DEPARTMENT OF COMMERCE

CIRCULAR
OF THE
BUREAU OF STANDARDS

S. W. STRATTON, Director

No. 55

MEASUREMENTS FOR THE HOUSEHOLD

[1st Edition]
Issued August 28, 1915

WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

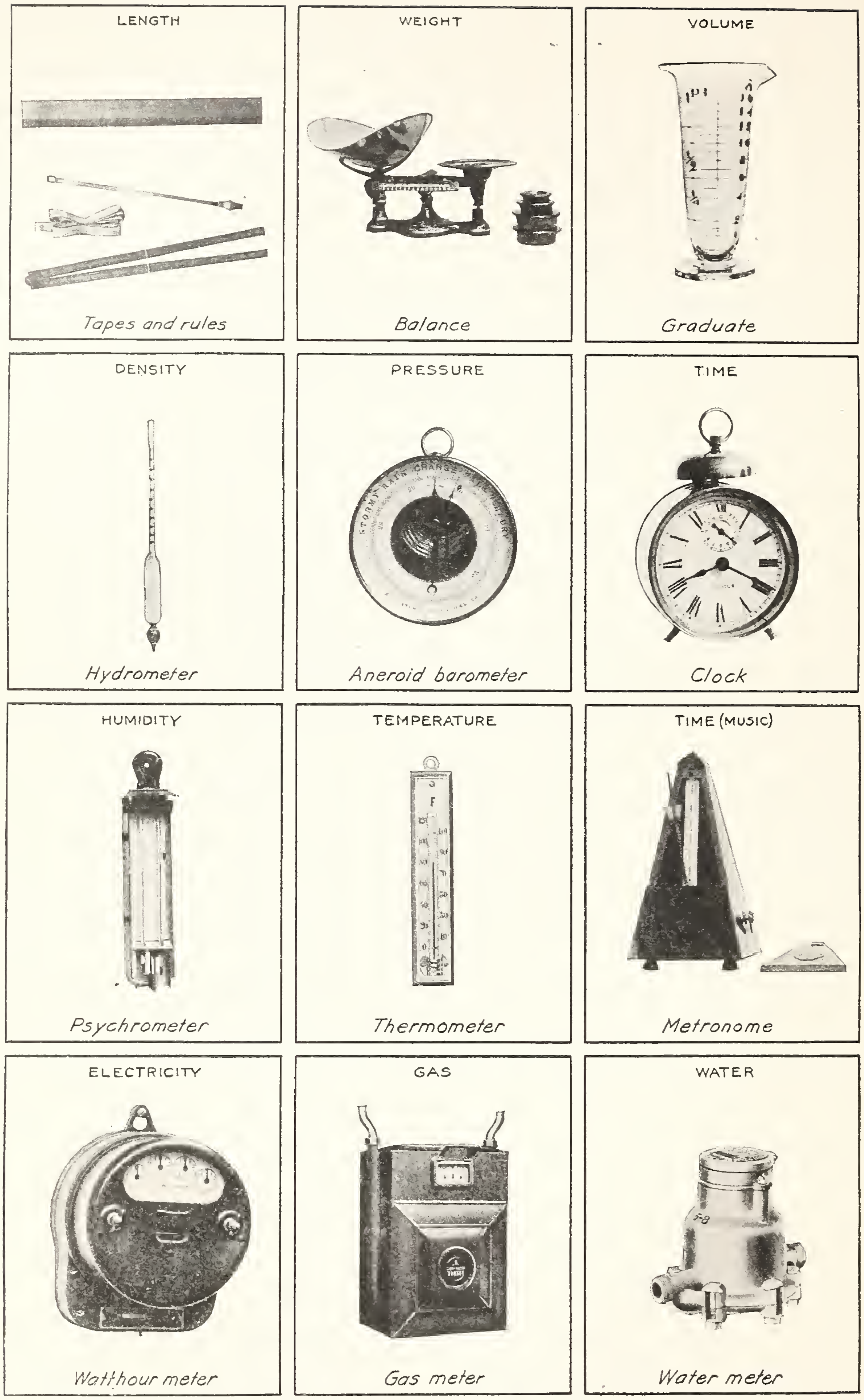


Fig. 1.—*A group of typical measuring instruments used in the home*

The efficient management of the home requires a set of suitable measuring appliances. The group shown above emphasizes the variety of measurements needed by the modern household. The pictures do not show true relative sizes nor is the list complete. Other types are found in many modern houses and other forms of those shown above are recommended for special purposes

DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 55

MEASUREMENTS FOR THE HOUSEHOLD

[1st Edition]
Issued August 28, 1915

WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
45 CENTS PER COPY

CONTENTS

MEASUREMENTS FOR THE HOUSEHOLD

I. INTRODUCTION

1. Purpose of this Circular

The purpose of this circular is (1) to give information as to units, methods, and instruments of measurement useful in household activities, (2) to describe available means of assuring correct quantity in articles bought by weight and measure, and (3) to give other facts of interest which would awaken an appreciation of the rôle of measurement in daily life.

