	Per cent. combined H_2O	Per cent. H_2SO_4	Per cent. 100 % H_2SO_4
84.7	16.71	67.99	15.30	83.29	103.76
84.8	17.26	67.54	15.20	82.74	103.88
84.9	17.80	67.10	15.10	82.20	104.01
85.0	18.34	66.66	15.00	81.66	104.13
85.1	18.89	66.21	14.90	81.11	104.25
85.2	19.43	65.77	14.80	80.57	104.37
85.3	19.98	65.32	14.70	80.02	104.49
85.4	20.52	64.88	14.60	79.48	104.62
85.5	21.06	64.44	14.50	78.94	104.74
85.6	21.61	63.99	14.40	78.39	104.86
85.7	22.15	63.54	14.30	77.84	104.99
85.8	22.70	63.10	14.20	77.30	105.11
85.9	23.24	62.66	14.10	76.76	105.23
86.0	23.79	62.21	14.00	76.21	105.35
86.1	24.33	61.77	13.90	75.67	105.48
86.2	24.88	61.32	13.80	75.12	105.60
86.3	25.42	60.88	13.70	74.58	105.72
86.4	25.96	60.44	13.60	74.04	105.84
86.5	26.51	59.99	13.50	73.49	105.97
86.6	27.05	59.54	13.40	72.94	106.09
86.7	27.60	59.10	13.30	72.40	106.21
86.8	28.14	58.66	13.20	71.86	106.33
86.9	28.69	58.21	13.10	71.31	106.46
87.0	29.23	57.77	13.00	70.77	106.58
87.1	29.77	57.33	12.90	70.23	106.70
87.2	30.32	56.88	12.80	69.68	106.82
87.3	30.86	56.44	12.70	69.14	106.95
87.4	31.41	55.99	12.60	68.59	107.07
87.5	31.95	55.55	12.50	68.05	107.19
87.6	32.50	55.10	12.40	67.50	107.31
87.7	33.04	54.66	12.30	66.96	107.44
87.8	33.59	54.21	12.20	66.41	107.56

FUMING SULPHURIC ACID

Per cent. total SO_3 as units—(*Concluded*)

Per cent. total SO_3	Per cent. free SO_3	Per cent. combined SO_3	Per cent. combined H_2O	Per cent. H_2SO_4	Per cent. 100 % H_2SO_4
87.9	34.13	53.77	12.10	65.87	107.68
88.0	34.67	53.33	12.00	65.33	107.80
88.1	35.22	52.88	11.90	64.78	107.93
88.2	35.76	52.44	11.80	64.24	108.05
88.3	36.31	51.99	11.70	63.69	108.17
88.4	36.85	51.55	11.60	63.15	108.29
88.5	37.40	51.10	11.50	62.60	108.41
88.6	37.94	50.66	11.40	62.06	108.54
88.7	38.49	50.21	11.30	61.51	108.66
88.8	39.03	49.77	11.20	60.97	108.78
88.9	39.57	49.33	11.10	60.43	108.90
89.0	40.12	48.88	11.00	59.88	109.03
89.1	40.66	48.44	10.90	59.34	109.15
89.2	41.21	47.99	10.80	58.79	109.27
89.3	41.75	47.54	10.70	58.24	109.40
89.4	42.30	47.10	10.60	57.70	109.52
89.5	42.84	46.66	10.50	57.16	109.64
89.6	43.38	46.22	10.40	56.62	109.76
89.7	43.93	45.77	10.30	56.07	109.89
89.8	44.47	45.33	10.20	55.53	110.01
89.9	45.02	44.88	10.10	54.98	110.13
90.0	45.56	44.44	10.00	54.44	110.25
91.0	51.01	39.99	9.00	48.99	111.48
92.0	56.45	35.55	8.00	43.55	112.70
93.0	61.89	31.11	7.00	38.11	113.93
94.0	67.34	26.66	6.00	32.66	115.15
95.0	72.78	22.22	5.00	27.22	116.37
96.0	78.23	17.77	4.00	21.77	117.60
97.0	83.67	13.33	3.00	16.33	118.82
98.0	89.11	8.89	2.00	10.89	120.05
99.0	94.56	4.44	1.00	5.44	121.28
100.0	100.00	0.00	0.00	0.00	122.50

FUMING SULPHURIC ACID

Equivalent per cent. 100 per cent. H_2SO_4 as units

Per cent. 100 % H_2SO_4	Per cent. total SO_3	Per cent. free SO_3	Per cent. combined SO_3	Per cent. combined H_2O	Per cent. H_2SO_4
100.0	81.63	0.00	81.63	18.37	100.00
100.1	81.71	0.44	81.27	18.29	99.56
100.2	81.79	0.89	80.90	18.21	99.11
100.3	81.87	1.33	80.54	18.13	98.67
100.4	81.96	1.78	80.18	18.04	98.22
100.5	82.04	2.22	79.82	17.96	97.78
100.6	82.12	2.67	79.45	17.88	97.33
100.7	82.20	3.11	79.09	17.80	96.89
100.8	82.28	3.56	78.72	17.72	96.44
100.9	82.36	4.00	78.36	17.64	96.00
101.0	82.45	4.44	78.01	17.55	95.56
101.1	82.53	4.89	77.64	17.47	95.11
101.2	82.61	5.33	77.28	17.39	94.67
101.3	82.69	5.78	76.91	17.31	94.22
101.4	82.77	6.22	76.55	17.23	93.78
101.5	82.85	6.67	76.18	17.15	93.33
101.6	82.94	7.11	75.83	17.06	92.89
101.7	83.02	7.55	75.47	16.98	92.45
101.8	83.10	8.00	75.10	16.90	92.00
101.9	83.18	8.44	74.74	16.82	91.56
102.0	83.26	8.89	74.37	16.74	91.11
102.1	83.34	9.33	74.01	16.66	90.67
102.2	83.43	9.78	73.65	16.57	90.22
102.3	83.51	10.22	73.29	16.49	89.78
102.4	83.59	10.67	72.92	16.41	89.33
102.5	83.67	11.11	72.56	16.33	88.89
102.6	83.75	11.55	72.20	16.25	88.45
102.7	83.83	12.00	71.83	16.17	88.00
102.8	83.92	12.44	71.48	16.08	87.56
102.9	84.00	12.89	71.11	16.00	87.11
103.0	84.08	13.33	70.75	15.92	86.67
103.1	84.16	13.78	70.38	15.84	86.22
103.2	84.24	14.22	70.02	15.76	85.78
103.3	84.32	14.66	69.66	15.68	85.34
103.4	84.41	15.11	69.30	15.59	84.89
103.5	84.49	15.55	68.94	15.51	84.45
103.6	84.57	16.00	68.57	15.43	84.00
103.7	84.65	16.44	68.21	15.35	83.56
103.8	84.73	16.89	67.84	15.27	83.11
103.9	84.81	17.33	67.48	15.19	82.67
104.0	84.90	17.78	67.12	15.10	82.22
104.1	84.98	18.22	66.76	15.02	81.78
104.2	85.06	18.66	66.40	14.94	81.34
104.3	85.14	19.11	66.03	14.86	80.89

FUMING SULPHURIC ACID

Equivalent per cent. 100 per cent. H_2SO_4 as units—(*Continued*)

Per cent. 100 % H_2SO_4	Per cent. total SO_3	Per cent. free SO_3	Per cent. combined SO_3	Per cent. combined H_2O	Per cent. H_2SO_4
104.4	85.22	19.55	65.67	14.78	80.45
104.5	85.30	20.00	65.30	14.70	80.00
104.6	85.38	20.44	64.94	14.62	79.56
104.7	85.47	20.89	64.58	14.53	79.11
104.8	85.55	21.33	64.22	14.45	78.67
104.9	85.63	21.77	63.86	14.37	78.23
105.0	85.71	22.22	63.49	14.29	77.78
105.1	85.79	22.66	63.13	14.21	77.34
105.2	85.87	23.11	62.76	14.13	76.89
105.3	85.96	23.55	62.41	14.04	76.45
105.4	86.04	24.00	62.04	13.96	76.00
105.5	86.12	24.44	61.68	13.88	75.56
105.6	86.20	24.89	61.31	13.80	75.11
105.7	86.28	25.33	60.95	13.72	74.67
105.8	86.36	25.77	60.59	13.64	74.23
105.9	86.45	26.22	60.23	13.55	73.78
106.0	86.53	26.66	59.87	13.47	73.34
106.1	86.61	27.11	59.50	13.39	72.89
106.2	86.69	27.55	59.14	13.31	72.45
106.3	86.77	28.00	58.77	13.23	72.00
106.4	86.85	28.44	58.41	13.15	71.56
106.5	86.94	28.88	58.06	13.06	71.12
106.6	87.02	29.33	57.69	12.98	70.67
106.7	87.10	29.77	57.33	12.90	70.23
106.8	87.18	30.22	56.96	12.82	69.78
106.9	87.26	30.66	56.60	12.74	69.34
107.0	87.34	31.11	56.23	12.66	68.89
107.1	87.43	31.55	55.88	12.57	68.45
107.2	87.51	32.00	55.51	12.49	68.00
107.3	87.59	32.44	55.15	12.41	67.56
107.4	87.67	32.88	54.79	12.33	67.12
107.5	87.75	33.33	54.42	12.25	66.67
107.6	87.83	33.77	54.06	12.17	66.23
107.7	87.92	34.22	53.70	12.08	65.78
107.8	88.00	34.66	53.34	12.00	65.34
107.9	88.08	35.11	52.97	11.92	64.89
108.0	88.16	35.55	52.61	11.84	64.45
108.1	88.24	35.99	52.25	11.76	64.01
108.2	88.32	36.44	51.88	11.68	63.56
108.3	88.41	36.88	51.53	11.59	63.12
108.4	88.49	37.33	51.16	11.51	62.67
108.5	88.57	37.77	50.80	11.43	62.23
108.6	88.65	38.22	50.43	11.35	61.78
108.7	88.73	38.66	50.07	11.27	61.34

FUMING SULPHURIC ACID

Equivalent per cent. 100 per cent. H_2SO_4 as units—(*Concluded*)

Per cent. 100 % H_2SO_4	Per cent. total SO_3	Per cent. free SO_3	Per cent. combined SO_3	Per cent. combined H_2O	Per cent. H_2SO_4
108.8	88.82	39.11	49.71	11.18	60.89
108.9	88.90	39.55	49.35	11.10	60.45
109.0	88.98	39.99	48.99	11.02	60.01
109.1	89.06	40.44	48.62	10.94	59.56
109.2	89.14	40.88	48.26	10.86	59.12
109.3	89.22	41.33	47.89	10.78	58.67
109.4	89.30	41.77	47.53	10.70	58.23
109.5	89.38	42.22	47.16	10.62	57.78
109.6	89.47	42.66	46.81	10.53	57.34
109.7	89.55	43.10	46.45	10.45	56.90
109.8	89.63	43.55	46.08	10.37	56.45
109.9	89.71	43.99	45.72	10.29	56.01
110.0	89.79	44.44	45.35	10.21	55.56
111.0	90.61	48.88	41.73	9.39	51.12
112.0	91.43	53.33	38.10	8.57	46.67
113.0	92.24	57.77	34.47	7.76	42.23
114.0	93.06	62.21	30.85	6.94	37.79
115.0	93.87	66.66	27.21	6.13	33.34
116.0	94.69	71.10	23.59	5.31	28.90
117.0	95.51	75.54	19.97	4.49	24.46
118.0	96.32	79.99	16.33	3.68	20.01
119.0	97.14	84.43	12.71	2.86	15.57
120.0	97.96	88.88	9.08	2.04	11.12
121.0	98.77	93.32	5.45	1.23	6.68
122.0	99.59	97.76	1.83	0.39	2.22
122.5	100.00	100.00	0.00	0.00	0.00

SPECIFIC-GRAVITY TEST SULPHURIC ACID

76.07–82.5 per cent. SO_3

T. J. SULLIVAN

On account of the irregular specific gravity of sulphuric acid between 76.07 and 81.9 per cent. SO_3 specific gravity cannot be used for determining the strength. The principle of this table is to dilute such acids to a strength where specific gravity may be used. The table is extended to 82.5 per cent. SO_3 which is very convenient for plant use. Strengths, 81.9 per cent. SO_3 or over may again be determined by using direct specific-gravity readings. Over 82.5 per cent. SO_3 the dilution test cannot be

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used with accuracy as the sudden evolution of heat upon mixing with water causes the solution to splash about and some, therefore, may be lost.

The table is calculated for mixing equal volumes of water and acid at 15.56°C. The following formula is used:

Let A = density of water at 15.56°C. (0.99904)

B = specific gravity of acid $\frac{15.56°}{15.56°}$C.

C = weight of SO_3 in B

D = percentage SO_3 in mixture

E = specific gravity of mixture corresponding to D

Then

$$\frac{100\,C}{A + B} = D$$

The temperature allowance for each degree Centigrade is 0.00081 specific gravity. If the specific gravity of the diluted solution is observed at any of the following given temperatures, above 15.56°C. add, below—deduct, the corresponding specific-gravity correction. Then consult the table under the caption "Specific gravity of the diluted solution" for the value of the corrected specific gravity.

°C.	Specific gravity correction	°C.	Specific gravity correction
10	.0046	23	.0060
11	.0037	24	.0069
12	.0029	25	.0077
13	.0021	26	.0085
14	.0013	27	.0093
15	.0005	28	.0101
16	.0004	29	.0109
17	.0012	30	.0117
18	.0020	31	.0125
19	.0028	32	.0133
20	.0036	33	.0141
21	.0044	34	.0150
22	.0052	35	.0158

SPECIFIC GRAVITY OF THE DILUTED SOLUTION $\frac{15.56°}{15.56°}$C.

Per cent. SO_3	Specific gravity	Per cent. SO_3	Specific gravity
76.07	1.5061	79.2	1.5345
76.1	1.5064	79.3	1.5354
76.2	1.5072	79.4	1.5363
76.3	1.5081	79.5	1.5372
76.4	1.5089	79.6	1.5381
76.5	1.5099	79.7	1.5389
76.6	1.5108	79.8	1.5398
76.7	1.5117	79.9	1.5408
76.73	1.5120	80.0	1.5417
76.8	1.5127	80.1	1.5424
76.9	1.5137	80.2	1.5431
77.0	1.5147	80.3	1.5439
77.1	1.5156	80.4	1.5449
77.2	1.5164	80.5	1.5458
77.3	1.5173	80.6	1.5467
77.4	1.5183	80.7	1.5475
77.5	1.5192	80.8	1.5484
77.55	1.5196	80.82	1.5485
77.6	1.5200	80.9	1.5493
77.7	1.5209	81.0	1.5501
77.8	1.5218	81.1	1.5509
77.9	1.5227	81.2	1.5518
78.0	1.5237	81.3	1.5526
78.1	1.5247	81.4	1.5534
78.2	1.5256	81.5	1.5542
78.3	1.5264	81.6	1.5551
78.37	1.5271	81.63	1.5554
78.4	1.5273	81.7	1.5563
78.5	1.5283	81.8	1.5577
78.6	1.5291	81.9	1.5590
78.7	1.5301	82.0	1.5604
78.8	1.5310	82.1	1.5616
78.9	1.5319	82.2	1.5628
79.0	1.5328	82.3	1.5639
79.1	1.5336	82.4	1.5652
79.18	1.5343	82.5	1.5664

Two hundred cubic centimeters of acid at 15.56°C. and 200 c.c. of water at 15.56°C. are a convenient amount to mix.

Obtain the temperature of both the acid and water. If they vary from 15.56°C. use the amounts given below for the various temperatures, calculated as follows:

$$\frac{200\ (\text{specific gravity at } 15.56°\text{C.})}{\text{specific gravity at } t°\text{C.}}$$

Temp.	Acid	Water	Temp.	Acid	Water
10°C	199.4 c.c.	199.9 c.c.	23°C.	200.8 c.c.	200.3 c.c.
11	199.5	199.9	24	200.9	200.4
12	199.6	199.9	25	201.0	200.4
13	199.7	199.9	26	201.1	200.5
14	199.8	200.0	27	201.3	200.5
15	199.9	200.0	28	201.4	200.6
15.56	200.0	200.0	29	201.5	200.6
16	200.1	200.0	30	201.6	200.7
17	200.2	200.1	31	201.7	200.7
18	200.3	200.1	32	201.8	200.8
19	200.4	200.1	33	201.9	200.9
20	200.5	200.2	34	202.0	201.0
21	200.6	200.2	35	202.1	201.0
22	200.7	200.3			

Example.—A sample of acid is drawn from a storage tank and the temperature is found to be 30°C.

The temperature of the water to be used is 24°.

After consulting the preceding tables to ascertain the amount to use for those temperatures, 201.6 c.c. acid and 200.4 c.c. water are mixed and the mixture then cooled.

The specific gravity of the mixture is found to be 1.5388 and the temperature at the time of its determination 20°.

The corresponding specific gravity correction at 20° is 0.0036

$$1.5388 + 0.0036 = 1.5424$$

80.1 per cent. SO_3 corresponds to 1.5424 specific gravity.

SULPHURIC ACID

Per cent. SO_3 corresponding to even percentages H_2SO_4

Per cent. H_2SO_4	Per cent. SO_3	Per cent. H_2SO_4	Per cent. SO_3	Per cent. H_2SO_4	Per cent. SO_3
1	.82	35	28.57	68	55.51
2	1.63	36	29.39	69	56.32
3	2.45	37	30.20	70	57.14
4	3.27	38	31.02	71	57.96
5	4.08	39	31.84	72	58.77
6	4.90	40	32.65	73	59.59
7	5.71	41	33.47	74	60.41
8	6.53	42	34.28	75	61.22
9	7.35	43	35.10	76	62.04
10	8.16	44	35.92	77	62.86
11	8.98	45	36.73	78	63.67
12	9.80	46	37.55	79	64.49
13	10.61	47	38.37	80	65.30
14	11.43	48	39.18	81	66.12
15	12.24	49	40.00	82	66.94
16	13.06	50	40.82	83	67.75
17	13.88	51	41.63	84	68.57
18	14.69	52	42.45	85	69.39
19	15.51	53	43.26	86	70.20
20	16.33	54	44.08	87	71.02
21	17.14	55	44.90	88	71.83
22	17.96	56	45.71	89	72.65
23	18.77	57	46.54	90	73.47
24	19.59	58	47.36	91	74.28
25	20.41	59	48.17	92	75.10
26	21.22	60	48.99	93	75.92
27	22.04	61	49.79	94	76.73
28	22.86	62	50.61	95	77.55
29	23.67	63	51.43	96	78.36
30	24.49	64	52.24	97	79.18
31	25.31	65	53.06	98	80.00
32	26.12	66	53.88	99	80.81
33	26.94	67	54.69	100	81.63
34	27.75				

Sulphuric Acid

Per cent. H_2SO_4 corresponding to even percentages SO_3

Per cent. SO_3	Per cent. H_2SO_4	Per cent. SO_3	Per cent. H_2SO_4	Per cent. SO_3	Per cent. H_2SO_4
1	1.23	29	35.53	56	67.60
2	2.45	30	36.75	57	68.83
3	3.68	31	37.98	58	70.05
4	4.90	32	39.20	59	71.28
5	6.13	33	40.43	60	72.50
6	7.35	34	41.65	61	73.73
7	8.58	35	42.88	62	74.95
8	9.80	36	44.10	63	76.18
9	11.03	37	45.33	64	77.40
10	12.25	38	46.55	65	78.63
11	13.48	39	47.78	66	79.85
12	14.70	40	49.00	67	81.08
13	15.93	41	50.23	68	82.30
14	17.15	42	51.45	69	83.53
15	18.38	43	52.68	70	84.75
16	19.60	44	53.90	71	85.98
17	20.83	45	55.13	72	87.20
18	22.05	46	56.35	73	88.43
19	23.28	47	57.58	74	89.65
20	24.50	48	58.80	75	90.88
21	25.73	49	59.03	76	93.10
22	26.95	50	60.25	77	93.33
23	28.18	51	61.48	78	94.55
24	29.40	52	62.70	79	95.78
25	30.63	53	63.93	80	98.00
26	31.85	54	65.15	81	98.23
27	33.08	55	66.38	81.63	100.00
28	34.30				

ACID CALCULATIONS, USE OF SPECIFIC-GRAVITY TABLES, ESTIMATING STOCKS, ETC.

Correction for temperature must be made when determining the specific gravity. As an example illustrating the use to which the specific-gravity tables may be put: suppose it is required to calculate the number of pounds of 50°Bé. sulphuric acid in a storage tank, the following data being given:

Calculating the volume in the tank we find 2100 cu. ft. at a temperature of 38°C.

A sample taken from the tank and specific gravity determined in the laboratory shows 56.88°Bé. at 33°C. Correction must be made for temperature in order to reduce it to 15.56°C., the temperature for which the tables are constructed:

$$33 - 15.56 = 17.44 \text{ difference}$$

From the table under the caption "Allowance for temperature" it is seen that the allowance for 60°Bé. is 0.047°Bé. for each degree Centigrade and that the correction for 50°Bé. is 0.050°Bé. As the acid in question is about midway between these points, the allowance for each degree Centigrade is very nearly 0.048°Bé.

The correction for temperature is

$$17.44 \times 0.048 = 0.84°\text{Bé.}$$

and as the standard temperature, 15.56°C., is lower than 33°, the temperature at which the Baumé of the sample was taken, this amount must be added.

The Baumé of the acid at 15.56°C. is, then,

$$56.88 + 0.84 = 57.72°\text{Bé.}$$

The Baumé of the acid at 38°C., the temperature of the acid in the tank, is calculated,

$$38 - 15.56 = 22.44 \text{ difference}$$
$$22.44 \times 0.048 = 1.08°\text{Bé.}$$

and as the density of the acid is lowered as the temperature is raised

$$57.72 - 1.08 = 56.64°\text{Bé. at } 38°\text{C.}$$

The easiest way to obtain the specific gravity corresponding to this degree Baumé is by interpolating the given data:

57°Bé. = 1.6477 specific gravity
56°Bé. = 1.6292 specific gravity
0.0185 difference

56.64 − 56.00 = 0.064°Bé. difference
0.0185 × 0.064 = 0.0118
1.6292 + 0.0118 = 1.6410 specific gravity corresponding to 56.64°Bé

Then as 2100 cu. ft. are in the tank, the pounds are

2100 × 62.37 × 1.641 = 214,933 lb. 57.72°Bé.

If it is required to calculate this acid on a 50°Bé. basis, the pounds of 50°Bé. corresponding to 57.72°Bé. is easily found by interpolating from the table.

58°Bé. = 119.59 per cent. 50°Bé.
57°Bé. = 117.00 per cent. 50°Bé.
2.59 per cent. 50°Bé. difference
57.72 − 57.00 = 0.72°Bé. difference
2.59 × 0.72 = 1.86
117 + 1.86 = 118.86 per cent. 50°Bé. acid corresponding to 57.72°Bé. acid
214,933 × 1.1886 = 255,469 lb. of 50°Bé.

If it is required to calculate on a "pounds SO_3" basis, the percentage SO_3 in 57.72°Bé. acid is calculated from the table by interpolation.

58°Bé. = 60.70 per cent. SO_3
57°Bé. = 59.39 per cent. SO_3
1.31 difference

0.72 × 1.31 = 0.94
59.39 + 0.94 = 60.33 per cent. SO_3 corresponding to 57.72°Bé.
214,933 × 0.6033 = 129,669 lb. SO_3.

DILUTION AND CONCENTRATION OF SULPHURIC ACID TO FORM SOLUTIONS OF ANY DESIRED STRENGTH

1. To Prepare a Definite Amount of Dilute Solution, by Mixing a Strong Solution with a Weak Solution.—

Let X = quantity of weak solution to be used in the mixture
Y = quantity of strong solution to be used in the mixture
A = strength of strong solution
B = strength of desired solution
C = strength of weak solution
D = desired quantity

$$X = \frac{D(A - B)}{A - C}$$

$$Y = D - X$$

Example 1.—How many pounds of 60.7 per cent. SO_3 and how many pounds of 80.0 per cent. SO_3 must be mixed to obtain 70,000 lb. of 76.07 per cent. SO_3?

$$X = 70{,}000(80.0 - 76.07)/(80.0 - 60.7) = 14{,}254 \text{ lb.}$$
$$Y = 70{,}000 - 14{,}254 = \underline{55{,}746} \text{ lb.}$$
$$X + Y = 70{,}000 \text{ lb.}$$

If water is to be used for diluting, the formula may be some what simplified.

$$X = D - Y$$

$$Y = \frac{BD}{A}$$

2. To Prepare a Definite Amount of a Stronger Solution, by Mixing a Weaker Solution with a Stronger Solution.—This formula is the reverse of formula (1).

Let X = quantity of strong solution to be used in the mixture
Y = quantity of weak solution to be used in the mixture
A = strength of strong solution
B = strength of desired solution
C = strength of weak solution
D = desired quantity

$$X = \frac{D(B - C)}{A - C}$$

$$Y = D - X$$

Example 2.—How many pounds of 60.7 per cent. SO_3 and how many pounds of 80.0 per cent. SO_3 must be mixed to obtain 70,000 lb. of 76.07 per cent. SO_3?

$$X = 70{,}000(76.07 - 60.7)/(80.0 - 60.7) = 55{,}746 \text{ lb.}$$
$$Y = 70{,}000 - 55{,}746 = 14{,}254 \text{ lb.}$$
$$X + Y = 70{,}000 \text{ lb.}$$

3. Dilution of a Definite Amount of a Stronger Solution, thus Producing a Greater Amount of a more Dilute Solution.—

Let X = quantity of diluting solution that must be added
A = strength of solution to be diluted
B = strength of desired solution
C = strength of diluting solution
D = quantity of solution to be diluted
$D + X$ = total quantity of corrected solution

$$X = \frac{D(A - B)}{B - C}$$

Example 3.—How many pounds of a 60.7 per cent. SO_3 must be added to 70,000 lb. of 80.0 per cent. $SO_3$to make a whole of 76.07 per cent. SO_3?

$$X = 70{,}000(80.0 - 76.07)/(76.07 - 60.7) = 17{,}899 \text{ lb. } 60.7 \text{ per cent.}$$
$$D + X = 70{,}000 + 17{,}899 = 87{,}899 \text{ lb. } 76.07 \text{ per cent.}$$

Calculating the same example by ratios, where X = the amount of diluting solution that must be added.

Examples 1 and 2 show 14,254 lb. of 60.7 per cent. SO_3 must be mixed with 55,746 lb. of 80.0 per cent. SO_3 to make a whole of 76.07 per cent. SO_3.

Therefore we have the ratio

$$14{,}254 : 55{,}746 :: X : 70{,}000$$

$X = 17{,}899$ lbs. 60.7 per cent. that must be added.

4. Concentration of a Definite Amount of a Weaker Solution, thus Producing a Greater Amount of a More Concentrated Solution.—

Let X = quantity of strengthening solution that must be added
A = strength of strengthening solution
B = strength of desired solution
C = strength of solution to be corrected
D = quantity of solution to be corrected
$D + X$ = total quantity of corrected solution

$$X = \frac{D(B - C)}{A - B}$$

Example 4.—How many pounds of 80.0 per cent. SO_3 must be added to 70,000 lb. of 60.7 per cent. SO_3 to make a whole of 76.07 per cent. SO_3?

$$X = 70{,}000(76.07 - 60.7)/(80.0 - 76.07) = 273{,}766$$
$$D + X = 70{,}000 + 273{,}766 = 343{,}766$$

This may also be calculated by ratio, where X = the amount of strengthening solution that must be added.

Examples 1 and 2 show 55,746 lb. of 80.0 per cent. SO_3 must be mixed with 14,254 lb. of 60.7 per cent. SO_3 to make a whole of 76.07 per cent. SO_3.

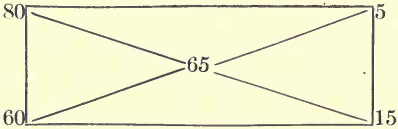
Therefore we have the ratio

$$55{,}746 : 14{,}254 :: X : 70{,}000$$

$X = 273{,}766$ lb. 80.0 per cent. that must be added.

5. Rectangle Method for Dilution and Concentration of Sulphuric Acid to Form Solutions of any Desired Strength.—The figures expressing the strengths of the two solutions are written in the two left-hand corners of a rectangle, and the figure expressing the desired strength is placed on the intersection of the two diagonals of this rectangle.

Now subtract the figures on the diagonals, the smaller from the larger, and write the result at the other end of the respective diagonal. These figures then indicate what quantities of the solution whose strength is given on the other end of the respective horizontal line, must be taken to obtain a solution of the desired strength.



Example 5.—To make a 65 per cent. SO_3 acid by mixing an 80 per cent. SO_3 and a 60 per cent. SO_3 acid we prepare the above figure which indicates that we have to take 5 parts by weight of the 80 per cent. acid and 15 parts by weight of 60 per cent. acid to obtain 20 parts (5 + 15) of the 65 per cent. acid.

Or $\frac{5}{20}$ parts of an 80 per cent. SO_3 and $\frac{15}{20}$ parts of a 60 per cent. SO_3 will, if mixed, give 1 part of a 65 per cent. SO_3. Suppose it is desired to mix 500 lb. Proceed as follows:

$$500 \times \frac{5}{20} = 125 \text{ lb. 80 per cent. } SO_3$$
$$500 \times \frac{15}{20} = \underline{375} \text{ lb. 60 per cent. } SO_3$$
$$500$$

Suppose it is required to know how much 60 per cent. SO_3 must be added to 500 lb. 80 per cent. SO_3 to make a whole of 65 per cent. SO_3.

Proceed as follows:

$$\frac{500}{\frac{5}{20}} - 500 = 1500 \text{ lb. 60 per cent. } SO_3$$

Or $\frac{15}{5} \times 500 = 1500$

Suppose it is required to know how much 80 per cent. SO_3 must be added to 500 lb. 60 per cent. SO_3 to make a whole of 65 per cent. SO_3.

Proceed as follows:

$$\frac{500}{15/20} - 500 = 167 \text{ lb. } 80 \text{ per cent. } SO_3$$

Or $$5/15 \times 500 = 167$$

Notes.—1. When mixtures of non-fuming acid are calculated, either the SO_3 or H_2SO_4 percentages may be used. When non-fuming and fuming acid are to be mixed or fuming acid of one strength to be mixed with fuming acid of another strength, SO_3, percentages should be used unless the H_2SO_4 percentage of the fuming acid be expressed in its equivalent to 100 per cent. H_2SO_4. For instance an acid of 85.30 per cent. SO_3 has an actual H_2SO_4 content of 80 per cent. and its 100 per cent. equivalent would be 104.49 per cent.

2. These formulas are accurate when the weights of solutions are considered. If the specific gravities are closely related, the formulas may be used for volumes. When this assumption is not permissible, the weights may be calculated, and knowing the weights of the components, the volumes requisite calculated from the formula—

$$\text{Volume} = \frac{\text{Mass}}{\text{Weight}}$$

On mixing such solutions, to use this formula, it must be assumed that the volumes are additive, *i.e.*, no change of volume takes place upon mixing.

To illustrate the use of this formula: Example 1 shows 14,254 lb. of 60.7 per cent. SO_3 must be mixed with 55,746 lb. of 80.0 per cent. SO_3 to obtain 70,000 lb. of 76.07 per cent. SO_3.

76.07 per cent. SO_3 weighs 114.47 lb. per cubic foot at 15.56°C.

$$\frac{70{,}000}{114.47} = 611.5 \text{ cu. ft.} = \text{volume of } 70{,}000 \text{ lb. } 76.07 \text{ per cent.}$$

60.7 per cent. SO_3 weighs 103.95 lb. per cubic foot at 15.56°C.

$$\frac{14{,}254}{103.95} = 137.1 \text{ cu. ft.} = \text{volume of } 14{,}254 \text{ lb., } 60.7 \text{ per cent.}$$

$$611.5 - 137.1 = 474.4$$

Therefore, 474.4 cu. ft. of 80.0 per cent. mixed with 137.1 cu. ft. of 60.7 per cent. will make 611.5 cu. ft. or 70,000 lb. of 76.07 per cent.

In using this method it must also be assumed that both acids used in mixing are 15.56°C., unless the coefficients of expansion be calculated for differences in temperature. This, however, is unnecessary as very accurate results may be obtained without this calculation.

Table for Mixing 59°Bé.[1] Sulphuric Acid

Giving percentage (by volume) of various strengths *weak acid to use* with various strengths strong acid

59°Bé. = 62.03 per cent. SO_3 = 75.99 per cent. H_2SO_4

Degrees Baumé Weak acid	Per cent. SO_3 in strong acid			
	79.5	80.0	80.5	81.0
54.0	77.4	78.1	78.5	79.2
54.2	78.1	78.7	79.0	79.7
54.4	78.7	79.4	79.7	80.3
54.6	79.4	80.0	80.3	81.0
54.8	80.0	80.7	81.0	81.6
55.0	80.8	81.3	81.6	82.3
55.2	81.5	82.0	82.3	82.9
55.4	82.1	82.6	82.9	83.6
55.6	82.9	83.3	83.7	84.2
55.8	83.7	84.1	84.6	85.0
56.0	84.6	84.9	85.4	85.9
56.2	85.4	85.7	86.2	86.7
56.4	86.2	86.5	87.0	87.5
56.6	87.0	87.3	87.8	88.3
56.8	87.8	88.3	88.6	89.1
57.0	88.8	89.3	89.6	89.9
57.2	89.8	90.2	90.6	90.7
57.4	90.7	91.2	91.5	91.7
57.6	91.7	92.2	92.5	92.7
57.8	92.9	93.2	93.5	93.7
58.0	94.0	94.3	94.5	94.6
58.2	95.1	95.5	95.5	95.6
58.4	96.3	96.6	96.6	96.6
58.6	97.4	97.7	97.7	97.7
58.8	98.7	98.9	98.9	98.9
59.0	100.0	100.0	100.0	100.0

[1] It is advisable to ship or store 59° instead of 60° during the winter months on account of its much lower freezing point.

Table for Mixing 60°Bé. Sulphuric Acid

Giving percentage (by volume) of various strengths *weak acid to use* with various strengths strong acid

60°Bé. = 63.40 per cent. SO_3 = 77.67 per cent. H_2SO_4

Degrees Baumé Weak acid	Per cent. in strong acid			
	79.5	80.0	80.5	81.0
55.0	75.3	76.1	76.6	77.2
55.2	75.9	76.8	77.2	77.9
55.4	76.6	77.4	77.9	78.5
55.6	77.2	78.1	78.5	79.2
55.8	77.9	78.7	79.2	79.8
56.0	78.7	79.4	79.8	80.5
56.2	79.5	80.2	80.7	81.1
56.4	80.3	81.0	81.5	81.8
56.6	81.1	81.8	82.3	82.6
56.8	82.0	82.6	83.1	83.4
57.0	82.8	83.4	83.9	84.2
57.2	83.7	84.2	84.7	85.0
57.4	84.7	85.0	85.5	85.9
57.6	85.7	86.0	86.3	86.7
57.8	86.7	87.0	87.3	87.6
58.0	87.6	88.0	88.3	88.6
58.2	88.6	88.9	89.3	89.6
58.4	89.8	90.1	90.2	90.6
58.6	90.9	91.2	91.4	91.5
58.8	92.0	92.4	92.6	92.7
59.0	93.2	93.5	93.7	93.8
59.2	94.5	94.8	94.8	95.0
59.4	95.8	96.1	96.1	96.1
59.6	97.1	97.4	97.4	97.4
59.8	98.5	98.7	98.7	98.7
60.0	100.0	100.0	100.0	100.0

Table for Mixing 66°Bé. Sulphuric Acid

Giving percentage (by volume) of various strengths *strong acid to use* with various strengths weak acid

66°Bé. = 76.07 per cent. SO_3 = 93.19 per cent. H_2SO_4

Degrees Baumé Weak acid	Per cent. SO_3 in strong acid												
	79.0	79.2	79.4	79.6	79.8	80.0	80.2	80.4	80.6	80.8	81.0	81.2	81.4
50	87.5	86.7	85.9	85.0	84.4	83.7	82.9	82.3	81.6	81.0	80.3	79.7	79.0
51	87.2	86.3	85.5	84.7	83.9	83.3	82.4	81.8	81.1	80.5	79.8	79.0	78.4
52	86.7	85.9	85.0	84.2	83.4	82.8	82.0	81.1	80.5	79.8	79.2	78.4	77.7
53	86.2	85.4	84.6	83.7	82.9	82.1	81.3	80.5	79.7	79.0	78.4	77.7	77.1
54	85.5	84.7	83.9	83.1	82.3	81.5	80.7	79.8	79.0	78.2	77.6	76.9	76.3
55	84.9	83.9	83.1	82.3	81.5	80.7	79.8	79.0	78.2	77.4	76.6	75.9	75.3
56	84.2	83.3	82.4	81.5	80.7	79.8	79.0	78.2	77.4	76.6	75.8	75.0	74.3
57	83.4	82.4	81.5	80.5	79.7	78.9	78.1	77.2	76.4	75.6	74.8	74.0	73.0
58	82.4	81.5	80.5	79.5	78.5	77.6	76.6	75.8	75.0	74.2	73.3	72.5	71.7
59	81.3	80.2	79.2	78.2	77.2	76.3	75.3	74.3	73.3	72.5	71.7	71.1	70.2
60	79.8	78.7	77.6	76.4	75.5	74.5	73.5	72.5	71.5	70.7	69.9	69.1	68.1
61	78.1	76.9	75.8	74.6	73.5	72.4	71.4	70.4	69.4	68.5	67.6	66.8	65.9

FORMATION OF MIXTURES OF SULPHURIC AND NITRIC ACIDS OF DEFINITE COMPOSITION

(So-called "Mixed Acids")

"Mixed acid" is a commercial term, generally meaning a mixture of nitric and sulphuric acids. Such mixtures are extensively used in manufacturing processes. On account of the relative high cost of concentrated nitric acid, compared with that of the dilute acid, the concentrated acid is diluted with a weak solution of the acid, instead of with water, using a minimum quantity of concentrated and a maximum quantity of dilute nitric acid. Water, as such, is seldom used.

Example 1.—Calculate the quantities of acids necessary to make a mixture ("mix") of 60,000 lb. of a mixed acid to consist of

	Per cent.
H_2SO_4 (add as 98 per cent. H_2SO_4)........	46.00
HNO_3 (add as 61.4 per cent. and as 95.5 per cent.)........................	49.00
H_2O..............................	5.00
	100.00

60,000 × 0.46 = 27,600 lb. H_2SO_4 called for
60,000 × 0.49 = 29,400 lb. HNO_3 called for
60,000 × 0.05 = 3,000 lb. H_2O called for
60,000

27,600/0.98 = 28,163 lb. 98 per cent. H_2SO_4 to take
60,000 − 28,163 = 31,837 lb. still to add

29,400 lb. of 100 per cent. nitric acid are called for; the weight of material still to be added, after the 98 per cent. sulphuric acid is added, is 31,837. This makes

29,400/31,837 × 100 = 92.35 per cent. HNO_3 to be added

To make 31,837 lb. of an acid of this concentration from 95.5 per cent. and 61.4 per cent. nitric acid, using formula (2).

31,837 (92.35 − 61.4)/(95.50 − 61.4) = 28,896 lb. 94.5 per cent. HNO_3 to take.

31,837 − 28,896 = 2,941 lb. 61.4 per cent. HNO_3 to take

So, to make the mix, use

H_2SO_4 = 28,163 lb. 98.0 per cent.
HNO_3 = 28,896 lb. 95.5 per cent.
HNO_3 = 2,941 lb. 61.4 per cent.
60,000 lb.

Strengthening a Mixed Acid by Means of a Fuming Sulphuric Acid

Example 2.—Let it be required to make 61,320 lb. of a mixed acid of the composition:

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	Per cent.
HNO_3 (add as 94.5 per cent. HNO_3)	56.00
H_2SO_4 (add as 98.56 per cent. H_2SO_4 and as 20 per cent. fuming sulphuric acid, a minimum of which is to be taken)	41.00
H_2O	3.00
	100.00

The tank in which the acid is to be mixed already contains 2,604 lb. of the remains of a previous mix of the composition:

	Per cent.
HNO_3	52.00
H_2SO_4	42.50
H_2O	5.50

Solution.—

$61,320 \times 0.56 = 34,339$ lb. HNO_3 called for
$61,320 \times 0.41 = 25,141$ lb. H_2SO_4 called for
$61,320 \times 0.03 = 1,840$ lb. H_2O called for

$2,604 \times 0.52 = 1,354$ lb. HNO_3 in tank
$2,604 \times 0.425 = 1,107$ lb. H_2SO_4 in tank
$2,604 \times 0.055 = 143$ lb. H_2O in tank

Thus we have:

Required:	25,141 lb. H_2SO_4	34,339 lb. HNO_3	1,840 lb. H_2O
In tank:	1,107	1,354	143
To be added:	24,034 lb. H_2SO_4	32,985 lb. HNO_3	1,697 lb. H_2O

If the attempt were made to calculate the weights of acid to add by the previous method, it would be seen that the method would not work as too much water would be added with the sulphuric acid and, hence, a nitric acid stronger than 94.5 per cent. HNO_3 would have to be used to complete the mix; hence, fuming sulphuric acid will have to be employed.

Thus:

$24,034/0.9856 = 24,385$ lb. 98.56 per cent. H_2SO_4
$24,385 - 24,034 = 351$ lb. H_2O added with the 98.56 per cent. H_2SO_4
$1,697 - 351 = 1,346$ lb. H_2O remaining

Adding this water with the nitric acid would call for a stronger nitric acid than 94.5 per cent. HNO_3, as is seen from the following:

$32,985 + 1,346 = 34,331$ lb. HNO_3 and H_2O still to add
$32,985/34,331 \times 100 = 96.08$ per cent. HNO_3 required to complete the mix.

Going back to the original figures after this preliminary calculation which has shown the necessity of using fuming sulphuric acid; first calculating the weight of nitric acid to be added:

$32,985/0.945 = 34,905$ lb. 94.5 per cent. HNO_3 to add
$34,905 - 32,985 = 1,920$ lb. H_2O added with the 94.5 per cent. HNO_3

But the mix only calls for 1,697 lb. of water, hence

$1,920 - 1,697 = 223$ lb. H_2O will be added in excess. This water must be taken up with fuming sulphuric acid. Now to the acid already in the tank the following quantities of acid must be added:

H_2SO_4	= 24,034	lb. 100 per cent. H_2SO_4
HNO_3	= 32,985	lb. 100 per cent. HNO_3
H_2O	= 1,697	lb. 100 per cent. H_2O
	58,716	

In adding 34,905 lb. of 94.5 per cent. HNO_3 there remain only

$58,716 - 34,905 = 23,811$ lb. of sulphuric acid to add. To adjust proportions and not add more acid than called for is done by adding fuming sulphuric acid which takes up the water from the nitric acid. The percentage strength of the sulphuric acid requisite is

$$24,034/23,811 \times 100 = 100.94 \text{ per cent. } H_2SO_4$$

The percentage of SO_3 in 100.94 per cent. H_2SO_4 is $0.8163 \times 100.94 = 82.40$ per cent.

In 98.56 per cent. H_2SO_4 the percentage of SO_3 is $0.8163 \times 98.56 = 80.45$ per cent.

In 20 per cent. fuming sulphuric acid the percentage of SO_3 is $0.8163\ (100 - 20) + 20 = 85.30$ per cent.

Then, to make 23,811 lb. of 100.94 per cent. H_2SO_4 from 20.00 per cent. fuming and 98.56 per cent. H_2SO_4 require:

23,811 (82.40 − 80.45)/(85.30 − 80.45) = 9,573 lb. 20 per cent. fuming sulphuric acid,

$$23{,}811 - 9{,}573 = 14{,}238 \text{ lb. } 98.56 \text{ per cent. } H_2SO_4$$

So, to make the mix, add to the acid already in the tank:

HNO_3 = 34,905 lb. 94.50 per cent.
H_2SO_4 = 14,238 lb. 98.56 per cent.
H_2SO_4 = 9,573 lb. 20.00 per cent.

The amount of 20 per cent. fuming to use may be calculated by another method. Where it is found that 223 lb. of H_2O will be added in excess, calculate how many pounds of 20 per cent. will be necessary to take up this water.

4.4438 × 223 = 991 lb. free SO_3 and this is contained in 4,955 lb. 20 per cent.

20 per cent. fuming sulphuric acid is equivalent to 104.49 per cent. 100 per cent. H_2SO_4.

The addition of these 4,955 lb. 20 per cent. corresponds to an addition of—

$$4{,}955 \times 104.49/100 = 5{,}177 \text{ lb. of } 100 \text{ per cent. } H_2SO_4$$

24,034 − 5,177 = 18,857 lb. of 100 per cent. H_2SO_4 that are yet to be added.

Now calculate how much 20 per cent. fuming and 98.56 per cent. H_2SO_4 will be required to prepare this 18,857 lb. 100 per cent. H_2SO_4.

Example 3.—It is frequently desired to prepare a "mix" from a mixed acid already on hand by adding to it the requisite amounts of sulphuric and nitric acid to bring it up to the desired concentration. Thus it may be required to fortify a "spent" mixed acid, or it may be that after adding the calculated amounts of ingredients to make a batch of mixed acid that the mixed acid resulting does not analyze up to specifications. It must then be adjusted by a further addition of the deficient constituent.

Thus, suppose a mixed acid of the following composition is desired:

	Per cent.
H_2SO_4	60.00
HNO_3	22.50
H_2O	17.50
	100.00

and there is on hand a supply of mixed acid of the composition:

	Per cent.
H_2SO_4	60.12
HNO_3	20.23
H_2O	19.65
	100.00

A 97.5 per cent. H_2SO_4 and a 90.5 per cent. HNO_3 are on hand. How many pounds of each of these two acids and of the mixed acid on hand must be taken to make each 1000 lb. of the required mixture without adding any water?

Let x = weight of mixed acid to take
y = weight of 97.5 per cent. H_2SO_4 to take
z = weight of 90.5 per cent. HNO_3 to take

Then $x(0.6012)$ = weight H_2SO_4 (100 per cent.) in the mixed acid on hand.
$y(0.975)$ = weight H_2SO_4 (100 per cent.) actually added, when adding the 97.5 per cent. acid.
$x(0.2023)$ = weight HNO_3 (100 per cent.) in the mixed acid on hand.
$z(0.905)$ = weight HNO_3 (100 per cent.) actually added, when adding the 90.5 per cent. acid.
$y(0.025)$ = weight H_2O contained in the H_2SO_4 (97.5 per cent.).
$z(0.095)$ = weight H_2O contained in the HNO_3 (90.5 per cent.).
$x(0.1965)$ = weight H_2O in the mixed acid on hand.

1000 lb. of the desired mixture must evidently contain:

600 lb. H_2SO_4
225 lb. HNO_3
175 lb. H_2O

Therefore we have the following equations:

$$(1)\ x(0.6012) + y(0.975) = 600 \text{ lb. } H_2SO_4$$
$$(2)\ x(0.2023) + z(0.905) = 225 \text{ lb. } HNO_3$$
$$(3)\ x(0.1965) + y(0.025) + z(0.905) = 175 \text{ lb. } H_2O$$
$$y = (600 - x0.6012)/0.975 = 615.38 - x(0.61662)$$
$$z = (225 - x0.2023)/0.905 = 248.62 - x(0.22354)$$

Substituting these two equations in equation (3), we obtain:

$$0.1965x + 15.38 - 0.01542x + 23.62 - 0.02124x = 175$$
$$0.15984x = 136.$$
$$x = 850.85 \text{ lb. of the mixed acid on hand to take.}$$

Substituting in equation (1):

$y = (600 - 511.53)/0.975 = 90.74$ lb. of 97.5 per cent. H_2SO_4 to take.

Substituting in equation (2):

$z = (225 - 172.13)/0.905 = 58.41$ lb. of 90.5 per cent. HNO_3 to take.

Therefore for each 1000 lb. of the desired mixture use

Mixed acid	850.85
97.5 per cent. H_2SO_4	90.74
90.50 per cent. HNO_3	58.41
	1000.00

The ratios of these values may be used either to prepare a definite amount of mixed acid or to correct a definite amount of "spent" acid. Knowing the ratios per 1,000 lb. the quantities requisite for any weight of acid are readily calculated.

"Melting point" is understood to be the temperature to which the mercury of the thermometer, dipping into the solidifying liquid, rises and at which it remains constant.

It should be noticed that large quantities of fuming acid, such as exists in transportation vessels, frequently do not behave in accord with the given data, because during the carriage and storage a separation often takes place in the acid, crystals of a different concentration being formed, which, of course, possess a correspondingly different melting point.

The figures given in parentheses signify the melting points of freshly made fuming acid, which has not polymerized.

BOILING POINTS, SULPHURIC ACID

(Lunge, *Ber.* 11, 370)

Per cent. H_2SO_4	Boiling point, °C.	Per cent. H_2SO_4	Boiling point, °C.	Per cent. H_2SO_4	Boiling point, °C.
5	101	56	133	82	218.5
10	102	60	141.5	84	227
15	103.5	62.5	147	86	238.5
20	105	65	153.5	88	251.5
25	106.5	67.5	161	90	262.5
30	108	70	170	91	268
35	110	72	174.5	92	274.5
40	114	74	180.5	93	281.5
45	118.5	76	189	94	288.5
50	124	78	199	95	295
53	128.5	80	207		

100 per cent. begins to boil at 290° and rises to 338° (Marignac).

MELTING POINTS OF SULPHURIC ACID

Knietsch (*Ber.*, 1901, p. 4100) gives the following melting points of sulphuric acid, non-fuming and fuming from 1 to 100 per cent. SO_3.

NOTE.—Melting and freezing points of sulphuric acid are not the same. The mono-hydrate (100 per cent. H_2SO_4) for instance has a freezing point of about 0°C. and a melting point of 10°C. From my own determinations, 88.1 per cent. total SO_3 for instance, upon cooling gradually, at 18°C., begins to freeze, solidifies with a rise of temperature and remains constant at 26°C. 18° would really be the freezing point and 26° the melting point. Knietsch gives his melting points as the temperature where the solidifying liquid remains constant.

An acid cooled below its melting point will not solidify until it reaches its freezing point unless it be agitated or a fragment of a crystal introduced.

Sulphuric Acid, Melting Points

Per cent. total SO_3	Melting point		Per cent total SO_3	Melting point		Per cent. free SO_3	Melting point	
	°C.	°F.		°C.	°F.		°C.	°F.
1	−0.6	30.9	69	7.0	44.6	0	10.0	50.0
2	−1.0	30.2	70	4.0	39.2	5	3.5	38.3
3	−1.7	28.9	71	−1.0	30.2	10	−4.8	23.4
4	−2.0	28.4	72	−7.2	19.0	15	−11.2	11.8
5	−2.7	27.1	73	−16.2	2.8	20	−11.0	12.2
6	−3.6	25.5	74	−25.0	−13.0	25	−0.6	30.9
7	−4.4	24.1	75	−34.0	−29.2	30	+15.2	59.4
8	−5.3	22.5	76	−32.0	−25.6	35	26.0	78.8
9	−6.0	21.2	77	−28.2	−18.8	40	33.8	92.8
10	−6.7	19.9	78	−16.5	+2.3	45	34.8	94.6
11	−7.2	19.0	79	−5.2	22.6	50	28.5	83.3
12	−7.9	17.8	80	+3.0	37.4	55	18.4	65.1
13	−8.2	17.2	81	7.0	44.6	60	0.7	33.3
14	−9.0	15.8	81.63	10.0	50.0	65	0.8	33.4
15	−9.3	15.3	82	8.2	46.8	70	9.0	48.2
16	−9.8	14.4	83	−0.8	30.6	75	17.2	63.0
17	−11.4	11.5	84	−9.2	15.4	80	22.0	71.6
18	−13.2	8.2	85	−11.0	12.2	85	33.0	91.4
19	−15.2	4.6	86	−2.2	28.0	90	34.0	93.2
20	−17.1	1.2	87	+13.5	56.3	95	36.0	96.8
21	−22.5	−8.5	88	26.0	78.8	100	40.0	104.0
22	−31.0	−23.8	89	34.2	93.6			
23	−40.1	−40.2	90	34.2	93.6			
..	Below		91	25.8	78.4	85	(27.0)	(80.6)
..	−40.0		92	14.2	57.6	90	(25.0)	(77.0)
61	−40.0	−40.0	93	0.8	33.4	95	(26.0)	(78.8)
62	−20.0	−4.0	94	4.5	40.1	100	(15.0)	(59.0)
63	−11.5	+11.3	95	14.8	58.6			
64	−4.8	23.4	96	20.3	68.6			
65	−4.2	24.4	97	29.2	84.6			
66	+1.2	34.2	98	33.8	92.8			
67	8.0	46.4	99	36.0	96.8			
68	8.0	46.4	100	40.0	104.0			

Sulphuric Acid—Tension of Aqueous Vapor[1]

Readings in millimeters of mercurial pressure

Per cent. H_2SO_4	Per cent. SO_3	Approximate degrees Baumé	Temperatures, °C.					
			10°	15°	20°	25°	30°	35°
44	35.92	37.0	4.4	6.1	8.5	11.5	15.5	20.9
46	37.55	38.5	4.0	5.5	7.7	10.5	14.5	19.7
48	39.18	39.9	3.7	5.0	7.1	9.6	13.4	18.1
50	40.82	41.4	3.3	4.5	6.5	8.8	12.0	16.4
52	42.45	42.8	3.0	4.0	5.8	7.9	10.9	14.5
54	44.08	44.2	2.6	3.6	5.0	7.0	9.5	12.5
56	45.71	45.7	2.2	3.1	4.3	6.0	8.1	11.0
58	47.36	47.1	1.9	2.6	3.5	5.1	7.2	9.1
60	48.99	48.5	1.6	2.1	3.0	4.3	6.1	7.5
62	50.61	49.9	1.4	1.8	2.6	3.6	5.0	6.5
64	52.24	51.2	1.2	1.6	2.2	3.0	4.0	5.5
66	53.88	52.6	1.1	1.4	1.8	2.5	3.5	4.5
68	55.51	53.9	0.9	1.2	1.5	2.1	3.0	3.8
70	57.14	55.2	0.8	1.0	1.3	1.8	2.5	3.3
72	58.77	56.5	0.7	0.8	1.0	1.4	2.0	2.8
74	60.41	57.8	0.5	0.6	0.6	1.2	1.7	2.1
76	62.04	59.0	0.4	0.4	0.5	1.0	1.4	1.8
78	63.67	60.2	0.3	0.3	0.4	0.8	1.1	1.4
80	65.30	61.3	0.2	0.2	0.3	0.6	0.8	1.1
82	66.94	62.3	0.1	0.1	0.2	0.4	0.5	0.5

[1] Sorel: Lunge's "Sulphuric Acid and Alkali," vol. I, part I, p. 312, 4th edition.

Note.—The corresponding per cent. SO_3 and approximate degree Baumé (American Standard) were calculated from the given per cent. H_2SO_4

SULPHURIC ACID—TENSION OF AQUEOUS VAPOR—(*Continued*)

Readings in millimeters of mercurial pressure

Per cent. H_2SO_4	Per cent. SO_3	Approximate degrees Baumé	Temperature, °C.					
			40°	45°	50°	55°	60°	65°
44	35.92	37.0	28.1	37.4	48.3			
46	37.55	38.5	26.3	33.6	44.4	59.6	76.5	96.4
48	39.18	39.9	23.9	30.5	40.1	53.5	69.0	86.8
50	40.82	41.4	21.4	27.4	35.9	47.4	61.3	77.0
52	42.45	42.8	18.9	24.1	31.5	41.5	54.0	67.9
54	44.08	44.2	16.5	21.3	27.8	36.2	47.2	59.9
56	45.71	45.7	14.2	18.5	24.1	31.0	41.6	51.6
58	47.36	47.1	12.0	15.8	20.4	26.1	34.5	44.0
60	48.99	48.5	10.0	13.0	16.9	21.6	28.7	36.7
62	50.61	49.9	8.1	10.5	13.9	17.7	23.9	30.0
64	52.24	51.2	6.5	8.2	10.9	14.0	18.7	23.9
66	53.88	52.6	5.4	6.5	8.9	11.5	15.2	19.1
68	55.51	53.9	4.5	5.4	7.2	9.5	12.3	15.4
70	57.14	55.2	3.8	4.4	5.9	7.5	9.5	12.1
72	58.77	56.5	3.2	3.6	4.8	6.0	7.5	9.5
74	60.41	57.8	2.6	3.1	3.9	4.9	6.0	7.5
76	62.04	59.0	2.1	2.5	3.0	4.0	4.8	5.9
78	63.67	60.2	1.7	2.1	2.4	3.0	3.5	4.0
80	65.30	61.3	1.3	1.6	1.9	2.4	2.9	3.3
82	66.94	62.3	0.9	1.1	1.4	1.7	2.0	2.3

Sulphuric Acid—Tension of Aqueous Vapor—(*Concluded*)

Readings in millimeters of mercurial pressure

Per cent. H_2SO_4	Per cent SO_3	Approximate degrees Baumé	Temperature, °C.					
			70°	75°	80°	85°	90°	95°
44	35.92	37.0						
46	37.55	38.5						
48	39.18	39.9	107.2	132.1				
50	40.82	41.4	95.6	118.1	152.0	192.6	236.7	
52	42.45	42.8	84.5	104.5	131.2	166.5	207.9	251.5
54	44.08	44.2	74.8	92.6	116.1	146.8	183.5	222.0
56	45.71	45.7	65.0	80.6	100.9	128.2	160.0	195.0
58	47.36	47.1	55.4	68.4	86.2	110.6	138.5	169.5
60	48.99	48.5	46.1	56.7	72.3	94.0	118.7	146.0
62	50.61	49.9	37.7	46.2	59.7	78.2	100.7	125.0
64	52.24	51.2	30.3	37.4	48.0	63.8	83.7	105.0
66	53.88	52.6	24.2	30.3	39.0	52.5	70.0	88.0
68	55.51	53.9	19.4	24.4	31.4	42.5	56.0	72.0
70	57.14	55.2	15.5	19.8	25.5	33.9	44.4	57.0
72	58.77	56.5	12.0	15.4	20.0	26.2	33.7	43.4
74	60.41	57.8	9.5	12.1	15.4	19.5	24.5	31.5
76	62.04	59.0	7.5	9.5	11.8	15.0	18.5	22.0
78	63.67	60.2	5.7	7.0	8.5	10.5	13.0	15.8
80	65.30	61.3	4.1	5.0	6.2	7.5	9.3	11.0
82	66.94	62.3	2.7	3.2	3.9	4.7	5.6	6.8

Sulphuric Acid—Strength for Equilibrium with Atmospheric Moisture[1]

Ninety-three thousand pounds of sulphuric acid, with an exposed surface of 1260 sq. ft. and a depth of 10 in., had decreased in strength from 86 to 52.12 per cent. H_2SO_4 after standing in a lead pan, protected from rain, for 42 days (Sept. 9 to Oct. 21, 1916). Air was bubbled through a 2-liter sample of this acid for 7 consecutive days, when the solution was tested and found to contain 52.18 per cent. H_2SO_4. The average temperature of the laboratory was 74°F., the average vapor of the air (7 tests)

[1] W. W. Scott: "Standard Methods of Chemical Analysis," 1917, p. 502.

was 0.2223 gram H_2O per standard cubic foot. The average humidity for September and October was 68 per cent.; the average temperature 62°F. The average humidity for the past 33 years was 72 per cent.; the average temperature 57°F.

Preparation of the Monohydrate (100 Per Cent. H_2SO_4)

One hundred per cent. H_2SO_4 cannot be made by concentrating a weaker acid. The strongest acid obtainable by concentration is about 98.3 per cent. H_2SO_4.

It may be prepared by strengthening a weaker acid with SO_3 or fuming sulphuric acid.

Acid between about 98 per cent. and 100 per cent. crystallize at a little below 0°C. One hundred per cent. acid may be obtained from this strength acid by cooling it to below 0° and separating the crystals which form at about that temperature, melting them and recrystallizing a few times.

Pounds Sulphuric Acid Obtainable from 100 Pounds Sulphur

Grade	Recovery						
	100 Per cent.	95 Per cent.	90 Per cent.	85 Per cent.	80 Per cent.	75 Per cent.	70 Per cent.
50° Baumé	491.97	467.37	442.77	418.17	393.58	368.98	344.38
60° Baumé	393.86	374.17	354.47	334.78	315.09	295.40	275.70
66° Baumé	328.26	311.85	295.43	279.02	262.61	246.20	229.78
98 per cent. H_2SO_4	312.15	296.54	280.94	265.33	249.72	234.11	218.51
100 per cent. H_2SO_4	305.91	290.61	275.32	260.02	244.73	229.43	214.14
10 per cent. free SO_3	299.17	284.21	269.25	254.29	239.34	224.38	209.42
20 per cent. free SO_3	292.75	278.11	263.48	248.84	234.20	219.56	204.93
30 per cent. free SO_3	286.57	272.24	257.91	243.58	229.26	214.93	200.60
40 per cent. free SO_3	280.65	266.62	252.59	238.55	224.52	210.49	196.46
100 per cent. SO_3	249.72	237.23	224.75	212.26	199.78	187.29	174.80

Pounds Sulphuric Acid Obtainable from 100 Pounds SO_3

Grade	Recovery						
	100 Per cent.	95 Per cent.	90 Per cent.	85 Per cent.	80 Per cent.	75 Per cent.	70 Per cent.
50° Baumé	197.01	187.16	177.31	167.46	157.61	147.76	137.91
60° Baumé	157.72	149.83	141.95	134.06	126.18	118.29	110.40
66° Baumé	131.45	124.88	118.31	111.73	105.16	98.59	92.02
98 per cent. H_2SO_4	125.00	118.75	112.50	106.25	100.00	93.75	87.50
100 per cent. H_2SO_4	122.50	116.38	110.25	104.13	98.00	91.88	85.75
10 per cent. free SO_3	119.80	113.81	107.82	101.83	95.84	89.85	83.86
20 per cent. free SO_3	117.23	111.37	105.51	99.65	93.78	87.92	82.06
30 per cent. free SO_3	114.76	109.02	103.28	97.55	91.81	86.07	80.33
40 per cent. free SO_3	112.38	106.76	101.14	95.52	89.90	84.29	78.67

Pounds Sulphur Required to Make 100 Pounds Sulphuric Acid

Grade	Recovery						
	100 Per cent.	95 Per cent.	90 Per cent.	85 Per cent.	80 Per cent.	75 Per cent.	70 Per cent.
50° Baumé	20.33	21.40	22.59	23.92	25.41	27.11	29.04
60° Baumé	25.39	26.73	28.21	29.87	31.74	33.85	36.27
66° Baumé	30.46	32.06	33.84	35.84	38.08	40.61	43.51
98 per cent. H_2SO_4	32.04	33.73	35.60	37.69	40.05	42.72	45.77
100 per cent. H_2SO_4	32.69	34.41	36.32	38.46	40.86	43.59	46.70
10 per cent. free SO_3	33.42	35.18	37.13	39.32	41.78	44.56	47.74
20 per cent. free SO_3	34.15	35.95	37.94	40.18	42.69	45.53	48.79
30 per cent. free SO_3	34.89	36.73	38.77	41.05	43.61	46.52	49.84
40 per cent. free SO_3	35.63	37.51	39.59	41.92	44.54	47.51	50.90
100 per cent. SO_3	40.04	42.15	44.49	47.11	50.05	53.39	57.20

THE QUANTITATIVE ESTIMATION OF SULPHUR DIOXIDE IN BURNER GAS

Reich's Test

This is usually determined by Reich's process which consists of aspirating the gas through a measured quantity of iodine contained in a wide-neck bottle and colored blue by adding starch solution. This bottle is connected with a larger bottle fitted as an aspirator by a siphon. Water is siphoned from this into a 500-c.c. graduated cylinder drawing the gas through the reaction bottle. As soon as the SO_2 contained in the gas enters the iodine solution the free iodine is converted into hydriodic acid and after a time the liquid will be decolorized, which at last happens very suddenly and can be very accurately observed. The reaction takes place as follows:

$$2I + SO_2 + 2H_2O = 2HI + H_2SO_4$$

In this process no SO_2 escapes unabsorbed if the reaction bottle is constantly shaken. The operation may be stopped when the solution is but faint as it generally disappears on shaking a little longer. The volume of water in the cylinder is read off. It is equal to that of the gas aspirated when increased by that of the SO_2 absorbed.

When several testings have been made, the decolorized liquid after a short time, again turns blue, because then its percentage of HI has become so large that it decomposes on standing and liberates iodine. This liquid must then be poured away and replaced with fresh water and starch.

For estimating burner gas the usual charge in the reaction bottle is 10 c.c. of deci-normal iodine solution along with about 300 c.c. water and a little starch solution. Ten cubic centimeter hundredth-normal iodine solution is usually used for estimating the exit gas. If the gas is very rich in SO_2, 20–25 c.c. should be used.

Calculation of Results.—One liter of sulphur dioxide weighs 2.9266 grams at 0°C. and a barometric pressure of 760 mm.

Deci-normal iodine solution contains 12.69 grams iodine per liter. Each cubic centimeter of solution contains 0.01269 gram I which is an equivalent to 0.003203 gram SO_2 = 1.094 c.c. under standard conditions.

Let x = per cent. SO_2 in gas

$$a = \text{c.c. } \frac{N}{10} \text{ I used}$$

$$b = \text{c.c. gas used}$$

Then $$x = \frac{109.4a}{b + 1.094a}$$

Since calculations are under standard conditions it will be necessary to convert the volumes obtained in the tests to these conditions, using the formula

$$V = V^\circ \frac{P^\circ - w}{760\,(1 + 0.00367t)}$$

V° = measured volume
P° = observed barometric pressure
t = temperature of gas.
w = aqueous vapor pressure at temperature of test

For all practical purposes, however, this calculation may be neglected.

Preparation of Iodine Solution.—To prepare N/10 iodine solution weigh out 12.69 grams of pure resublimed iodine. Dissolve about 25 grams potassium iodide with water using just enough to put it in solution. Place the weighed iodine in this solution and stir until completely dissolved. Fill with water to 1 liter.

To prepare N/100 iodine solution either weigh 1.269 grams iodine, dissolve and dilute to 1 liter or take 100 c.c. of the N/10 solution and dilute to 1 liter.

Iodine solution should be kept in a cool place and protected from direct sunlight. Well-stoppered dark-colored glass bottles are suitable containers.

Preparation of Starch Solution.—To prepare, take about 3 grams arrow-root starch and mix with water to a thin paste. Place this into about a liter of boiling water and continue to boil about a half hour. After cooling add a few drops chloroform which preserves it and prevents souring. Keep in well-stoppered bottles.

Reich's Test for SO_2

Per cent. SO_2 corresponding to volume of water

Burner gas 10 c.c. $\frac{N}{10}$ I solution						Exit gas 10 c.c. $\frac{N}{100}$ I solution			
Cubic centimeters water	Per cent. SO_2	Cubic centimeters water	Per cent. SO_2	Cubic centimeters water	Per cent. SO_2	Cubic centimeters water	Per cent. SO_2	Cubic centimeters water	Per cent. SO_2
1,035	1.0	385	2.8	200	5.2	2,185	.05	270	.40
1,030	1.1	375	2.8	195	5.3	1,820	.06	265	.41
940	1.1	370	2.9	190	5.4	1,560	.07	260	.42
935	1.2	360	2.9	185	5.6	1,365	.08	255	.43
865	1.2	355	3.0	180	5.7	1,215	.09	245	.44
860	1.3	350	3.0	175	5.9	1,090	.10	240	.45
800	1.3	345	3.1	170	6.0	990	.11	235	.46
795	1.4	340	3.1	165	6.2	910	.12	230	.47
740	1.4	335	3.2	160	6.4	840	.13	225	.48
735	1.5	330	3.2	155	6.6	780	.14	220	.50
690	1.5	325	3.3	150	6.8	730	.15	200	.55
685	1.6	320	3.3	145	7.0	680	.16	180	.60
655	1.6	315	3.4	140	7.2	640	.17	165	.65
650	1.7	310	3.4	135	7.5	605	.18	155	.70
615	1.7	303	3.5	130	7.8	575	.19	145	.75
610	1.8	300	3.5	125	8.0	545	.20	135	.80
580	1.8	295	3.6	120	8.3	520	.21	130	.85
575	1.9	290	3.6	115	8.7	495	.22	120	.90
550	1.9	285	3.7	110	9.0	475	.23	115	.95
545	2.0	280	3.8	105	9.4	455	.24	110	1.00
525	2.0	275	3.8	100	9.9	435	.25	105	1.05
520	2.1	270	3.9	95	10.3	420	.26	100	1.10
500	2.1	265	4.0			405	.27	95	1.15
495	2.2	260	4.0			390	.28	90	1.20
475	2.2	255	4.1			375	.29	85	1.25
470	2.3	250	4.2			365	.30	80	1.35
450	2.3	245	4.3			350	.31	75	1.45
445	2.4	240	4.4			340	.32	70	1.55
440	2.4	235	4.4			330	.33	65	1.65
435	2.5	230	4.5			320	.34	60	1.80
420	2.5	225	4.6			310	.35	55	1.95
415	2.6	220	4.7			300	.36	50	2.15
405	2.6	215	4.8			295	.37		
400	2.7	210	4.9			285	.38		
390	2.7	205	5.1			280	.39		

TEST FOR TOTAL ACIDS IN BURNER GAS

Since Reich's test takes no account of the SO_3 always present in burner gas it is quite practicable and accurate to estimate the total acids ($SO_2 + SO_3$) either along with the Reich's test or exclusively. This is performed in the same apparatus, but the absorbing bottle is preferably provided with a gas entrance tube, closed at the bottom and perforated by numerous pin holes, through which the gas bubbles. A deci-normal solution of sodium hydroxide is employed of which 10 c.c. are diluted to about 300 c.c. and tinged red with phenolphthalein. The gas is aspirated through it slowly, exactly as in Reich's test, with continuous shaking. Especially toward the end, the shaking must be continued for a while (say a half a minute) each time aspirating a few cubic centimeters of gas through the liquid, until the color is completely discharged.

The calculation is made exactly as with the iodine test, counting all the acids as SO_2.

If the ore contains much organic matter as when coal gases are burnt, the carbon dioxide acting on the phenolphthalein will render this method inaccurate.

Methyl orange cannot be used with any degree of accuracy as it acts differently toward sulphurous acid and sulphuric acid. It can, however, be used if the SO_2 is determined at the same time and then proper calculations made.

CALCULATING THE PERCENTAGE OF SO_2 CONVERTED TO SO_3 WHEN THE SO_2 IN THE BURNER AND EXIT GASES IS KNOWN—AS USED IN THE CONTACT PROCESS

1. If a equals the quantity (not per cent.) of SO_2 in one volume of entrance gas and X equals the fraction of this that is converted to SO_3, then aX equals the quantity of SO_2 converted to SO_3. As two volumes of SO_2 combine with one volume of oxygen to

form two of SO_3 the contraction due to the formation and absorption of SO_3 is equal to

$$\frac{3aX}{2} \text{ and the final volume is } 1 - \frac{3aX}{2}$$

If b equals the fraction that the SO_2 is of the exit gas $b\left(1 - \frac{3aX}{2}\right)$ equals the quantity of unconverted SO_2 in the exit gas and $X = \frac{a - b\left(1 - \frac{3aX}{2}\right)}{a}$

Or reducing to its simplest form

$$X = \frac{2a - 2b}{2a - 3ab}$$

And $100X$ equals the per cent. of SO_2 converted to SO_3.

2. Or let x = per cent. conversion
a = per cent. SO_2 in roaster gas.
b = per cent. SO_2 in exit gas

$$x = \frac{100^2\,(2a - 2b)}{200a - 3ab}$$

Per Cent. SO_2 Converted to SO_3

Per cent. SO_2 Burner gas	Per cent. SO_2 in exit gas							
	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40
2.0	97.6	95.1	92.7	90.3	87.8	85.4	82.9	80.5
2.1	97.7	95.4	93.1	90.8	88.4	86.1	83.8	81.4
2.2	97.8	95.6	93.4	91.2	89.0	86.8	84.5	82.3
2.3	97.9	95.8	93.7	91.6	89.5	87.4	85.2	83.1
2.4	98.0	96.0	94.0	91.9	89.9	87.9	85.9	83.8
2.5	98.1	96.1	94.2	92.3	90.3	88.4	86.5	84.5
2.6	98.2	96.3	94.5	92.6	90.7	88.9	87.0	85.1
2.7	98.2	96.4	94.7	92.9	91.1	89.3	87.5	85.7
2.8	98.3	96.6	94.9	93.1	91.4	89.7	88.0	86.2
2.9	98.4	96.7	95.0	93.4	91.7	90.1	88.4	86.7
3.0	98.4	96.8	95.2	93.6	92.0	90.4	88.8	87.2
3.1	98.5	96.9	95.4	93.8	92.3	90.7	89.2	87.6
3.2	98.5	97.0	95.5	94.0	92.5	91.0	89.5	88.0
3.3	98.6	97.1	95.7	94.2	92.8	91.3	89.9	88.4
3.4	98.6	97.2	95.8	94.4	93.0	91.6	90.2	88.8
3.5	98.6	97.3	95.9	94.6	93.2	91.8	90.5	89.1
3.6	98.7	97.4	96.1	94.7	93.4	92.1	90.8	89.4
3.7	98.7	97.4	96.2	94.9	93.6	92.3	91.0	89.7
3.8	98.8	97.5	96.3	95.0	93.8	92.5	91.3	90.0
3.9	98.8	97.6	96.4	95.2	93.9	92.7	91.5	90.3
4.0	98.8	97.7	96.5	95.3	94.1	92.9	91.7	90.5
4.1	98.9	97.7	96.6	95.4	94.3	93.1	91.9	90.8
4.2	98.9	97.8	96.6	95.5	94.4	93.3	92.2	91.0
4.3	98.9	97.8	96.7	95.6	94.5	93.4	92.3	91.2
4.4	98.9	97.9	96.8	95.7	94.7	93.6	92.5	91.3
4.5	99.0	97.9	96.9	95.8	94.8	93.8	92.7	91.7
4.6	99.0	98.0	97.0	95.9	94.9	93.9	92.9	91.9
4.7	99.0	98.0	97.0	96.0	95.0	94.0	93.0	92.0
4.8	99 1	98.1	97.1	96.1	95.2	94.2	93.2	92.2
4.9	99.1	98.1	97.2	96.2	95.3	94.3	93.4	92.4

Per Cent. SO_2 Converted to SO_3—(*Continued*)

Per cent. SO_2 Burner gas	Per cent. SO_2 in exit gas							
	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
2.0	78 0	75.6	73.1	70.6	68.2	65.7	63.2	60.7
2.1	79.1	76.8	74.4	72.1	69.7	67.4	65.0	62.7
2.2	80.1	77.9	75.6	73.4	71.2	68.9	66.7	64.4
2.3	81.0	78.9	76.7	74.6	72.5	70.3	68.2	66.0
2.4	81.8	79.8	77.7	75.7	73.6	71.6	69.5	67.5
2.5	82.6	80.6	78.7	76.7	74.7	72.8	70.8	68.8
2.6	83.3	81.4	79.5	77.6	75.7	73.9	72.0	70.1
2.7	83.9	82.1	80.3	78.5	76.7	74.9	73.0	71.2
2.8	84.5	82.8	81.0	79.3	77.5	75.8	74.1	72.3
2.9	85.1	83.4	81.7	80.0	78.4	76.7	75.0	73.3
3.0	85.6	84.0	82.4	80.7	79.1	77.5	75.9	74.2
3.1	86.1	84.5	82.9	81.4	79.8	78.2	76.7	75.1
3.2	86.5	85.0	83.5	82.0	80.5	79.0	77.4	75.9
3.3	87.0	85.5	84.0	82.6	81.1	79.6	78.2	76.7
3.4	87.4	85.9	84.5	83.1	81.7	80.3	78.8	77.4
3.5	87.7	86.4	85.0	83.6	82.2	80.9	79.5	78.1
3.6	88.1	86.8	85.4	84.1	82.8	81.4	80.1	78.7
3.7	88.4	87.1	85.8	84.6	83.2	81.9	80.6	79.3
3.8	88.8	87.5	86.2	85.0	83.7	82.4	81.2	79.9
3.9	89.1	87.8	86.6	85.4	84.2	82.9	81.7	80.5
4.0	89.4	88.2	87.0	85.8	84.6	83.4	82.2	81.0
4.1	89.6	88.5	87.3	86.1	85.0	83.8	82.6	81.5
4.2	89.9	88.8	87.6	86.5	85.4	84.2	83.1	81.9
4.3	90.1	89.0	87.9	86.8	85.7	84.6	83.5	82.4
4.4	90.4	89.3	88.2	87.2	86.1	85.0	83.9	82.8
4.5	90.6	89.6	88.5	87.5	86.4	85.3	84.3	83.2
4.6	90.8	89.8	88.8	87.8	86.7	85.7	84.6	83.6
4.7	91.0	90.0	89.0	88.0	87.0	86.0	85.0	84.0
4.8	91.2	90.3	89.3	88.3	87.3	86.3	85.3	84.3
4.9	91.4	90.5	89.5	88.6	87.6	86.6	85.7	84.7

PER CENT. SO_2 CONVERTED TO SO_3—(*Continued*)

Per cent. SO_2 Burner gas	Per cent. SO_2 in exit gas								
	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25
2.0	58.2	55.8	53.3	50.8	48.3	45.7	43.2	40.7	38.2
2.1	60.3	57.9	55.6	53.2	50.8	48.4	46.0	43.6	41.2
2.2	62.2	59.9	57.6	55.4	53.1	50.8	48.6	46.3	44.0
2.3	63.9	61.7	59.5	57.4	55.2	53.0	50.9	48.7	46.5
2.4	65.4	63.4	61.3	59.2	57.1	55.1	53.0	50.9	48.8
2.5	66.9	64.9	62.9	60.9	58.9	56.9	54.9	52.9	51.0
2.6	68.2	66.3	64.4	62.5	60.6	58.7	56.7	54.8	52.9
2.7	69.4	67.6	65.8	63.9	62.1	60.2	58.4	56.6	54.7
2.8	70.5	68.8	67.0	65.3	63.5	61.7	60.0	58.2	56.4
2.9	71.6	69.9	68.2	66.5	64.8	63.1	61.4	59.7	58.0
3.0	72.6	71.0	69.3	67.7	66.0	64.4	62.7	61.1	59.5
3.1	73.5	71.9	70.4	68.8	67.2	65.6	64.0	62.4	60.8
3.2	74.4	72.9	71.3	69.8	68.3	66.7	65.2	63.6	62.1
3.3	75.2	73.7	72.2	70.8	69.3	67.8	66.3	64.8	63.3
3.4	76.0	74.5	73.1	71.7	70.2	68.8	67.3	65.9	64.4
3.5	76.7	75.3	73.9	72.5	71.1	69.7	68.3	66.9	65.5
3.6	77.4	76.0	74.7	73.3	72.0	70.6	69.2	67.9	66.5
3.7	78.0	76.7	75.4	74.1	72.8	71.4	70.1	68.8	67.5
3.8	78.6	77.4	76.1	74.8	73.5	72.2	71.0	69.7	68.4
3.9	79.2	78.0	76.7	75.5	74.2	73.0	71.7	70.5	69.2
4.0	79.8	78.6	77.4	76.1	74.9	73.7	72.5	71.3	70.1
4.1	80.3	79.1	77.9	76.8	75.6	74.4	73.2	72.0	70.8
4.2	80.8	79.7	78.5	77.4	76.2	75.0	73.9	72.7	71.6
4.3	81.3	80.1	79.0	78.0	76.8	75.7	74.6	73.4	72.3
4.4	81.7	80.6	79.5	78.5	77.4	76.3	75.2	74.1	73.0
4.5	82.2	81.1	80.0	79.0	77.9	76.8	75.7	74.7	73.6
4.6	82.6	81.5	80.5	79.5	78.4	77.4	76.3	75.3	74.2
4.7	83.0	82.0	80.9	79.9	78.9	77.9	76.9	75.8	74.8
4.8	83.4	82.4	81.4	80.4	79.4	78.4	77.4	76.4	75.4
4.9	83.7	82.7	81.8	80.8	79.8	78.8	77.9	76.9	75.9