In the scientific investigations of numerous questions the Bureau of Standards has accumulated general information which may be known to the industries concerned, and hence of less novelty to them, but is often of great value and importance to the general public. For example, watchmakers are familiar with the construction and adjustment of watches and clocks, and the best methods of caring for them, but the ordinary purchaser who uses them is often at a loss to obtain the most elementary knowledge of how to properly care for them. In the same way, to electrical and gas engineers information given in this circular is everyday knowledge, but the householder, while deeply concerned about the indications of his meters and the quality of the gas supplied to him, often finds it difficult, if not impossible, to secure simple technical information that is often of great value to him. It was with the purpose of making the results of the work of the Bureau available to the public in so far as this work is related to the work of the household that this circular has been prepared.

2. Rôle of Measurement in Daily Life

Household measurements suggest many interesting phases of the art of measurement. The significance of measurements in our civilization and their effect upon everyday life may not be fully appreciated. From the beginning of life measurement is important. The infant should weigh about so much, and the number of pounds is one measure of its condition. Its weight should increase at a normal rate, and here the weight becomes an index of nutrition and good health. The measure of body temperature is an advance indicator of illness. Especially in recent scientific studies of childhood is the importance of measurement keenly realized. The response of muscles and nerves—the measure of the so-called time reactions and sense perception—are elements in studying educational methods, especially subnormal cases. It is possible to set certain approximate standards for the normal child and its growth. Measurements are made of the speed, strength, and fatigue of its reactions; of its height, girth, and other dimensions. Muscle measures and strength tests indicate normal growth or the effectiveness of physical training. The ergograph measures endurance, and the chronograph records perceptions and reaction times. The focusing power of the eyes is measured, and with these measurements the optician can perfect the vision by adapting the measured curvature of glass to the measured defect of vision. The correct measures of the body determine the comfort and effectiveness of clothing.

Modern industry owes its efficiency largely to careful measurements which control processes, or fix the dimensions, proportions, and properties of products. Accurate parts of machines or accessories make it possible to manufacture the parts separately and assemble them without special hand fitting. Anyone may then order repair parts, knowing that they will fit into the machine. In many industries the measured control of heat, electric current, or power is essential to efficient operation. Bread should rise at a definite temperature, steel should be quenched at a certain stage in cooling to give the best results, and similar account must be taken of many things to secure the desired quality.

Properties of materials are measured or tested, and this gives a means of controlling quality. Measurement guides the processes of all industries and keeps their output up to certain standards. Careful determinations of the properties of materials are coming to mean more and more to business and industry, and the determination of properties of standard materials is an ever-increasing part of the work of this Bureau.

3. Measures of Trade and Their Inspection

The Bureau of Standards is also active in the phase of measurements that touches the household very directly—the weighing and measuring of goods bought, sold, and transported. Much inaccuracy and fraud exist. Weights and standards and instruments are subject to accident, deterioration, and tampering. For these reasons systematic inspection of trade weights and measures is regarded as a function of the Government. In order that the standards throughout a country should be uniform, the custody of the fundamental standards rests with the National Government, which is authorized to fix the standards of weight and measure. In the United States the actual inspection service, being necessarily local, has been left to the States and cities. This Bureau's work has been (1) to provide the States with standardized sets of weights and measures, (2) to encourage and stimulate intelligent interest in the State and local regulation and inspection of weights and measures, (3) to cooperate with the local sealers regarding the technical details of inspection service, and (4) to gather data regarding the standards and instruments in use.

4. Measurements of Household Products and Processes

Improved precision has slowly evolved from the guesswork of earlier times. For example, terms like the "pinch of salt," "speck of pepper," "handful of rice," "sweeten to taste" (units of vague magnitude) have gradually been replaced by definite amounts specified and measured. A process is uncertain of success unless the effect of all the factors entering into it is known. In factories where food is prepared on a large scale, temperatures are carefully measured or determined automatically, and amounts and times are accurately controlled. These methods, which make for efficiency and economy, are being used more and more in the household.

Such measurements as require costly or delicate apparatus can not yet be expected to be common in the home; and some still think that the measurement of temperature of rooms, of ovens and sirups, and the weighing of purchases, etc., are unimportant. However, scales, thermometers, and a few other simple measuring appliances can be obtained for a small expenditure, and this circular will attempt to show some of the advantages of their use. Measuring instruments for household use which are automatic, or which may easily be operated without special training are becoming more and more available.

5. Household Measuring Appliances

A large variety of measuring appliances are used in connection with the household work. (See Fig. 1.) A description of the kinds of appliances will be found in more or less detail in the several sections of this circular; they include the following groups:

1. A test set of weights and measures for checking purchases and other purposes.

2. Meters for measuring the delivery for household use of gas, water, and electricity.

3. Special measuring instruments, such as thermometers, hygrometers, barometers, hydrometers, and time pieces, for measuring temperature, moisture, pressure, density, and time.

4. Special measures used in cooking.

The efficient management of the modern household is greatly promoted by the careful use of well-selected measuring appliances, and one of the purposes of this circular is to guide the housewife in the selection and use of such appliances.