Per Cent. SO_2 Converted to SO_3—(*Continued*)

Per cent. SO_2 Burner gas	Per cent. SO_2 in exit gas							
	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40
5.0	99.1	98.2	97.2	96.3	95.4	94.4	93.5	92.6
5.1	99.1	98.2	97.3	96.4	95.5	94.5	93.6	92.7
5.2	99.1	98.2	97.3	96.4	95.6	94.7	93.8	92.9
5.3	99.2	98.3	97.4	96.5	95.7	94.8	93.9	93.0
5.4	99.2	98.3	97.4	96.6	95.7	94.9	94.0	93.2
5.5	99.2	98.3	97.5	96.7	95.8	95.0	94.1	93.3
5.6	99.2	98.4	97.5	96.7	95.9	95.1	94.3	93.4
5.7	99.2	98.4	97.6	96.8	96.0	95.2	94.4	93.6
5.8	99.2	98.4	97.6	96.9	96.1	95.3	94.5	93.7
5.9	99.2	98.5	97.7	96.9	96.1	95.4	94.6	93.8
6.0	99.3	98.5	97.7	97.0	96.2	95.4	94.7	93.9
6.1	99.3	98.5	97.8	97.0	96.3	95.5	94.8	94.0
6.2	99.3	98.5	97.8	97.1	96.3	95.6	94.9	94.1
6.3	99.3	98.6	97.9	97.1	96.4	95.7	95.0	94.2
6.4	99.3	98.6	97.9	97.2	96.5	95.8	95.0	94.3
6.5	99.3	98.6	97.9	97.2	96.5	95.8	95.1	94.4
6.6	99.3	98.6	98.0	97.3	96.6	95.9	95.2	94.5
6.7	99.3	98.7	98.0	97.3	96.6	96.0	95.3	94.6
6.8	99.3	98.7	98.0	97.4	96.7	96.0	95.4	94.7
6.9	99.4	98.7	98.1	97.4	96.8	96.1	95.4	94.8
7.0	99.4	98.7	98.1	97.4	96.8	96.2	95.5	94.9
7.1	99.4	98.7	98.1	97.5	96.9	96.2	95.6	94.9
7.2	99.4	98.8	98.1	97.5	96.9	96.3	95.7	95.0
7.3	99.4	98.8	98.2	97.6	97.0	96.3	95.7	95.1
7.4	99.4	98.8	98.2	97.6	97.0	96.4	95.8	95.2
7.5	99.4	98.8	98.2	97.6	97.0	96.4	95.8	95.2
7.6	99.4	98.8	98.3	97.7	97.1	96.5	95.9	95.3
7.7	99.4	98.9	98.3	97.7	97.1	96.5	96.0	95.4
7.8	99.4	98.9	98.3	97.7	97.2	96.6	96.0	95.5
7.9	99.5	98.9	98.3	97.8	97.2	96.6	96.1	95.5
8.0	99.5	98.9	98.4	97.8	97.3	96.7	96.1	95.6

Per Cent. SO_2 Converted to SO_3—(*Continued*)

Per cent. SO_2 Burner gas	Per cent. SO_2 in exit gas							
	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
5.0	91.6	90.7	89.7	88.8	87.9	86.9	86.0	85.0
5.1	91.8	90.9	90.0	89.0	88.1	87.2	86.3	85.3
5.2	92.0	91.1	90.2	89.3	88.4	87.5	86.6	85.6
5.3	92.1	91.3	90.4	89.5	88.6	87.7	86.8	85.9
5.4	92.3	91.4	90.6	89.7	88.8	88.0	87.1	86.2
5.5	92.5	91.6	90.8	89.9	89.1	88.2	87.4	86.5
5.6	92.6	91.8	90.9	90.1	89.3	88.4	87.6	86.8
5.7	92.7	91.9	91.1	90.3	89.5	88.7	87.8	87.0
5.8	92.9	92.1	91.3	90.5	89.7	88.9	88.1	87.3
5.9	93.0	92.2	91.4	90.7	89.9	89.1	88.3	87.5
6.0	93.1	92.4	91.6	90.8	90.1	89.3	88.5	87.7
6.1	93.3	92.5	91.7	91.0	90.2	89.5	88.7	87.9
6.2	93.4	92.6	91.9	91.2	90.4	89.7	88.9	88.2
6.3	93.5	92.8	92.0	91.3	90.6	89.8	89.1	88.4
6.4	93.6	92.9	92.2	91.5	90.7	90.0	89.3	88.6
6.5	93.7	93.0	92.3	91.6	90.9	90.2	89.5	88.8
6.6	93.8	93.1	92.4	91.7	91.1	90.4	89.7	89.0
6.7	93.9	93.2	92.6	91.9	91.2	90.5	89.8	89.1
6.8	94.0	93.4	92.7	92.0	91.3	90.7	90.0	89.3
6.9	94.1	93.5	92.8	92.1	91.5	90.8	90.2	89.5
7.0	94.2	93.6	92.9	92.3	91.6	91.0	90.3	89.7
7.1	94.3	93.7	93.0	92.4	91.7	91.1	90.5	89.8
7.2	94.4	93.8	93.1	92.5	91.9	91.2	90.6	90.0
7.3	94.5	93.9	93.2	92.6	92.0	91.4	90.8	90.1
7.4	94.6	94.0	93.3	92.7	92.1	91.5	90.9	90.3
7.5	94.6	94.0	93.4	92.8	92.2	91.6	91.0	90.4
7.6	94.7	94.1	93.5	93.0	92.4	91.8	91.2	90.6
7.7	94.8	94.2	93.6	93.1	92.5	91.9	91.3	90.7
7.8	94.9	94.3	93.7	93.2	92.6	92.0	91.4	90.8
7.9	95.0	94.4	93.8	93.3	92.7	92.1	91.5	91.0

PER CENT. SO_2 CONVERTED TO SO_3—(*Continued*)

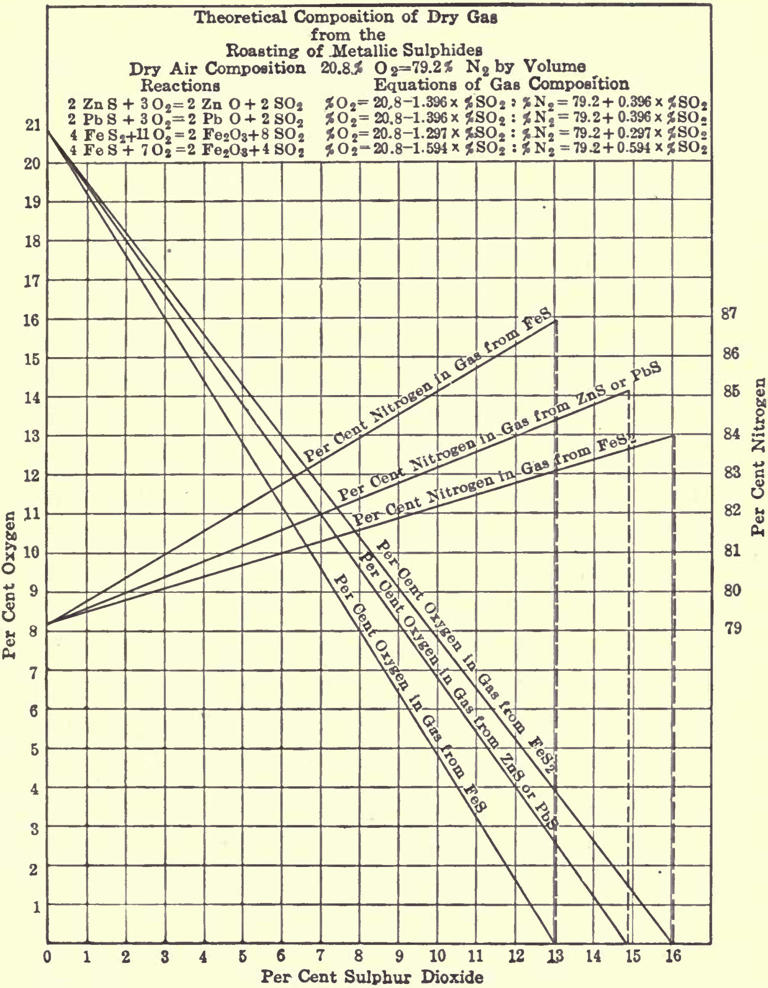
Per cent. SO_2 Burner gas	Per cent. SO_2 in exit gas								
	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25
5.0	84.1	83.1	82.2	81.2	80.3	79.3	78.4	77.4	76.4
5.1	84.4	83.5	82.6	81.6	80.7	79.7	78.8	77.9	76.9
5.2	84.7	83.8	82.9	82.0	81.1	80.2	79.2	78.3	77.4
5.3	85.1	84.2	83.3	82.4	81.5	80.6	79.7	78.8	77.9
5.4	85.4	84.5	83.6	82.7	81.6	80.8	79.9	79.1	78.3
5.5	85.6	84.8	83.9	83.1	82.2	81.3	80.5	79.6	78.6
5.6	85.9	85.1	84.2	83.4	82.5	81.7	80.9	80.0	79.2
5.7	86.2	85.4	84.5	83.7	82.9	82.1	81.2	80.4	79.6
5.8	86.5	85.6	84.8	84.0	83.2	82.4	81.6	80.8	79.9
5.9	86.7	85.9	85.1	84.3	83.5	82.7	81.9	81.1	80.3
6.0	86.9	86.2	85.4	84.6	83.8	83.0	82.2	81.4	80.6
6.1	87.2	86.4	85.7	84.9	84.1	83.3	82.6	81.8	81.0
6.2	87.4	86.7	85.9	85.2	84.4	83.6	82.9	82.1	81.4
6.3	87.6	86.9	86.2	85.4	84.7	83.9	83.2	82.4	81.7
6.4	87.8	87.1	86.4	85.7	84.9	84.2	83.5	82.7	82.0
6.5	88.1	87.3	86.6	85.9	85.2	84.5	83.8	83.0	82.3
6.6	88.3	87.6	86.9	86.1	85.4	84.7	84.0	83.3	82.6
6.7	88.4	87.8	87.1	86.4	85.7	85.0	84.3	83.6	82.9
6.8	88.6	88.0	87.3	86.6	85.9	85.2	84.5	83.9	83.2
6.9	88.8	88.2	87.5	86.8	86.1	85.5	84.8	84.1	83.4
7.0	89.0	88.3	87.7	87.0	86.4	85.7	85.0	84.4	83.7
7.1	89.2	88.5	87.9	87.2	86.6	85.9	85.3	84.6	84.0
7.2	89.3	88.7	88.1	87.4	86.8	86.1	85.5	84.9	84.2
7.3	89.5	88.9	88.3	87.6	87.0	86.4	85.7	85.1	84.5
7.4	89.7	89.0	88.4	87.8	87.2	86.5	85.9	85.2	84.6
7.5	89.8	89.2	88.6	88.0	87.4	86.8	86.1	85.5	84.9
7.6	90.0	89.4	88.8	88.2	87.6	87.0	86.4	85.8	85.2
7.7	90.1	89.5	88.9	88.3	87.7	87.1	86.6	86.0	85.4
7.8	90.3	89.7	89.1	88.5	87.9	87.3	86.7	86.2	85.6
7.9	90.4	89.8	89.3	88.7	88.1	87.5	86.9	86.4	85.8

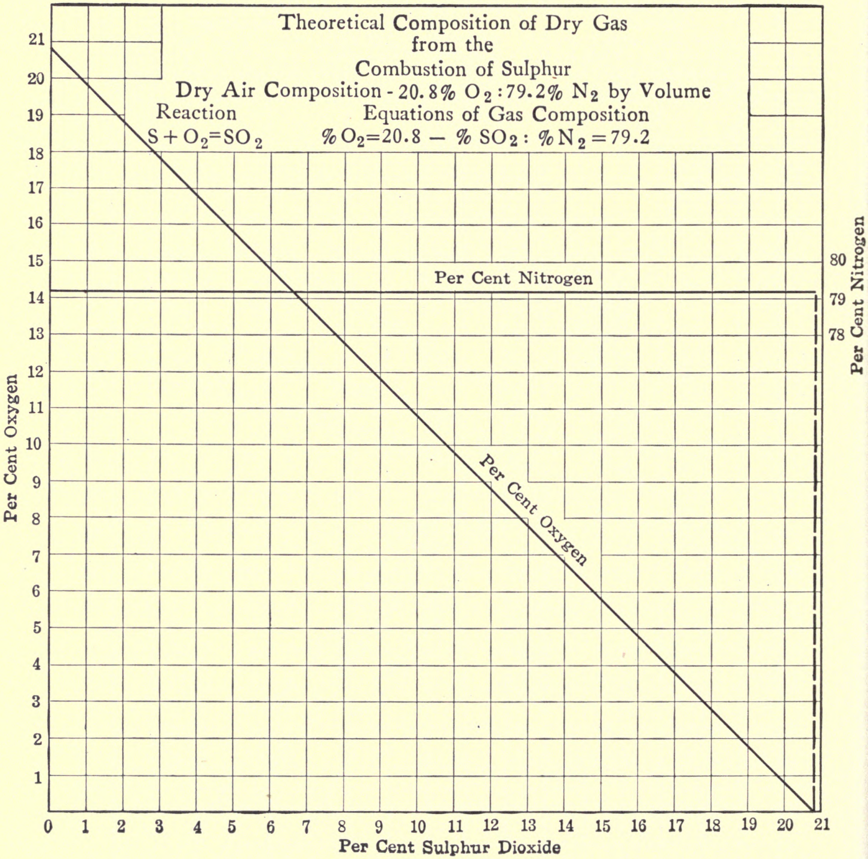
PER CENT. SO_2 CONVERTED TO SO_3—(*Continued*)

Per cent. SO_2 Burner gas	Per cent. SO_2 in exit gas							
	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85
8.0	94.5	93.9	93.3	92.8	92.2	91.7	91.1	90.5
8.1	94.5	94.0	93.4	92.9	92.3	91.8	91.2	90.7
8.2	94.6	94.1	93.5	93.0	92.4	91.9	91.3	90.8
8.3	94.7	94.1	93.6	93.1	92.5	92.0	91.5	90.9
8.4	94.8	94.2	93.7	93.2	92.6	92.1	91.6	91.0
8.5	94.8	94.3	93.8	93.3	92.7	92.2	91.7	91.2
8.6	94.9	94.4	93.9	93.3	92.8	92.3	91.8	91.3
8.7	95.0	94.5	93.9	93.4	92.9	92.4	91.9	91.4
8.8	95.0	94.5	94.0	93.5	93.0	92.5	92.0	91.5
8.9	95.1	94.6	94.1	93.6	93.1	92.6	92.1	91.6
9.0	95.2	94.7	94.2	93.7	93.2	92.7	92.2	91.7
9.1	95.2	94.7	94.3	93.8	93.3	92.8	92.3	91.8
9.2	95.3	94.8	94.3	93.8	93.4	92.9	92.4	91.9
9.3	95.3	94.9	94.4	93.9	93.4	93.0	92.5	92.0
9.4	95.4	94.9	94.5	94.0	93.5	93.1	92.6	92.1
9.5	95.5	95.0	94.5	94.1	93.6	93.1	92.7	92.2
9.6	95.5	95.1	94.6	94.1	93.7	93.2	92.8	92.3
9.7	95.6	95.1	94.7	94.2	93.8	93.3	92.9	92.4
9.8	95.6	95.2	94.7	94.3	93.8	93.4	93.0	92.5
9.9	95.7	95.2	94.8	94.4	93.9	93.5	93.0	92.6
10.0	95.7	95.3	94.9	94.4	94.0	93.5	93.1	92.7

PER CENT. SO_2 CONVERTED TO SO_3—(*Concluded*)

Per cent. SO_2 Burner gas	Per cent. SO_2 in exit gas							
	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25
8.0	90.0	89.4	88.8	88.3	87.7	87.1	86.6	86.0
8.1	90.1	89.5	89.0	88.4	87.9	87.3	86.7	86.2
8.2	90.2	89.7	89.1	88.6	88.0	87.5	86.9	86.4
8.3	90.4	89.8	89.3	88.7	88.2	87.7	87.1	86.6
8.4	90.5	90.0	89.4	88.9	88.4	87.8	87.3	86.7
8.5	90.6	90.1	89.6	89.0	88.5	88.0	87.5	86.9
8.6	90.8	90.2	89.7	89.2	88.7	88.1	87.6	87.1
8.7	90.9	90.4	89.8	89.3	88.8	88.3	87.8	87.3
8.8	91.0	90.5	90.0	89.5	89.0	88.5	87.9	87.4
8.9	91.1	90.6	90.1	89.6	89.1	88.6	88.1	87.6
9.0	91.2	90.7	90.2	89.7	89.2	88.7	88.3	87.8
9.1	91.3	90.9	90.4	89.9	89.4	88.9	88.4	87.9
9.2	91.4	91.0	90.5	90.0	89.5	89.0	88.5	88.1
9.3	91.6	91.1	90.6	90.1	89.6	89.2	88.7	88.2
9.4	91.7	91.2	90.7	90.2	89.8	89.3	88.8	88.4
9.5	91.8	91.3	90.8	90.4	89.9	89.4	89.0	88.5
9.6	91.9	91.4	90.9	90.5	90.0	89.6	89.1	88.6
9.7	92.0	91.5	91.1	90.6	90.1	89.7	89.2	88.8
9.8	92.1	91.6	91.2	90.7	90.3	89.8	89.4	88.9
9.9	92.2	91.7	91.3	90.8	90.4	89.9	89.5	89.0
10.0	92.2	91.8	91.4	90.9	90.5	90.0	89.6	89.2


Theoretical Composition of Dry Gas
from the
Roasting of Metallic Sulphides
Dry Air Composition 20.8% O2=79.2% N2 by Volume
Reactions
Equations of Gas Composition
2 ZnS + 3 O2 = 2 ZnO + 2 SO2
2 PbS + 3 O2 = 2 PbO + 2 SO2
4 FeS2 + 11 O2 = 2 Fe2O3 + 8 SO2
4 FeS + 7 O2 = 2 Fe2O3 + 4 SO2
%O2 = 20.8 − 1.396 × %SO2 : %N2 = 79.2 + 0.396 × %SO2
%O2 = 20.8 − 1.396 × %SO2 : %N2 = 79.2 + 0.396 × %SO2
%O2 = 20.8 − 1.297 × %SO2 : %N2 = 79.2 + 0.297 × %SO2
%O2 = 20.8 − 1.594 × %SO2 : %N2 = 79.2 + 0.594 × %SO2
Per Cent Nitrogen in Gas from FeS
Per Cent Nitrogen in Gas from ZnS or PbS
Per Cent Nitrogen in Gas from FeS2
Per Cent Oxygen in Gas from FeS2
Per Cent Oxygen in Gas from ZnS or PbS
Per Cent Oxygen in Gas from FeS
Per Cent Oxygen
Per Cent Nitrogen
Per Cent Sulphur Dioxide
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
87
86
85
84
83
82
81
80
79


Theoretical Composition of Dry Gas
from the
Combustion of Sulphur
Dry Air Composition - 20.8% O2 : 79.2% N2 by Volume
Reaction
S + O2 = SO2
Equations of Gas Composition
%O2 = 20.8 – % SO2 : %N2 = 79.2
Per Cent Nitrogen
Per Cent Oxygen
Per Cent Oxygen
Per Cent Nitrogen
80
79
78
Per Cent Sulphur Dioxide
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

QUALITATIVE TESTS—SULPHURIC ACID

Nitrogen Acids

Diphenylamine Test.—A few grams diphenylamine is dissolved in strong sulphuric acid, free from nitrogen oxides. Put about 2 or 3 c.c. of the acid to be tested in a test-tube and add about 1 c.c. of the diphenylamine solution so that the layers overlay gradually. In case of dilute acids proceed in the opposite manner. The slightest trace of nitrogen acids is proved by the appearance of a brilliant blue color at the point of contact of the liquids. In the presence of selenium the diphenylamine test fails as the same color is produced.

Ferrous-sulphate Test.—A saturated solution of ferrous sulphate is added to the acid to be tested in a test-tube. Incline the test-tube so the layers overlay gradually. Hold the tube upright and tap gently. In presence of nitric acid a brown ring forms at the junction of the two solutions. Ferrous sulphate should be present in excess, otherwise the brown color is destroyed by the free nitric acid. If only a trace of nitric acid is present a pink color is produced.

Selenium

Ferrous-sulphate Test.—Selenium in sulphuric acid can be recognized by adding a strong solution of ferrous sulphate. A brownish-red color will make its appearance which after a while turns into a red precipitate (not vanishing upon heating) like the brown color produced by nitrogen acids.

Sodium-sulphite Test.—Overlay about 4 c.c. weak hydrochloric acid containing a granule of sodium sulphite dissolved. A red zone on warming shows the presence of selenium.

Lead

Dilute the acid to about five times its volume with dilute alcohol. If any lead is present it will be precipitated as the white sulphate, $PbSO_4$.

Iron

Boil the acid, if free from nitrogen, with a drop of nitric acid to oxidize the iron. Dilute a little, allow to cool and add a solution of potassium thiocyanate. A red color proves the presence of iron.

Arsenic

Marsh Test.—In the presence of nascent hydrogen, both arsenic and arsenious compounds are reduced, and arsine (or arseniuretted hydrogen) AsH_3 is evolved.

Hydrogen is slowly generated from zinc and dilute sulphuric acid, both materials being free from arsenic. The issuing gas is passed through a piece of tube which has been drawn out so as to produce one or two constricted places in its length. As soon as the air is expelled from the apparatus, the issuing hydrogen is inflamed.

A small quantity of the acid to be tested is then introduced and a piece of cold white porcelain depressed upon the flame. If any arsenic is present, a rich brown-black metallic looking stain will be deposited. The deposit being volatile and the flame very hot, the stain will again disappear if the flame is allowed to impinge for more than a moment or two on the same spot.

If the drawn-out tube is heated near one of the constrictions, the arseniuretted hydrogen will be decomposed and an arsenic mirror will be deposited in the tube.

Hydrogen-sulphide Test.—The acid is diluted and hydrogen sulphide gas passed through. If any arsenic is present it will be precipitated as yellow arsenious sulphide, A_2S_3.

THE QUANTITATIVE ANALYSIS OF SULPHURIC ACID

The quantitative analysis of sulphuric acid, volumetrically, is made by titrating a weighed quantity. The titration is performed by means of a standard normal sodium-hydroxide solution which is controlled by a standard normal sulphuric-acid solution and results are either expressed as per cent. SO_3 or per cent. H_2SO_4. In the following methods all calculations will be for per cent. of SO_3. The methods may easily be extended to express as per cent. H_2SO_4 if desired.

Standard Normal Acid

The strength of the standard normal sulphuric-acid solution is fixed by chemically pure sodium carbonate which is the ultimate standard for acidimetric and alkalimetric volumetric analysis.

Preparation of Sodium Carbonate

Sodium bicarbonate made by the ammonia-soda process may be obtained in exceedingly pure form. The impurities that may be present are silica, magnesium, ammonia, arsenic, lime, sodium sulphate and sodium chloride. With the exception of silica and lime the impurities may be readily removed by washing the sodium bicarbonate several times with cold water and decanting the supernatant solution of each washing from the difficultly soluble bicarbonate. The washing is continued until the material is free from chlorine, as sodium chloride is the principal impurity, and its removal leaves an exceedingly pure product. The bicarbonate is then dried between large filter papers in a hot-air oven protected from acid gases, at 100°C. and kept in a sealed bottle until used.

Sodium carbonate is made from this pure sodium bicarbonate by igniting in a platinum crucible at 290–300°C. to constant weight in an electric oven. If a constant-temperature oven is not available a simple oven may be improvised by use of a sand bath and a sheet-iron or clay cylinder shell covered at the upper end. A thermometer passing through this shield registers the temperature and at the same time serves as a stirrer as it should be stirred occasionally. The sand on the outside of the crucible should reach the same level as the bicarbonate inside so the contents is entirely surrounded by an atmosphere of comparatively even temperature.

Sodium carbonate intended for standardization of acids should not be heated over 300°C. and if heating is carried on at this temperature for a sufficient length of time (1 to 5 hours) constant weight will be obtained and one may be sure that neither bicarbonate or water is left behind and yet no sodium oxide or carbon dioxide has been formed as may happen if heating is carried on to a low red heat. While the carbonate is still hot place about 2 grams each in several small tared glass-stoppered weighing bottles. Keep in a desiccator up to the time of weighing and titrating, allowing plenty of time to cool.

To test for purity dissolve about 5 grams in water which ought to yield a perfectly clear, colorless solution. If after acidifying this solution with nitric acid, no opalescence is caused by barium chloride or silver nitrate, the salt may be taken as sufficiently pure.

For exceedingly accurate work the material is analyzed and allowance made for impurities that still remain. The error caused by any such impurities is so small, that for all practical purposes it may be neglected.

Chemically pure sodium carbonate prepared by a reliable manufacturer is sufficiently pure but should be ignited at 290–300°C. for 1 hour as a precaution.

Standardizing the Standard Acid

Wash each weighed amount of sodium carbonate (as titrated) into a 350-c.c. beaker and add enough water to dissolve. Methyl orange is used as an indicator and the cold solution of sodium carbonate is colored just perceptibly yellow by adding a drop or two of the indicator. If too much is used the color will be too intense and the transition too pink on neutralization will be less sharp. A change to pink takes place only when all the carbonate has been neutralized and the solution slightly acidified. An excess of acid (0.5 to 1 c.c.) is added as this is necessary to drive out all the carbon dioxide. The solution is then heated to boiling to aid in expelling the CO_2. Upon heating the color fades, but as soon as the carbon dioxide has been expelled, cool by placing the beaker in running water and the pink color will return. Transfer the solution from the beaker into the titrating vessel washing very carefully. The excess of acid is titrated with standard sodium hydroxide, the caustic being added drop by drop, then cutting the drops from the tip of the burette until a fraction of a drop produces a yellow straw color. A comparison solution having the color of the end point sought for may be prepared by using a slight amount of methyl orange, a few drops of standard alkali and diluting to about the same amount as the solution to be titrated.

If all the CO_2 is not expelled an intermediate color is observed due to its action on the indicator, the color passing from pink through orange to yellow and *vice versa*. This transition through orange, however, is much more noticeable when weaker standard solutions, fifth normal, etc., are used.

Phenolphthalein as an indicator is colorless in an acid solution and a pinkish-red in an alkaline solution. If phenolphthalein is used, special precautions must be taken as to the exclusion of CO_2. The solution must be well boiled, the standard solutions should be CO_2-free; CO_2-free water should be used and some chemists even claim that the CO_2 contained in the air, which comes into contact with the liquid upon cooling, may cause trouble in accurate work.

Preparation and Calculation of the Standard Acid

A normal solution of sulphuric acid contains 40.03 grams SO_3 per liter (0.04003 gram per cubic centimeter). To prepare, determine the per cent. SO_3 in the chemically pure acid that the solution is to be prepared from.

Let x = grams c.p. acid to be used per liter

y = per cent. SO_3 in c.p. acid

Then
$$x = \frac{100 \times 40.03}{y}$$

Titrate an aliquot portion of the newly prepared solution against a weighed quantity of sodium carbonate or if accurate standard alkali solution is at hand it may similarly be employed for examining the provisional acid. Adjustment to normal strength may now be made.

Thus far standard solutions have been considered as being adjusted to normality. Calculations are simplified to a great extent by using normal solutions, but to adjust solutions to be just normal is a matter of considerable difficulty. It is a general practice to calculate the strength of the standard solutions, not attempting to have the normality more than approximate, the exact strength, however, always being known and used in all calculations.

Following is given the method for calculating the grams SO_3 per cubic centimeter in the standard acid solution. The grams SO_3 per cubic centimeter may be used directly in calculations or reduced to per cent. normality. For instance, a normal solution contains 0.04003 gram SO_3 per cubic centimeter. Suppose a solution is found to contain 0.0395 gram per cubic centimeter. Then the per cent. normality of this solution would be:

$$\frac{0.0395}{0.04003} = 0.9868N$$

Molecular weight SO_3 = 80.06
Molecular weight Na_2CO_3 = 106.005

$$\frac{80.06}{106.005} = 0.7552 = \text{gram } SO_3 \text{ neutralized by 1 gram } Na_2CO_3$$

Let x = gram SO_3 per cubic centimeter in standard acid
a = grams Na_2CO_3 neutralized
b = cubic centimeters standard acid neutralized (cubic centimeters acid − cubic centimeters alkali in back titration.)

$$x = \frac{a \times 0.7552}{b}$$

It is necessary to know the relative strengths of the standard acid and alkali solutions so that the value of the alkali solution used in producing the desired neutralization may be ascertained. When the two solutions are exactly equivalent cubic centimeters to cubic centimeters, subtraction of the alkali used from the acid used gives the correct amount of acid used. If the solutions are not exactly equivalent the alkali reading should be multiplied by a factor of its per cent. relation to the acid solution in order to equalize the two. For example, in determining the relation between the acid and alkali we find it requires 29.7 c.c. of alkali to neutralize 30 c.c. of acid.

The factor then would be:

$$\frac{30}{29.7} = 1.0101$$

The temperature of the standard acid should be observed at the time of its standardization for future use. The coefficient of expansion is 0.000325 c.c. or 0.000013 gram SO_3 per cubic centimeter per degree Centigrade for average laboratory temperatures (25°C.).

Example:

Weight of Na_2CO_3 used	= 2 grams
Cubic centimeters acid used	= 39.17 c.c.
Cubic centimeters alkali used	= 0.92 c.c.
29.7 c.c. alkali will neutralize 30 c.c. of acid	= 1.0101 (factor)
Temperature of acid	= 23°C.

$$0.92 \times 1.0101 = 0.93$$

$$39.17 - 0.93 = 38.24$$

$$\frac{2 \times 0.7552}{38.24} = 0.039498 \text{ gram } SO_3 \text{ per cubic centimeter at } 23°C.$$

Standard Sodium Hydroxide

A normal solution of sodium hydroxide contains 40.008 grams NaOH per liter (0.040008 gram per cubic centimeter). It is not essential to have the solution "just normal" but for simplifying calculations it should be as nearly equivalent to the standard acid as possible.

Standard sodium hydroxide is prepared by dissolving approximately 50 grams NaOH per liter. The solution may then be adjusted to proper strength. This solution is controlled by standardizing against the standard sulphuric-acid solution using methyl orange as indicator.

Run a quantity of the standard alkali into the titrating vessel, add a drop or two of the indicator which will give a yellow straw color. Now titrate with the standard acid, toward neutralization drop by drop then cutting the drops from the tip of the burette until a fraction of a drop produces a pink color.

Observe the temperature of the standard acid and if it varies from the time of its standardization use the given coefficient of expansion and calculate to the temperature observed at the time of the alkali standardization.

Let x = gram SO_3 equivalent per cubic centimeter standard alkali

a = gram SO_3 per cubic centimeter standard acid

b = cubic centimeters standard acid used

c = cubic centimeters standard alkali used

$$x = \frac{a \times b}{c}$$

Observe the temperature of the standard alkali at the time of its standardization for future use. The coefficient of expansion is 0.00026 c.c. or 0.000011 gram SO_3 equivalent per cubic centimeter per degree Centigrade for average laboratory temperatures (25°C.).

Example:

Gram SO_3 per cubic centimeter standard acid at 23° = 0.039498

Temperature acid at time of alkali standardization = 27°

$$27° - 23° = 4°$$

$$4 \times 0.000013 = 0.000052$$

0.039498 − 0.000052 = 0.039446 gram SO_3 per cubic centimeter standard acid at 27°C.

Cubic centimeters standard acid used = 30
Cubic centimeters standard alkali used = 29.7
Temperature standard alkali = 26°

$\frac{0.039446 \times 30}{29.7}$ = 0.039844 gram SO_3 equivalent per cubic centimeter standard alkali at 26°C.

Sodium hydroxide purified by alcohol is not suitable for preparing a standard solution as it does not drain properly in the burette, producing an oily appearance.

When employing methyl orange as an indicator an ordinary sodium hydroxide solution may be employed without any special precautions. When intended to be used with phenolphthalein it should be as free as possible from carbonate as this would interfere with the indicator. Also the solution should be protected against the absorption of CO_2 from the air. CO_2 free water should be used.

A solution entirely free from carbonate is difficult to prepare and preserve when in constant use. By adding 1 to 2 grams of barium hydroxide or barium chloride per liter of the standard solution the carbonate will be precipitated. It is advisable to add only an amount to precipitate the carbonate as the presence of barium would produce an opalescence with sulphuric acid when titrated. Or a better method would be to add the barium hydroxide in slight excess to precipitate the carbonate, then add enough sulphuric acid to precipitate the excess barium.

Protecting the Strength of the Standard Solutions

The standard solution containers should be well stoppered and the air drawn into the bottle purified from CO_2 and acid fumes. This can be accomplished by drawing the air through a sodium-hydroxide solution or sodium calcium oxide then through calcium chloride. Some chemists claim that if vapor is lost from the standard reagents and this replaced by dry air, as is the common practice, the solution gradually changes in strength. They recommend drawing through a sodium-hydroxide solution only, thus purifying the air from CO_2 and acid fumes and at the same time saturating the air with moisture.

Burettes

Fifty cubic-centimeter burettes, graduated in tenths, with a mark passing entirely around the tube are very convenient. The eye can be held so that the marks appear to be a straight line drawn across the tube, thus lessening chances of error in reading. One hundred cubic-centimeter burettes graduated in tenths would be too long for convenient manipulation.

In extremely accurate work, where it is desired to have a titration of 75 to 100 c.c., the chamber burette is convenient. The chamber located in the upper portion of the tube holds 75 c.c. and the lower portion drawn out into a uniform bore tube holding 25 c.c., is graduated.

Burettes should be connected to the reservoir of standard solutions by means of an arm at the base.

Burettes should be allowed to drain 2 min. before taking readings. Readings should be in hundredths of a cubic centimeter. Meniscus readers are of great value.

Observing Temperature

Thermometers may be suspended from the stoppers of the reservoirs.

The burette may be water-jacketed with a large glass tube and the thermometer suspended along side of the burette.

The thermometer may be inserted in the upright siphon tube from the reservoir at the base of the burette.

Titrating Vessels

White porcelain dishes (500-c.c. capacity) or 4-in. casseroles are best adapted for titrating vessels on account of the clear white background, enabling the analyst to see the end point clearly.

Preparing Indicator Solution

Methyl orange may be prepared by dissolving 1 gram of the reagent per liter of water.

Phenolphthalein may be prepared by dissolving 1 gram of the reagent per liter of neutral 95 per cent. alcohol.

Methods of Weighing Acid

Non-fuming.—Tared, glass-stoppered, conical-shape weighing bottles about 15-c.c. capacity are very convenient. Weigh about 1.5 to 2 grams for each titration. Wash into the titrating vessel, dilute to 150–200 c.c. and titrate.

Fuming.—Fuming acid must be confined during weighing and until diluted with water without loss of SO_3. If the acid is wholly or partly crystallized, heat moderately until it becomes liquid and mix thoroughly before sampling. Acid which is not far removed from real SO_3 in composition would give off too much SO_3 in this operation. Such acid should be weighed out in a stoppered bottle and mixed in this with a known and exactly analyzed quantity of a weaker acid at a temperature from 30° to 40°C. In this way an acid that will remain liquid at ordinary temperatures can be formed. Of course the amount of diluting acid added will have to be taken into calculations.

A few methods for weighing follow:

1. Lunge-Rey Pipette.—This consists of a small bulb with a stop-cock at each end, the tube from one being capillary. The capillary tube is covered with a ground on light glass cup which is weighed with the pipette. The whole apparatus is weighed, the stop-cock next to the capillary is closed and the air in the bulb exhausted by applying suction at the other (upper) tube, the stop-cock is closed thus sealing the vacuum. The capillary tube is then dipped into the acid to be sampled, the lower stop-cock then opened and the acid will be drawn into the bulb. The lower stop-cock is closed and the capillary covered with the cup and the whole again weighed. The pipette is emptied by placing the capillary under water, opening both stop-cocks and allowing the acid to run out, then washing thoroughly. Dilute to 150 to 200 c.c. and titrate.

2. Glass-tube Method.—Some chemists use glass tubes bent in different shapes for weighing fuming acid. The acid is drawn into the tube by applying suction and emptied by submerging under water and allowing to run out by gravity, regulating the outflow by placing a finger over the end of the tube or by regulating the flow of water sometimes used to force the acid out.

3. Glass-bulb Method.—In the bulb method thin glass bulbs of about 2-c.c. capacity are used. The bulbs have a capillary tube from two sides, one about ½ in. long which is sealed and used as a handle and the other about 3 in. long. These bulbs may be easily made by an amateur glass blower. After weighing the bulb, heat moderately over a low alcohol flame, then place the long tube into the acid to be sampled and allow to cool. The contraction of the air upon cooling will draw the acid into the bulb. Draw 1.5 to 2 grams. Seal the end with the flame, wipe the acid off carefully and weigh. Insert the bulb along with about 50 c.c. water in a well-stoppered bottle, large enough to allow the bulb to be placed loosely. Give the bottle a vigorous shake so as to break the bulb. A sudden vibration occurs from the contact of the acid with the water and clouds of SO_3 rise which will be absorbed by a little shaking. When the SO_3 fumes are completely absorbed, open the bottle and crush the capillary tubes with a glass rod. Wash into the titrating vessel, dilute to 150–200 c.c. and titrate.

Advantages of the bulb method:

1. Convenience in handling as compared to the awkwardness of the other methods.

2. To facilitate drying the tubes or pipette, requires that they be rinsed in alcohol, followed by ether, then heating, dry air

being aspirated through. This requires a great deal of time and work which is eliminated by the bulb method.

3. In diluting, strong fuming acid cannot be run directly into water in an open vessel without great chances of loss. SO_3 fumes may escape unabsorbed. Also loss may occur through the bumping and splashing caused by the sudden evolution of heat when the acid comes into contact with water. The bulb method does not have these objections.

4. If solid acid is being analyzed, using the bulb method it only has to be kept liquid long enough to draw into the bulb while with the other methods it also must be kept in the liquid state to empty from the tube or pipette.

Titration of Acid

As indicator methyl orange is used and so much is only taken than the pink color produced is quite visible, say a drop. A yellow straw-colored end point is sought for and to be certain of neutralization it is best to titrate back, cutting a fraction of a drop off the tip of the burette until a faint trace of pink is observed.

If phenolphthalein is used as an indicator titrate with alkali until a pinkish-red is observed.

Nitrous acid destroys the coloring matter of methyl orange, but commercial acid seldom contains sufficient amount to cause any trouble. If any difficulty is encountered, the indicator should be added or renewed shortly toward neutralization or an excess of alkali added, then methyl orange, and the solution then titrated back with standard acid.

Let x = per cent. SO_3

a = gram SO_3 equivalent per cubic centimeter in standard alkali

b = cubic centimeters standard alkali neutralized (cubic centimeters alkali used − cubic centimeters acid used)

c = grams acid (weight of sample)

$$x = \frac{a \times b \times 100}{c}$$

If the temperature of the standard alkali differs from the time of its standardization adjust the temperature correction before making calculations.

Example:

Grams acid (weight of sample)	= 1.9845
Cubic centimeters standard alkali used	= 40.00
Temperature of standard alkali	= 22°C.
Gram SO_3 equivalent per cubic centimeter standard alkali at 26°C.	= 0.039844
26° − 22°C.	= 4.0°
4 × 0.000011	= 0.000044
0.039844 + 0.000044	= 0.039888
$\frac{0.039888 \times 40 \times 100}{1.9845}$	= 80.39 per cent. SO_3

Thus far all operations have been carried on under the assumption that no SO_2 is present in the sulphuric acid. If SO_2 is present, operations and calculations must be extended according to the indicator used.