6. Educational Value of Household Measurements

Apart from the direct use of the results of measurements in the household, they are, when properly made, of educational value. Hazy ideas of process and dimension become clear and definiteness of thought is gained. Opportunities for measurement are a means of education for children which should not be ignored. The habit of thinking in terms of units and definite quantities can not fail to increase the efficiency of the individual and the household. The practical measurement of purchases may be made a means of education in appreciating and estimating quantities. Boys may easily construct rough measuring instruments and devise methods of measurement of such things as air pressure, wind velocity, temperature, etc. The measurement of areas and volumes of rooms; the heights and weights of individuals; of the growth of children, etc.—are all matters which lend themselves to educational uses. Some of the information given in the chapters of this circular, for example, on light, on gas meters, on the use of clocks, on humidity, etc., may lead to observations and experiments of considerable educational value. In general, it may be said that the educational and other uses of household measurements are almost unlimited and but little realized.

7. Units and Tables

In the appendix will be found tables of units and special data regarding measurements. Many of the units used are somewhat vague and in some cases the terms are ambiguous. For example, the *ounce* used in the drug store is not the same as the ounce used in the grocery store, even when the same commodity is purchased, and the *fluid ounce* is different from either, and is not a weight at all. It will thus be seen that for more careful work in connection with measurements the exact value of the units used should be clearly known. The growing use of the metric system throughout the world is rapidly introducing simplicity and definiteness in place of existing confusion, since in that system there is but one name for each unit and the unit has but one value throughout the world. Since the American Pharmacopœia now uses the metric system as the only system of measurement in the formulas for drugs and medicines, a knowledge of the metric system is increasingly desirable, especially in connection with the prescription and use of medicine and other compounds. In domestic science and related sciences the knowledge of the metric system is indispensable to the best work, since everywhere the more technical aspects of these subjects usually involve the use of the metric system. A pamphlet descriptive of the metric system may be obtained upon application to this Bureau.

8. Revision Notice

A revised edition of this circular is in preparation and the cooperation of all interested is invited to make it as useful as possible. Suggestions will be gladly welcomed and correspondence on the subject is invited. The Bureau will be pleased to answer specific questions on the subject of the circular.

II. COMMODITIES

1. Measurement as a Factor in Purchasing

Many careful housewives scrutinize the *apparent prices* charged for the various commodities and the *quality* of goods delivered. But unless the *quantity* actually delivered is determined, the *actual cost price* of the commodities is not ascertained. Dishonest merchants may attract trade by quoting prices lower than the prevailing market price and then, by delivering amounts short in weight or measure, actually receive either the full market price or even an enhanced price for the commodity. Not only do such merchants make illegal profits on their goods in this way, but they also attract trade to the detriment of merchants who quote a higher price but deliver full amounts and whose goods may therefore be even cheaper to the buyer than those of the dishonest competitor.

2. The Elimination of False Measure

When fraudulent short weight or measure is discovered the purchaser should take steps to have the offender punished, even if the loss on the individual purchase is small, since other losses from this cause may be important in the aggregate. To fail to do this neglects the rights of other purchasers at that store who may not have detected short weight or measure delivered to them, and also the right of the honest merchant to protection, since his trade may be taken away on account of prices in his competitor's store, which are apparently, but not actually lower ones. When any purchaser finds that short weight or measure is being delivered by any tradesman, a complaint should be made to the local sealer or inspector of weights and measures, and details of the imposition given. It is then the duty of the latter to prevent further fraud by this tradesman. Only by concerted action of purchasers can dishonest practices of this kind be completely checked.

This course might be more often followed were it not for the fact that the average woman objects, and rightly objects, to appearing in municipal court as complainant or witness in the ac-