Sulphur dioxide dissolves in water forming sulphurous acid. When phenolphthalein is used as an indicator the reaction is

$$H_2SO_3 + 2NaOH = Na_2SO_3 + 2H_2O$$

With methyl orange, the point of neutrality is reached when the acid salt $NaHSO_3$ has been formed thus requiring only one-half as much alkali for neutralization as when phenolphthalein is used

$$H_2SO_3 + NaOH = NaHSO_3 + H_2O$$

Determine the amount of SO_2 present by titrating a separate sample with N/10 iodine using starch as an indicator. The end point is reached when a blue color is observed.

Let x = per cent. SO_2

a = cubic centimeters N/10 I used; 1 cc. = 0.0032 gram SO_2

b = grams acid in sample

$$x = \frac{a \times 0.0032 \times 100}{b}$$

$$\frac{SO_3}{SO_2} = \frac{80.06}{64.06} = 1.25$$

Using phenolphthalein:

Per cent. SO_3 as total acidity − (per cent. $SO_2 \times 1.25$) = actual per cent. SO_3.

Using methyl orange:

Per cent. SO_3 as total acidity − 0.5 (per cent. $SO_2 \times 1.25$) = actual per cent. SO_3.

If it is desired to calculate fuming acid as per cent. free SO_3, no SO_2 being present, the formulas given under the caption "Formulas for use in sulphuric-acid calculations" may be used. If SO_2 is present it should be calculated as follows:

Example.—Methyl orange is used as indicator:

Total acidity per cent. SO_3 = 83.5
Per cent. SO_2 = 2.0

		Per cent.
Actual total SO_3 =	83.5 − 0.5 (2 × 1.25)	= 82.25
H_2O =	100.0 − (82.25 + 2.0)	= 15.75
Combined SO_3 =	15.75 × 4.4438	= 69.99
Free SO_3 =	82.25 − 69.99	= 12.26
H_2SO_4 =	15.75 + 69.99	= 85.74

Therefore the composition of the acid would be:

	Per cent.
H_2SO_4 =	85.74
Free SO_3 =	12.26
SO_2 =	2.00
	100.00

QUANTITATIVE DETERMINATION OF LEAD, IRON AND ZINC IN SULPHURIC ACID

Lead

Weigh 100 grams of the acid and dilute with an equal volume of water and twice its volume of alcohol. Upon cooling the lead settles as a white precipitate of sulphate. Filter directly on an asbestos mat in a tared Gooch crucible, wash several times with dilute alcohol, dry and weigh as lead sulphate.

$$1 \text{ gram } PbSO_4 = 0.68324 \text{ gram Pb.}$$

Iron

Weigh 100 grams of the acid, add a few drops of hydrogen peroxide to oxidize the iron. Make alkaline by adding ammonia which will precipitate the iron, heat to boiling and filter. Dissolve the precipitate from the filter with dilute sulphuric acid, wash with hot water, add about 10 c.c. concentrated sulphuric acid and pass through pure zinc shavings. Wash the latter thoroughly and then titrate with potassium permanganate. This is best employed as an empirical solution prepared by dissolving 564 mg. $KMnO_4$ per liter.

1 c.c. = 0.001 gram Fe or 0.001 per cent. Fe on a 100-gram sample.

Zinc

Weigh 100 grams acid, dilute to about 400 c.c., neutralize with ammonia and filter off the iron. Pass through H_2S gas, allow the ZnS to settle. Decant the supernatant liquor. Dissolve the precipitate with hydrochloric acid, neutralize with ammonia, add a small amount of ammonium chloride and an excess of 10 c.c. hydrochloric acid. Dilute to about 250 c.c., heat to boiling and titrate while hot with potassium ferrocyanide using uranium nitrate on a spot plate as indicator.

THE ANALYSIS OF MIXED ACID AND NITRATED SULPHURIC ACID

Mixed acid is the technical name for a mixture of strong sulphuric acid and nitric acid. The analysis includes the determination of H_2SO_4, HNO_3 and lower oxides which may be calculated as N_2O_3, N_2O_5, HNO_2 or even as N_2O_4 and in the case of fuming sulphuric acid being present the determination of SO_3. In the presence of the latter HNO_3 is supposed to lose its combined water according to the reaction:

$$2HNO_3 + SO_3 = H_2SO_4 + N_2O_5$$

If any SO_2 should be present it is assumed that it is oxidized to SO_3 with the formation of H_2SO_4 and the anhydrides SO_3 and N_2O_3 according to the reaction:

$$N_2O_5 + H_2O + 2SO_2 = N_2O_3 + SO_3 + H_2SO_4$$

Some chemists prefer to express the reaction:

$$2HNO_3 + SO_2 = H_2SO_4 + N_2O_4$$

The analysis is carried out by three titrations:

(*a*) Determination of total acidity.

(*b*) Determination of sulphuric acid, including free SO_3 in the case of fuming acid.

(*c*) Determination of lower oxides of nitrogen.

(*a*) **Total Acidity.**—The sample is accurately weighed by one of the procedures recommended for fuming sulphuric acid and diluted with water as described. If methyl orange is employed as indicator, either add it only toward the end of the titration or renew it as destroyed or add an excess of alkali, then the indicator and titrate back. Calculate as per cent. SO_3.

(*b*) **Sulphuric Acid.**—A second sample is weighed and diluted as in the case of total acids. The solution is evaporated on a steam bath to expel the volatile acids, lower oxides and nitric. The evaporation is hastened by blowing a current of hot, dry, pure air over the sample. About 5 c.c. water are added and this again evaporated. The acid is then diluted with water and titrated with the standard alkali. Calculate as per cent. SO_3 which gives the actual per cent.

(*c*) **Lower Oxides.**—A third sample is weighed and diluted as in the case of total acids. The solution is titrated immediately with N/10 $KMnO_4$, the reagent being added rapidly at first and finally drop by drop as the end point is approached. The reaction at the end is apt to be slow so that time must be allowed for complete oxidation. The titration is completed when a pink color is obtained that does not fade in 3 min.

Organic matter is also oxidized by $KMnO_4$ hence will interfere if present. If organic matter is present the titration should be made with N/10 iodine solution.

$KMnO_4$ reacts with nitrous acid or a nitrate as follows:

$$2KMnO_4 + 5HNO_2 + 3H_2SO_4 = K_2SO_4 + 5HNO_3 + 3H_2O + 2MnSO_4$$

$$4KMnO_4 + 5N_2O_3 + 6H_2SO_4 = 2K_2SO_4 + 4MnSO_4 + 5N_2O_5 + 6H_2O$$

Therefore 1 c.c. N/10 $KMnO_4$ = 0.0019 gram N_2O_3
0.0046 gram N_2O_4
0.00235 gram HNO_2

The $KMnO_4$ solution is standardized against sodium oxalate. Reaction:

$$5Na_2C_2O_4 + 2KMnO_4 + 8H_2SO_4 = K_2SO_4 + 2MnSO_4 + 5Na_2SO_4 + 10CO_2 + 8H_2O.$$

Example.—Mixed acid analysis – free SO_3 absent.

The total acidity in terms of SO_3 is found to be 67.76 per cent.
The total SO_3 after evaporation = 34.55 per cent.
The N_2O_3 = 0.096 per cent.

To calculate the composition of the mixed acid:

$$67.76 - 34.55 = 33.21 \text{ per cent. } HNO_3 + HNO_2 \text{ as } SO_3.$$

The amount of acidity as nitric acid is:

$$\frac{2HNO_3}{SO_3} = \frac{2(63.018)}{80.06} \times 33.21 = 52.27 \text{ per cent. } HNO_3 + HNO_2 \text{ as } HNO_3.$$

The equivalent of N_2O_3 in HNO_3 is:

$$\frac{2HNO_3}{N_2O_3} = \frac{2(63.018)}{76.02} \times 0.096 = 0.16 \text{ per cent}$$

The amount of nitric acid present is:

$$52.27 - 0.16 = 52.11 \text{ per cent. } HNO_3.$$

The amount of sulphuric acid present is:

$$\frac{H_2SO_4}{SO_3} = \frac{98.076}{80.06} \times 34.55 = 42.33 \text{ per cent. } H_2SO_4.$$

From these figures the analysis of the mixed acid is:

	H_2SO_4	=	42.33
	HNO_3	=	52.11
	N_2O_3	=	0.10
By difference	H_2O	=	5.46
			100.00 per cent.

Example.—Mixed acid analysis – free SO_3 present.

Nitric acid in the presence of free SO_3 is assumed to be the anhydride N_2O_5.

The total acidity in terms of SO_3 is found to be 84 per cent.

The total SO_3 after evaporation 82 per cent.

84 − 82 = 2 per cent. SO_3 difference.

The equivalent N_2O_5 is:

$$\frac{N_2O_5}{SO_3} = \frac{108.02}{80.06} \times 2 = 2.698 \text{ per cent. } N_2O_5.$$

$$\text{Water} = 100 - (82 + 2.698) = 15.302 \text{ per cent.}$$

Combined SO_3	= 15.302 × 4.4438	= 68.00
Free SO_3	= 82 − 68	= 14.00
H_2SO_4	= 68 + 15.30	= 83.30

From these figures the analysis of the mixed acid is:

$$H_2SO_4 = 83.30$$
$$\text{Free } SO_3 = 14.00$$
$$N_2O_5 = 2.70$$

100.00 per cent.

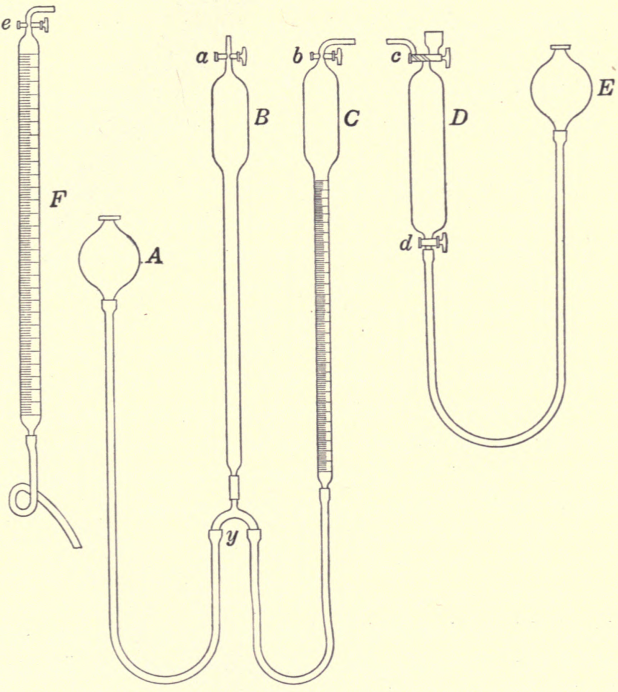
Du Pont Nitrometer Method

The principle of the nitrometer method for the determination of nitrogen acids in sulphuric acid and mixed acid is the reaction between sulphuric acid and nitrogen acids in the presence of mercury. This converts all nitrogen acids into NO:

$$2HNO_3 + 3H_2SO_4 + 3Hg. = 4H_2O + 3HgSO_4 + 2NO$$

There are several types of nitrometers, the Du Pont having proved to be the most accurate and convenient, in fact, in the United States it is now practically accepted as the standard nitrometer apparatus. The United States government uses it exclusively in all nitrometer work. By use of this apparatus, direct readings in per cent. may be obtained, without recourse to correction of the volume of gas to standard conditions and calculations such as are required with ordinary nitrometers.

The apparatus consists of a generating bulb *D* of 300 c.c. capacity with its reservoir *E* connected with heavy walled rubber tubing. *D* carries two glass stop-cocks as is shown in illustration. *c* is a two way stop-cock communicating with either the cup or the right angle capillary exit tube. *C* is the chamber reading burette, calibrated to read in percentages of nitrogen and graduated from 10 to 14 per cent., divided into one-hundredths. Between 171.8 and 240.4 c.c. of gas must be generated to obtain a reading. *B* is the ungraduated compensating burette very similar in form to the reading burette *C*. *A* is the leveling bulb which is connected with *B* and *C* with heavy walled rubber tubing by the glass connection *y*. By raising or lowering this bulb the standard pressure of the system may be obtained. *F* is a measuring burette that may be used in place of *C* where a wider range of measurement is desired. It can be used for the measurement of small as well as large amounts of gas. It is most commonly graduated to hold 300.1 milligrams of NO at 20°C. and 760 mm. pressure and this volume is divided into 100 units (subdivided in tenths) each unit being equivalent to 3.001 milligrams of NO.



When compensated, the gas from ten times the molecular weight in milligrams of any nitrate of the formula RNO_3 (or five times the molecular weight of $R(NO_3)_2$) should exactly fill the burette. This simplifies all calculations; for example, the per cent. nitric acid in a mixed acid would be:

$$\frac{\text{Burette reading} \times 63.02}{\text{Grams acid taken} \times 100} = \text{per cent. } HNO_3$$

Standardizing the Apparatus.—The apparatus having been arranged and the various parts filled with mercury, the instrument is standardized as follows:

20 to 30 c.c. of sulphuric acid are drawn into the generating bulb through the cup, and at the same time about 210 c.c. of air; cocks *c* and *d* are closed and the bulb well shaken; this thoroughly desiccates the air which is then run over into the compensating burette until the mercury is about on a level with the 12.30 per cent. mark on the reading burette, the two being held in the same relative position, after which the compensating burette is sealed off by closing stop-cock *a*. A further quantity of air is desiccated in the same manner and run into the reading burette so as to fill up to about the same mark; the cock *b* is then closed and a small glass U-tube filled with sulphuric acid (not water) is attached to the exit tube of the reading burette; when the mercury columns are balanced and the enclosed air cooled down, the cock *b* is carefully opened and when the sulphuric acid balances in the U-tube, and the mercury columns in both burettes are at the same level, then the air in each one is under the same conditions of temperature and pressure. A reading is now made from the burette and the barometric pressure and temperature carefully noted using the formula:

$$V_t = \frac{V_o P_o (273 + t)}{P_t 273}$$

The volume this enclosed air would occupy at 760 mm. pressure and 20°C. is found. The cock *b* is again closed and the reservoir *A* manipulated so as to bring the mercury in both burettes to the same level and in the reading burette to the calculated value as well. A strip of paper is now pasted on the compensating burette at the level of the mercury and the standardization is complete.

The better and most rapid method of standardizing is to fill the compensating chamber with desiccated air as stated in the previous method and then to introduce into the generating chamber 1 gram of pure potassium nitrate dissolved in 2 to 4 c.c. of water, the cup is rinsed out with 20 c.c. 66°Bé. sulphuric acid, making three or four washings of it, each lot being drawn separately into the bulb. The generating bulb is then shaken vigorously, care being taken that stopcock *d* is open, until apparently all gas is formed. Then close cock *d* and repeat the shaking for two minutes. The generated gas is then transferred into the measuring burette. The columns in both burettes are balanced so that the reading burette is at 13.85 (per cent. N in KNO_3). A strip of paper is pasted on the compensating burette at the level of the mercury and the standardization is accomplished. By this method the temperature and pressure readings and the calculations are avoided.

Making the Test.—The acid is weighed, the amount being governed by its nitrogen content and transferred into the cup of the generating bulb. If any free SO_3 is present the acid should be mixed after weighing with 95 per cent. reagent sulphuric acid. The sample is drawn into the bulb; the cup is then rinsed with three or four washings of 95 per cent. sulphuric acid, the total quantity being 20 c.c. Care should be exercised that no air enters the bulb when drawing the acid in.

To generate the gas, the bulb is shaken vigorously until apparently all the gas is formed, taking care that stop-cock *d* has been left open; this cock is then closed and the shaking repeated for two minutes. The reservoir *A* is then lowered until about 60 c.c. of mercury and 20 c.c. of acid are left in the generating bulb. There will remain then sufficient space for 220 c.c. of gas. If too much mercury is left in the bulb the mixture will be so thick that it will be found difficult to complete the reaction, a long time will be required for the residue to settle and some of the gas is liable to be held in suspension by the mercury, so that inaccurate results follow.

The generated gas is now transferred to the reading burette, and after waiting a couple of minutes to allow for cooling, both burettes are balanced, so that in the compensating tube the mercury column is on a level with the paper mark, as well as with the column in the reading burette; the reading is then taken:

$$\frac{HNO_3}{N} = \frac{63.018}{14.01} = 4.4981$$

$$\frac{\text{Burette reading}}{\text{Weight acid taken}} \times 4.4981 = \text{per cent. } HNO_3$$

Note.—The generating bulb should be flushed out with 95 per cent. sulphuric acid after every determination.

A test should always be made to see whether the glass stopcocks are tight. They will hardly remain so without greasing occasionally with vaseline, but this ought to be done very slightly, so as to avoid any grease getting into the bore, for if it comes in contact with acid, troublesome froth will be formed.

Ferrous-sulphate Method

Nitric acid may be estimated quantitatively in sulphuric acid and mixed acid by titration with ferrous sulphate in the presence of strong sulphuric acid. The strong sulphuric acid is used as the medium in which the titration is performed. This method checks the nitrometer method very well and very accurate results may be obtained.

The following equation represents the reaction taking place:

$$4FeSO_4 + 2HNO_3 + 2H_2SO_4 = 2Fe_2(SO_4)3 + N_2O_3 + 3H_2O$$

For detailed procedure the analyst is referred to Scott's "Standard Methods of Chemical Analysis."

CALIBRATION OF STORAGE TANKS AND TANK CARS

One of the problems often confronted in acid practice is the accurate calibration of storage tanks and tank cars. When these are merely of upright cylindrical shape, the solution is very simple, but when the cylinder has bumped ends and lies on its side, it becomes more complicated as there are two variables to be considered, that is, the cylinder and the spherical segments at the ends.

Methods based on the assumption that the tank is a true cylinder are applicable with accuracy only to cases when the tank has flat heads. In the majority of cases met with in practice, however, the mechanical advantages to be gained have required that the heads of the tanks be bumped. To such tanks it is impossible to apply the aforementioned method of calculation without the introduction of considerable error.

General practice of tank design is to have the radius of the tank head equal to the diameter of the tank. On account of the almost universal acceptance of this practice of construction, the proposition will be confined to the above condition. In subsequent calculations, therefore, advantage of the above condition will be taken, which results in making the diameter of the base of the spherical segment equal to the radius of the sphere.

Procedure.—Treat the tank as consisting of two component parts:

1. The content of the material in the cylindrical portion of the tank, *i.e.*, the tank exclusive of the bumped ends.
2. The content of the material held by the bumped ends.

Treating the two component volumes separately, designate them as:

$$\begin{aligned} \text{Vol. A} &= \text{volume of cylinder.} \\ \text{Vol. B} &= \text{volume of single bumped end.} \\ \text{Total volume} &= \text{Vol. A} + 2\ \text{Vol. B.} \end{aligned}$$

Vol. A is equal to the product of the length of the cylinder and the area of the segment of the circle.

Vol. B may be expressed as the volume of a portion of a spherical segment.

To calibrate a tank for each vertical inch of height, determine these component volumes for every inch of height and add them together.

Determination of Vol. A

Calculate the height of the segment as a decimal fraction of the diameter of the tank $\left(\frac{h}{d}\right)$. Consult the following table and find the corresponding coefficient.

Vol. A = (Coefficient) × (Square of diameter) × (Length of tank)

If the tank is filled to over one-half, calculate the volume of the empty space and deduct this from the total capacity of the cylinder.

Then Vol. A = (Total capacity of cylinder) − (Volume of empty space)

$\frac{h}{d}$	Coefficient	$\frac{h}{d}$	Coefficient	$\frac{h}{d}$	Coefficient	$\frac{h}{d}$	Coefficient
.001	.00004	.021	.00403	.041	.01093	.061	.01972
.002	.00012	.022	.00432	.042	.01133	.062	.02020
.003	.00022	.023	.00462	.043	.01173	.063	.02068
.004	.00034	.024	.00492	.044	.01214	.064	.02117
.005	.00047	.025	.00523	.045	.01256	.065	.02166
.006	.00062	.026	.00555	.046	.01297	.066	.02216
.007	.00078	.027	.00587	.047	.01339	.067	.02265
.008	.00095	.028	.00619	.048	.01382	.068	.02316
.009	.00114	.029	.00653	.049	.01425	.069	.02366
.010	.00133	.030	.00687	.050	.01468	.070	.02417
.011	.00153	.031	.00721	.051	.01512	.071	.02468
.012	.00175	.032	.00756	.052	.01556	.072	.02520
.013	.00197	.033	.00791	.053	.01601	.073	.02571
.014	.00220	.034	.00827	.054	.01646	.074	.02624
.015	.00244	.035	.00864	.055	.01691	.075	.02676
.016	.00269	.036	.00901	.056	.01737	.076	.02729
.017	.00294	.037	.00938	.057	.01783	.077	.02782
.018	.00320	.038	.00976	.058	.01830	.078	.02836
.019	.00347	.039	.01015	.059	.01877	.079	.02889
.020	.00375	.040	.01054	.060	.01924	.080	.02944

$\frac{h}{d}$	Coefficient	$\frac{h}{d}$	Coefficient	$\frac{h}{d}$	Coefficient	$\frac{h}{d}$	Coefficient
.081	.02998	.116	.05081	.151	.07459	.186	.10077
.082	.03053	.117	.05145	.152	.07531	.187	.10155
.083	.03108	.118	.05209	.153	.07603	.188	.10233
.084	.03163	.119	.05274	.154	.07675	.189	.10312
.085	.03219	.120	.05339	.155	.07747	.190	.10390
.086	.03275	.121	.05404	.156	.07819	.191	.10468
.087	.03331	.122	.05469	.157	.07892	.192	.10547
.088	.03387	.123	.05535	.158	.07965	.193	.10626
.089	.03444	.124	.05600	.159	.08038	.194	.10705
.090	.03501	.125	.05666	.160	.08111	.195	.10784
.091	.03559	.126	.05733	.161	.08185	.196	.10864
.092	.03616	.127	.05799	.162	.08258	.197	.10943
.093	.03674	.128	.05866	.163	.08332	.198	.11023
.094	.03732	.129	.05933	.164	.08406	.199	.11103
.095	.03791	.130	.06000	.165	.08480	.200	.11182
.096	.03850	.131	.06067	.166	.08555	.201	.11263
.097	.03909	.132	.06135	.167	.08629	.202	.11343
.098	.03968	.133	.06203	.168	.08704	.203	.11423
.099	.04028	.134	.06271	.169	.08779	.204	.11504
.100	.04088	.135	.06339	.170	.08854	.205	.11584
.101	.04148	.136	.06407	.171	.08929	.206	.11665
.102	.04208	.137	.06476	.172	.09004	.207	.11746
.103	.04269	.138	.06545	.173	.09080	.208	.11827
.104	.04330	.139	.06614	.174	.09156	.209	.11908
.105	.04391	.140	.06683	.175	.09231	.210	.11990
.106	.04452	.141	.06753	.176	.09307	.211	.12071
.107	.04514	.142	.06823	.177	.09384	.212	.12153
.108	.04576	.143	.06892	.178	.09460	.213	.12235
.109	.04638	.144	.06963	.179	.09537	.214	.12317
.110	.04701	.145	.07033	.180	.09614	.215	.12399
.111	.04763	.146	.07103	.181	.09690	.216	.12481
.112	.04826	.147	.07174	.182	.09768	.217	.12563
.113	.04889	.148	.07245	.183	.09845	.218	.12646
.114	.04953	.149	.07316	.184	.09922	.219	.12729
.115	.05017	.150	.07388	.185	.10000	.220	.12811

$\frac{h}{d}$	Coefficient	$\frac{h}{d}$	Coefficient	$\frac{h}{d}$	Coefficient	$\frac{h}{d}$	Coefficient
.221	.12894	.256	.15876	.291	.18996	.326	.22228
.222	.12977	.257	.15964	.292	.19087	.327	.22322
.223	.13061	.258	.16051	.293	.19177	.328	.22415
.224	.13144	.259	.16139	.294	.19269	.329	.22509
.225	.13227	.260	.16226	.295	.19360	.330	.22603
.226	.13311	.261	.16314	.296	.19451	.331	.22697
.227	.13395	.262	.16402	.297	.19542	.332	.22792
.228	.13478	.263	.16490	.298	.19634	.333	.22886
.229	.13562	.264	.16578	.299	.19725	.334	.22980
.230	.13647	.265	.16666	.300	.19817	.335	.23075
.231	.13731	.266	.16755	.301	.19909	.336	.23169
.232	.13815	.267	.16843	.302	.20000	.337	.23263
.233	.13900	.268	.16932	.303	.20092	.338	.23358
.234	.13984	.269	.17020	.304	.20184	.339	.23453
.235	.14069	.270	.17109	.305	.20276	.340	.23547
.236	.14154	.271	.17198	.306	.20368	.341	.23642
.237	.14239	.272	.17287	.307	.20461	.342	.23737
.238	.14324	.273	.17376	.308	.20553	.343	.23832
.239	.14409	.274	.17465	.309	.20645	.344	.23927
.240	.14495	.275	.17554	.310	.20738	.345	.24022
.241	.14580	.276	.17644	.311	.20830	.346	.24117
.242	.14666	.277	.17733	.312	.20923	.374	.24212
.243	.14751	.278	.17823	.313	.21016	.348	.24307
.244	.14837	.279	.17912	.314	.21108	.349	.24403
.245	.14923	.280	.18002	.315	.21201	.350	.24498
.246	.15009	.281	.18092	.316	.21294	.351	.24594
.247	.15095	.282	.18182	.317	.21387	.352	.24689
.248	.15182	.283	.18272	.318	.21480	.353	.24785
.249	.15268	.284	.18362	.319	.21573	.354	.24880
.250	.15355	.285	.18452	.320	.21667	.355	.24976
.251	.15441	.286	.18543	.321	.21760	.356	.25072
.252	.15528	.287	.18633	.322	.21853	.357	.25167
.253	.15615	.288	.18724	.323	.21947	.358	.25263
.254	.15702	.289	.18814	.324	.22040	.359	.25359
.255	.15789	.290	.18905	.325	.22134	.360	.25455

$\frac{h}{d}$	Coefficient	$\frac{h}{d}$	Coefficient	$\frac{h}{d}$	Coefficient	$\frac{h}{d}$	Coefficient
.361	.25551	.396	.28945	.431	.32392	.466	.35873
.362	.25647	.397	.29043	.432	.32491	.467	.35972
.363	.25743	.398	.29141	.433	.32590	.468	.36072
.364	.25840	.399	.29239	.434	.32689	.469	.36172
.365	.25936	.400	.29337	.435	.32788	.470	.36272
.366	.26032	.401	.29435	.436	.32887	.471	.36372
.367	.26129	.402	.29533	.437	.32987	.472	.36471
.368	.26225	.403	.29631	.438	.33086	.473	.36571
.369	.26321	.404	.29729	.439	.33185	.474	.36671
.370	.26418	.405	.29827	.440	.33284	.475	.36771
.371	.26515	.406	.29926	.441	.33384	.476	.36871
.372	.26611	.407	.30024	.442	.33483	.477	.36971
.373	.26708	.408	.30122	.443	.33582	.478	.37071
.374	.26805	.409	.30220	.444	.33682	.479	.37171
.375	.26901	.410	.30319	.445	.33781	.480	.37270
.376	.26998	.411	.30417	.446	.33880	.481	.37370
.377	.27095	.412	.30516	.447	.33980	.482	.37470
.378	.27192	.413	.30614	.448	.34079	.483	.37570
.379	.27289	.414	.30713	.449	.34179	.484	.37670
.380	.27386	.415	.30811	.450	.34278	.485	.37770
.381	.27483	.416	.30910	.451	.34378	.486	.37870
.382	.27580	.417	.31008	.452	.34477	.487	.37970
.383	.27678	.418	.31107	.453	.34577	.488	.38070
.384	.27775	.419	.31206	.454	.34676	.489	.38170
.385	.27872	.420	.31304	.455	.34776	.490	.38270
.386	.27970	.421	.31403	.456	.34876	.491	.38370
.387	.28067	.422	.31502	.457	.34975	.492	.38470
.388	.28164	.423	.31601	.458	.35075	.493	.38570
.389	.28262	.424	.31699	.459	.35175	.494	.38670
.390	.28359	.425	.31798	.460	.35274	.495	.38770
.391	.28457	.426	.31897	.461	.35374	.496	.38870
.392	.28555	.427	.31996	.462	.35474	.497	.38970
.393	.28652	.428	.32095	.463	.35573	.498	.39070
.394	.28750	.429	.32194	.464	.35673	.499	.39170
.395	.28848	.430	.32293	.465	.35773	.500	.39270

Determination of Vol. B

Calculate the height of the portion of the spherical segment as a decimal fraction of the diameter of the tank $\left(\frac{h}{d}\right)$. Consult the following table and find the corresponding coefficient or interpolate to find the approximate coefficient if necessary.

$\frac{h}{d}$	Coefficient
.05	.00017
.10	.00085
.15	.00221
.20	.00420
.25	.00687
.30	.01048
.35	.01386
.40	.01805
.45	.02234
.50	.02697

Vol. B = (Coefficient) × (Cube of diameter)

If the tank is filled to over one-half, calculate the volume of the empty space and deduct this from the total capacity of the bumped end.

Then Vol. B = (Total capacity of bumped end) − (Volume of empty space).

Determination of Total Capacity

Calculate one-half the volume of the tank by the previous methods. Double this result which gives the total capacity.

Or Vol. A = (Square of diameter) × (0.7854) × (Length of tank)

Vol. B = $0.5236 \times h(3a^2 + h^2)$.

Where a = radius of base of segment

h = height of segment

r = radius of sphere

The height of the segment can better be calculated than measured.

If h = height of segment

R = radius of sphere

r = radius of base of segment

$$h = R - \sqrt{R^2 - r^2}$$

Total capacity = Vol. A + 2 Vol. B.

Cubic feet × 7.48 = gallons

CIRCUMFERENCE AND AREA OF CIRCLES, SQUARES, CUBES, SQUARE AND CUBE ROOTS

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
1.0	3.142	0.7854	1.000	1.000	1.0000	1.0000
1.1	3.456	0.9503	1.210	1.331	1.0488	1.0323
1.2	3.770	1.1310	1.440	1.728	1.0955	1.0627
1.3	4.084	1.3273	1.690	2.197	1.1402	1.0914
1.4	4.398	1.5394	1.960	2.744	1.1832	1.1187
1.5	4.712	1.7672	2.250	3.375	1.2247	1.1447
1.6	5.027	2.0106	2.560	4.096	1.2649	1.1696
1.7	5.341	2.2698	2.890	4.913	1.3038	1.1935
1.8	5.655	2.5447	3.240	5.832	1.3416	1.2164
1.9	5.969	2.8353	3.610	6.859	1.3784	1.2386
2.0	6.283	3.1416	4.000	8.000	1.4142	1.2599
2.1	6.597	3.4636	4.410	9.261	1.4491	1.2806
2.2	6.912	3.8013	4.840	10.648	1.4832	1.3006
2.3	7.226	4.1548	5.290	12.167	1.5166	1.3200
2.4	7.540	4.5239	5.760	13.824	1.5492	1.3389
2.5	7.854	4.9087	6.250	15.625	1.5811	1.3572
2.6	8.168	5.3093	6.760	17.576	1.6125	1.3751
2.7	8.482	5.7256	7.290	19.683	1.6432	1.3925
2.8	8.797	6.1575	7.840	21.952	1.6733	1.4095
2.9	9.111	6.6052	8.410	24.389	1.7029	1.4260
3.0	9.425	7.0686	9.00	27.000	1.7321	1.4422
3.1	9.739	7.5477	9.61	29.791	1.7607	1.4581
3.2	10.053	8.0425	10.24	32.768	1.7889	1.4736
3.3	10.367	8.5530	10.89	35.937	1.8166	1.4888
3.4	10.681	9.0792	11.56	39.304	1.8439	1.5037
3.5	10.996	9.6211	12.25	42.875	1.8708	1.5183
3.6	11.310	10.179	12.96	46.656	1.8974	1.5326
3.7	11.624	10.752	13.69	50.653	1.9235	1.5467
3.8	11.938	11.341	14.44	54.872	1.9494	1.5605
3.9	12.252	11.946	15.21	59.319	1.9748	1.5741

Circumference and Area of Circles, Squares, Cubes, Square and Cube Roots—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
4.0	12.566	12.566	16.00	64.000	2.0000	1.5874
4.1	12.881	13.203	16.81	68.921	2.0249	1.6005
4.2	13.195	13.854	17.64	74.088	2.0494	1.6134
4.3	13.509	14.522	18.49	79.507	2.0736	1.6261
4.4	13.823	15.205	19.36	85.184	2.0976	1.6386
4.5	14.137	15.904	20.25	91.125	2.1213	1.6510
4.6	14.451	16.619	21.16	97.336	2.1448	1.6631
4.7	14.765	17.349	22.09	103.823	2.1680	1.6751
4.8	15.080	18.096	23.04	110.592	2.1909	1.6869
4.9	15.394	18.857	24.01	117.649	2.2136	1.6985
5.0	15.708	19.635	25.00	125.000	2.2361	1.7100
5.1	16.022	20.428	26.01	132.651	2.2583	1.7213
5.2	16.336	21.237	27.04	140.608	2.2804	1.7325
5.3	16.650	22.062	28.09	148.877	2.3022	1.7435
5.4	16.965	22.902	29.16	157.464	2.3238	1.7544
5.5	17.279	23.758	30.25	166.375	2.3452	1.7652
5.6	17.593	24.630	31.36	175.616	2.3664	1.7758
5.7	17.907	25.518	32.49	185.193	2.3875	1.7863
5.8	18.221	26.421	33.64	195.112	2.4083	1.7967
5.9	18.535	27.340	34.81	205.379	2.4290	1.8070
6.0	18.850	28.274	36.00	216.000	2.4495	1.8171
6.1	19.164	29.225	37.21	226.981	2.4698	1.8272
6.2	19.478	30.191	38.44	238.328	2.4900	1.8371
6.3	19.792	31.173	39.69	250.047	2.5100	1.8469
6.4	20.106	32.170	40.96	262.144	2.5298	1.8566
6.5	20.420	33.183	42.25	274.625	2.5495	1.8663
6.6	20.735	34.212	43.56	287.496	2.5691	1.8758
6.7	21.049	35.257	44.89	300.763	2.5884	1.8852
6.8	21.363	36.317	46.24	314.432	2.6077	1.8945
6.9	21.677	37.393	47.61	328.509	2.6268	1.9038

CIRCUMFERENCE AND AREA OF CIRCLES, SQUARES, CUBES, SQUARE AND CUBE ROOTS—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
7.0	21.991	38.485	49.00	343.000	2.6458	1.9129
7.1	22.305	39.592	50.41	357.911	2.6646	1.9920
7.2	22.619	40.715	51.84	373.248	2.6833	1.9310
7.3	22.934	41.854	53.29	389.017	2.7019	1.9399
7.4	23.248	43.008	54.76	405.224	2.7203	1.9487
7.5	23.562	44.179	56.25	421.875	2.7386	1.9574
7.6	23.876	45.365	47.76	438.976	2.7568	1.9661
7.7	24.190	46.566	59.29	456.533	2.7749	1.9747
7.8	24.504	47.784	60.84	474.552	2.7929	1.9832
7.9	24.819	49.017	62.41	493.039	2.8107	1.9916
8.0	25.133	50.266	64.00	512.000	2.8284	2.0000
8.1	25.447	51.530	65.61	531.441	2.8461	2.0083
8.2	25.761	52.810	67.24	551.368	2.8636	2.0165
8.3	26.075	54.106	68.89	571.787	2.8810	2.0247
8.4	26.389	55.418	70.56	592.704	2.8983	2.0328
8.5	26.704	56.745	72.25	614.125	2.9155	2.0408
8.6	27.018	58.088	73.96	636.056	2.9326	2.0488
8.7	27.332	59.447	75.69	658.503	2.9496	2.0567
8.8	27.646	60.821	77.44	681.472	2.9665	2.0646
8.9	27.960	62.211	79.21	704.969	2.9833	2.0724
9.0	28.274	63.617	81.00	729.000	3.0000	2.0801
9.1	28.588	65.039	82.81	753.571	3.0166	2.0878
9.2	28.903	66.476	84.64	778.688	3.0332	2.0954
9.3	29.217	67.929	86.49	804.357	3.0496	2.1029
9.4	29.531	69.398	88.36	830.584	3.0659	2.1105
9.5	29.845	70.882	90.25	857.375	3.0822	2.1179
9.6	30.159	72.382	92.16	884.736	3.0984	2.1253
9.7	30.473	73.898	94.09	912.673	3.1145	2.1327
9.8	30.788	75.430	96.04	941.192	3.1305	2.1400
9.9	31.102	76.977	98.01	970.299	3.1464	2.1472

Circumference and Area of Circles, Squares, Cubes, Square and Cube Roots—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
10.0	31.416	78.540	100.00	1,000.000	3.1623	2.1544
10.1	31.730	80.119	102.01	1,030.301	3.1780	2.1616
10.2	32.044	81.713	104.04	1,061.208	3.1937	2.1687
10.3	32.358	83.323	106.09	1,092.727	3.2094	2.1757
10.4	32.673	84.949	108.16	1,124.864	3.2249	2.1828
10.5	32.987	86.590	110.25	1,157.625	3.2404	2.1897
10.6	33.301	88.247	112.36	1,191.016	3.2558	2.1967
10.7	33.615	89.920	114.49	1,225.043	3.2711	2.2036
10.8	33.929	91.609	116.64	1,259.712	3.2863	2.2104
10.9	34.243	93.313	118.81	1,295.029	3.3015	2.2172
11.0	34.558	95.033	121.00	1,331.000	3.3166	2.2239
11.1	34.872	96.769	123.21	1,367.631	3.3317	2.2307
11.2	35.186	98.520	125.44	1,404.928	3.3466	2.2374
11.3	35.500	100.29	127.69	1,442.897	3.3615	2.2441
11.4	35.814	102.07	129.96	1,481.544	3.3754	2.2506
11.5	36.128	103.87	132.25	1,520.875	3.3912	2.2572
11.6	36.442	105.68	134.56	1,560.896	3.4059	2.2637
11.7	36.757	107.51	136.89	1,601.613	3.4205	2.2702
11.8	37.071	109.36	139.24	1,643.032	3.4351	2.2766
11.9	37.385	111.22	141.61	1,685.159	3.4496	2.2831
12.0	37.699	113.10	144.00	1,728.000	3.4641	2.2894
12.1	38.013	114.99	146.41	1,771.561	3.4785	2.2957
12.2	38.327	116.90	148.84	1,815.848	3.4928	2.3021
12.3	38.642	118.82	151.29	1,860.867	3.5071	2.3084
12.4	38.956	120.76	153.76	1,906.624	3.5214	2.3146
12.5	39.270	122.72	156.25	1,953.125	3.5355	2.3208
12.6	39.584	124.69	158.76	2,000.376	3.5496	2.3270
12.7	39.898	126.68	161.29	2,048.383	3.5637	2.3331
12.8	40.212	128.68	163.84	2,097.152	3.5777	2.3392
12.9	40.527	130.70	166.41	2,146.689	3.5917	2.3453

CIRCUMFERENCE AND AREA OF CIRCLES, SQUARES, CUBES, SQUARE AND CUBE ROOTS—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
13.0	40.841	132.73	169.00	2,197.000	3.6056	2.3513
13.1	41.155	134.78	171.61	2,248.091	3.6194	2.3573
13.2	41.469	136.85	174.24	2,299.968	3.6332	2.3633
13.3	41.783	138.93	176.89	2,352.637	3.6469	2.3693
13.4	42.097	141.03	179.56	2,406.104	3.6606	2.3752
13.5	42.412	143.14	182.25	2,460.375	3.6742	2.3811
13.6	42.726	145.27	184.96	2,515.456	3.6878	2.3870
13.7	43.040	147.41	187.69	2,571.353	3.7013	2.3928
13.8	43.354	149.57	190.44	2,628.072	3.7148	2.3986
13.9	43.668	151.75	193.21	2,685.619	3.7283	2.4044
14.0	43.892	153.94	196.00	2,744.000	3.7417	2.4101
14.1	44.296	156.15	198.81	2,803.221	3.7550	2.4159
14.2	44.611	158.37	201.64	2,863.288	3.7683	2.4216
14.3	44.925	160.61	204.49	2,924.207	3.7815	2.4272
14.4	45.239	162.86	207.36	2,985.984	3.7947	2.4329
14.5	45.553	165.13	210.25	3,048.625	3.8079	2.4385
14.6	45.867	167.42	213.16	3,112.136	3.8210	2.4441
14.7	46.181	169.72	216.09	3,176.523	3.8341	2.4497
14.8	46.496	172.03	219.04	3,241.792	3.8471	2.4552
14.9	46.810	174.37	222.01	3,307.949	3.8600	2.4607
15.0	47.124	176.72	225.00	3,375.000	3.8730	2.4662
15.1	47.438	179.08	228.09	3,442.951	3.8859	2.4717
15.2	47.752	181.46	231.04	3,511.808	3.8987	2.4772
15.3	48.066	183.85	234.09	3,581.577	3.9115	2.4825
15.4	48.381	186.27	237.16	3,652.264	3.9243	2.4879
15.5	48.695	188.69	240.25	3,723.875	3.9370	2.4933
15.6	49.009	191.13	243.36	3,796.416	3.9497	2.4986
15.7	49.323	193.59	246.49	3,869.893	3.9623	2.5039
15.8	49.637	196.07	249.64	3,944.312	3.9749	2.5092
15.9	49.951	198.56	252.81	4,019.679	3.9875	2.5146

CIRCUMFERENCE AND AREA OF CIRCLES, SQUARES, CUBES, SQUARE AND CUBE ROOTS—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
16.0	50.265	201.06	256.00	4,096.000	4.0000	2.5198
16.1	50.580	203.58	259.21	4,173.281	4.0125	2.5251
16.2	50.894	206.13	262.44	4,251.528	4.0249	2.5303
16.3	51.208	208.67	265.69	4,330.747	4.0373	2.5355
16.4	51.522	211.24	268.56	4,410.944	4.0497	2.5406
16.5	51.836	213.83	272.25	4,492.125	4.0620	2.5458
16.6	52.150	216.42	275.56	4,574.296	4.0743	2.5509
16.7	52.465	219.04	278.89	4,657.463	4.0866	2.5561
16.8	52.779	221.67	282.24	4,741.632	4.0988	2.5612
16.9	53.093	224.32	285.61	4,826.809	4.1110	2.5663
17.0	53.407	226.98	299.00	4,913.000	4.1231	2.5713
17.1	53.721	229.66	292.41	5,000.211	4.1352	2.5763
17.2	54.035	232.35	295.84	5,088.448	4.1473	2.5813
17.3	54.350	235.06	299.29	5,177.717	4.1593	2.5863
17.4	54.664	237.79	302.76	5,268.024	4.1713	2.5913
17.5	54.978	240.53	306.25	5,359.375	4.1833	2.5963
17.6	55.292	243.29	309.76	5,451.776	4.1952	2.6012
17.7	55.606	246.06	313.29	5,545.233	4.2071	2.6061
17.8	55.920	248.85	316.84	5,639.752	4.2190	2.6109
17.9	56.235	251.65	320.41	5,735.339	4.2308	2.6158
18.0	56.549	254.47	324.00	5,832.000	4.2426	2.6207
18.1	56.863	257.30	327.61	5,929.741	4.2544	2.6256
18.2	57.177	260.16	331.24	6,028.568	4.2661	2.6304
18.3	57.491	263.02	334.89	6,128.487	4.2778	2.6352
18.4	57.805	265.90	338.56	6,229.504	4.2895	2.6400
18.5	58.119	268.80	342.25	6,331.625	4.3012	2.6448
18.6	58.434	271.72	345.96	6,434.856	4.3128	2.6495
18.7	58.748	274.65	349.69	6,539.203	4.3243	2.6543
18.8	59.062	277.59	353.44	6,644.672	4.3459	2.6590
18.9	59.376	280.55	357.21	6,751.269	4.3474	2.6637

Circumference and Area of Circles, Squares, Cubes, Square and Cube Roots—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
19.0	59.690	283.53	361.00	6,859.000	4.3589	2.6684
19.1	60.004	286.52	364.81	6,967.871	4.3703	2.6731
19.2	60.319	289.53	368.64	7,077.888	4.3818	2.6777
19.3	60.633	292.55	372.49	7,189.057	4.3942	2.6824
19.4	60.947	295.59	376.36	7,301.384	4.4045	2.6869
19.5	61.261	298.65	380.25	7,414.875	4.4159	2.6916
19.6	61.575	301.72	284.16	7,529.536	4.4272	2.6962
19.7	61.889	304.81	388.09	7,642.373	4.4385	2.7008
19.8	62.204	307.91	392.04	7,762.392	4.4497	2.7053
19.9	62.518	311.03	396.01	7,880.599	4.4609	2.7098
20.0	62.832	314.16	400.00	8,000.000	4.4721	2.7144
20.1	63.146	317.31	404.01	8,120.601	4.4833	2.7189
20.2	63.460	320.47	408.04	8,242.408	4.4944	2.7234
20.3	63.774	323.66	412.09	8,365.427	4.5055	2.7279
20.4	64.088	326.85	416.16	8,489.664	4.5166	2.7324
20.5	64.403	330.06	420.25	8,615.125	4.5277	2.7368
20.6	64.717	333.29	424.36	8,741.816	4.5387	2.7413
20.7	65.031	336.54	428.49	8,869.743	4.5497	2.7457
20.8	65.345	339.80	432.64	8,998.912	4.5607	2.7502
20.9	65.659	343.07	436.81	9,129.329	4.5716	2.7545
21.0	65.973	346.36	441.00	9,261.000	4.5826	2.7589
21.1	66.288	349.67	445.21	9,393.931	4.5935	2.7633
21.2	66.602	352.99	449.44	9,528.128	4.6043	2.7676
21.3	66.916	356.33	453.69	9,663.597	4.6152	2.7720
21.4	67.230	359.68	457.96	9,800.344	4.6260	2.7763
21.5	67.544	363.05	462.25	9,938.375	4.6368	2.7806
21.6	67.858	366.44	466.56	10,077.696	4.6476	2.7849
21.7	68.173	369.84	470.89	10,218.313	4.6583	2.7893
21.8	68.487	373.25	475.24	10,360.232	4.6690	2.7935
21.9	68.801	376.69	479.41	10,503.459	4.6797	2.7978

CIRCUMFERENCE AND AREA OF CIRCLES, SQUARES, CUBES, SQUARE AND CUBE ROOTS—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
22.0	69.115	380.13	484.00	10,648.000	4.6904	2.8021
22.1	69.429	383.60	488.41	10,793.861	4.7011	2.8063
22.2	69.743	387.08	462.84	10,941.048	4.7117	2.8105
22.3	70.058	390.57	497.29	11,089.567	4.7223	2.8147
22.4	70.372	394.08	501.76	11,239.424	4.7329	2.8189
22.5	70.686	397.61	506.25	11,390.625	4.7434	2.8231
22.6	71.000	401.15	510.76	11,543.176	4.7539	2.8273
22.7	71.314	404.71	515.29	11,697.083	4.7644	2.8314
22.8	71.628	408.28	519.84	11,852.352	4.7749	2.8356
22.9	71.942	411.87	524.41	12,008.989	4.7854	2.8397
23.0	72.257	415.48	529.00	12,167.000	4.7958	2.8438
23.1	72.571	419.10	533.61	12,326.391	4.8062	2.8479
23.2	72.885	422.73	538.24	12,487.168	4.8166	2.8521
23.3	73.199	426.39	542.89	12,649.337	4.8270	2.8562
23.4	73.513	430.05	547.56	12,812.904	4.8373	2.8603
23.5	73.827	433.74	552.25	12,977.875	4.8477	2.8643
23.6	74.142	437.44	556.96	13,144.256	4.8580	2.8684
23.7	74.456	441.15	561.69	13,312.053	4.8683	2.8724
23.8	74.770	444.88	566.44	13,481.272	4.8785	2.8765
23.9	75.084	448.63	571.21	13,651.919	4.8888	2.8805
24.0	75.398	452.39	576.00	13,824.000	4.8990	2.8845
24.1	75.712	456.17	580.81	13,997.521	4.9092	2.8885
24.2	76.027	459.96	585.64	14,172.488	4.9192	2.8925
24.3	76.341	463.77	590.49	14,348.907	4.9295	2.8965
24.4	76.655	467.60	595.36	14,526.784	4.9396	2.9004
24.5	76.969	471.44	600.25	14,706.125	4.9497	2.9044
24.6	77.283	475.29	605.16	14,886.936	4.9598	2.9083
24.7	77.597	479.16	610.09	15,069.223	4.9699	2.9123
24.8	77.911	483.05	615.04	15,252.992	4.9799	2.9162
24.9	78.226	486.96	620.01	15,438.249	4.9899	2.9201

Circumference and Area of Circles, Squares, Cubes, Square and Cube Roots—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
25.0	78.540	490.87	625.00	15,625.000	5.0000	2.9241
25.1	78.854	494.81	630.01	15,813.251	5.0099	2.9279
25.2	79.168	498.76	635.04	16,003.008	5.0199	2.9318
25.3	79.482	502.73	640.09	16,194.277	5.0299	2.9356
25.4	79.796	506.71	645.16	16,387.064	5.0398	2.9395
25.5	80.111	510.71	650.25	16,581.375	5.0497	2.9434
25.6	80.425	514.72	655.36	16,777.216	5.0596	2.9472
25.7	80.739	518.75	660.49	16,974.593	5.0695	2.9510
25.8	81.053	522.79	665.64	17,173.512	5.0793	2.9549
25.9	81.367	526.85	670.81	17,373.979	5.0892	2.9586
26.0	81.681	530.93	676.00	17,576.000	5.0990	2.9624
26.1	81.996	535.02	681.21	17,779.581	5.1088	2.9662
26.2	82.310	539.13	686.44	17,984.728	5.1185	2.9701
26.3	82.624	543.25	691.69	18,191.447	5.1283	2.9738
26.4	82.938	547.39	696.96	18,399.744	5.1380	2.9776
26.5	83.252	551.55	702.25	18,609.625	5.1478	2.9814
26.6	83.566	555.72	707.56	18,821.096	5.1575	2.9851
26.7	83.881	559.90	712.89	19,034.163	5.1672	2.9888
26.8	84.195	564.10	718.24	19,248.832	5.1768	2.9926
26.9	84.509	568.32	723.61	19,465.109	5.1865	2.9963
27.0	84.823	572.56	729.00	19,683.000	5.1962	3.0000
27.1	85.137	576.80	734.41	19,902.511	5.2057	3.0037
27.2	85.451	581.07	739.84	20,123.648	5.2153	3.0074
27.3	85.765	585.35	745.29	20,346.417	5.2249	3.0111
27.4	86.080	589.65	750.76	20,570.824	5.2345	3.0147
27.5	86.394	593.96	756.25	20,796.875	5.2440	3.0184
27.6	86.708	598.29	761.76	21,024.576	5.2535	3.0221
27.7	87.022	602.63	767.29	21,253.933	5.2630	3.0257
27.8	87.336	606.99	772.84	21,484.952	5.2725	3.0293
27.9	87.650	611.36	778.41	21,717.639	5.2820	3.0330

Circumference and Area of Circles, Squares, Cubes, Square and Cube Roots—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
28.0	87.965	615.75	784.00	21,952.000	5.2915	3.0366
28.1	88.279	620.16	789.61	22,188.041	5.3009	3.0402
28.2	88.593	624.58	795.24	22,425.768	5.3103	3.0438
28.3	88.907	629.02	800.89	22,665.187	5.3197	3.0474
28.4	89.221	633.47	806.56	22,906.304	5.3291	3.0510
28.5	89.535	637.94	812.25	23,149.125	5.3385	3.0546
28.6	89.850	642.42	817.96	23,393.656	5.3478	3.0581
28.7	90.164	646.93	823.69	23,639.903	5.3572	3.0617
28.8	90.478	651.44	829.44	23,887.872	5.3665	3.0652
28.9	90.792	655.97	835.21	24,137.569	5.3758	3.0688
29.0	91.106	660.52	841.00	24,389.000	5.3852	3.0723
29.1	91.420	665.08	846.81	24,642.171	5.3944	3.0758
29.2	91.735	669.66	852.64	24,897.088	5.4037	3.0794
29.3	92.049	674.26	858.49	25,153.757	5.4129	3.0829
29.4	92.363	678.87	864.36	25,412.184	5.4221	3.0864
29.5	92.677	683.49	870.25	25,672.375	5.4313	3.0899
29.6	92.991	688.13	876.16	25,934.336	5.4405	3.0934
29.7	93.305	692.79	882.09	26,198.073	5.4497	3.0968
29.8	93.619	697.47	888.04	26,463.592	5.4589	3.1003
29.9	93.934	702.15	894.01	26,730.899	5.4680	3.1038
30.0	94.248	706.86	900.00	27,000.000	5.4772	3.1072
30.1	94.562	711.58	906.01	27,270.901	5.4863	3.1107
30.2	94.876	716.32	912.04	27,543.608	5.4954	3.1141
30.3	95.190	721.07	918.09	27,818.127	5.5045	3.1176
30.4	95.504	725.83	924.16	28,094.464	5.5136	3.1210
30.5	95.819	730.62	930.25	28,372.625	5.5226	3.1244
30.6	96.133	735.42	936.36	28,652.616	5.5317	3.1278
30.7	96.447	740.23	942.49	28,934.443	5.5407	3.1312
30.8	96.761	745.06	948.64	29,218.112	5.5497	3.1346
30.9	97.075	749.91	954.81	29,503.629	5.5587	3.1380

CIRCUMFERENCE AND AREA OF CIRCLES, SQUARES, CUBES, SQUARE AND CUBE ROOTS—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
31.0	97.389	754.77	961.00	29,791.000	5.5678	3.1414
31.1	97.704	759.65	967.21	30,080.231	5.5767	3.1448
31.2	98.018	764.54	973.44	30,371.328	5.5857	3.1481
31.3	98.332	769.45	979.69	30,664.297	5.5946	3.1515
31.4	98.646	774.37	985.96	30,959.144	5.6035	3.1549
31.5	98.960	779.31	992.25	31,255.875	5.6124	3.1582
31.6	99.274	784.27	998.56	31,554.496	5.6213	3.1615
31.7	99.588	789.24	1,004.89	31,855.013	5.6302	3.1648
31.8	99.903	794.23	1,011.24	32,157.432	5.6391	3.1681
31.9	100.22	799.23	1,017.61	32,461.759	5.6480	3.1715
32.0	100.53	804.25	1,024.00	32,768.000	5.6569	3.1748
32.1	100.85	809.28	1,030.41	33,076.161	5.6656	3.1781
32.2	101.16	814.33	1,036.84	33,386.248	5.6745	3.1814
32.3	101.47	819.40	1,043.29	33,698.267	5.6833	3.1847
32.4	101.79	824.49	1,049.76	34,012.224	5.6921	3.1880
32.5	102.10	829.58	1,056.25	34,328.125	5.7008	3.1913
32.6	102.42	834.69	1,062.76	34,645.976	5.7056	3.1945
32.7	102.73	839.82	1,069.29	34,965.783	5.7183	3.1978
32.8	103.04	844.96	1,075.84	35,287.552	5.7271	3.2010
32.9	103.36	850.12	1,082.41	35,611.289	5.7358	3.2043
33.0	103.67	855.30	1,089.00	35,937.000	5.7447	3.2075
33.1	103.99	860.49	1,095.61	36,264.691	5.7532	3.2108
33.2	104.30	865.70	1,102.24	36,594.368	5.7619	3.2140
33.3	104.62	870.92	1,108.89	36,925.037	5.7706	3.2172
33.4	104.93	876.19	1,115.56	37,259.704	5.7792	3.2204
33.5	105.24	881.41	1,122.25	37,595.375	5.7879	3.2237
33.6	105.56	886.68	1,128.96	37,933.056	5.7965	3.2269
33.7	105.87	891.97	1,135.69	38,272.753	5.8051	3.2301
33.8	106.19	897.27	1,142.44	38,614.472	5.8137	3.2332
33.9	106.50	902.59	1,149.21	38,958.219	5.8223	3.2364

CIRCUMFERENCE AND AREA OF CIRCLES, SQUARES, CUBES, SQUARE AND CUBE ROOTS—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
34.0	106.81	907.92	1,156.00	39,304.000	5.8310	3.2396
34.1	107.13	913.27	1,162.81	39,651.821	5.8395	3.2424
34.2	107.44	918.63	1,169.64	40,001.688	5.8480	3.2460
34.3	107.76	924.01	1,176.49	40,353.607	5.8566	3.2491
34.4	108.07	929.41	1,183.36	40,707.584	5.8751	3.2522
34.5	108.38	934.82	1,190.25	41,063.525	5.8736	3.2554
34.6	108.70	940.25	1,197.16	41,421.736	5.8821	3.2586
34.7	109.01	945.69	1,204.09	41,781.923	5.8906	3.2617
34.8	109.33	951.15	1,211.04	42,144.192	5.8991	3.2648
34.9	109.64	956.62	1,218.01	42,508.549	5.9076	3.2679
35.0	109.96	962.11	1,225.00	42,875.000	5.9161	3.2710
35.1	110.27	967.62	1,232.01	43,243.551	5.9245	3.2742
35.2	110.58	973.14	1,239.04	43,614.208	5.9326	3.2773
35.3	110.90	978.68	1,246.09	43,986.977	5.9413	3.2804
35.4	111.21	984.23	1,253.16	44,361.864	5.9497	3.2835
35.5	111.53	989.80	1,260.25	44,738.875	5.9581	3.2866
35.6	111.84	995.38	1,267.36	45,118.016	5.9665	3.2897
35.7	112.15	1,000.98	1,274.49	45,499.293	5.9749	3.2927
35.8	112.47	1,006.60	1,281.64	45,882.712	5.9833	3.2958
35.9	112.78	1,012.23	1,288.81	46,268.279	5.9916	3.2989
36.0	113.10	1,017.88	1,296.00	46,656.000	6.0000	3.3019
36.1	113.41	1,023.54	1,303.21	47,045.881	6.0083	3.3050
36.2	113.73	1,029.22	1,310.44	47,437.928	6.0166	3 3080
36.3	114.04	1,034.91	1,317.69	47,832.147	6.0249	3.3111
36.4	114.35	1,040.62	1,324.96	48,228.544	6.0332	3.3141
36.5	114.67	1,046.35	1,332.25	48,627.125	6.0415	3.3171
36.6	114.98	1,052.09	1,339.56	49,017.896	6.0497	3.3202
36.7	115.30	1,057.84	1,346.89	49,430.863	6.0580	3.3232
36.8	115.61	1,063.62	1,354.24	49,836.032	6.0663	3.3262
36.9	115.92	1,069.41	1,361.61	50,243.409	6.0745	3.3292

CIRCUMFERENCE AND AREA OF CIRCLES, SQUARES, CUBES, SQUARE AND CUBE ROOTS—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
37.0	116.24	1,075.21	1,369.00	50,653.000	6.0827	3.3322
37.1	116.55	1,081.03	1,376.41	51,064.811	6.0909	3.3352
37.2	116.87	1,086.87	1,383.84	51,478.848	6.0991	3.3382
37.3	117.18	1,092.72	1,391.29	51,895.117	6.1073	3.3412
37.4	117.50	1,098.58	1,398.76	52,313.624	6.1155	3.3442
37.5	117.81	1,104.47	1,406.25	52,734.375	6.1237	3.3472
37.6	118.12	1,110.36	1,413.76	53,157.376	6.1318	3.3501
37.7	118.44	1,116.28	1,421.29	53,582.633	6.1400	3.3531
37.8	118.75	1,122.21	1,428.84	54,010.152	6.1481	3.3561
37.9	119.07	1,128.15	1,436.41	54,439.939	6.1563	3.3590
38.0	119.38	1,134.11	1,444.00	54,872.000	6.1644	3.3620
38.1	119.69	1,140.09	1,451.61	55,306.341	6.1725	3.3649
38.2	120.01	1,146.08	1,459.24	55,742.968	6.1806	3.3679
38.3	120.32	1,152.09	1,466.89	56,181.887	6.1887	3.3708
38.4	120.64	1,158.12	1,474.56	96,623.104	6.1967	3.3737
38.5	120.95	1,164.16	1,482.25	57,066.625	6.2048	3.3767
38.6	121.27	1,170.21	1,489.96	57,512.456	6.2129	3.3797
38.7	121.58	1,176.28	1,497.69	57,960.603	6.2209	3.3825
38.8	121.80	1,182.37	1,505.44	58,411.072	6.2289	3.3854
38.9	122.21	1,188.47	1,513.21	58,863.869	6.2370	3.3883
39.0	122.52	1,194.59	1,521.00	59,319.000	6.2450	3.3912
39.1	122.84	1,200.72	1,528.81	59,776.471	6.2530	3.3941
39.2	123.15	1,206.87	1,536.64	60,236.288	6.2610	3.3970
39.3	123.46	1,213.04	1,544.49	60,698.457	6.2689	3.3999
39.4	123.78	1,219.22	1,552.36	61,162.984	6.2769	3.4028
39.5	124.09	1,225.42	1,560.25	61,629.875	6.2849	3.4056
39.6	124.41	1,231.63	1,568.16	62,099.136	6.2928	3.4085
39.7	124.72	1,237.86	1,576.09	62,570.773	6.3008	3.4114
39.8	125.04	1,244.10	1,584.04	63,044.792	6.3087	3.4142
39.9	125.35	1,250.36	1,592.01	63,521.199	6.3166	3.4171

CIRCUMFERENCE AND AREA OF CIRCLES, SQUARES, CUBES, SQUARE AND CUBE ROOTS—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
40.0	125.66	1,256.64	1,600.00	64,000.000	6.3245	3.4200
40.1	125.98	1,262.93	1,608.01	64,481.201	6.3325	3.4228
40.2	126.29	1,269.24	1,616.04	64,964.808	6.3404	3.4256
40.3	126.61	1,275.56	1,624.09	65,450.827	6.3482	3.4285
40.4	126.92	1,281.90	1,632.16	65,939.264	6.3561	3.4313
40.5	127.23	1,288.25	1,640.25	66,430.126	6.3639	3.4341
40.6	127.55	1,294.62	1,648.36	66,923.416	6.3718	3.4370
40.7	127.86	1,301.00	1,656.49	67,419.143	6.3796	3.4398
40.8	128.18	1,307.41	1,664.64	67,917.312	6.3875	3.4426
40.9	128.49	1,313.82	1,672.81	68,417.929	6.3953	3.4454
41.0	128.81	1,320.25	1,681.00	68,921.000	6.4031	3.4482
41.1	129.12	1,326.70	1,689.21	69,426.531	6.4109	3.4510
41.2	129.43	1,333.17	1,697.44	69,934.528	6.4187	3.4538
41.3	129.75	1,339.65	1,705.69	70,444.997	6.4265	3.4566
41.4	130.06	1,346.14	1,713.96	70,957.944	6.4343	3.4594
41.5	130.38	1,352.65	1,722.25	71,473.375	6.4421	3.4622
41.6	130.69	1,359.18	1,730.56	71,991.296	6.4498	3.4650
41.7	131.00	1,365.72	1,738.89	72,511.719	6.4575	3.4677
41.8	131.32	1,372.28	1,747.24	73,034.632	6.4653	3.4705
41.9	131.63	1,378.85	1,755.61	73,560.059	6.4730	3.4733
42.0	131.95	1,385.44	1,764.00	74,088.000	6.4807	3.4760
42.1	132.26	1,392.05	1,772.41	74,618.461	6.4884	3.4788
42.2	132.58	1,398.67	1,780.84	75,151.448	6.4961	3.4815
42.3	132.89	1,405.31	1,789.29	75,686.967	6.5038	3.4843
42.4	133.20	1,411.96	1,797.76	76,225.024	6.5115	3.4870
42.5	133.52	1,418.63	1,806.25	76,765.625	6.5192	3.4898
42.6	133.83	1,425.31	1,814.76	77,308.776	6.5268	3.4925
42.7	134.15	1,432.01	1,823.29	77,854.483	6.5345	3.4952
42.8	134.46	1,438.72	1,831.84	78,402.752	6.5422	3.4980
42.9	134.77	1,445.45	1,840.45	78,953.589	6.5498	3.5007

Circumference and Area of Circles, Squares, Cubes, Square and Cube Roots—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
43.0	135.09	1,452.20	1,849.00	79,507.000	6.5574	3.5034
43.1	135.40	1,458.96	1,857.61	80,062.991	6.5651	3.5061
43.2	135.72	1,465.74	1,866.24	80,621.568	6.5727	3.5088
43.3	136.03	1,472.54	1,874.89	81,182.737	6.5803	3.5115
43.4	136.35	1,479.34	1,883.56	81,746.504	6.5879	3.5142
43.5	136.66	1,486.17	1,892.25	82,312.875	6.5954	3.5169
43.6	136.97	1,493.01	1,900.96	82,881.856	6.6030	3.5196
43.7	137.29	1,499.87	1,909.69	83,453.453	6.6106	3.5223
43.8	137.60	1,506.74	1,918.44	84,027.672	6.6182	3.5250
43.9	137.92	1,513.63	1,927.21	84,604.519	6.6257	3.5277
44.0	138.23	1,520.53	1,936.00	85,184.000	6.6333	3.5303
44.1	138.54	1,527.45	1,944.81	85,766.121	6.6408	3.5330
44.2	138.86	1,534.39	1,953.64	86,350.888	6.6483	3.5357
44.3	139.17	1,541.34	1,962.49	86,938.307	6.6558	3.5384
44.4	139.49	1,541.30	1,971.36	87,528.384	6.6633	3.5410
44.5	139.80	1,555.28	1,980.25	88,121.125	6.6708	3.5437
44.6	140.12	1,562.28	1,989.16	88,716.536	6.6783	3.5463
44.7	140.43	1,569.30	1,998.09	89,314.623	6.6858	3.5490
44.8	140.74	1,576.33	2,007.04	89,915.392	6.6933	3.5516
44.9	141.06	1,583.37	2,016.01	90,518.849	6.7007	3.5543
45.0	141.37	1,590.43	2,025.00	91,125.000	6.7082	3.5569
45.1	141.69	1,597.51	2,034.01	91,733.851	6.7156	3.5595
45.2	142.00	1,604.60	2,043.04	92,345.408	6.7231	3.5621
45.3	142.31	1,611.71	2,052.09	92,959.677	6.7305	3.5648
45.4	142.63	1,618.83	2,061.16	93,576.664	6.7379	3.5674
45.5	142.94	1,625.97	2,070.25	94,196.375	6.7454	3.5700
45.6	143.26	1,633.13	2,079.36	94,818.816	6.7528	3.5726
45.7	143.57	1,640.30	2,088.49	95,443.993	6.7602	3.5752
45.8	143.88	1,647.48	2,097.64	96,071.912	6.7676	3.5778
45.9	144.20	1,654.68	2,106.81	96,702.579	6.7749	3.5805

Circumference and Area of Circles, Squares, Cubes, Square and Cube Roots—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
46.0	144.51	1,661.90	2,116.00	97,336.000	6.7823	3.5830
46.1	144.83	1,669.14	2,125.21	97,972.181	6.7897	3.5856
46.2	145.14	1,676.39	2,134.44	98,611.128	6.7971	3.5882
46.3	145.46	1,683.65	2,143.69	99,252.847	6.8044	3.5908
46.4	145.77	1,690.93	2,152.96	99,897.344	6.8117	3.5934
46.5	146.08	1,698.23	2,162.25	100,544.625	6.8191	3.5960
46.6	146.40	1,705.54	2,171.56	101,194.696	6.8264	3.5986
46.7	146.71	1,712.87	2,180.89	101,847.563	6.8337	3.6011
46.8	147.03	1,720.21	2,190.24	102,503.232	6.8410	3.6037
46.9	147.34	1,727.57	2,199.61	103,161.709	6.8484	3.6063
47.0	147.65	1,734.94	2,209.00	103,823.000	6.8556	3.6088
47.1	147.97	1,742.34	2,218.41	104,487.111	6.8629	3.6114
47.2	148.28	1,749.74	2,227.84	105,154.048	6.8702	3.6139
47.3	148.60	1,757.16	2,237.29	105,823.817	6.8775	3.6165
47.4	148.91	1,764.60	2,246.76	106,496.424	6.8847	3.6190
47.5	149.23	1,772.05	2,256.25	107,171.875	6.8920	3.6216
47.6	149.54	1,779.52	2,265.76	107,850.176	6.8993	3.6241
47.7	149.85	1,787.01	2,275.29	108,531.333	6.9065	3.6267
47.8	150.17	1,794.51	2,284.84	109,215.352	6.9137	3.6292
47.9	150.48	1,802.03	2,294.41	109,902.239	6.9209	3.6317
48.0	150.80	1,809.56	2,304.00	110,592.000	6.9282	3.6342
48.1	151.11	1,817.11	2,313.61	111,284.641	6.9354	3.6368
48.2	151.42	1,824.67	2,323.24	111,980.168	6.9426	3.6393
48.3	151.74	1,832.25	2,332.89	112,678.587	6.9498	3.6418
48.4	152.05	1,839.84	2,342.56	113,379.904	6.9570	3.6443
48.5	152.37	1,847.45	2,352.25	114,084.125	6.9642	3.6468
48.6	152.68	1,855.08	2,361.96	114,791.256	6.9714	3.6493
48.7	153.00	1,862.72	2,371.69	115,501.303	6.9785	3.6518
48.8	153.31	1,870.38	2,381.44	116,214.272	6.9857	3.6543
48.9	153.62	1,878.05	2,391.21	116,930.169	6.9928	3.6568

CIRCUMFERENCE AND AREA OF CIRCLES, SQUARES, CUBES, SQUARE AND CUBE ROOTS—(*Continued*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
49.0	153.94	1,885.74	2,401.00	117,649.000	7.0000	3.6593
49.1	154.25	1,893.45	2,410.81	118,370.771	7.0071	3.6618
49.2	154.57	1,901.17	2,420.64	119,095.488	7.0143	3.6643
49.3	154.88	1,908.90	2,430.49	119,823.157	7.0214	3.6668
49.4	155.19	1,916.65	2,440.36	120,553.784	7.0285	3.6692
49.5	155.51	1,924.42	2,450.25	121,287.375	7.0356	3.6717
49.6	155.82	1,932.21	2,460.16	122,023.936	7.0427	3.6742
49.7	156.14	1,940.00	2,470.09	122,763.473	7.0498	3.6767
49.8	156.45	1,947.82	2,480.04	123,505.992	7.0569	3.6791
49.9	156.77	1,955.65	2,490.01	124,251.499	7.0640	3.6816
50.0	157.08	1,963.50	2,500.00	125,000.000	7.0711	3.6840
51.0	160.22	2,042.82	2,601.00	132,651.000	7.1414	3.7084
52.0	163.36	2,123.72	2,704.00	140,608.000	7.2111	3.7325
53.0	166.50	2,206.19	2,809.00	148,877.000	7.2801	3.7563
54.0	169.64	2,290.22	2,916.00	157,464.000	7.3485	3.7798
55.0	172.78	2,375.83	3,025.00	166,375.000	7.4162	3.8030
56.0	175.93	2,463.01	3,136.00	175,616.000	7.4833	3.8259
57.0	179.07	2,551.76	3,249.00	185,193.000	7.5498	3.8485
58.0	182.21	2,642.08	3,364.00	195,112.000	7.6158	3.8709
59.0	185.35	2,733.97	3,481.00	205,379.000	7.6811	3.8930
60.0	188.49	2,827.44	3,600.00	216,000.000	7.7460	3.9149
61.0	191.63	2,922.47	3,721.00	226,981.000	7.8102	3.9365
62.0	194.77	3,019.07	3,844.00	238,328.000	7.8740	3.9579
63.0	197.92	3,117.25	3,969.00	250,047.000	7.9373	3.9791
64.0	201.06	3,216.99	4,096.00	262,144.000	8.0000	4.0000
65.0	204.20	3,318.31	4,225.00	274,625.000	8.0623	4.0207
66.0	207.34	3,421.20	4,356.00	287,496.000	8.1240	4.0412
67.0	210.48	3,525.66	4,489.00	300,763.000	8.1854	4.0615
68.0	213.63	3,631.69	4,624.00	314,432.000	8.2462	4.0817
69.0	216.77	3,739.29	4,761.00	328,509.000	8.3066	4.1016

Circumference and Area of Circles, Squares, Cubes, Square and Cube Roots—(*Concluded*)

n	πn ○	$\pi \frac{n^2}{4}$ ●	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
70.0	219.91	3,848.46	4,900.00	343,000.000	8.3666	4.1213
71.0	223.05	3,959.20	5,041.00	357,911.000	8.4261	4.1408
72.0	226.19	4,071.51	5,184.00	373,248.000	8.4853	4.1602
73.0	229.33	4,185.39	5,329.00	389,017.000	8.5440	4.1793
74.0	232.47	4,300.85	5,476.00	405,224.000	8.6023	4.1983
75.0	235.62	4,417.87	5,625.00	421,875.000	8.6603	4.2172
76.0	238.76	4,536.47	5,776.00	438,976.000	8.7178	4.2358
77.0	241.90	4,656.63	5,929.00	456,533.000	8.7750	4.2543
78.0	245.04	4,778.37	6,084.00	474,552.000	8.8318	4.2727
79.0	248.18	4,901.68	6,241.00	493,039.000	8.8882	4.2908
80.0	251.32	5,026.56	6,400.00	512,000.000	8.9443	4.3089
81.0	254.47	5,153.01	6,561.00	531,441.000	9.0000	4.3267
82.0	257.61	5,281.03	6,724.00	551,368.000	9.0554	4.3445
83.0	260.75	5,410.62	6,889.00	571,787.000	9.1104	4.3621
84.0	263.89	5,541.78	7,056.00	592,704.000	9.1652	4.3795
85.0	267.03	5,674.50	7,225.00	614,125.000	9.2195	4.3968
86.0	270.17	5,808.81	7,396.00	636,056.000	9.2736	4.4140
87.0	273.32	5,944.69	7,569.00	658,503.000	9.3274	4.4310
88.0	276.46	6,082.13	7,744.00	681,472.000	9.3808	4.4480
89.0	279.60	6,221.13	7,921.00	704,969.000	9.4330	4.4647
90.0	282.74	6,361.74	8,100.00	729,000.000	9.4868	4.4814
91.0	285.88	6,503.89	8,281.00	753,571.000	9.5394	4.4979
92.0	289.02	6,647.62	8,464.00	778,688.000	9.5917	4.5144
93.0	292.17	6,792.92	8,649.00	804,357.000	9.6437	4.5307
94.0	295.31	6,939.78	8,836.00	830,584.000	9.6954	4.5468
95.0	298.45	7,088.23	9,025.00	857,375.000	9.7468	4.5629
96.0	301.59	7,238.24	9,216.00	884,736.000	9.7980	4.5789
97.0	304.73	7,389.83	9,409.00	912,673.000	9.8489	4.5947
98.0	307.87	7,542.98	9,604.00	941,192.000	9.8995	4.6104
99.0	311.02	7,697.68	9,801.00	970,299.000	9.9499	4.6261
100.0	314.16	7,854.00	10,000.00	1,000,000.000	10.0000	4.6416

DECIMALS OF A FOOT FOR EACH 1/64 IN.