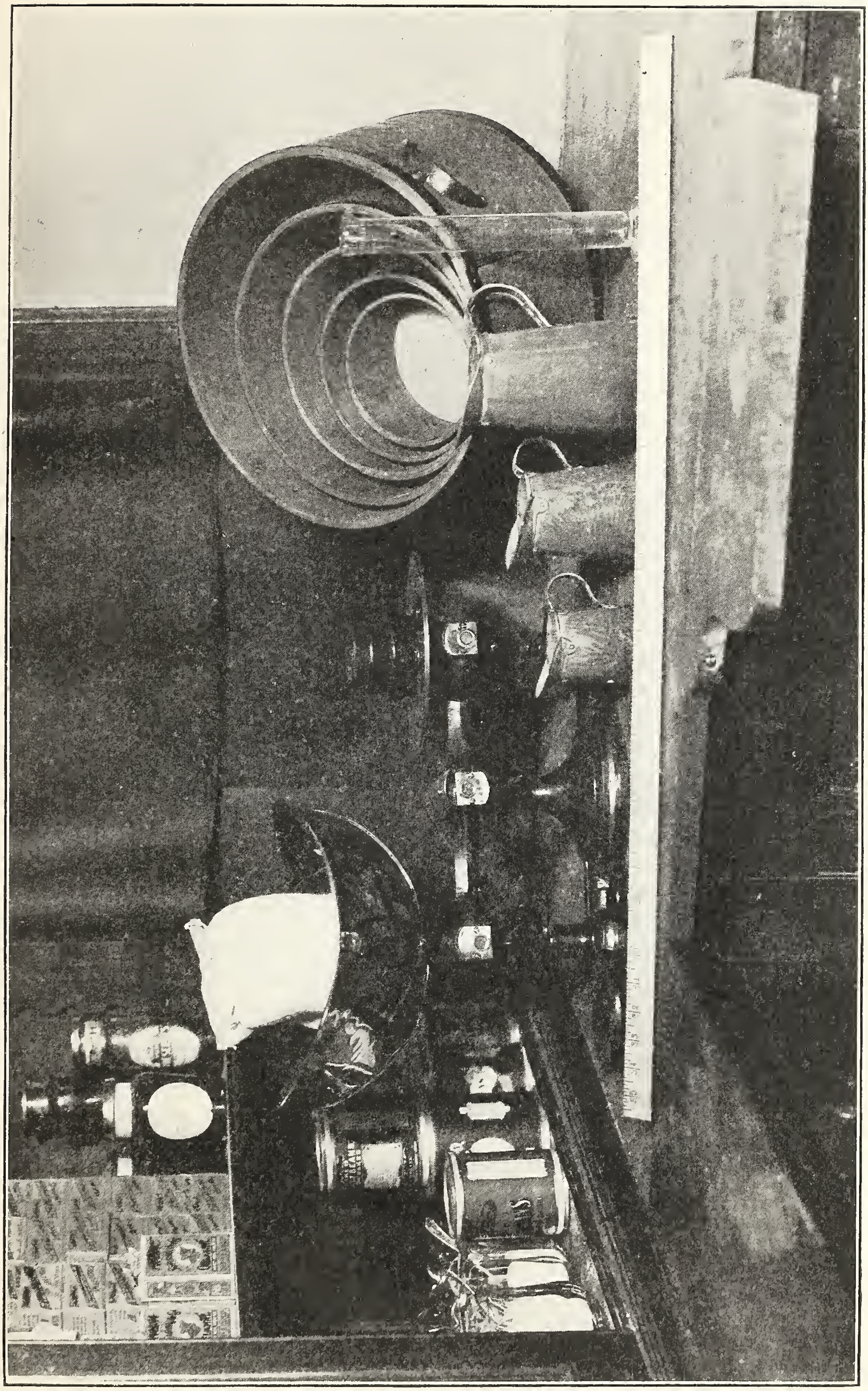


Fig. 2.—*Household weights and measures test set, A*

This equipment is suggested primarily for checking commodities purchased, but is adapted to many other household uses.

tion. But this is not necessary. The official receiving such a complaint need not take action upon the facts of the particular case or cases presented. Its only effect may be the pointing out of a merchant whose business methods are questionable, and he may then proceed to obtain information and evidence on his own account. If upon investigation he is unable to gather evidence of fraud, it indicates that the shortages discovered may have been accidental and not the general rule; but if he does obtain such evidence he may safely proceed on the assumption that the frauds are deliberate ones, and his duty to proceed against the merchant and to remedy conditions by legal action will be clear.

3. National Net-Content-of-Container Law

Congress recently enacted a law which is a very great aid in the buying of foodstuffs in package form. This law is an amendment to the pure-food act, and is popularly known as the "net-weight amendment." In brief, it requires that foodstuffs in package form must bear a statement showing the net amount of commodity actually contained in the package. Up to this time, in purchasing food commodities in the original package, the housewife has usually been limited to comparisons of quality and apparent price, which is of course the price per package. In comparing two brands of a food in packages of equal size these comparisons were trustworthy. When there was a difference in the size of package, however, economy in buying could not be obtained from a knowledge of these two factors alone. (See Fig. 8.) There might be a large difference in price per unit of quantity which would outweigh an apparent difference in price per package, or slight difference in the quality; but with the quantity labeled upon each package the purchaser has all essential facts at hand to compare unit prices.

Thus, we may compare two brands of package goods. Two packages of raisins sell for 10 cents and 12 cents per package, respectively. The purchaser might consider that the 12-cent brand was worth 2 cents (or 20 per cent) more than the 10-cent brand, but upon examination of the labels, however, if it appeared that the former contained 16 ounces and the latter only 12 ounces, he might conclude that the difference in price outweighed the advantages conceded for the higher priced package.

Again, a package of crackers may sell for 10 cents per package and crackers in bulk for 10 cents per pound. The purchaser might consider the package goods more desirable and disregard the weight. Under these conditions the package brand would naturally be selected. But the quantity is now marked on the package. Suppose in the case mentioned above the weight is 10 ounces. The cost per pound of the package goods is therefore 16 cents and of those in bulk 10 cents. The knowledge thus conveyed, that the brand somewhat better in quality or flavor was 60 per cent higher in price, might entirely outweigh the slight difference in quality and persuade the purchaser that the bulk goods were the better for the purpose. Therefore the careful