Inch	0 in.	1 in.	2 in.	3 in.	4 in.	5 in.
0	0	.0833	.1667	.2500	.3333	.4167
1/64	.0013	.0846	.1680	.2513	.3346	.4180
1/32	.0026	.0859	.1693	.2526	.3359	.4193
3/64	.0039	.0872	.1706	.2539	.3372	.4206
1/16	.0052	.0885	.1719	.2552	.3385	.4219
5/64	.0065	.0898	.1732	.2565	.3398	.4232
3/32	.0078	.0911	.1745	.2578	.3411	.4245
7/64	.0091	.0924	.1758	.2591	.3424	.4258
1/8	.0104	.0937	.1771	.2604	.3437	.4271
9/64	.0117	.0951	.1784	.2617	.3451	.4284
5/32	.0130	.0964	.1797	.2630	.3464	.4297
11/64	.0143	.0977	.1810	.2643	.3477	.4310
3/16	.0156	.0990	.1823	.2656	.3490	.4323
13/64	.0169	.1003	.1836	.2669	.3503	.4336
7/32	.0182	.1016	.1849	.2682	.3516	.4349
15/64	.0195	.1029	.1862	.2695	.3529	.4362
1/4	.0208	.1042	.1875	.2708	.3542	.4375
17/64	.0221	.1055	.1888	.2721	.3555	.4388
9/32	.0234	.1068	.1901	.2734	.3568	.4401
19/64	.0247	.1081	.1914	.2747	.3581	.4414
5/16	.0260	.1094	.1927	.2760	.3594	.4427
21/64	.0273	.1107	.1940	.2773	.3607	.4440
11/32	.0286	.1120	.1953	.2786	.3620	.4453
23/64	.0299	.1133	.1966	.2799	.3633	.4466
3/8	.0312	.1146	.1979	.2812	.3646	.4479
25/64	.0326	.1159	.1992	.2826	.3659	.4492
13/32	.0339	.1172	.2005	.2839	.3672	.4505
27/64	.0352	.1185	.2018	.2852	.3685	.4518
7/16	.0365	.1198	.2031	.2865	.3698	.4531
29/64	.0378	.1211	.2044	.2878	.3711	.4544
15/32	.0391	.1224	.2057	.2891	.3724	.4557
31/64	.0404	.1237	.2070	.2904	.3737	.4570
1/2	.0417	.1250	.2083	.2917	.3750	.4583

Decimals of a Foot for Each 1/64 In.—(*Continued*)

Inch	6 in.	7 in.	8 in.	9 in.	10 in.	11 in.
0	.5000	.5833	.6667	.7500	.8333	.9167
1/64	.5013	.5846	.6680	.7513	.8346	.9180
1/32	.5026	.5859	.6693	.7526	.8359	.9193
3/64	.5039	.5872	.6706	.7539	.8372	.9206
1/16	.5052	.5885	.6719	.7552	.8385	.9219
5/64	.5065	.5898	.6732	.7565	.8398	.9232
3/32	.5078	.5911	.6745	.7578	.8411	.9245
7/64	.5091	.5924	.6758	.7591	.8424	.9258
1/8	.5104	.5937	.6771	.7604	.8437	.9271
9/64	.5117	.5951	.6784	.7617	.8451	.9284
5/32	.5130	.5964	.6797	.7630	.8464	.9297
11/64	.5143	.5977	.6810	.7643	.8477	.9310
3/16	.5156	.5990	.6823	.7656	.8490	.9323
13/64	.5169	.6003	.6836	.7669	.8503	.9336
7/32	.5182	.6016	.6849	.7682	.8516	.9349
15/64	.5195	.6029	.6862	.7695	.8529	.9362
1/4	.5208	.6042	.6875	.7708	.8542	.9375
17/64	.5221	.6055	.6888	.7721	.8555	.9388
/32	.5234	.6068	.6901	.7734	.8568	.9401
19/64	.5247	.6081	.6914	.7747	.8581	.9414
5/16	.5260	.6094	.6927	.7760	.8594	.9427
21/64	.5273	.6107	.6940	.7773	.8607	.9440
11/32	.5286	.6120	.6953	.7786	.8620	.9453
23/64	.5299	.6133	.6966	.7799	.8633	.9466
3/8	.5312	.6146	.6979	.7812	.8646	.9479
25/64	.5326	.6159	.6992	.7826	.8659	.9492
13/32	.5339	.6172	.7005	.7839	.8672	.9505
27/64	.5352	.6185	.7018	.7852	.8685	.9518
7/16	.5365	.6198	.7031	.7865	.8698	.9531
29/64	.5378	.6211	.7044	.7878	.8711	.9544
15/32	.5391	.6224	.7057	.7891	.8724	.9557
31/64	.5404	.6237	.7070	.7904	.8737	.9570
1/2	.5417	.6250	.7083	.7917	.8750	.9583

Decimals of a Foot for Each 1/64 In.—(*Continued*)

Inch	0 in.	1 in.	2 in.	3 in.	4 in.	5 in.
33/64	.0430	.1263	.2096	.2930	.3763	.4596
17/32	.0443	.1276	.2109	.2943	.3776	.4609
35/64	.0456	.1289	.2122	.2956	.3789	.4622
9/16	.0469	.1302	.2135	.2969	.3802	.4635
37/64	.0482	.1315	.2148	.2982	.3815	.4648
19/32	.0495	.1328	.2161	.2995	.3828	.4661
39/64	.0508	.1341	.2174	.3008	.3841	.4674
5/8	.0521	.1354	.2188	.3021	.3854	.4688
41/64	.0534	.1367	.2201	.3034	.3867	.4701
21/32	.0547	.1380	.2214	.3047	.3880	.4714
43/64	.0560	.1393	.2227	.3060	.3893	.4727
11/16	.0573	.1406	.2240	.3073	.3906	.4740
45/64	.0586	.1419	.2253	.3086	.3919	.4753
23/32	.0599	.1432	.2266	.3099	.3932	.4766
47/64	.0612	.1445	.2279	.3112	.3945	.4779
3/4	.0625	.1458	.2292	.3125	.3958	.4792
49/64	.0638	.1471	.2305	.3138	.3971	.4805
25/32	.0651	.1484	.2318	.3151	.3984	.4818
51/64	.0664	.1497	.2331	.3164	.3997	.4831
13/16	.0677	.1510	.2344	.3177	.4010	.4844
53/64	.0690	.1523	.2357	.3190	.4023	.4857
27/32	.0703	.1536	.2370	.3203	.4036	.4870
55/64	.0716	.1549	.2383	.3216	.4049	.4883
7/8	.0729	.1562	.2396	.3229	.4062	.4896
57/64	.0742	.1576	.2409	.3242	.4076	.4909
29/32	.0755	.1589	.2422	.3255	.4089	.4922
59/64	.0768	.1602	.2435	.3268	.4102	.4935
15/16	.0781	.1615	.2448	.3281	.4115	.4948
61/64	.0794	.1628	.2461	.3294	.4128	.4961
31/32	.0807	.1641	.2474	.3307	.4141	.4974
63/64	.0820	.1654	.2487	.3320	.4154	.4987
1						

DECIMALS OF A FOOT FOR EACH 1/64 IN.—(*Concluded*)

Inch	6 in.	7 in.	8 in.	9 in.	10 in.	11 in.
33/64	.5430	.6263	.7096	.7930	.8763	.9596
17/32	.5443	.6276	.7109	.7943	.8776	.9609
35/64	.5456	.6289	.7122	.7956	.8789	.9622
9/16	.5469	.6302	.7135	.7969	.8802	.9635
37/64	.5482	.6315	.7148	.7982	.8815	.9648
19/32	.5495	.6328	.7161	.7995	.8828	.9661
39/64	.5508	.6341	.7174	.8008	.8841	.9674
5/8	.5521	.6354	.7188	.8021	.8854	.9688
41/64	.5534	.6367	.7201	.8034	.8867	.9701
21/32	.5547	.6380	.7214	.8047	.8880	.9714
43/64	.5560	.6393	.7227	.8060	.8893	.9727
11/16	.5573	.6406	.7240	.8073	.8906	.9740
45/64	.5586	.6419	.7253	.8086	.8919	.9753
23/32	.5599	.6432	.7266	.8099	.8932	.9766
47/64	.5612	.6445	.7279	.8112	.8945	.9779
3/4	.5625	.6458	.7292	.8125	.8958	.9792
49/64	.5638	.6471	.7305	.8138	.8971	.9805
25/32	.5651	.6484	.7318	.8151	.8984	.9818
51/64	.5664	.6497	.7331	.8164	.8997	.9831
13/16	.5677	.6510	.7344	.8177	.9010	.9844
53/64	.5690	.6523	.7357	.8190	.9023	.9857
27/32	.5703	.6536	.7370	.8203	.9036	.9870
55/64	.5716	.6549	.7383	.8216	.9049	.9883
7/8	.5729	.6562	.7396	.8229	.9062	.9896
57/64	.5742	.6576	.7409	.8242	.9076	.9909
29/32	.5755	.6589	.7422	.8255	.9089	.9922
59/64	.5768	.6602	.7435	.8268	.9102	.9935
15/16	.5781	.6615	.7448	.8281	.9115	.9948
61/64	.5794	.6628	.7461	.8294	.9128	.9961
31/32	.5807	.6641	.7474	.8307	.9141	.9974
63/64	.5820	.6654	.7487	.8320	.9154	.9987
1						1.0000

Decimals of an Inch for Each 1/64th

1/32ds	1/64ths	Decimal	Fraction	1/32ds	1/64ths	Decimal	Fraction
	1	.015625			33	.515625	
1	2	.03125		17	34	.53125	
	3	.046875			35	.546875	
2	4	.0625	1–16	18	36	.5625	9–16
	5	.078125			37	.578125	
3	6	.09375		19	38	.59375	
	7	.109375			39	.609375	
4	8	.125	1–8	20	40	.625	5–8
	9	.140625			41	.640625	
5	10	.15625		21	42	.65625	
	11	.171875			43	.671875	
6	12	.1875	3–16	22	44	.6875	11–16
	13	.203125			45	.703125	
7	14	.21875		23	46	.71875	
	15	.234375			47	.734375	
8	16	.25	1–4	24	48	.75	3–4
	17	.265625			49	.765625	
9	18	.28125		25	50	.78125	
	19	.296875			51	.796875	
10	20	.3125	5–16	26	52	.8125	13–16
	21	.328125			53	.828125	
11	22	.34375		27	54	.84375	
	23	.359375			55	.859375	
12	24	.375	3–8	28	56	.875	7–8
	25	.390625			57	.890625	
13	26	.40625		29	58	.90625	
	27	.421875			59	.921875	
14	28	.4375	7–16	30	60	.9375	15–16
	29	.453125			61	.953125	
15	30	.46875		31	62	.96875	
	31	.484375			63	.984375	
16	32	.5	1–2	32	64	1.0	1

BELTING RULES

To Find Speed of Belt.—Multiply the circumference of either pulley in inches by the number of its revolutions per minute.

Divide by 12 and the result is the speed of the belt in feet per minute.

To Find Length of Belt.—Multiply the distance between the shaft centers by 2 and add to the result one-half the sum of the circumferences of the two pulleys.

To Find Diameter of Pulley Necessary to Make Any Required Number of Revolutions.—Multiply the diameter of the pulley, the speed of which is known, by its revolutions, and divide by the number of revolutions at which the other pulley is required to run.

To Find Diameter of Driving Pulley.—Multiply diameter of driven pulley by its revolutions and divide the product by the revolution of the driving pulley.

To Find Revolution of Driving Pulley.—Multiply diameter of driven pulley by its revolution and divide the product by the diameter of the driving pulley.

To Find the Approximate Length of Belting in a Roll.—Add together the diameter of the roll and the hole in the center, in inches. Multiply by the number of coils in the roll, and then multiply by 0.131. The result will be the approximate number of feet of belting in the roll.

ANTI-FREEZING LIQUIDS FOR PRESSURE AND SUCTION GAGES

33°Bé. sulphuric acid is a very good anti-freezing liquid to use in permanent pressure and suction gages. This acid has a specific gravity of 1.295 and a freezing point of −97°F. If a gage is to be made with two separate glass tubes, construct as follows: Bend the tubes on the bottom at right angles so they meet—join with rubber tubing and wire fast—then wrap with ordinary electrician's friction tape. In this way a connection is made that resists weather and the acid will have but little action on the rubber. To obtain water readings from the acid readings it is, of course, necessary to multiply by 1.295.

For gages where high suction and pressures are to be read, mercury with a specific gravity of 13.595 and a freezing point of −39.1°F. is very satisfactory.

Anti-freezing Solutions for Suction and Pressure Gages. Readings in Inches Converted into Approximate Inches of Water

33°Bé. sulphuric acid = 1.295 specific gravity = −97°F. freezing point

Acid	Water	Acid	Water	Acid	Water	Acid	Water	Acid	Water
1	1 1/2	7 1/2	9 1/2	14	18	20 1/2	26 1/2	27	35
1 1/2	2	8	10 1/2	14 1/2	19	21	27	27 1/2	35 1/2
2	2 1/2	8 1/2	11	15	19 1/2	21 1/2	28	28	36 1/2
2 1/2	3	9	11 1/2	15 1/2	20	22	28 1/2	28 1/2	37
3	4	9 1/2	12 1/2	16	20 1/2	22 1/2	29	29	37 1/2
3 1/2	4 1/2	10	13	16 1/2	21 1/2	23	30	29 1/2	38
4	5	10 1/2	13 1/2	17	22	23 1/2	30 1/2	30	39
4 1/2	6	11	14	17 1/2	22 1/2	24	31	30 1/2	39 1/2
5	6 1/2	11 1/2	15	18	23 1/2	24 1/2	31 1/2	31	40
5 1/2	7	12	15 1/2	18 1/2	24	25	32 1/2	31 1/2	41
6	8	12 1/2	16	19	24 1/2	25 1/2	33	32	41 1/2
6 1/2	8 1/2	13	17	19 1/2	25 1/2	26	33 1/2	32 1/2	42
7	9	13 1/2	17 1/2	20	26	26 1/2	34 1/2	33	42 1/2

Mercury = 13.595 specific gravity = −39.1°F. freezing point

Hg	H_2O	Hg	H_2O	Hg	H_2O	Hg	H_2O	Hg	H_2O
1/16	1	7/8	12	1 11/16	23	2 1/2	34	3 5/16	45
1/8	1 1/2	15/16	12 1/2	1 3/4	24	2 9/16	35	3 3/8	46
3/16	2 1/2	1	13 1/2	1 13/16	24 1/2	2 5/8	35 1/2	3 7/16	47
1/4	3 1/2	1 1/16	14 1/2	1 7/8	25 1/2	2 11/16	36 1/2	3 1/2	47 1/2
5/16	4 1/2	1 1/8	15 1/2	1 15/16	26 1/2	2 3/4	37 1/2	3 9/16	48 1/2
3/8	5	1 3/16	16	2	27	2 13/16	38	3 5/8	49 1/2
7/16	6	1 1/4	17	2 1/16	28	2 7/8	39	3 11/16	50
1/2	7	1 5/16	18	2 1/8	29	2 15/16	40	3 3/4	51
9/16	7 1/2	1 3/8	18 1/2	2 3/16	29 1/2	3	41	3 13/16	52
5/8	8 1/2	1 7/16	19 1/2	2 1/4	30 1/2	3 1/16	41 1/2	3 7/8	52 1/2
11/16	9 1/2	1 1/2	20 1/2	2 5/16	31 1/2	3 1/8	42 1/2	3 15/16	53 1/2
3/4	10	1 9/16	21 1/2	2 3/8	32 1/2	3 3/16	43 1/2	4	54 1/2
13/16	11	1 5/8	22	2 7/16	33	3 1/4	44	4 1/16	55

FLANGES AND FLANGED FITTINGS

Much confusion has resulted in the past, due to the various standards for flange dimensions and bolting adopted by manufacturers and engineering societies. In 1912, the American Society of Mechanical Engineers and the Master Steam and Hot Water Fitters' Association adopted what is known as "The 1912 U. S. Standard," and in the same year, at a meeting of manufacturers in New York City, the "Manufacturer's Standard" was promulgated. The disadvantages of having two standards in existence were immediately recognized, and committees of the A. S. M. E. and the manufacturers united in a compromise known as the "American Standard," to be effective after Jan. 1, 1914.

Notes on the American Standard.—The following notes apply to the American Standard for flanges and flanged fittings:

(*a*) Standard and extra heavy reducing elbows carry the same dimensions center-to-face as regular elbows of largest straight size.

Standard and extra heavy tees, crosses and laterals, reducing on run only, carry same dimensions face-to-face as largest straight size.

Flanged fittings for lower working pressures than 125 lb. conform to this standard in all dimensions except thickness of shell.

Where long-radius fittings are specified, reference is had only to elbows made in two center-to-face dimensions and known as elbows and long-radius elbows, the latter being used only when so specified.

Standard weight fittings are guaranteed for 125 lb. working pressure and extra heavy fittings for 250 lb.

Extra heavy fittings and flanges have a raised surface 1/16 in. high inside of bolt holes for gaskets. Standard weight fittings and flanges are plain-faced. Bolt holes are 1/8 in. larger in diameter than bolts, and straddle the center line.

The size of all fittings scheduled indicates the inside diameter of ports.

The face-to-face dimension of reducers, either straight or eccentric, for all pressures, is the same as that given in table of dimensions.

Square-head bolts with hexagonal nuts are recommended. For 1 5/8-in. and larger bolts, studs with a nut on each end are satisfactory. Hexagonal nuts for pipe sizes up to 46 in. on the 125-lb. standard, and up to 16 in. on the 250-lb. standard can be conveniently pulled up with open wrenches of minimum design of heads. For larger pipe sizes (up to 100 in. on 125-lb., and to 48 in. on 250-lb. standard) use box wrenches.

Twin elbows, whether straight or reducing, carry same dimensions center-to-face and face-to-face as regular straight-size ells and tees.

Side outlet elbows and side outlet tees, whether straight or reducing sizes, carry same dimensions center-to-face and face-to-face as regular tees having same reductions.

(*b*) Bull-head tees, or tees increasing on outlet, have same center-to-face and face-to-face dimensions as a straight fitting of the size of the outlet.

Tees, crosses and laterals 16 in. and smaller, reducing on the outlet use the same dimensions as straight sizes of the larger port. Sizes 18 in. and larger, reducing on the outlet or branch, are made in two lengths, depending on sizes of outlet or branch as given in dimension table.

(*c*) The dimensions of reducing flanged fittings are always regulated by the reductions of the outlet or branch.

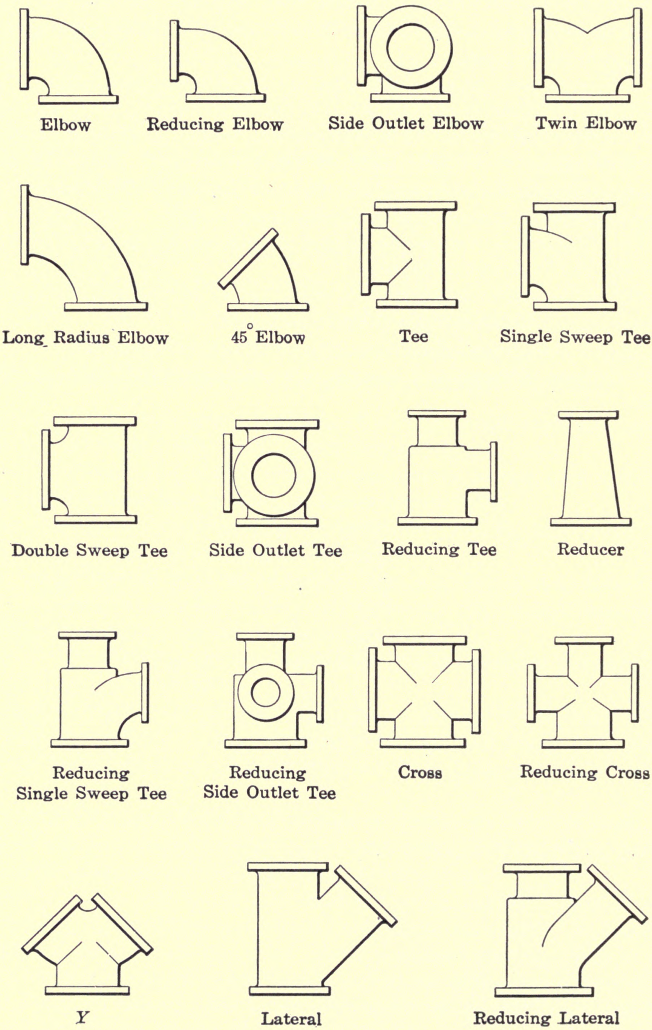
(*d*) For fittings reducing on the run only, always use the long-body pattern.

Y's are special and are made to suit conditions.

(*e*) Double-sweep tees are not made reducing on the run.

Steel flanges, fittings and valves are recommended for superheated steam.

AMERICAN STANDARD
Names of Fittings



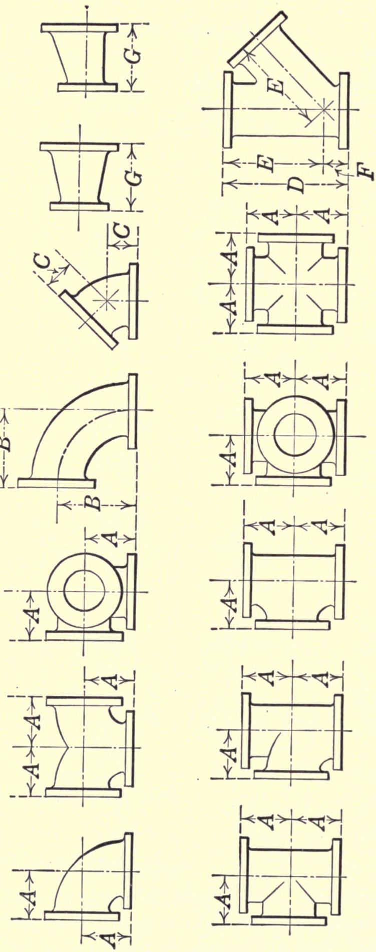
TEMPLATES FOR DRILLING STANDARD AND LOW-PRESSURE FLANGED VALVES AND FITTINGS[1]

American Standard

Size, inches	Diameter of flanges, inches	Thickness of flanges, inches	Bolt circle diameter, inches	Number of bolts	Size of bolts, inches
1	4	7/16	3	4	7/16
1 1/4	4 1/2	1/2	3 3/8	4	7/16
1 1/2	5	9/16	3 7/8	4	1/2
2	6	5/8	4 3/4	4	5/8
2 1/2	7	11/16	5 1/2	4	5/8
3	7 1/2	3/4	6	4	5/8
3 1/2	8 1/2	13/16	7	4	5/8
4	9	15/16	7 1/2	8	5/8
4 1/2	9 1/4	15/16	7 3/4	8	3/4
5	10	15/16	8 1/2	8	3/4
6	11	1	9 1/2	8	3/4
7	12 1/2	1 1/16	10 3/4	8	3/4
8	13 1/2	1 1/8	11 3/4	8	3/4
9	15	1 1/8	13 1/4	12	3/4
10	16	1 3/16	14 1/4	12	7/8
12	19	1 1/4	17	12	7/8
14	21	1 3/8	18 3/4	12	1
15	22 1/4	1 3/8	20	16	1
16	23 1/2	1 7/16	21 1/4	16	1
18	25	1 9/16	22 3/4	16	1 1/8
20	27 1/2	1 11/16	25	20	1 1/8
22	29 1/2	1 13/16	27 1/4	20	1 1/4
24	32	1 7/8	29 1/2	20	1 1/4
26	34 1/4	2	31 3/4	24	1 1/4
28	36 1/2	2 1/16	34	28	1 1/4
30	38 3/4	2 1/8	36	28	1 3/8

[1] These templates are in multiples of four, so that fittings may be made to face in any quarter and bolt holes straddle the center line. Bolt holes are drilled 1/8 in. larger than the nominal diameter of bolts.

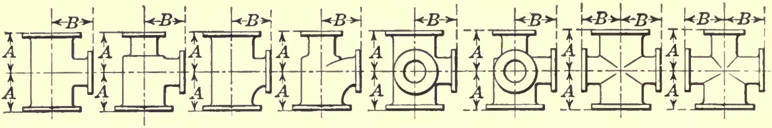
General Dimensions of Standard Flanged Fittings—Straight Sizes
American Standard



Size, inches	Face-to-face tees and crosses *A–A*	Center-to-face ells, tees and crosses *A*	Center-to-face long-radius ells *B*	Center-to-face 45-degree ells *C*	Face-to-face laterals *D*	Center-to-face laterals *E*	Center-to-face laterals *F*	Face-to-face reducers *G*	Diameter of flanges	Thickness of flanges	Minimum metal thickness of body
1	7	3½	5	1¾	7½	5¾	1¾	.....	4	7/16	7/16
1¼	7½	3¾	5½	2	8	6¼	1¾	.....	4½	½	7/16
1½	8	4	6	2¼	9	7	2	.....	5	9/16	7/16
2	9	4½	6½	2½	10½	8	2½	.....	6	5/8	7/16
2½	10	5	7	3	12	9½	2½	.....	7	11/16	7/16
3	11	5½	7¾	3	13	10	3	6	7½	¾	7/16
3½	12	6	8½	3½	14½	11½	3	6½	8½	13/16	7/16
4	13	6½	9	4	15	12	3	7	9	15/16	½
4½	14	7	9½	4	15½	12½	3	7½	9¼	15/16	½
5	15	7½	10¼	4½	17	13½	3½	8	10	15/16	½
6	16	8	11½	5	18	14½	3½	9	11	1	9/16
7	17	8½	12¾	5½	20½	16½	4	10	12½	1 1/16	5/8
8	18	9	14	5½	22	17½	4½	11	13½	1⅛	5/8
9	20	10	15¼	6	24	19½	4½	11½	15	1⅛	11/16
10	22	11	16½	6½	25½	20½	5	12	16	1 3/16	¾
12	24	12	19	7½	30	24½	5½	14	19	1¼	13/16
14	28	14	21½	7½	33	27	6	16	21	1⅜	⅞
15	29	14½	22¾	8	34½	28½	6	17	22¼	1⅜	⅞
16	30	15	24	8	36½	30	6½	18	23½	1 7/16	1
18	33	16½	26½	8½	39	32	7	19	25	1 9/16	1 1/16
20	36	18	29	9½	43	35	8	20	27½	1 11/16	1⅛
22	40	20	31½	10	46	37½	8½	22	29½	1 13/16	1 3/16
24	44	22	34	11	49½	40½	9	24	32	1⅞	1¼
26	46	23	36½	13	53	44	9	26	34¼	2	1 5/16
28	48	24	39	14	56	46½	9½	28	36½	2 1/16	1⅜
30	50	25	41½	15	59	49	10	30	38¾	2⅛	1 7/16

General Dimensions of Standard Reducing Tees and Crosses (Short-body Pattern)

American Standard



Size, inches	Size of outlets and smaller[1]	Center-to-face run, *A*	Center-to-face outlet, *B*
1 to 16	All reducing fittings from 1 to 16 in. inclusive have the same center-to-face dimensions as straight-size fittings		
18	12	13	15½
20	14	14	17
22	15	14	18
24	16	15	19
26	18	16	20
28	18	16	21
30	20	18	23

Long-body patterns are used when outlets are larger than given in the above table, therefore have same dimensions as straight-size fittings. The dimensions of "reducing flanged fittings" are always regulated by the reduction of the outlet.

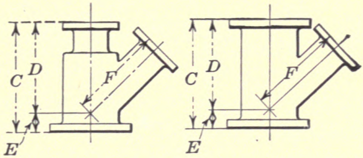
Fittings reducing on the run only, the long-body pattern will always be used, except double-sweep tees, on which the reduced end is always longer than the regular fittings.

Bull heads or tees having outlets larger than the run will be the same length center-to-face of all openings as a tee with all openings of the size of the outlet. For example, a 12 by 12 by 18-in. tee will be governed by the dimensions of the 18-in. long-body tee, namely, 16½ in. center-to-face of all openings and 33 in. face-to-face.

Reducing elbows carry same center-to-face dimension as regular elbows of largest straight size.

GENERAL DIMENSIONS OF STANDARD REDUCING LATERALS (SHORT-BODY PATTERN)

American Standard

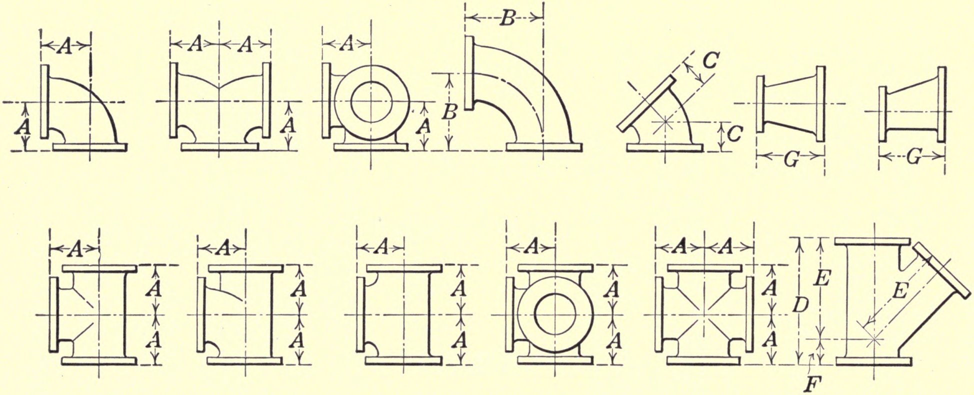


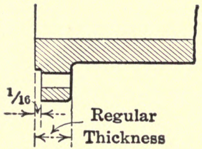
Size, inches	Size of branches and smaller[1]	Face-to-face run, *C*	Center-to-face run, *D*	Center-to-face run, *E*	Center-to-face branch, *F*
1 to 16	All reducing fittings 1 to 16 in. inclusive have the same center-to-face dimensions as straight-size fittings				
18	9	26	25	1	27½
20	10	28	27	1	29½
22	10	29	28½	½	31½
24	12	32	31½	½	34½
26	12	35	35	0	38
28	14	37	37	0	40
30	15	39	39	0	42

[1] **Long-body patterns** are used when branches are larger than given in the above table, therefore have same dimensions as straight-size fittings.

The dimensions of "reducing flanged fittings" are always regulated by the reduction of the branch; fittings reducing on the run only, the long-body pattern will always be used.

General Dimensions of Extra Heavy Flanged Fittings—Straight Sizes
American Standard



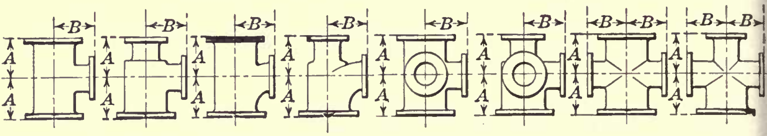


Note:- All extra heavy flanges have a 1/16″ inch Raised Face inside of bolt holes. This Raised Face is included in face to face, center to face and thickness of flange dimension.

Size, inches	Face-to-face tees and crosses *A–A*	Center-to-face ells, tees, and crosses *A*	Center-to-face long-radius ells *B*	Center-to-face 45° ells *C*	Face-to-face laterals *D*	Center-to-face laterals *E*	Center-to-face laterals *F*	Face-to-face reducers *G*	Diameter of flanges	Thickness of flanges	Minimum metal thickness of body
1	8	4	5	2	8½	6½	2	.....	4½	11/16	½
1¼	8½	4¼	5½	2½	9½	7¼	2¼	.....	5	¾	½
1½	9	4½	6	2¾	11	8½	2½	.....	6	13/16	½
2	10	5	6½	3	11½	9	2½	.....	6½	⅞	½
2½	11	5½	7	3½	13	10½	2½	.....	7½	1	9/16
3	12	6	7¾	3½	14	11	3	6	8¼	1⅛	9/16
3½	13	6½	8½	4	15½	12½	3	6½	9	1 3/16	9/16
4	14	7	9	4½	16½	13½	3	7	10	1¼	⅝
4½	15	7½	9½	4½	18	14½	3½	7½	10½	1 5/16	⅝
5	16	8	10¼	5	18½	15	3½	8	11	1⅜	11/16
6	17	8½	11½	5½	21½	17½	4	9	12½	1 7/16	¾
7	18	9	12¾	6	23½	19	4½	10	14	1½	13/16
8	20	10	14	6	25½	20½	5	11	15	1⅝	13/16
9	21	10½	15¼	6½	27½	22½	5	11½	16¼	1¾	⅞
10	23	11½	16½	7	29½	24	5½	12	17½	1⅞	15/16
12	26	13	19	8	33½	27½	6	14	20½	2	1
14	30	15	21½	8½	37½	31	6½	16	23	2⅛	1⅛
15	31	15½	22¾	9	39½	33	6½	17	24½	2 3/16	1 3/16
16	33	16½	24	9½	42	34½	7½	18	25½	2¼	1¼
18	36	18	26½	10	45½	37½	8	19	28	2⅜	1⅜
20	39	19½	29	10½	49	40½	8½	20	30½	2½	1½
22	41	20½	31½	11	53	43½	9½	22	33	2⅝	1 9/16
24	45	22½	34	12	57½	47½	10	24	36	2¾	1⅝
26	48	24	36½	13	....	....	....	26	38¼	2 13/16	1 13/16
28	52	26	39	14	....	....	....	28	40¾	2 15/16	1⅞
30	55	27½	41½	15	....	....	....	30	43	3	2

General Dimensions of Extra Heavy Reducing Tees and Crosses (Short-body Pattern)

American Standard



Size, inches	Size of outlets and smaller[1]	Face-to-face run, *AA*	Center-to-face run, *A*	Center-to-face outlet, *B*
1 to 16	All reducing fittings 1 to 16 in. inclusive have the same center-to-face dimensions as straight-size fittings			
18	12	28	14	17
20	14	31	15½	18½
22	15	33	16½	20
24	16	34	17	21½
26	18	38	19	23
28	18	38	19	24
30	20	41	20½	25½

[1] **Long-body patterns** are used when outlets are larger than given in the above table, therefore have same dimensions as straight-size fittings. The dimensions of "reducing flanged fittings" are always regulated by the reduction of the outlet.

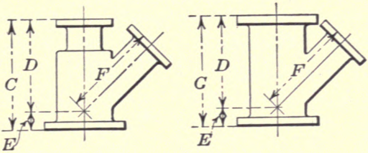
Fittings reducing on the run only, the long-body pattern will always be used, except double-sweep tees, on which the reduced end is always longer than the regular fitting.

Bull heads or tees having outlets larger than the run will be the same length center-to-face of all openings as a tee with all openings of the size of the outlet. For example, a 12 by 12 by 18-in. tee will be governed by the dimensions of the 18-in. long-body tee, namely, 18 in. center-to-face of all openings and 36 in. face-to-face.

Reducing elbows carry same center-to-face dimension as regular elbows of largest straight size.

General Dimensions of Extra Heavy Reducing Laterals (Short-body Pattern)

American Standard



Size, inches	Size of branches and smaller[1]	Face-to-face run, *C*	Center-to-face run, *D*	Center-to-face run, *E*	Center-to-face branch, *F*
1 to 16	All reducing fittings 1 to 16 in. inclusive have the same center-to-face dimensions as straight-size fittings				
18	9	34	31	3	32½
20	10	37	34	3	36
22	10	40	37	3	39
24	12	44	41	3	43

[1] **Long-body patterns** are used when branches are larger than given in the above table, therefore, have same dimensions as straight-size fittings.

The dimensions of "reducing flanged fittings" are always regulated by the reduction of the branch; fittings reducing on the run only, the long-body pattern will always be used.

Templates for Drilling Extra Heavy Flanged Valves and Fittings[1]
American Standard

Size, inches	Diameter of flanges, inches	Thickness of flanges, inches	Bolt circle diameter, inches	Number of bolts	Size of bolts
1	4½	1 1/16	3¼	4	½
1¼	5	¾	3¾	4	½
1½	6	13/16	4½	4	⅝
2	6½	⅞	5	4	⅝
2½	7½	1	5⅞	4	¾
3	8¼	1⅛	6⅝	8	¾
3½	9	1 3/16	7¼	8	¾
4	10	1¼	7⅞	8	¾
4½	10½	1 5/16	8½	8	¾
5	11	1⅜	9¼	8	¾
6	12½	1 7/16	10⅝	12	¾
7	14	1½	11⅞	12	⅞
8	15	1⅝	13	12	⅞
9	16¼	1¾	14	12	1
10	17½	1⅞	15¼	16	1
12	20½	2	17¾	16	1⅛
14	23	2⅛	20¼	20	1⅛
15	24½	2 3/16	21½	20	1¼
16	25½	2¼	22½	20	1¼
18	28	2⅜	24¾	24	1¼
20	30½	2½	27	24	1⅜
22	33	2⅝	29¼	24	1½
24	36	2¾	32	24	1⅝
26	38¼	2 13/16	34½	28	1⅝
28	40¾	2 15/16	37	28	1⅝
30	43	3	39¼	28	1¾

[1] These templates are in multiples of four, so that fittings may be made to face in any quarter and bolt holes straddle the center line. Bolt holes are drilled ⅛ in. larger than nominal diameter of bolts.

WEIGHTS OF CAST-IRON FLANGED FITTINGS

(American Standard Dimensions)

Size, inches	Approximate weight per piece, pounds							
	Standard (125 lb.)				Extra heavy (250 lb.)			
	Ell	45° Ell	Tee	Cross	Ell	45° Ell	Tee	Cross
2	18	15	26	34	23	20	38	80
2½	22	20	34	43	34	29	50	85
3	30	27	45	58	46	38	70	90
3½	37	33	55	74	57	44	75	115
4	45	38	67	89	67	61	100	140
4½	46	43	75	100	85	70	120	170
5	63	53	90	121	95	85	130	190
6	75	68	115	152	125	105	190	250
7	100	90	150	200	160	145	235	325
8	120	100	170	236	190	175	280	370
9	150	130	220	305	240	195	330	480
10	205	160	285	400	320	250	450	580
12	285	230	430	570	450	380	680	900
14	390	300	550	750	640	520	970	1,300
15	440	330	660	800	750	570	1,050	1,400
16	525	400	760	1,000	840	675	1,255	1,675

Nominal Weight of Cast-iron Pipe Without Flanges, Pounds per Foot[1]

Inside diameter, inches	Thickness of metal in inches								
	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼
2	5.5	8.7	12.3	16.1	20.3	24.7	29.5	34.5	40.0
2½	6.8	10.6	14.7	19.2	24.0	29.0	34.4	40.0	46.0
3	7.9	12.4	17.2	22.2	27.6	32.3	39.3	45.6	52.2
3½	9.2	14.3	19.6	25.3	31.3	37.6	44.2	51.1	58.3
4	10.4	16.1	22.1	28.4	35.0	41.9	49.1	56.6	64.4
4½	11.7	18.0	24.5	31.5	38.7	46.2	54.0	62.1	70.6
5	12.9	19.8	27.0	34.5	42.3	50.5	58.9	67.7	76.7
5½	14.1	21.6	29.5	37.6	46.0	54.8	63.8	73.2	82.8
6	15.3	23.5	31.9	40.7	49.7	59.1	68.7	78.7	89.0
7	17.8	27.2	36.8	46.8	57.1	67.7	78.5	89.7	101.0
8	20.3	30.8	41.7	52.9	64.4	76.2	88.4	101.0	114.0
9	22.7	34.5	46.6	59.1	71.8	84.8	98.2	112.0	126.0
10	25.2	38.2	51.5	65.2	79.2	93.4	108.0	123.0	138.0
11	27.6	41.9	56.5	71.3	86.5	102.0	118.0	134.0	150.0
12	30.1	46.6	61.4	77.5	93.9	111.0	128.0	145.0	163.0
13	32.5	49.2	66.3	83.6	101.0	119.0	137.0	156.0	175.0
14	35.0	52.9	71.2	89.7	109.0	128.0	147.0	167.0	187.0
15	....	56.6	76.1	95.9	116.0	136.0	157.0	178.0	199.0
16	....	60.3	81.0	102.0	123.0	145.0	167.0	189.0	212.0
18	....	67.7	90.8	114.0	138.0	162.0	187.0	211.0	236.0
20	....	....	101.0	127.0	153.0	179.0	206.0	233.0	261.0
22	....	....	110.0	139.0	168.0	197.0	226.0	255.0	285.0
24	....	....	120.0	151.0	182.0	214.0	245.0	278.0	310.0
26	....	....	130.0	163.0	197.0	231.0	265.0	299.0	334.0
28	....	....	140.0	175.0	211.0	248.0	284.0	321.0	358.0
30	....	....	149.0	188.0	226.0	265.0	304.0	343.0	383.0

[1] Approximate weight of each flanged joint = weight of 1 ft. of pipe. Values in table are theoretical, and based on cast iron weighing 450 lb. per cubic foot.

STANDARD CAST-IRON FLANGED PIPE
(Standard Dimensions)

Nominal diameter, inches	Dameter of flange, inches	Diameter of bolt circle, inches	Number of bolts	Diameter of bolts, inches	Class A 100 foot head 43 pounds pressure				Class B 200 foot head 86 pounds pressure				Class C 300 foot head 130 pounds pressure				Class D 400 foot head 173 pounds pressure			
					Thickness, inches	Weight, pounds per			Thickness, inches	Weight, pounds per			Thickness, inches	Weight, pounds per			Thickness, inches	Weight, pounds per		
						Foot	Length	Single flange		Foot	Length	Single flange		Foot	Length	Single flange		Foot	Length	Single flange
3	7.50	6.00	4	5/8	0.39	13.0	168	5.8	0.42	14.6	188	6.3	0.45	15.5	199	6.6	0.48	16.4	211	7.1
4	9.00	7.50	8	5/8	0.42	18.0	234	9.0	0.45	20.1	259	9.1	0.48	21.3	275	9.7	0.52	22.8	295	10.4
6	11.00	9.50	8	3/4	0.44	27.9	358	11.8	0.48	31.1	398	12.3	0.51	32.9	421	12.8	0.55	35.3	451	13.7
8	13.50	11.75	8	3/4	0.46	38.7	498	16.9	0.51	42.7	549	18.2	0.56	48.0	614	19.0	0.60	51.2	654	20.1
10	16.00	14.25	12	7/8	0.50	51.9	671	23.9	0.57	58.8	759	26.6	0.62	65.5	840	27.3	0.68	71.4	916	29.6
12	19.00	17.00	12	7/8	0.54	67.0	876	35.8	0.62	76.4	998	40.4	0.68	85.4	1109	42.0	0.75	93.7	1216	45.6
14	21.00	18.75	12	1	0.57	82.3	1070	41.4	0.66	94.7	231	47.3	0.74	108.1	1397	49.6	0.82	119.2	1539	54.5
16	23.50	21.25	16	1	0.60	98.8	1290	52.5	0.70	114.6	1495	60.1	0.80	133.3	1727	63.9	0.89	147.5	1910	70.2
18	25.00	22.75	16	1 1/8	0.64	118.3	1528	54.5	0.75	137.8	1779	62.5	0.87	162.4	2083	66.9	0.96	178.4	2287	73.4
20	27.50	25.00	20	1 3/8	0.67	137.4	1783	66.8	0.80	163.1	2114	78.7	0.92	190.6	2454	83.3	1.03	212.3	2731	92.1
24	32.00	29.50	20	1 1/4	0.76	186.5	2424	92.9	0.89	217.3	2821	106.8	1.04	257.6	3321	114.7	1.16	286.0	3686	126.9
30	38.75	36.00	28	1 3/8	0.88	266.1	3486	146.1	1.03	312.6	4077	162.9	1.20	366.9	4759	178.1	1.37	421.2	5436	191.0

NOTE.—Thickness of flange equals approximately 1½ times thickness of pipe plus ⅛ inch. Flanges drilled to "American 1914 Standard" template for low-pressure flanged fittings. Bolt holes drilled ⅛ inch larger than bolts. Twelve foot lengths are faced 1/16 inch short for gaskets.