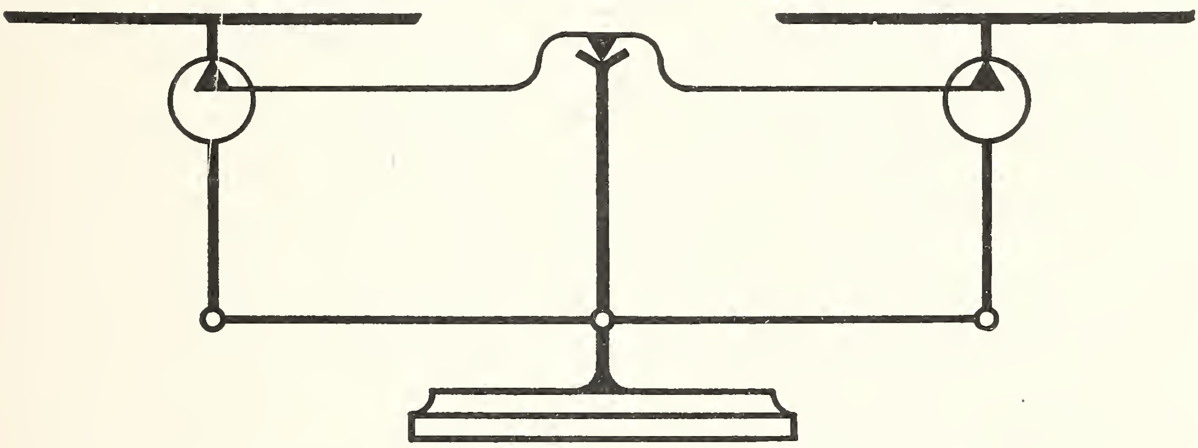


FIG. 3.—*Diagram of the equal-arm balance.* (*See Figs. 1 and 2*)

The pans of this balance are carried on the knife edges (the triangles shown at the bearing points under the pans, at equal distances from the center or fulcrum knife edge). The scale comes to balance when the weights on the two pans are equal. The load to be weighed is placed on one pan and known weights are added to the other until the scale is in balance. The correct name for this type is "the equal arm stabilized scale."

purchaser should first examine the labels on the packages, observe the net contents, and determine therefrom the price per unit weight. If these precautions are neglected, much of the value of an excellent protective statute will be lost.

4. Household Weights and Measures Test Set

(*a*) ACCURACY NEEDED IN HOUSEHOLD MEASUREMENT OF PURCHASES.—Every household should have a set of weights and measures by which purchases may be checked, and short weight or short measure detected. The measuring apparatus should be well made and of sufficient accuracy. Otherwise the measurements will not be reliable enough to warrant making a definite complaint, except in cases of considerable shortage.

FIG. 4.—*Household weights and measures test set, B*

This equipment is suggested primarily for checking commodities purchased, but is also adapted to many other household uses.

If measurements made with apparatus of uncertain reliability show small apparent shortages, suspicion should fall upon the apparatus, not the dealer, until the apparatus has been checked by suitable standards.

The purchasers of measuring apparatus will seldom be able unaided to verify its accuracy. They should therefore have the various pieces tested and sealed by the local sealer of weights and measures at the time of purchase. They should preferably be purchased with the understanding that acceptance will depend upon passing the official tests.

(*b*) APPARATUS SUITABLE FOR HOUSEHOLD INSPECTION.—The set of apparatus (see Figs. 2 and 4) should include the following:

Weighing scale.—A scale of from 10 to 30 pounds capacity or more, graduated to 1 ounce or less. (A 20-pound scale will be suitable.)

Liquid measures.—One quart, 1 pint, and ½ pint. A 4-ounce glass graduate subdivided to 1 dram or less for measuring small quantities of liquids and determining the errors on larger amounts.

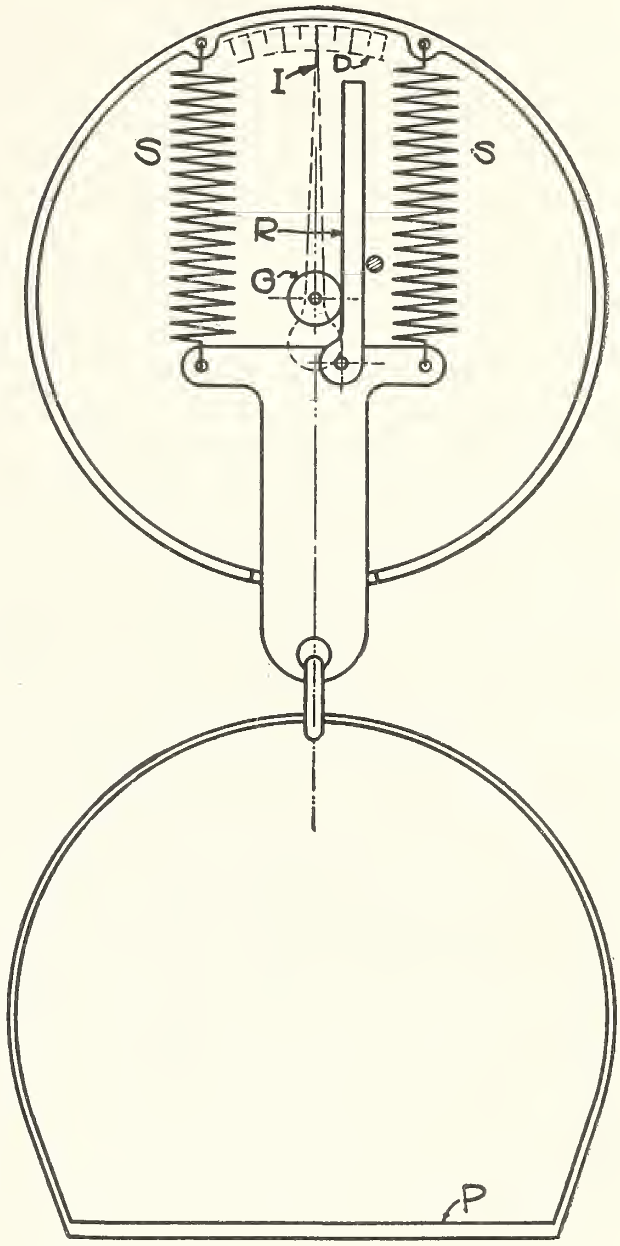


FIG. 5.—*Diagram of the spring balance*

The load placed on the pan P stretches the two springs S, S. The motion of the cross bar below the springs is transmitted through the vertical toothed bar or rack R turning the small gear G, mounted on a spindle bearing the pointer I. The pointer rotates over the dial, a portion of which with the pointer is shown in dotted outline.

Dry measures.—Nest of ½ bushel to 1 quart. (See following discussion as to the advisability of these.)

Length measures.—A yard measure, or a tape 3 or 6 feet in length.

The specifications and tolerances to which the apparatus should conform are usually obtainable at the local inspector's office. However, certain suggestions may be of value in this connection.

(*c*) The weighing scale.—Several varieties of scales for the purpose of household weighings are obtainable. A very convenient form is a hanging pan spring scale of about 10 or 20 pounds capacity. A scale of this type has several advantages. It automatically indicates the weight of articles placed upon it. (See Fig. 5.) It has, moreover, no loose weights which are liable to be mislaid. It may be suspended from a bracket on the wall and therefore does not require table space. If a folding bracket is employed to swing the scale back against the wall, no space that can be otherwise utilized to advantage is required. A fairly accurate scale of this character can be purchased for a reasonable sum.

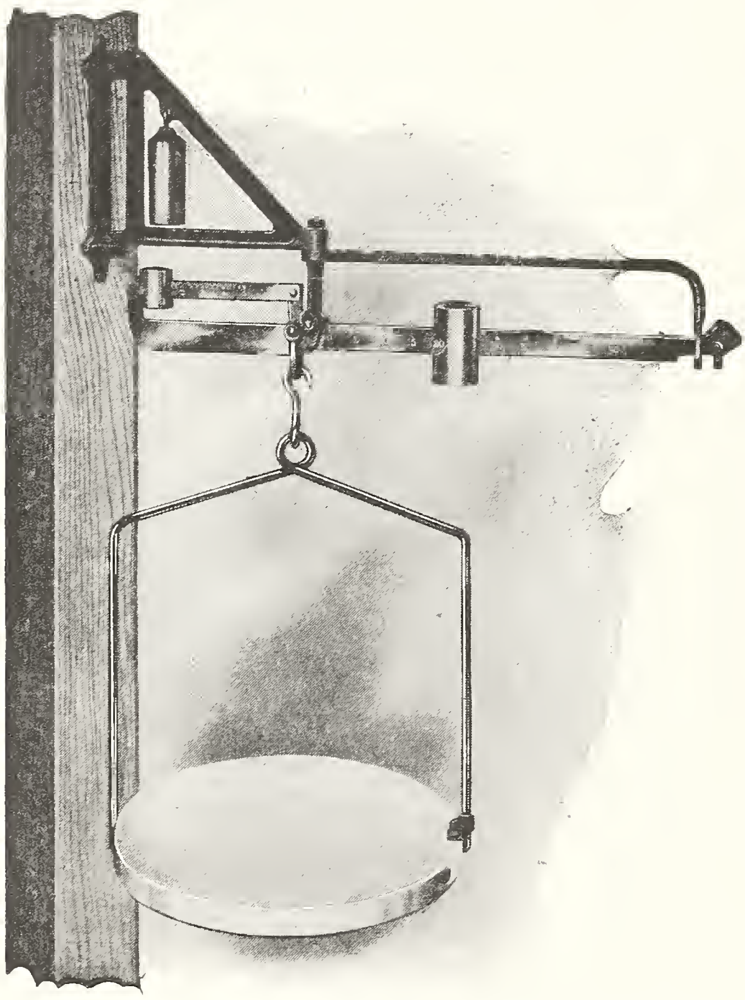


Fig. 6.—*Folding household scale of the steelyard type*

If table space is available, however, a counter beam scale of either the equal or unequal arm type may be preferred. (See Fig. 3.) This has the advantage of being more reliable, but the cheaper ones do not automatically indicate the weight, but require the addition of loose weights or the moving of a sliding poise. Counter beam scales are usually higher in price than spring scales.