Standard Cast-iron Flanged Pipe (High Pressure)
(Standard Dimensions)

Nominal diameter, inches	Diameter of flange, inches	Diameter of bolt circle, inches	Number of bolts	Diameter of bolts, inches	Class E 500 foot head 217 pounds pressure				Class F 600 foot head 260 pounds pressure				Class G 700 foot head 304 pounds pressure				Class H 800 foot head 347 pounds pressure			
					Thickness, inches	Weight, pounds per			Thickness, inches	Weight, pounds per			Thickness, inches	Weight, pounds per			Thickness, inches	Weight, pounds per		
						Foot	Length	Single flange		Foot	Length	Single flange		Foot	Length	Single flange		Foot	Length	Single flange
6	12.50	10.63	12	3/4	0.58	37.7	495	21.3	0.61	39.5	519	22.2	0.65	42.9	560	22.9	0.69	45.2	591	24.1
8	15.00	13.00	12	7/8	0.66	54.7	718	31.2	0.71	60.6	794	33.1	0.75	65.1	849	33.9	0.80	68.8	897	36.0
10	17.50	15.25	16	1	0.74	78.8	1032	43.5	0.80	84.7	1109	46.5	0.86	92.5	1207	47.9	0.92	98.5	1284	51.0
12	20.50	17.75	16	1 1/8	0.82	104.2	1378	64.0	0.89	112.4	1487	68.7	0.97	124.6	1639	71.6	1.04	132.9	1748	76.4
14	23.00	20.25	20	1 1/8	0.90	133.1	1762	82.7	0.99	146.2	1935	90.0	1.07	160.2	2108	92.8	1.16	172.6	2271	100.0
16	25.50	22.50	20	1 1/4	0.98	165.0	2192	106.0	1.08	180.8	2398	114.2	1.18	199.2	2627	118.6	1.27	215.0	2834	127.1
18	28.00	24.75	24	1 1/4	1.07	202.3	2680	126.3	1.17	219.8	2915	138.8	1.28	244.6	3230	147.1	1.39	264.1	3488	159.0
20	30.50	27.00	24	1 3/8	1.15	241.1	3200	153.4	1.27	262.5	3487	168.3	1.39	294.4	3894	180.7	1.51	318.3	4210	195.4
24	36.00	32.00	24	1 5/8	1.31	328.5	4431	244.3	1.45	361.6	4877	268.9	1.75	446.2	5413	295.0	1.88	476.9	6355	316.0
30	43.00	39.25	28	1 3/4	1.55	484.7	6534	358.5	1.73	538.0	7265	405.2								

Note.—Thickness of flange equals approximately 1½ times thickness of pipe plus ⅛ inch. Flanges drilled to "American 1914 Standard" template for extra heavy flanged fittings. Bolt holes drilled ⅛ inch larger than bolts. Twelve foot lengths are faced 1/16 inch short for gaskets.

STANDARD WROUGHT-IRON AND STEEL PIPE

(Standard Dimensions)

Diameter			Nominal thickness, inches	Circumference		Transverse areas			Length of pipe per square foot of		Length of pipe containing 1 cu. ft., foot	Nominal weight per foot, pounds	No. of threads per inch of screw
Nominal internal, inches	Actual external, inches	Approx. internal diameter, inches		External, inches	Internal, inches	External, square inches	Internal, square inches	Metal, square inches	External surface, feet	Internal surface, feet			
1/8	0.405	0.27	0.068	1.27	0.85	0.13	0.06	0.07	9.44	14.15	2,513.00	0.24	27
1/4	0.540	0.36	0.088	1.70	1.14	0.23	0.10	0.12	7.08	10.49	1,383.30	0.42	18
3/8	0.675	0.49	0.091	2.12	1.55	0.36	0.19	0.17	5.66	7.76	751.20	0.57	18
1/2	0.840	0.62	0.109	2.63	1.95	0.55	0.30	0.25	4.55	6.15	472.40	0.85	14
3/4	1.050	0.82	0.113	3.30	2.59	0.87	0.53	0.33	3.64	4.64	270.00	1.13	14
1	1.315	1.05	0.134	4.13	3.29	1.36	0.86	0.50	2.90	3.65	166.90	1.68	11½
1¼	1.660	1.38	0.140	5.22	4.34	2.16	1.50	0.67	2.30	2.77	96.25	2.27	11½
1½	1.900	1.61	0.145	5.97	5.06	2.84	2.04	0.80	2.01	2.37	70.66	2.72	11½
2	2.375	2.07	0.154	7.46	6.49	4.43	3.36	1.07	1.61	1.85	42.91	3.65	11½
2½	2.875	2.47	0.204	9.03	7.75	6.49	4.78	1.71	1.33	1.55	30.10	5.79	8
3	3.500	3.07	0.217	11.00	9.63	9.62	7.39	2.24	1.09	1.25	19.50	7.57	8
3½	4.000	3.55	0.226	12.57	11.15	12.57	9.89	2.68	0.96	1.08	14.57	9.11	8
4	4.500	4.03	0.237	14.14	12.65	15.90	12.73	3.18	0.85	0.95	11.31	10.79	8
4½	5.000	4.51	0.246	15.71	14.16	19.64	15.96	3.68	0.76	0.85	9.02	12.54	8
5	5.563	5.05	0.259	17.48	15.85	24.31	19.99	4.32	0.69	0.76	7.20	14.62	8

STANDARD WROUGHT-IRON AND STEEL PIPE—(*Concluded*)

(Standard Dimensions)

Diameter			Nominal thickness, inches	Circumference		Transverse areas			Length of pipe per square foot of		Length of pipe containing 1 cu. ft., foot	Nominal weight per foot, pounds	No. of threads per inch of screw
Nominal internal, inches	Actual external, inches	Approx. internal diameter, inches		External, inches	Internal, inches	External, square inches	Internal, square inches	Metal, square inches	External surface, feet	Internal surface, feet			
6	6.625	6.07	0.280	20.81	19.05	34.47	28.89	5.59	0.58	0.63	4.98	18.97	8
7	7.625	7.02	0.301	23.96	22.06	45.66	38.74	6.92	0.50	0.54	3.72	23.54	8
8	8.625	8.07	0.276	27.10	25.35	58.43	51.15	7.28	0.44	0.47	2.82	24.69	8
8	8.625	7.98	0.322	27.10	25.07	58.43	50.02	8.41	0.44	0.48	2.88	28.55	8
9	9.625	8.94	0.344	30.24	28.08	72.76	62.72	10.04	0.40	0.43	2.29	33.91	8
10	10.750	10.19	0.278	33.77	32.01	90.76	81.55	9.21	0.36	0.37	1.76	31.20	8
10	10.750	10.14	0.306	33.77	31.86	90.76	80.75	10.01	0.36	0.38	1.78	34.24	8
10	10.750	10.02	0.366	33.77	31.47	90.76	78.82	11.94	0.36	0.38	1.82	40.48	8
11	11.750	11.00	0.375	36.91	34.56	108.43	95.03	13.40	0.33	0.35	1.51	45.56	8
12	12.750	12.09	0.328	40.06	37.98	127.68	114.80	12.88	0.30	0.32	1.25	43.77	8
12	12.750	12.00	0.375	40.06	37.70	127.68	113.10	14.59	0.30	0.32	1.27	49.56	8

NOTE.—Sizes 8, 10 and 12 inch standard pipe are made in several weights. Sizes larger than 12 inch are governed by outside diameter and thickness of wall.

EXTRA STRONG WROUGHT-IRON AND STEEL PIPE
(Standard Dimensions)

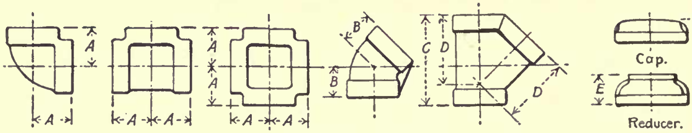
Diameter			Nominal thickness, inches	Circumference		Transverse areas			Length of pipe per square foot of		Nominal weight per foot, pounds
Nominal internal, inches	Actual external, inches	Approx. internal diameter, inches		External, inches	Internal, inches	External, square inches	Internal, square inches	Metal, square inches	External surface, feet	Internal surface, feet	
1/8	0.405	0.21	0.100	1.27	0.64	0.13	0.03	0.10	9.43	18.63	0.31
1/4	0.540	0.29	0.123	1.70	0.92	0.23	0.07	0.16	7.08	12.99	0.54
3/8	0.675	0.42	0.127	2.12	1.32	0.36	0.14	0.22	5.66	9.07	0.74
1/2	0.840	0.54	0.149	2.64	1.70	0.55	0.23	0.32	4.55	7.05	1.09
3/4	1.050	0.74	0.157	3.30	2.31	0.87	0.43	0.44	3.64	5.11	1.47
1	1.315	0.95	0.182	4.13	2.99	1.36	0.71	0.65	2.90	4.02	2.17
1 1/4	1.660	1.27	0.194	5.22	4.00	2.16	1.27	0.89	2.30	3.00	2.99
1 1/2	1.900	1.49	0.203	5.97	4.69	2.84	1.75	1.03	2.01	2.56	3.63
2	2.375	1.93	0.221	7.46	6.07	4.43	2.94	1.50	1.61	1.98	5.02
2 1/2	2.875	2.32	0.280	9.03	7.27	6.49	4.21	2.28	1.33	1.65	7.66
3	3.500	2.89	0.304	11.00	9.09	9.62	6.57	3.05	1.09	1.33	10.25
3 1/2	4.000	3.36	0.321	12.57	10.55	12.57	8.86	3.71	0.96	1.14	12.50
4	4.500	3.82	0.341	14.14	12.00	15.90	11.45	4.46	0.85	1.00	14.98
4 1/2	5.000	4.28	0.360	15.71	13.45	19.64	14.39	5.25	0.76	0.89	17.61
5	5.563	4.81	0.375	17.48	15.12	24.31	18.19	6.11	0.69	0.79	20.78
6	6.625	5.75	0.437	20.81	18.07	34.47	25.98	8.50	0.58	0.66	28.57
7	7.625	6.63	0.500	23.96	20.81	45.66	34.47	11.19	0.50	0.60	38.05
8	8.625	7.63	0.500	27.10	23.96	58.43	45.66	12.76	0.44	0.50	43.34
9	9.625	8.63	0.500	30.24	27.10	72.76	58.43	14.33	0.40	0.44	48.73
10	10.750	9.75	0.500	33.77	30.63	90.76	74.66	16.10	0.36	0.40	54.73
11	11.750	10.75	0.500	36.91	33.77	108.43	90.76	17.67	0.33	0.35	60.07
12	12.750	11.75	0.500	40.06	36.91	127.68	108.43	19.25	0.30	0.33	65.41

Double Extra Strong Wrought-iron and Steel Pipe
(Standard Dimensions)

Diameter			Nominal thickness, inches	Circumference		Transverse areas			Length of pipe per square foot of		Nominal weight per foot, pounds
Nominal internal, inches	Actual external, inches	Approx. internal diameter, inches		External, inches	Internal, inches	External, square inches	Internal, square inches	Metal, square inches	External surface, feet	Internal surface, feet	
½	0.840	0.25	0.294	2.64	0.77	0.55	0.05	0.51	4.55	15.67	1.70
¾	1.050	0.43	0.308	3.30	1.33	0.87	0.14	0.73	3.64	9.05	2.44
1	1.315	0.60	0.358	4.13	1.84	1.36	0.27	1.09	2.90	6.51	3.65
1¼	1.660	0.89	0.382	5.22	2.78	2.16	0.62	1.55	2.30	4.32	5.20
1½	1.900	1.10	0.400	5.97	3.42	2.84	0.93	1.91	2.01	3.51	6.40
2	2.375	1.50	0.436	7.46	4.68	4.43	1.74	2.69	1.61	2.56	9.02
2½	2.875	1.77	0.552	9.03	5.51	6.49	2.42	4.07	1.33	2.18	13.70
3	3.500	2.30	0.600	11.00	7.18	9.62	4.10	5.52	1.09	1.67	18.60
3½	4.000	2.73	0.636	12.57	8.53	12.57	5.79	6.77	0.96	1.41	22.80
4	4.500	3.15	0.674	14.14	9.85	15.90	7.72	8.18	0.85	1.22	27.50
4½	5.000	3.58	0.710	15.71	11.20	19.64	9.98	9.66	0.76	1.07	32.50
5	5.563	4.06	0.750	17.48	12.76	24.31	12.97	11.34	0.69	0.94	38.10
6	6.625	4.89	0.864	20.81	15.32	34.47	18.67	15.81	0.58	0.78	53.10
7	7.625	5.87	0.875	23.96	18.46	45.66	27.11	18.56	0.50	0.65	63.08
8	8.625	6.87	0.875	27.10	21.60	58.43	37.12	21.31	0.44	0.55	72.42

Standard Outside Diameter (O. D.) Steel Pipe
(Nominal weight in lb. per running ft.)

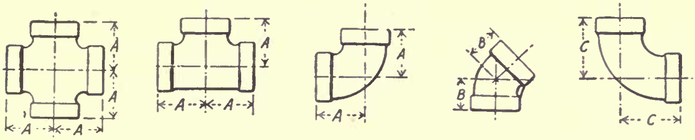
Outside diameter, inches	Thickness in inches											
	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	7/8	1	1 1/8
14	36.8	45.7	54.6	63.4	72.2	80.8	89.4	97.8	106	123	139	155
15	39.4	49.1	58.6	68.1	77.5	86.8	96.0	105.0	114	132	150	167
16	42.1	52.4	62.6	72.8	82.9	92.8	103.0	113.0	122	141	160	178
17	44.8	55.7	66.6	77.5	88.2	98.8	109.0	120.0	130	151	171	191
18	47.4	59.1	70.7	82.1	93.5	105.0	116.0	127.0	138	160	182	203
20	.....	65.8	78.7	91.5	104.0	117.0	129.0	142.0	154	179	203	227
21	.....	69.1	82.7	96.2	110.0	123.0	136.0	149.0	162			
22	.....	72.4	86.7	101.0	115.0	129.0	143.0	157.0	170			
24	.....	.....	94.7	110.0	126.0	141.0	156.0	171.0	186			
26	.....	.....	103.0	120.0	136.0	153.0	170.0	186.0	202			
28	.....	.....	.....	129.0	147.0	165.0	183.0	201.0	218			
30	.....	.....	.....	138.0	158.0	177.0	196.0	215.0	234			



STANDARD SCREWED FITTINGS
(Approximate Weights and Dimensions)

Size, inches	Malleable iron									
	Dimensions in inches						Weight in pounds per 100 pieces			
	A	*B*	*C*	*D*	*E*	*F*	Ells	45° Ells	Tees	Crosses
1/4	13/16	3/4	......	......	1	5/8	13	11	14	
3/8	15/16	13/16	......	......	1 1/8	3/4	17	14	23	21
1/2	1 1/8	7/8	2 1/2	1 11/16	1 1/4	7/8	27	21	35	42
3/4	1 5/16	1	2 7/8	2	1 7/16	1 1/16	39	32	55	54
1	1 7/16	1 1/8	3 7/16	2 7/16	1 11/16	1 3/16	60	50	80	96
1 1/4	1 3/4	1 5/16	4 1/16	2 15/16	2 1/16	1 1/4	105	80	136	152
1 1/2	1 15/16	1 7/16	4 1/2	3 5/16	2 5/16	1 5/16	131	111	183	197
2	2 1/4	1 11/16	5 7/16	4 1/16	2 13/16	1 7/16	232	197	285	340
2 1/2	2 11/16	1 15/16	6 1/4	4 11/16	3 1/4	1 5/8	420	350	428	575
3	3 1/8	2 3/16	7 1/4	5 9/16	3 11/16	1 3/4	637	483	742	960
3 1/2	3 7/16	2 3/8	......	......	4	1 15/16	940	665	1,000	1,040
4	3 3/4	2 5/8	8 7/8	6 15/16	4 3/8	2	1,100	775	1,200	1,550
	Cast iron									
1/4	13/16	3/4	......	......	......	......	14	......	20	
3/8	15/16	13/16	......	......	......	......	24	24	32	
1/2	1 1/8	7/8	2 1/2	1 7/8	......	......	40	37	53	70
3/4	1 5/16	1	3	2 1/4	......	......	55	55	81	100
1	1 7/16	1 1/8	3 1/2	2 3/4	......	......	93	84	122	150
1 1/4	1 3/4	1 5/16	4 1/4	3 1/4	2 1/8	......	152	138	200	238
1 1/2	1 15/16	1 7/16	4 7/8	3 13/16	2 1/4	......	192	196	268	350
2	2 1/4	1 11/16	5 3/4	4 1/2	2 7/16	......	318	284	430	530
2 1/2	2 11/16	1 15/16	6 1/4	5 3/16	2 11/16	......	500	440	650	785
3	3 1/8	2 3/16	7 7/8	6 1/8	2 15/16	......	700	660	1,000	1,100
3 1/2	3 7/16	2 3/8	8 7/8	6 7/8	3 1/8	......	920	850	1,325	1,550
4	3 3/4	2 5/8	9 3/4	7 5/8	3 3/8	2 1/16	1,250	1,125	1,780	2,150
4 1/2	4 1/16	2 13/16	10 5/8	8 1/2	3 5/8	2 3/16	1,600	1,450	2,330	2,700
5	4 7/16	3 1/16	11 5/8	9 1/4	3 7/8	2 3/8	2,100	1,650	2,620	3,000
6	5 1/8	3 7/16	13 7/16	10 3/4	4 3/8	2 5/8	3,000	2,500	4,000	4,300
7	5 13/16	3 7/8	15 1/4	12 1/4	4 13/16	2 7/8	4,400	3,500	5,500	6,600
8	6 1/2	4 1/4	16 15/16	13 5/8	5 1/4	3 1/8	5,500	4,600	7,900	8,300
9	7 3/16	4 11/16	20 11/16	16 3/4	5 11/16	3 3/8	7,800	6,900	10,200	13,600
10	7 7/8	5 3/16	20 11/16	16 3/4	6 3/16	3 5/8	11,100	8,600	14,900	15,400
12	9 1/4	6	24 1/8	19 5/8	7 1/8	4 1/4	16,800	12,500	21,500	25,500

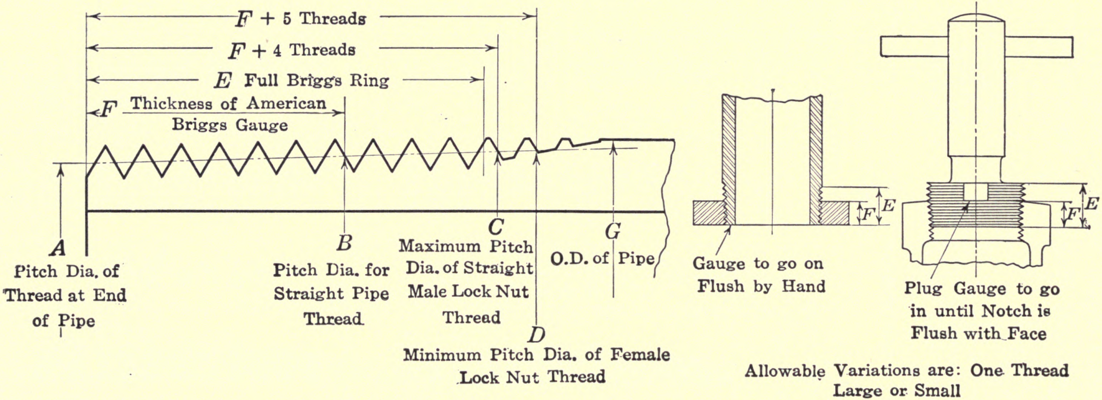
Extra Heavy Screwed Fittings
(Approximate Weights and Dimensions)



Size, inches	Malleable iron						
	Dimensions in inches			Weight in pounds per 100 pieces			
	A	*B*	*C*	Ells	45° Ells	Tees	Crosses
1/4	1 1/16	3/4	....	20	20	34	42 1/2
3/8	1 1/4	7/8	....	38	25	64	81
1/2	1 1/2	1	....	62	49	92	106
3/4	1 3/4	1 1/8	....	97	69	133	163
1	2	1 5/16	2 1/2	134	105	200	236
1 1/4	2 1/4	1 1/2	3	223	175	320	378
1 1/2	2 1/2	1 11/16	3 1/2	316	232	420	503
2	3	2	4	460	370	660	800
2 1/2	3 1/2	2 1/4	4 3/4	720	538	1,000	1,200
3	4 1/8	2 1/2	5 1/2	1,065	763	1,600	2,000
3 1/2	4 5/8	2 5/8	6 1/4	1,500	920	2,200	2,600
4	5 1/8	2 13/16	7	2,000	1,250	2,950	3,240
	Cast iron						
1	2	1 3/8	....	196	155	285	305
1 1/4	2 1/4	1 1/2	4 7/8	292	248	400	510
1 1/2	2 9/16	1 5/8	5 3/4	403	335	525	680
2	3	1 15/16	6 1/4	650	548	925	1,080
2 1/2	3 1/2	2 1/4	7 7/8	900	950	1,400	1,750
3	4 1/8	2 1/2	8 7/8	1,350	1,400	2,000	2,980
3 1/2	4 11/16	2 9/16	9 3/4	1,900	1,750	2,600	3,300
4	5 1/8	2 3/4	10 5/8	2,500	2,300	3,800	4,900
4 1/2	5 1/2	3	....	3,000	2,800	4,400	6,300
5	6 1/8	3 5/16	....	3,900	3,600	6,000	7,200
6	7 1/4	3 3/4	....	6,200	5,500	9,000	11,300
7	8 1/8	4	....	8,800	7,500	12,700	16,300
8	9 1/8	4 3/4	....	12,500	9,800	17,500	22,000
10	11 3/8	4 7/8	....	28,000	15,000	39,000	49,000
12	13 3/8	5 1/2	....	40,000	20,300	60,600	70,400

AMERICAN BRIGGS STANDARD FOR TAPER AND STRAIGHT PIPE THREADS AND LOCK-NUT THREADS

Adopted by the committee of manufacturers on standardization of fittings and valves and the American Society of American Engineers
September 17, 1913



A equals $G - (0.05\,G + 1.9) \times \frac{1}{N} + \frac{0.8}{N}$

B equals $A + (F \times 0.0625)$

C equals $B + \left(\frac{4}{N} \times 0.0625\right)$

D equals $B + \left(\frac{5}{N} \times 0.0625\right)$

E equals $(0.8\,G + 4.8) \times \frac{1}{N} + \frac{2}{N}$

F equals American Briggs Standard

N equals number of threads per inch

Total taper ¾ inch per foot

Depth of thread $\frac{0.8}{N}$

AMERICAN BRIGGS STANDARD PIPE THREADS—(*Continued*)

Size	A	B	C	D	E	F	G	Depth of thread	Threads per inch
1/8	0.36350	0.37475	0.38400	0.38632	0.2638	0.180	0.405	0.02962	27
1/4	0.47739	0.48989	0.50378	0.50725	0.4018	0.200	0.540	0.04444	18
3/8	0.61201	0.62701	0.64090	0.64437	0.4078	0.240	0.675	0.04444	18
1/2	0.75843	0.77843	0.79628	0.80075	0.5337	0.320	0.840	0.05714	14
3/4	0.96768	0.98886	1.00671	1.01118	0.5457	0.339	1.050	0.05714	14
1	1.21363	1.23863	1.26036	1.26580	0.6828	0.400	1.315	0.06956	11 1/2
1 1/4	1.55713	1.58338	1.60511	1.61055	0.7068	0.420	1.660	0.06956	11 1/2
1 1/2	1.79609	1.82234	1.84407	1.84951	0.7235	0.420	1.900	0.06956	11 1/2
2	2.26902	2.29627	2.31801	2.32344	0.7565	0.436	2.375	0.06956	11 1/2
2 1/2	2.71954	2.76216	2.79341	2.80122	1.1375	0.682	2.875	0.100	8
3	3.34063	3.38850	3.41975	3.42756	1.2000	0.766	3.500	0.100	8
3 1/2	3.83750	3.88881	3.92006	3.92787	1.2500	0.821	4.000	0.100	8
4	4.33438	4.38713	4.41838	4.42619	1.3000	0.844	4.500	0.100	8
4 1/2	4.83125	4.88593	4.91718	4.92499	1.3500	0.875	5.000	0.100	8
5	5.39074	5.44930	5.48055	5.48836	1.4063	0.937	5.563	0.100	8
6	6.44610	6.50597	6.53722	6.54503	1.5125	0.958	6.625	0.100	8
7	7.43985	7.50235	7.53360	7.54141	1.6125	1.000	7.625	0.100	8
8	8.43360	8.50003	8.53128	8.53909	1.7125	1.063	8.625	0.100	8
9	9.42735	9.49797	9.52922	9.53703	1.8125	1.130	9.625	0.100	8
10	10.54532	10.62094	10.65219	10.66000	1.9250	1.21	10.750	0.100	8
11	11.53907	11.61938	11.65063	11.65844	2.0250	1.285	11.750	0.100	8
12	12.53282	12.61782	12.64907	12.65688	2.1250	1.360	12.750	0.100	8
14 O.D.	13.7750	13.87262	13.90387	13.91168	2.250	1.562	14.00	0.100	8
15 O.D.	14.76875	14.87418	14.90543	14.91324	2.350	1.687	15.00	0.100	8
16 O.D.	15.76250	15.87575	15.90700	15.91481	2.450	1.812	16.00	0.100	8
17 O.D.	16.75625	16.87500	16.90625	16.91406	2.550	1.900	17.00	0.100	8
18 O.D.	17.7500	17.87500	17.90625	17.91406	2.650	2.000	18.00	0.100	8
20 O.D.	19.73750	19.87031	19.90156	19.90937	2.850	2.125	20.00	0.100	8
22 O.D	21.72500	21.86562	21.89687	21.90468	3.050	2.250	22.00	0.100	8
24 O.D.	23.71250	23.86093	23.89218	23.89999	3.250	2.375	24.00	0.100	8

Lead Pipe

Inside diameter, inches	Kind	Weight per foot, pounds	Inside diameter, inches	Kind	Weight per foot, pounds
⅜	Aqueduct	0.50	1¼	Aqueduct	2.00
	Ex. light	0.56		Ex. light	2.50
	Light	0.75		Light	3.00
	Medium	1.00		Medium	3.75
	Strong	1.50		Strong	4.75
	Ex. strong	2.00		Ex. strong	6.00
	Ex. ex. strong	2.63		Ex. ex. strong	6.75
½	Aqueduct	0.63	1½	Aqueduct	3.00
	Ex. light	0.75		Ex. light	3.50
	Light	1.00		Light	4.00
	Medium	1.25		Medium	5.00
	Strong	1.75		Strong	6.00
	Ex. strong	2.50		Ex. strong	7.50
	Ex. ex. strong	3.00		Ex. ex. strong	9.00
⅝	Aqueduct	0.75	1¾	Aqueduct	3.00
	Ex. light	1.25		Ex. light	3.75
	Light	1.75		Light	4.50
	Medium	2.00		Medium	5.50
	Strong	2.50		Strong	6.50
	Ex. strong	3.00		Ex. strong	8.00
	Ex. ex. strong	3.50			
¾	Aqueduct	1.00	2	Aqueduct	3.00
	Ex. light	1.50		Ex. light	4.00
	Light	2.00		Light	5.00
	Medium	2.25		Medium	7.00
	Strong	3.00		Strong	8.00
	Ex. strong	3.50		Ex. strong	9.00
	Ex. ex. strong	4.00		Ex. ex. strong	10.50
⅞	Aqueduct	1.50	2½	Aqueduct	4.00
	Ex. light	2.00		Light	6.00
	Light	2.50		Medium (3/16 in. thick)	8.00
	Medium	3.00		Strong (¼ in.)	11.00
	Strong	3.50		Ex. strong (5/16 inch)	14.00
				Ex. ex. strong (⅜ in.)	17.00
1	Aqueduct	1.50	3	Aqueduct	4.00
	Ex. light	2.00		Ex. light	4.75
	Light	2.50		Light	6.19
	Medium	3.25		Medium (3/16 in. thick)	9.00
	Strong	4.00		Strong (¼ in.)	12.00
	Ex. strong	4.75		Ex. strong (5/16 in.)	16.00
	Ex. ex. strong	5.50		Ex. ex. strong (⅜ in.)	20.00

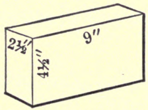
LEAD PIPE—(*Concluded*)

Inside diameter, inches	Kind	Weight per foot, pounds	Inside diameter, inches	Kind	Weight per foot, pounds
4	Aqueduct	5.00	6	Aqueduct	10.00
	Ex. light	6.00		Ex. light	13.00
	Light	8.00		Light (1/4 in. thick)	24.00
	Medium	10.00		Medium (3/8 in.)	36.50
	Strong (1/4 in. thick)	16.00		Strong (1/2 in.)	50.00
	Ex. strong (5/16 in.)	22.00			
	Ex. ex. strong (3/8 in.)	25.00			
5	Aqueduct	8.25	8	Light	30.50
	Ex. light	11.00		Medium	39.25
	Light	14.63		Strong	48.00
	Medium (1/4 in. thick)	20.00			
	Strong (3/8 in.)	30.25			
	Ex. strong (1/2 in.)	40.00			

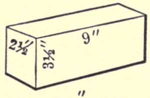
SHEET LEAD

Pounds per square foot	Thickness in inches	
	Fraction	Decimal
2	1/32	0.032
3	3/64	0.048
4	1/16	0.066
5	5/64	0.082
6	3/32	0.098
7	7/64	0.115
8	1/8	0.134
9	9/64	0.145
10	5/32	0.164
11	11/64	0.180
12	3/16	0.198
13	13/64	0.214
14	7/32	0.230
15	1/4	0.248
16	1/4	0.264
20	5/16	0.332
25	25/64	0.414
30	1/2	0.496
60	1	0.992

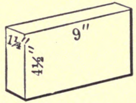
STANDARD 9" AND 9" SERIES BRICK SHAPES
ADOPTED BY
THE REFRACTORIES MANUFACTURERS ASSOCIATION
JULY 29. 1913



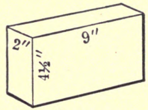
9" Straight
9" x 4½" x 2½"



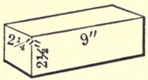
Small 9" Brick
9" x 3½" x 2½"



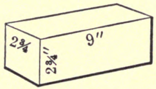
Split Brick
9" x 4½" x 1¼"



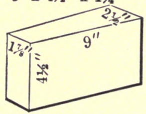
2" Brick
9" x 4½" x 2"



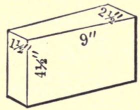
Soap
9" x 2¼" x 2½"



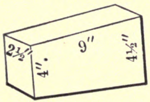
Checker
9" x 2¾" x 2¾"



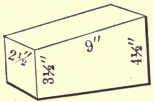
No. 1 Wedge
9" x 4½" x (2½"–1⅞")



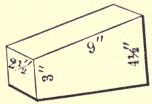
No. 2 Wedge
9" x 4½" x (2½"–1½")



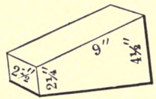
No. 1 Key
9" x (4½"–4") x 2½"



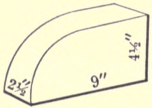
No. 2 Key
9" x (4½"–3½") x 2½"

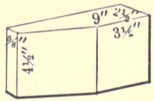


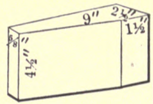
No. 3 Key
9" x (4½"–3") x 2½"

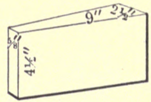


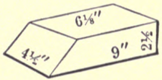
No. 4 Key
9" x (4½"–2¼") x 2½"

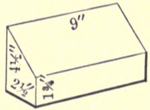

Jamb Brick
9" x 4½" x 2½"

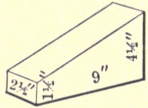

No. 1 Neck
9" x 4½" x 3½" x 2½" x ⅝"

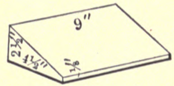

No. 2 Neck
9" x 4½" x 2½" x 1½" x ⅝"

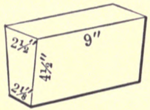

No. 3 Neck
9" x 4½" x 2½" x ⅝"

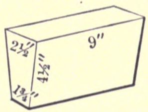

End Skew
(9"–6⅛") x 4½" x 2½"

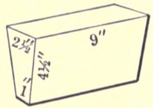

Side Skew
9" x (4½"—1¾") x 2½"

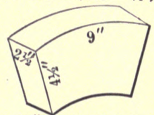

Edge Skew
9" x (4½"—1½") x 2½"

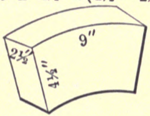

Feather Edge
9" x 4½" x (2½"—⅛")

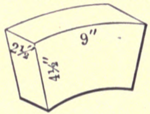

No. 1 Arch
9" x 4½" x (2½"—2⅛")

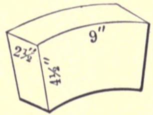

No. 2 Arch
9" x 4½" x (2½"—1¾")

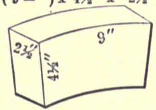

No. 3 Arch
9" x 4½" x (2½"—1")


24" Circle Brick
24" Ins. Diam. 33" Outs. Diam.
12 to a Circle
(9"—) x 4½" x 2½"


36" Circle Brick
36" Ins. Diam. 45" Outs. Diam.
15 to a Circle
(9"—) x 4½" x 2½"

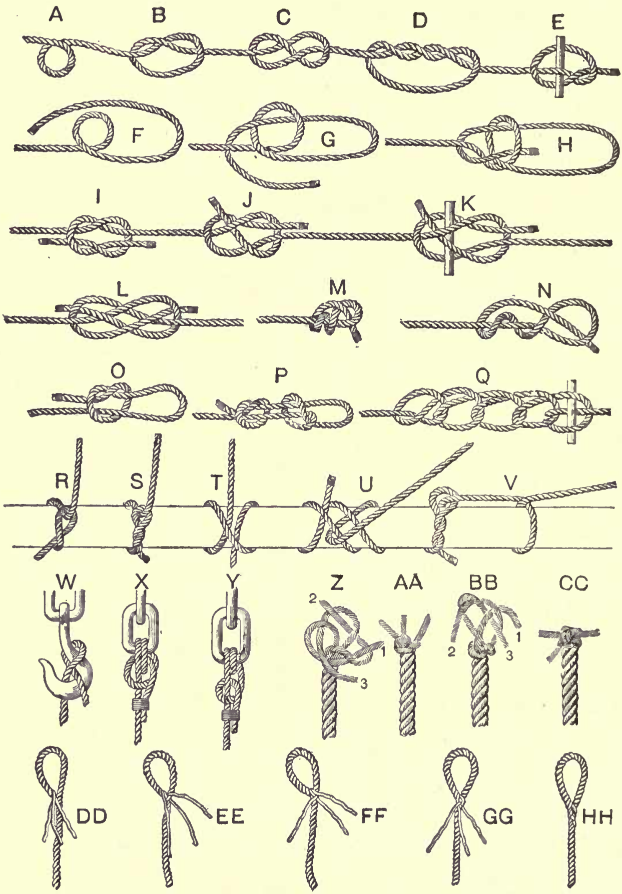

48" Circle Brick
48" Ins. Diam. 57" Outs. Diam.
20 to a Circle
(9"—) x 4½" x 2½"


60" Circle Brick
60" Ins. Diam. 69" Outs Diam.
25 to a Circle
(9"—) x 4½" x 2½"


72" Circle Brick
72" Ins. Diam. 81" Outs. Diam.
28 to a Circle
(9"—) x 4½" x 2½"

FIBER ROPE KNOTS AND HITCHES—AND HOW TO MAKE THEM[1]

The principle of a knot is that no 2 parts which would move in the same direction if the rope were to slip, should lie alongside



of and touching each other. This principle is clearly shown in the square knot (I).

[1] From LIDDELL'S "Metallurgists and Chemists' Handbook."

A great number of knots have been devised, of which a few of the most useful are herewith illustrated by courtesy of C. W. Hunt Company, of New York. In the engravings they are shown open, or before being drawn taut, in order to show the position of the parts. The names usually given to them are:

A. Bight of a rope.
B. Simple or overhand knot.
C. Figure 8 knot.
D. Double knot.
E. Boat knot.
F. Bowline, first step.
G. Bowline, second step.
H. Bowline, completed.
I. Square or reef knot.
J. Sheet bend or weaver's knot.
K. Sheet bend with a toggle.
L. Carrick bend.
M. "Stevedore" knot completed.
N. "Stevedore" knot commenced.
O. Slip knot.
P. Flemish loop.
Q. Chain knot with toggle.
R. Half-hitch.
S. Timber-hitch.
T. Clove-hitch.
U. Rolling-hitch.
V. Timber-hitch and half-hitch.
W. Blackwall-hitch.
X. Fisherman's bend.
Y. Round turn and half-hitch.
Z. Wall knot commenced.
AA. Wall knot completed.
BB. Wall knot crown commenced.
CC. Wall knot crown completed.
DD to HH. Eye splice commenced and completed.

The bowline (G) is one of the most useful knots; it will not slip, and after being strained is easily untied. It should be tied with facility by everyone who handles rope. Commence by making a bight in the rope, then put the end through the bight and under the standing part, as shown in the engraving, then pass the end again through the bight, and haul tight.

The square or reef knot (I) must not be mistaken for the "granny" knot that slips under a strain. Knots (H, K and M) are easily untied after being under strain. The knot (M) is useful when the rope passes through an eye and is held by the knot, as it will not slip, and is easily untied after being strained.

The wall knot looks complicated but is easily made by proceeding as follows:

Form a bight with strand 1, and pass the strand 2 around the end of it, and the strand 3 around the end of 2, and then through the bight of 1, as shown in engraving Z. Haul the ends taut, when the appearance is as shown in the engraving AA. The end of the strand 1 is now laid over the center of the knot, strand 2 laid over 1, and 3 over 2, when the end of 3 is passed through the bight of 1, as shown in the engraving BB. Haul all the strands taut, as shown in the engraving CC.

The "stevedore" knot (M), (N) is used to hold the end of a rope from passing through a hole. When the rope is strained the knot draws up tight, but it can be easily untied when the strain is removed.

If a knot or hitch of any kind is tied in a rope, its failure under stress is sure to occur at that place. Each fiber in the straight part of the rope takes proper share of the load, but in all knots the rope is cramped or has a short bend, which throws an overload on those fibers that are on the outside of the bend and one fiber after another breaks until the rope is torn apart. The shorter the bend in the standing rope, the weaker is the knot.