Another type of scale which is very suitable and which combines many of the advantages of each of the types mentioned above, is a beam scale of the steelyard type designed to hang from a bracket, and to fold back against the wall when not in use. Such a scale often has a larger capacity than the common forms of the types described above and thus may be used for every occasion which may arise. Scales of this construction, designed expressly for household use, are now on the market. (See Fig. 6.)

A type of spring scale has been much used in the past, namely, the so-called "family" scale, having the commodity pan or platform above the spring. Many of these are very cheap (often costing only $1 or less) but have been found exceedingly inaccurate. Unless exceptionally well built and correspondingly higher in price, this type is useless in properly checking the weight of deliveries of commodities received.

(*d*) Liquid measures and graduate.—The liquid measures should be cylindrical, or conical with the top diameter smaller than the bottom diameter, and made of metal, enameled ware, composition, or similar and suitable material. They should be strong and rigid enough to withstand ordinary usage without becoming bent, indented, or otherwise damaged.

The graduate may be cylindrical or conical in shape. The former is usually somewhat more accurate, while the latter is somewhat cheaper, is more easily cleaned, and can often be more readily procured. The graduation marks should be correctly placed and plainly numbered, so as to indicate readily the capacity of the graduate at all points. They should also be straight, clear-cut, and of sufficient length to allow accurate readings to be made.

(*e*) Dry measures.—The dry measures should be made of metal, or of well-varnished wood with a metal band around the top, or of similar and suitable material. They should preferably be cylindrical. If they are conical, the top diameter should exceed the bottom diameter by an amount not exceeding 10 per cent of the latter.

The diameters should in no case be less than those given below:

Measure	Minimum diameters
	Inches
½ bushel	13¾
1 peck	10⅞
½ peck	8½
2 quarts	6⅝
1 quart	5⅜
1 pint	4

(*f*) LENGTH MEASURES.—The yard measure should be made of well-dried wood with metal ends, or entirely of metal, or of other material of which the form and dimensions remain reasonably permanent under normal conditions. It should be subdivided into inches and their fractions, and also into the customary fractional subdivisions of the yard, i. e., halves, quarters, eighths, and sixteenths.

The tape should be of steel, or of wire-woven cloth when such construction gives it sufficient strength and permanency. At least 1 yard of this tape should be subdivided as above.

5. The Use of the Household Set in Checking Amounts of Commodities

The method of using this test set of weights and measures is quite simple, and the proper use will in most cases be evident to the housewife. Only a few suggestions upon the less obvious points, therefore, need be made here.

(*a*) USE OF SCALE, IN GENERAL.—The scale must be handled carefully and be kept *clean* and *dry*. The scale must also be kept *in balance*, otherwise every indicated weight will be incorrect. The ordinary counter beam scale is *in balance* if the beam comes to rest midway between the two stops which limit the swing. On a scale with a reading face, such as a spring scale, the indicator should point *exactly* to a definite and clear zero graduation.

Upon nearly every scale means of adjustment are provided by the manufacturer. Thus, a counter balance of the beam type is adjusted by turning the adjusting screw or balance ball, or by adding weight to or subtracting it from the shot cup under the pan, or by altering the amount of balancing material wherever placed. Some spring scales may be adjusted as described. Others are adjusted by loosening a screw in a slot in the indicator, turning the latter on its pinion to the proper position, and then tightening the screw. If the scale has a glass face, this must be removed before the adjustment can be made. A properly constructed scale will rarely get out of balance. Therefore these adjustments on such a scale will not often have to be made.

For weighing on a beam scale the commodity should be placed on the pan; the beam should be brought to a balance by moving a sliding poise or by adding and subtracting loose weights. The weights used should be accurately totaled or the exact graduation on the weighing beam read.

In weighing a commodity on a scale which automatically indicates the weight, it is necessary only to make the reading carefully. Fractional parts of ounces are sometimes estimated by noting the exact position of the indicator between divisions.

If when reading the scale different readings are obtained upon moving the eye to the right or left, or up or down, it is necessary to take care that the eye is squarely in front of the point of the scale which is being read.

If a commodity exceeds in weight the capacity of the scale, it may sometimes be divided into two or more parts for checking purposes, each not to exceed the capacity of the scale. By adding the separate weights of the various portions the total weight of the amount purchased is found.

The weight desired and the weight which should be furnished is always the net weight of the commodity, i. e., the commodity itself without wrappings or coverings of any kind. Therefore a commodity should not be weighed in a cardboard carton, or other heavy coverings, or, if weighed with these, the coverings should thereafter be weighed separately and this weight subtracted from the gross or total weight.

(*b*) Meat.—When shortages are found in the weight of meat purchased, a common excuse of the dealer is that the meat was trimmed after being weighed, and it has often been found that this excuse was used to cover up frauds in such sales. Therefore the housewife should require that all meat trimmings should be delivered to her by the dealer. This is fair, since they have been purchased and paid for at regular prices; and it is economical since they are often of use to the careful housewife. When such a demand is made, the total weight delivered should never be less than the amount charged for, and if it is so found a shortage may legitimately be claimed.