U. S. CUSTOMARY WEIGHTS AND MEASURES

Length

12 inches	= 1 foot
3 feet	= 1 yard
5½ yards	= 1 rod
320 rods 1760 yards 5280 feet	= 1 mile

Nautical Units

6080.2 feet	= 1 nautical mile
6 feet	= 1 fathom
120 fathoms	= 1 cable length
1 nautical mile per hour	= 1 knot

Surveyors Measure

7.92 inches	= 1 link
100 links 66 feet 4 rods	= 1 chain
80 chains	= 1 mile

Area

144 square inches	= 1 square foot
9 square feet	= 1 square yard
30¼ square yards	= 1 square rod
160 square rods 10 square chains	= 1 acre
640 acres	= 1 square mile

Volume

1728 cubic inches	= 1 cubic foot
27 cubic feet	= 1 cubic yard
1 cord of wood	= 128 cubic feet

Liquid Measure

4 gills	= 1 pint
2 pints	= 1 quart
4 quarts	= 1 gallon
7.4805 gallons	= 1 cubic foot

Apothecaries Liquid Measure

60 minims	=	1 liquid dram
8 drams	=	1 liquid ounce
16 ounces	=	1 pint

Dry Measure

2 pints	=	1 quart
8 quarts	=	1 peck
4 pecks	=	1 bushel

Avoirdupois Weight

16 drams = 437.5 grains	=	1 ounce
16 ounces = 7000 grains	=	1 pound
100 pounds	=	1 cental
2000 pounds	=	1 short ton
2240 pounds	=	1 long ton

Troy Weight

24 grains	=	1 pennyweight (dwt.)
20 pennyweights	=	1 ounce
12 ounces	=	1 pound

Apothecaries Weights

20 grains	=	1 scruple
3 scruples	=	1 dram
8 drams	=	1 ounce
12 ounces	=	1 pound

METRIC MEASURES

Length

Unit	Symbol	Value in meters
Micron	μ	0.000001
Millimeter	mm.	0.001
Centimeter	cm.	0.01
Decimeter	dm.	0.1
Meter (unit)	m.	1.0
Dekameter	dkm.	10.0
Hectometer	hm.	100.0
Kilometer	km.	1,000.0
Myriameter	Mm.	10,000.0
Megameter	.....	1,000,000.0

Area

Unit	Symbol	Value in square meters
Sq. millimeter	$mm.^2$	0.000001
Sq. centimeter	$cm.^2$	0.0001
Sq. decimeter	$dm.^2$	0.01
Sq. meter (centiare)	$m.^2$	1.0
Sq. dekameter (are)	a.	100.0
Hectare	ha.	10,000.0
Sq. kilometer	$km.^2$	1,000,000.0

Volume

Unit	Symbol	Value in liters
Milliliter	ml. or $cm.^3$	0.001
Liter (unit)	l. or $dm.^3$	1.0
Kiloliter	kl. or $m.^3$	1,000.0
Also		
Centiliter	cl.	0.01
Deciliter	dl.	0.1
Dekaliter	dkl.	10.0
Hectoliter	hl.	100.0

CUBIC MEASURE

Unit	Symbol	Value in cubic meters
Cubic kilometer	$km.^3$	10^9
Cubic hectometer	$hm.^3$	10^6
Cubic dekameter	$dkm.^3$	10^3
Cubic meter	$m.^3$	1
Cubic decimeter	$dm.^3$	10^{-3}
Cubic centimeter	$cm.^3$	10^{-6}
Cubic millimeter	$mm.^3$	10^{-9}
Cubic micron	μ^3	10^{-18}

Weight

Unit	Symbol	Value in grams
Microgram	.....	0.000001
Milligram	mg.	0.001
Centigram	cg.	0.01
Decigram	dg.	0.1
Gram (unit)	g.	1.0
Dekagram	dkg.	10.0
Hectogram	hg.	100.0
Kilogram	kg.	1,000.0
Myriagram	Mg.	10,000.0
Quintal	q.	100,000.0
Ton	t.	1,000,000.0

EQUIVALENTS OF METRIC AND CUSTOMARY (U. S.) WEIGHTS AND MEASURES[1]

Length

Metric		U. S. Standard
1 millimeter	=	0.03937 inch
1 centimeter	=	0.3937 inch
1 meter	=	39.37 inches
1 meter	=	3.28083 feet
1 meter	=	1.09361 yards
1 kilometer	=	0.62137 mile
U. S. Standard		**Metric**
1 inch	=	25.4001 millimeters
1 inch	=	2.5400 centimeters
1 foot	=	0.3048 meter
1 yard	=	0.9144 meter
1 mile	=	1.60935 kilometers

Area

Metric		U. S. Standard
1 square millimeter	=	0.00155 square inch
1 square centimeter	=	0.1550 square inch
1 square meter	=	10.7640 square feet
1 square meter	=	1.1960 square yards
1 square kilometer	=	0.3861 square mile
1 hectare	=	2.471 acres

[1] Table of equivalents, U. S. Bureau of Standards.

Area—(*Continued*)

U. S. Standard		Metric
1 square inch	=	645.16 square millimeters
1 square inch	=	6.452 square centimeters
1 square foot	=	0.0929 square meter
1 square yard	=	0.8361 square meter
1 square mile	=	2.5900 square kilometers
1 acre	=	0.4047 hectare

Volume

Metric		U. S. Standard
1 cubic millimeter	=	0.000061 cubic inch
1 cubic centimeter	=	0.0610 cubic inch
1 cubic meter	=	35.314 cubic feet
1 cubic meter	=	1.3079 cubic yards

U. S. Standard		Metric
1 cubic inch	=	16,387.2 cubic millimeters
1 cubic inch	=	16.3872 cubic centimeters
1 cubic foot	=	0.02832 cubic meter
1 cubic yard	=	0.7646 cubic meter

Capacity

Metric		U. S. Standard
1 milliliter (c.c.)	=	0.03381 liquid ounce
1 milliliter	=	0.2705 apothecaries' dram
1 milliliter	=	0.8115 apothecaries' scruple
1 liter	=	1.05668 liquid quarts
1 liter	=	0.9081 dry quart
1 liter	=	0.26417 liquid gallon
1 liter	=	0.11351 peck
1 dekaliter	=	1.1351 pecks
1 hectoliter	=	2.83774 bushels
1 hectoliter	=	26.4176 liquid gallons

Capacity—(*Continued*)

U. S. Standard		Metric
1 liquid ounce	=	29.574 milliliters (c.c.)
1 apothecaries' dram	=	3.6967 milliliters
1 apothecaries' scruple	=	1.2322 milliliters
1 liquid quart	=	0.94636 liter
1 dry quart	=	1.1012 liters
1 liquid gallon	=	3.78543 liters
1 peck	=	8.80982 liters
1 peck	=	0.88098 dekaliter
1 bushel	=	35.239 liters
1 bushel	=	0.35239 hectoliter

Mass

Metric		U. S. Standard
1 gram	=	15.4324 grains
1 gram	=	0.03527 avoirdupois ounce
1 gram	=	0.03215 troy ounce
1 kilogram	=	2.20462 avoirdupois pounds
1 kilogram	=	2.67923 troy pounds

U. S. Standard		Metric
1 grain	=	0.0648 gram
1 avoirdupois ounce	=	28.3495 grams
1 troy ounce	=	31.10348 grams
1 avoirdupois pound	=	0.45359 kilogram
1 troy pound	=	0.37324 kilogram

Comparison of Thermometric Scales

Fahrenheit degrees as units

°C. = $\frac{5}{9}$(°F. − 32)

F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.
−40	−40.0	+3	−16.1	+46	+7.8	+89	+31.7	+132	+55.6	+175	+79.4
39	39.4	4	15.6	47	8.3	90	32.2	133	56.1	176	80.0
38	38.9	5	15.0	48	8.9	91	32.8	134	56.7	177	80.6
37	38.3	6	14.4	49	9.4	92	33.3	135	57.2	178	81.1
36	37.8	7	13.9	50	10.0	93	33.9	136	57.8	179	81.7
35	37.2	8	13.3	51	10.6	94	34.4	137	58.3	180	82.2
34	36.7	9	12.8	52	11.1	95	35.0	138	58.9	181	82.8
33	36.1	10	12.2	53	11.7	96	35.6	139	59.4	182	83.3
32	35.6	11	11.7	54	12.2	97	36.1	140	60.0	183	83.9
31	35.0	12	11.1	55	12.8	98	36.7	141	60.6	184	84.4
30	34.4	13	10.6	56	13.3	99	37.2	142	61.1	185	85.0
29	33.9	14	10.0	57	13.9	100	37.8	143	61.7	186	85.6
28	33.3	15	9.4	58	14.4	101	38.3	144	62.2	187	86.1
27	32.8	16	8.9	59	15.0	102	38.9	145	62.8	188	86.7
26	32.2	17	8.3	60	15.6	103	39.4	146	63.3	189	87.2
25	31.7	18	7.8	61	16.1	104	40.0	147	63.9	190	87.8
24	31.1	19	7.2	62	16.7	105	40.6	148	64.4	191	88.3
23	30.6	20	6.7	63	17.2	106	41.1	149	65.0	192	88.9
22	30.0	21	6.1	64	17.8	107	41.7	150	65.6	193	89.4
21	29.4	22	5.6	65	18.3	108	42.2	151	66.1	194	90.0
20	28.9	23	5.0	66	18.9	109	42.8	152	66.7	195	90.6
19	28.3	24	4.4	67	19.4	110	43.3	153	67.2	196	91.1
18	27.8	25	3.9	68	20.0	111	43.9	154	67.8	197	91.7
17	27.2	26	3.3	69	20.6	112	44.4	155	68.3	198	92.2
16	26.7	27	2.8	70	21.1	113	45.0	156	68.9	199	92.8
15	26.1	28	2.2	71	21.7	114	45.6	157	69.4	200	93.3
14	25.6	29	1.7	72	22.2	115	46.1	158	70.0	201	93.9
13	25.0	30	1.1	73	22.8	116	46.7	159	70.6	202	94.4
12	24.4	31	0.6	74	23.3	117	47.2	160	71.1	203	95.0
11	23.9	32	0.0	75	23.9	118	47.8	161	71.7	204	95.6
10	23.3	33	+0.6	76	24.4	119	48.3	162	72.2	205	96.1
9	22.8	34	1.1	77	25.0	120	48.9	163	72.8	206	96.7
8	22.2	35	1.7	78	25.6	121	49.4	164	73.3	207	97.2
7	21.7	36	2.2	79	26.1	122	50.0	165	73.9	208	97.8
6	21.1	37	2.8	80	26.7	123	50.6	166	74.4	209	98.3
5	20.6	38	3.3	81	27.2	124	51.1	167	75.0	210	98.9
4	20.0	39	3.9	82	27.8	125	51.7	168	75.6	211	99.4
3	19.4	40	4.4	83	28.3	126	52.2	169	76.1	212	100.0
2	18.9	41	5.0	84	28.9	127	52.8	170	76.7		
1	18.3	42	5.6	85	29.4	128	53.3	171	77.2		
0	17.8	43	6.1	86	30.0	129	53.9	172	77.8		
+1	17.2	44	6.7	87	30.6	130	54.4	173	78.3		
2	16.7	45	7.2	88	31.1	131	55.0	174	78.9		

COMPARISON OF THERMOMETRIC SCALES
Centigrade degrees as units
$°F. = \frac{9}{5}°C. + 32$

C.	F.	C.	F.	C.	F.	C.	F.
−40	−40.0	−4	+24.8	+32	+89.6	+68	+154.4
39	38.2	3	26.6	33	91.4	69	156.2
38	36.4	2	28.4	34	93.2	70	158.0
37	34.6	1	30.2	35	95.0	71	159.8
36	32.8	0	32.0	36	96.8	72	161.6
35	31.0	+1	33.8	37	98.6	73	163.4
34	29.2	2	35.6	38	100.4	74	165.2
33	27.4	3	37.4	39	102.2	75	167.0
32	25.6	4	39.2	40	104.0	76	168.8
31	23.8	5	41.0	41	105.8	77	170.6
30	22.0	6	42.8	42	107.6	78	172.4
29	20.2	7	44.6	43	109.4	79	174.2
28	18.4	8	46.4	44	111.2	80	176.0
27	16.6	9	48.2	45	113.0	81	177.8
26	14.8	10	50.0	46	114.8	82	179.6
25	13.0	11	51.8	47	116.6	83	181.4
24	11.2	12	53.6	48	118.4	84	183.2
23	9.4	13	55.4	49	120.2	85	185.0
22	7.6	14	57.2	50	122.0	86	186.8
21	5.8	15	59.0	51	123.8	87	188.6
20	4.0	16	60.8	52	125.6	88	190.4
19	2.2	17	62.6	53	127.4	89	192.2
18	0.4	18	64.4	54	129.2	90	194.0
17	+1.4	19	66.2	55	131.0	91	195.8
16	3.2	20	68.0	56	132.8	92	197.6
15	5.0	21	69.8	57	134.6	93	199.4
14	6.8	22	71.6	58	136.4	94	201.2
13	8.6	23	73.4	59	138.2	95	203.0
12	10.4	24	75.2	60	140.0	96	204.8
11	12.2	25	77.0	61	141.8	97	206.6
10	14.0	26	78.8	62	143.6	98	208.4
9	15.8	27	80.6	63	145.4	99	210.2
8	17.6	28	82.4	64	147.2	100	212.0
7	19.4	29	84.2	65	149.0		
6	21.2	30	86.0	66	150.8		
5	23.0	31	87.8	67	152.6		

WATER[1]

Density: Weight in grams of 1 c.c. of water free from air		Volume: Volume in cubic centimeters of 1 gram of water	
Temperature, °C.	Density	Temperature, °C.	Volume
0	0.999868	0	1.000132
1	0.999927	1	1.000073
2	0.999968	2	1.000032
3	0.999992	3	1.000008
4	1.000000	4	1.000000
5	0.999992	5	1.000008
6	0.999986	6	1.000032
7	0.999929	7	1.000071
8	0.999876	8	1.000124
9	0.999808	9	1.000192
10	0.999727	10	1.000273
11	0.999632	11	1.000368
12	0.999525	12	1.000476
13	0.999404	13	1.000596
14	0.999271	14	1.000729
15	0.999126	15	1.000874
16	0.998970	16	1.001031
17	0.998801	17	1.001200
18	0.998622	18	1.001380
19	0.998432	19	1.001571
20	0.998230	20	1.001773
21	0.998019	21	1.001985
22	0.997797	22	1.002208
23	0.997565	23	1.002441
24	0.997323	24	1.002685
25	0.997071	25	1.002938
26	0.996810	26	1.003201
27	0.996539	27	1.003473
28	0.996259	28	1.003755
29	0.995971	29	1.004046
30	0.995673	30	1.004346
31	0.995367	31	1.004655
32	0.995052	32	1.004972
33	0.994729	33	1.005299
34	0.994398	34	1.005634
35	0.994058	35	1.005978

[1] According to THIESEN, SCHEEL and DIESSELHORST: *Wiss. Abh. der Physikalisch-Technischen Reichsanstalt.*, 3, 68–69, 1900.

DENSITY OF SOLUTIONS OF SULPHURIC ACID[1] (H_2SO_4) AT 20°C.[2]

(Calculated from Dr. J. Domke's table.[3] Adopted as the basis for standardization of hydrometers indicating per cent. of sulphuric acid at 20°C.)

Per cent. H_2SO_4	$D\frac{20}{4}$C.	Per cent. H_2SO_4	$D\frac{20}{4}$C.	Per cent. H_2SO_4	$D\frac{20}{4}$C.
0	0.99823	30	1.21850	60	1.49818
1	1.00506	31	1.22669	61	1.50904
2	1.01178	32	1.23492	62	1.51999
3	1.01839	33	1.24320	63	1.53102
4	1.02500	34	1.25154	64	1.54213
5	1.03168	35	1.25992	65	1.55333
6	1.03843	36	1.26836	66	1.56460
7	1.04527	37	1.27685	67	1.57595
8	1.05216	38	1.28543	68	1.58739
9	1.05909	39	1.29407	69	1.59890
10	1.06609	40	1.30278	70	1.61048
11	1.07314	41	1.31157	71	1.62213
12	1.08026	42	1.32043	72	1.63384
13	1.08744	43	1.32938	73	1.64560
14	1.09468	44	1.33843	74	1.65738
15	1.10199	45	1.34759	75	1.66917
16	1.10936	46	1.35686	76	1.68095
17	1.11679	47	1.36625	77	1.69268
18	1.12428	48	1.37574	78	1.70433
19	1.13183	49	1.38533	79	1.71585
20	1.13943	50	1.39505	80	1.72717
21	1.14709	51	1.40487	81	1.73827
22	1.15480	52	1.41481	82	1.74904
23	1.16258	53	1.42487	83	1.75943
24	1.17041	54	1.43503	84	1.76932
25	1.17830	55	1.44530	85	1.77860
26	1.18624	56	1.45568	85.5	1.78300
27	1.19423	57	1.46615	86	1.78721
28	1.20227	58	1.47673	86.5	1.79124
29	1.21036	59	1.48740	87	1.79509

Density of Solutions of Sulphuric Acid[1] (H_2SO_4) at 20°C.[2]—(*Concluded*)
(Calculated from Dr. J. Domke's table.[3] Adopted as the basis for standardization of hydrometers indicating per cent. of sulphuric acid at 20°C.)

Per cent. H_2SO_4	$D\frac{20}{4}$C.	Per cent. H_2SO_4	$D\frac{20}{4}$C.	Per cent. H_2SO_4	$D\frac{20}{4}$C.
87.5	1.79875	93.0	1.82790	96.0	1.83548
88.0	1.80223	93.2	1.82860	96.1	1.83560
88.5	1.80552	93.4	1.82928	96.2	1.83572
89.0	1.80864	93.6	1.82993	96.3	1.83584
89.5	1.81159	93.8	1.83055	96.4	1.83594
90.0	1.81438	94.0	1.83115	96.5	1.83604
90.2	1.81545	94.2	1.83172	96.6	1.83613
90.4	1.81650	94.4	1.83226	96.7	1.83621
90.6	1.81753	94.6	1.83276	96.8	1.83628
90.8	1.81853	94.8	1.83324	96.9	1.83634
91.0	1.81950	95.0	1.83368	97.0	1.83637
91.2	1.82045	95.1	1.83389	97.1	1.83639
91.4	1.82137	95.2	1.83410	97.2	1.83640
91.6	1.82227	95.3	1.83430	97.3	1.83640
91.8	1.82315	95.4	1.83449	97.4	1.83639
92.0	1.82401	95.5	1.83469	97.5	1.83637
92.2	1.82484	95.6	1.83486	97.6	1.83634
92.4	1.82564	95.7	1.83503	97.7	1.83629
92.6	1.82641	95.8	1.83520	97.8	1.83623
92.8	1.82717	95.9	1.83534	97.9	1.83615
				98.0	1.83605

[1] For general use the more extensive and elaborate "Standard Tables" under the caption, "Sulphuric acid—0°Bé.—100 per cent. H_2SO_4," should always be referred to.

[2] United States Bureau of Standards, *Circular* No. 19, 5th edition, March 30, 1916, p. 28.

The density values in this table are numerically the same as specific gravity at this temperature referred to water at 4°C. as unity.

[3] *Wiss. Abh. der Kaiserlichen Normal-Eichungs-Kommission,* 5, p. 131, 1900.

TEMPERATURE CORRECTIONS TO PER CENT. OF SULPHURIC ACID[1] DETERMINED BY HYDROMETER (STANDARD AT 20°C.)[2]

(Calculated from the same data as the preceding table, assuming Jena 16 III glass as the material used. 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.)

Observed per cent. H_2SO_4	Temperature in degrees Centigrade											
	0	5	10	15	25	30	35	40	45	50	55	60
	Subtract from observed per cent.				Add to observed per cent.							
0	.....	.....	.....	.....	0.16	0.35	0.59	0.86	1.17	1.5	1.9	2.1
5	0.59	0.49	0.36	0.20	0.24	0.50	0.79	1.11	1.45	1.8	2.2	2.6
10	0.92	0.72	0.51	0.27	0.29	0.60	0.93	1.28	1.65	2.0	2.4	2.8
20	1.39	1.06	0.72	0.36	0.37	0.75	1.14	1.53	1.93	2.3	2.7	3.1
30	1.64	1.23	0.82	0.41	0.41	0.82	1.24	1.65	2.07	2.5	2.9	3.3
40	1.65	1.24	0.82	0.41	0.41	0.82	1.22	1.62	2.03	2.4	2.8	3.2
50	1.56	1.17	0.78	0.39	0.38	0.77	1.15	1.52	1.90	2.3	2.6	3.0
60	1.52	1.14	0.76	0.38	0.37	0.74	1.11	1.48	1.84	2.2	2.6	2.9
70	1.54	1.15	0.76	0.38	0.38	0.75	1.13	1.50	1.86	2.2	2.6	3.0
80	1.72	1.30	0.87	0.44	0.45	0.90	1.36	1.83	2.31	2.8	3.3	3.8
81	1.76	1.34	0.92	0.44	0.47	0.93	1.42	1.93	2.44	3.0	3.5	4.0
82	1.84	1.41	0.96	0.47	0.50	1.00	1.51	2.04	2.58	3.1	3.7	4.3
83	1.94	1.48	1.00	0.50	0.53	1.06	1.59	2.18	2.78	3.4	4.0	4.6
84	2.05	1.57	1.06	0.53	0.55	1.12	1.74	2.36	3.0	3.7	4.4	5.1
85	2.20	1.67	1.13	0.57	0.61	1.23	1.88	2.57	3.3	4.0	4.9	5.8
86	2.36	1.80	1.22	0.62	0.66	1.35	2.08	2.84	3.7	4.6	5.5	
87	2.54	1.95	1.32	0.67	0.73	1.50	2.31	3.2	4.1	5.2		
88	2.75	2.12	1.44	0.74	0.81	1.67	2.59	3.6	4.7	6.0		
89	3.01	2.31	1.58	0.82	0.89	1.86	2.91	4.1	5.6			
90	3.27	2.53	1.73	0.91	0.99	2.10	3.4	4.9				
91	3.57	2.78	1.93	1.01	1.13	2.44	4.1					
92	3.91	3.06	2.13	1.12	1.32	3.00						
93	4.29	3.38	2.37	1.26	1.64							
94	4.75	3.77	2.69	1.46								
95	5.29	4.26	3.12	1.76								
96	5.96	4.88	3.65	2.19								
97	6.78	5.68	4.42	2.90								

[1] For general use the more extensive and elaborate "Standard Tables" under the caption, "Sulphuric acid—0°Bé.—100 per cent. H_2SO_4," should always be referred to.

[2] United States Bureau of Standards, *Circular* No. 19. 5th edition, March 30, 1916, p. 29.

SPECIFIC GRAVITY OF SULPHURIC ACID[1]

Table I.—Lunge, Isler and Naef (*Zeit. angew. Chem. Ind.*, 1890, 131; *Chem. Ind.*, 1883, 39). Specific gravities at $\frac{15°}{4°}$ *in vacuo.*

Table II.—In 1909 Lunge publishes this table with the following note: "This table is based on that which the author formerly worked out with Isler and Naef; some corrections introduced by the Imperial Standards Commission are incorporated." The table appears under the caption "Specific gravity of sulphuric acid at 60°F." (No mention is made to a comparison with water.)

The entire table is not reproduced here as all strengths up to 166° Twaddell have the same values as Table I.

Again in 1913 Lunge republishes Table I and no mention is made of his corrected table of 1909.

Note.—The given degrees Baumé in these tables do not check with the American Standard Baumé scale. This is the Baumé scale mostly used on the continent of Europe and is calculated by the following formula:

$$\text{Specific gravity} = \frac{144.3}{144.3 - \text{degrees Baumé}}$$

Water at 15° being put = 0° and sulphuric acid of 1.842 specific gravity at 15° = 66°Bé.

[1] These tables are published very extensively but cannot be recommended for general American use. The more extensive and elaborate "Standard Tables" should always be referred to. These can be found under the caption "Sulphuric acid – 0°Bé. – 100 per cent. H_2SO_4."

TABLE I.—SPECIFIC GRAVITY OF SULPHURIC ACID

Lunge, Isler, and Naef

Specific gravity at $\frac{15°}{4°}$ *in vacuo*	Degrees Baumé	Degrees Twaddell	100 parts by weight contain, grams		1 liter contains in kilograms	
			SO_3	H_2SO_4	SO_3	H_2SO_4
1.000	0.0	0	0.07	0.09	0.001	0.001
1.005	0.7	1	0.68	0.83	0.007	0.008
1.010	1.4	2	1.28	1.57	0.013	0.016
1.015	2.1	3	1.88	2.30	0.019	0.023
1.020	2.7	4	2.47	3.03	0.025	0.031
1.025	3.4	5	3.07	3.76	0.032	0.039
1.030	4.1	6	3.67	4.49	0.038	0.046
1.035	4.7	7	4.27	5.23	0.044	0.054
1.040	5.4	8	4.87	5.96	0.051	0.062
1.045	6.0	9	5.45	6.67	0.057	0.071
1.050	6.7	10	6.02	7.37	0.063	0.077
1.055	7.4	11	6.59	8.07	0.070	0.085
1.060	8.0	12	7.16	8.77	0.076	0.093
1.065	8.7	13	7.73	9.47	0.082	0.102
1.070	9.4	14	8.32	10.19	0.089	0.109
1.075	10.0	15	8.90	10.90	0.096	0.117
1.080	10.6	16	9.47	11.60	0.103	0.125
1.085	11.2	17	10.04	12.30	0.109	0.133
1.090	11.9	18	10.60	12.99	0.116	0.142
1.095	12.4	19	11.16	13.67	0.122	0.150
1.100	13.0	20	11.71	14.35	0.129	0.158
1.105	13.6	21	12.27	15.03	0.136	0.166
1.110	14.2	22	12.82	15.71	0.143	0.175
1.115	14.9	23	13.36	16.36	0.149	0.183
1.120	15.4	24	13.89	17.01	0.156	0.191
1.125	16.0	25	14.42	17.66	0.162	0.199
1.130	16.5	26	14.95	18.31	0.169	0.207
1.135	17.1	27	15.48	18.96	0.176	0.215
1.140	17.7	28	16.01	19.61	0.183	0.223
1.145	18.3	29	16.54	20.26	0.189	0.231
1.150	18.8	30	17.07	20.91	0.196	0.239
1.155	19.3	31	17.59	21.55	0.203	0.248
1.160	19.8	32	18.11	22.19	0.210	0.257

TABLE I.—SPECIFIC GRAVITY OF SULPHURIC ACID—(*Continued*)

Specific gravity at $\frac{15°}{4°}$ *in vacuo*	Degrees Baumé	Degrees Twaddell	100 parts by weight contain, grams		1 liter contains in kilograms	
			SO_3	H_2SO_4	SO_3	H_2SO_4
1.165	20.3	33	18.64	22.83	0.217	0.266
1.170	20.9	34	19.16	23.47	0.224	0.275
1.175	21.4	35	19.69	24.12	0.231	0.283
1.180	22.0	36	20.21	24.76	0.238	0.292
1.185	22.5	37	20.73	25.40	0.246	0.301
1.190	23.0	38	21.26	26.04	0.253	0.310
1.195	23.5	39	21.78	26.68	0.260	0.319
1.200	24.0	40	22.30	27.32	0.268	0.328
1.205	24.5	41	22.82	27.95	0.275	0.337
1.210	25.0	42	23.33	28.58	0.282	0.346
1.215	25.5	43	23.84	29.21	0.290	0.355
1.220	26.0	44	24.36	29.84	0.297	0.364
1.225	26.4	45	24.88	30.48	0.305	0.373
1.230	26.9	46	25.39	31.11	0.312	0.382
1.235	27.4	47	25.88	31.70	0.320	0.391
1.240	27.9	48	26.35	32.28	0.327	0.400
1.245	28.4	49	26.83	32.86	0.334	0.409
1.250	28.8	50	27.29	33.43	0.341	0.418
1.255	29.3	51	27.76	34.00	0.348	0.426
1.260	29.7	52	28.22	34.57	0.356	0.435
1.265	30.2	53	28.69	35.14	0.363	0.444
1.270	30.6	54	29.15	35.71	0.370	0.454
1.275	31.1	55	29.62	36.29	0.377	0.462
1.280	31.5	56	30.10	36.87	0.385	0.472
1.285	32.0	57	30.57	37.45	0.393	0.481
1.290	32.4	58	31.04	38.03	0.400	0.490
1.295	32.8	59	31.52	38.61	0.408	0.500
1.300	33.3	60	31.99	39.19	0.416	0.510
1.305	33.7	61	32.46	39.77	0.424	0.519
1.310	34.2	62	32.94	40.35	0.432	0.529
1.315	34.6	63	33.41	40.93	0.439	0.538
1.320	35.0	64	33.88	41.50	0.447	0.548
1.325	35.4	65	34.35	42.08	0.455	0.557
1.330	35.8	66	34.80	42.66	0.462	0.567

TABLE I.—SPECIFIC GRAVITY OF SULPHURIC ACID—(*Continued*)

Specific gravity at $\frac{15^\circ}{4^\circ}$ *in vacuo*	Degrees Baumé	Degrees Twaddell	100 parts by weight contain, grams		1 liter contains in kilograms	
			SO_3	H_2SO_4	SO_3	H_2SO_4
1.335	36.2	67	35.27	43.20	0.471	0.577
1.340	36.6	68	35.71	43.74	0.479	0.586
1.345	37.0	69	36.14	44.28	0.486	0.596
1.350	37.4	70	36.58	44.82	0.494	0.605
1.355	37.8	71	37.02	45.35	0.502	0.614
1.360	38.2	72	37.45	45.88	0.509	0.624
1.365	38.6	73	37.89	46.41	0.517	0.633
1.370	39.0	74	38.32	46.94	0.525	0.643
1.375	39.4	75	38.75	47.47	0.533	0.653
1.380	39.8	76	39.18	48.00	0.541	0.662
1.385	40.1	77	39.62	48.53	0.549	0.672
1.390	40.5	78	40.05	49.06	0.557	0.682
1.395	40.8	79	40.48	49.59	0.564	0.692
1.400	41.2	80	40.91	50.11	0.573	0.702
1.405	41.6	81	41.33	50.63	0.581	0.711
1.410	42.0	82	41.76	51.15	0.589	0.721
1.415	42.3	83	42.17	51.66	0.597	0.730
1.420	42.7	84	42.57	52.15	0.604	0.740
1.425	43.1	85	42.96	52.63	0.612	0.750
1.430	43.4	86	43.36	53.11	0.620	0.759
1.435	43.8	87	43.75	53.59	0.628	0.769
1.440	44.1	88	44.14	54.07	0.636	0.779
1.445	44.4	89	44.53	54.55	0.643	0.789
1.450	44.8	90	44.92	55.03	0.651	0.798
1.455	45.1	91	45.31	55.50	0.659	0.808
1.460	45.4	92	45.69	55.97	0.667	0.817
1.465	45.8	93	46.07	56.43	0.675	0.827
1.470	46.1	94	46.45	56.90	0.683	0.837
1.475	46.4	95	46.83	57.37	0.691	0.846
1.480	46.8	96	47.21	57.83	0.699	0.856
1.485	47.1	97	47.57	58.28	0.707	0.865
1.490	47.4	98	47.95	58.74	0.715	0.876
1.495	47.8	99	48.34	59.22	0.723	0.885

TABLE I.—SPECIFIC GRAVITY OF SULPHURIC ACID—(*Continued*)

Specific gravity at $\frac{15°}{4°}$ *in vacuo*	Degrees Baumé	Degrees Twaddell	100 parts by weight contain, grams		1 liter contains in kilograms	
			SO_3	H_2SO_4	SO_3	H_2SO_4
1.500	48.1	100	48.73	59.70	0.731	0.896
1.505	48.4	101	49.12	60.18	0.739	0.906
1.510	48.7	102	49.51	60.65	0.748	0.916
1.515	49.0	103	49.89	61.12	0.756	0.926
1.520	49.4	104	50.28	61.59	0.764	0.936
1.525	49.7	105	50.66	62.06	0.773	0.946
1.530	50.0	106	51.04	62.53	0.781	0.957
1.535	50.3	107	51.43	63.00	0.789	0.967
1.540	50.6	108	51.78	63.43	0.797	0.977
1.545	50.9	109	52.12	63.85	0.805	0.987
1.550	51.2	110	52.46	64.26	0.813	0.996
1.555	51.5	111	52.79	64.67	0.821	1.006
1.560	51.8	112	53.12	65.08	0.829	1.015
1.565	52.1	113	53.46	65.49	0.837	1.025
1.570	52.4	114	53.80	65.90	0.845	1.035
1.575	52.7	115	54.13	66.30	0.853	1.044
1.580	53.0	116	54.46	66.71	0.861	1.054
1.585	53.3	117	54.80	67.13	0.869	1.064
1.590	53.6	118	55.18	67.59	0.877	1.075
1.595	53.9	119	55.55	68.05	0.886	1.085
1.600	54.1	120	55.93	68.51	0.895	1.096
1.605	54.4	121	56.30	68.97	0.904	1.107
1.610	54.7	122	56.68	69.43	0.913	1.118
1.615	55.0	123	57.05	69.89	0.921	1.128
1.620	55.2	124	57.40	70.32	0.930	1.139
1.625	55.5	125	57.75	70.74	0.938	1.150
1.630	55.8	126	58.09	71.16	0.947	1.160
1.635	56.0	127	58.43	71.57	0.955	1.170
1.640	56.3	128	58.77	71.99	0.964	1.181
1.645	56.6	129	59.10	72.40	0.972	1.192
1.650	56.9	130	59.45	72.82	0.981	1.202
1.655	57.1	131	59.78	73.23	0.989	1.212
1.660	57.4	132	60.11	73.64	0.998	1.222
1.665	57.7	133	60.46	74.07	1.007	1.233

TABLE I.—SPECIFIC GRAVITY OF SULPHURIC ACID—(*Continued*)

Specific gravity at $\frac{15°}{4°}$ *in vacuo*	Degrees Baumé	Degrees Twaddell	100 parts by weight contain, grams		1 liter contains in kilograms	
			SO_3	H_2SO_4	SO_3	H_2SO_4
1.670	57.9	134	60.82	74.51	1.016	1.244
1.675	58.2	135	61.20	74.97	1.025	1.256
1.680	58.4	136	61.57	75.42	1.034	1.267
1.685	58.7	137	61.93	75.86	1.043	1.278
1.690	58.9	138	62.29	76.30	1.053	1.289
1.695	59.2	139	62.64	76.73	1.062	1.301
1.700	59.5	140	63.00	77.17	1.071	1.312
1.705	59.7	141	63.35	77.60	1.080	1.323
1.710	60.0	142	63.70	78.04	1.089	1.334
1.715	60.2	143	64.07	78.48	1.099	1.346
1.720	60.4	144	64.43	78.92	1.108	1.357
1.725	60.6	145	64.78	79.36	1.118	1.369
1.730	60.9	146	65.14	79.80	1.127	1.381
1.735	61.1	147	65.50	80.24	1.136	1.392
1.740	61.4	148	65.86	80.68	1.146	1.404
1.745	61.6	149	66.22	81.12	1.156	1.416
1.750	61.8	150	66.58	81.56	1.165	1.427
1.755	62.1	151	66.94	82.00	1.175	1.439
1.760	62.3	152	67.30	82.44	1.185	1.451
1.765	62.5	153	67.65	82.88	1.194	1.463
1.770	62.8	154	68.02	83.32	1.204	1.475
1.775	63.0	155	68.49	83.90	1.216	1.489
1.780	63.2	156	68.98	84.50	1.228	1.504
1.785	63.5	157	69.47	85.10	1.240	1.519
1.790	63.7	158	69.96	85.70	1.252	1.534
1.795	64.0	159	70.45	86.30	1.265	1.549
1.800	64.2	160	70.94	86.90	1.277	1.564
1.805	64.4	161	71.50	87.60	1.291	1.581
1.810	64.6	162	72.08	88.30	1.305	1.598
1.815	64.8	163	72.69	89.05	1.319	1.621
1.820	65.0	164	73.51	90.05	1.338	1.639
1.821	.....	....	73.63	90.20	1.341	1.643
1.822	65.1	....	73.80	90.40	1.345	1.647

TABLE I.—SPECIFIC GRAVITY OF SULPHURIC ACID—(*Concluded*)

Specific gravity at $\frac{15°}{4°}$ *in vacuo*	Degrees Baumé	Degrees Twaddell	100 parts by weight contain, grams		1 liter contains in kilograms	
			SO_3	H_2SO_4	SO_3	H_2SO_4
1.823	.....	....	73.96	90.60	1.348	1.651
1.824	65.2	....	74.12	90.80	1.352	1.656
1.825	.....	165	74.29	91.00	1.356	1.661
1.826	65.3	....	74.49	91.25	1.360	1.666
1.827	.....	....	74.69	91.50	1.364	1.671
1.828	65.4	....	74.86	91.70	1.368	1.676
1.829	.....	....	75.03	91.90	1.372	1.681
1.830	.....	166	75.19	92.10	1.376	1.685
1.831	65.5	....	75.35	92.30	1.380	1.690
1.832	.....	....	75.53	92.52	1.384	1.695
1.833	65.6	....	75.72	92.75	1.388	1.700
1.834	.....	....	75.96	93.05	1.393	1.706
1.835	65.7	167	76.27	93.43	1.400	1.713
1.836	.....	....	76.57	93.80	1.406	1.722
1.837	.....	....	76.90	94.20	1.412	1.730
1.838	65.8	....	77.23	94.60	1.419	1.739
1.839	.....	....	77.55	95.00	1.426	1.748
1.840	65.9	168	78.04	95.60	1.436	1.759
1.8405	.....	....	78.33	95.95	1.451	1.765
1.8410	.....	....	79.19	97.00	1.458	1.786
1.8415	.....	....	79.76	97.70	1.469	1.799
1.8410	.....	....	80.16	98.20	1.476	1.808
1.8405	.....	....	80.57	98.70	1.483	1.816
1.8400	.....	....	80.98	99.20	1.490	1.825
1.8395	.....	....	81.18	99.45	1.494	1.830
1.8390	.....	....	81.39	99.70	1.497	1.834
1.8385	.....	....	81.59	99.95	1.500	1.838

Allowance for Temperature

(Lunge)

Per degree Centigrade

Up to 1.170 = 0.0006 specific gravity
1.170 to 1.450 = 0.0007 specific gravity
1.450 to 1.580 = 0.0008 specific gravity
1.580 to 1.750 = 0.0009 specific gravity
1.750 to 1.840 = 0.0010 specific gravity

Table II.—Specific Gravity of Sulphuric Acid at 60°F.

(Lunge)

Specific gravity	Degrees Twaddell	100 parts by weight contain		1 liter contains in kilograms	
		SO_3	H_2SO_4	SO_3	H_2SO_4
1.830	166	75.19	92.10	1.376	1.685
1.831	...	75.46	92.43	1.382	1.692
1.832	...	75.69	92.70	1.386	1.698
1.833	...	75.89	92.97	1.391	1.704
1.834	...	76.12	93.25	1.396	1.710
1.835	167	76.35	93.56	1.402	1.717
1.836	...	76.57	93.80	1.405	1.722
1.837	...	76.90	94.20	1.412	1.730
1.838	...	77.23	94.60	1.419	1.739
1.839	...	77.55	95.00	1.426	1.748
1.840	168	78.04	95.60	1.436	1.759
1.8405	...	78.33	95.95	1.441	1.765
1.841	...	78.69	96.30	1.448	1.774
1.8415	...	79.47	97.35	1.463	1.792
1.8410	...	80.16	98.20	1.476	1.808
1.8405	...	80.43	98.52	1.481	1.814
1.8400	...	80.59	98.72	1.483	1.816
1.8395	...	80.63	98.77	1.484	1.817
1.8390	...	80.93	99.12	1.488	1.823
1.8385	...	81.08	99.31	1.490	1.826

SPECIFIC GRAVITY OF FUMING SULPHURIC ACID[1]

(Knietsch, *Ber.* 1901, p. 4101)

Per cent. free SO_3	Per cent. total SO_3	Specific gravity 35°C.	Per cent. free SO_3	Per cent. total SO_3	Specific gravity 35°C.
0	81.63	1.8186	52	91.18	1.9749
2	81.99	1.8270	54	91.55	1.9760
4	82.36	1.8360	56	91.91	1.9772 (max.)
6	82.73	1.8425	58	92.28	1.9754
8	83.09	1.8498	60	92.65	1.9738
10	83.46	1.8565	62	93.02	1.9709
12	83.82	1.8627	64	93.38	1.9672
14	84.20	1.8692	66	93.75	1.9636
16	84.56	1.8756	68	94.11	1.9600
18	84.92	1.8830	70	94.48	1.9564
20	85.30	1.8919	72	94.85	1.9502
22	85.66	1.9020	74	95.21	1.9442
24	86.03	1.9092	76	95.58	1.9379
26	86.40	1.9158	78	95.95	1.9315
28	86.76	1.9220	80	96.32	1.9251
30	87.14	1.9280	82	96.69	1.9183
32	87.50	1.9338	84	97.05	1.9115
34	87.87	1.9405	86	97.45	1.9046
36	88.24	1.9474	88	97.78	1.8980
38	88.60	1.9534	90	98.16	1.8888
40	88.97	1.9584	92	98.53	1.8800
42	89.33	1.9612	94	98.90	1.8712
44	89.70	1.9643	96	99.26	1.8605
46	90.07	1.9672	98	99.63	1.8488
48	90.41	1.9702	100	100.00	1.8370
50	90.81	1.9733			

[1] For more extensive tables on Fuming sulphuric acid, the tables of the author under the caption "Fuming sulphuric acid" are referred to.

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