(*c*) Poultry and fish.—Poultry drawn and dressed after weighing can not easily be checked as to weight, since the housewife will seldom desire to have the feathers, head, claws, etc., delivered. By observation or experiment one can soon learn what shrinkage in weight is naturally to be expected, and an investigation should be made in cases in which this proper shrinkage is exceeded. In cases in which fish are cleaned after weighing, similar precautions should be observed.

(*d*) Goods in original packages.—The purchaser should read the labels on the packages of goods purchased and the accuracy of the statements of quantity should be checked. If the contents are not to be removed at once, the package may be weighed gross when purchased and the weight noted on the outside. When empty the container may be weighed, and this weight, subtracted from the gross weight noted previously, gives the net weight. The law requires that this should equal that printed on the label.

(*e*) Liquids in bulk.—If a liquid commodity is purchased in bulk and only partly fills the receptacle in which it is delivered, upon pouring it into the measure of the *nominal* size corresponding to the amount purchased, it should completely fill that measure. If it does not fill the measure the delivery is short. If more of the same liquid of the same grade is at hand, the shortage can be immediately determined by putting a definite, noted quantity of the liquid into the graduate and from this amount completing the filling of the measure. The difference between the quantity of liquid remaining in the tolerance graduate and the original amount put in it is the shortage.

If there is not at hand any more of the commodity, the liquid under test may be poured out of the measure and the measure filled up with water to the same point that the commodity reached. This can usually be done by observing the top of the wet ring around the measure left by the commodity. Then by completing the filling of the measure with water from the graduate, the shortage may be found in the manner described above.

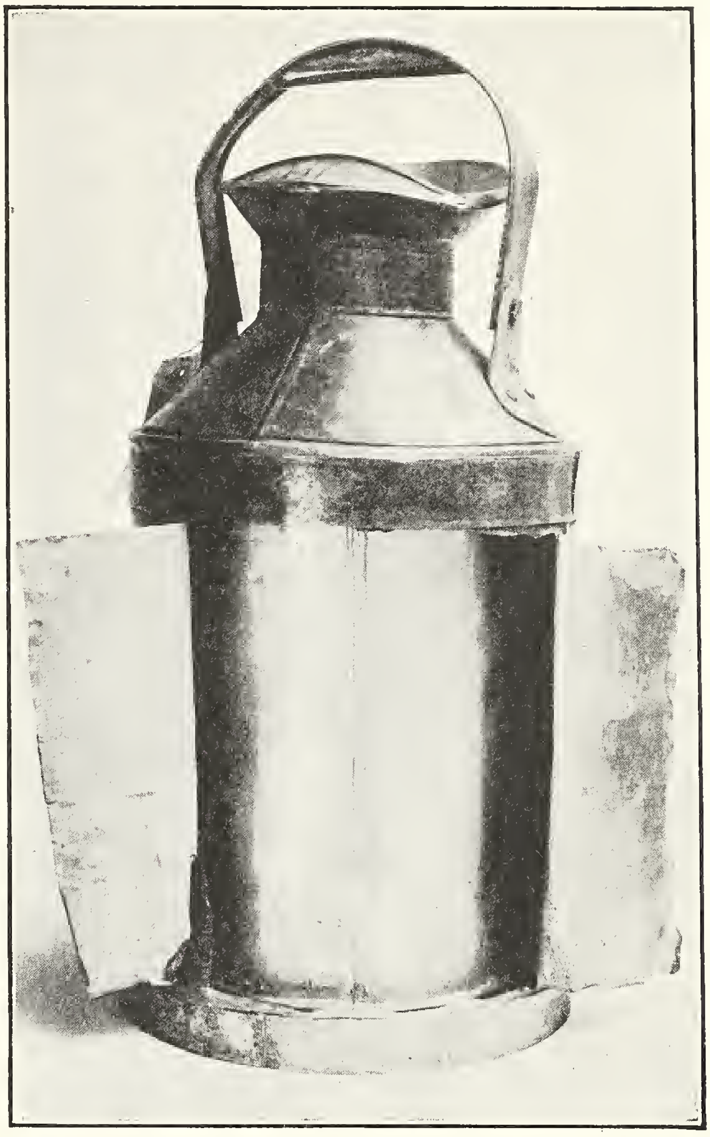


FIG. 7.—*Fraudulent 5-gallon measure (with side partially cut away, showing 3-gallon can inside)*

The purchaser sees only the 5-gallon measure but the 3-gallon measure is the one which is filled—a delivery 40 per cent short resulting.

(*f*) LIQUIDS IN CONTAINERS.—Liquid commodities bought in bottles, cans, or other containers may be checked as above described, or the following method may be found easier. The point to which the container is filled is first noted and the contents removed. Then, if the container is of the nominal size of one of the liquid test measures, this *measure* is filled with water until the water is just level with the top. This is then poured into the *container* until it is filled to the same point as before. If any water remains in the measure, the delivery is short by this amount. By pouring this into the graduate and noting its amount the shortage is determined. (Be sure that the container is filled to the same point in the test that it was when delivered, as the amount *actually delivered* and not the *capacity* of the container itself, is of importance in this case.)

When the container is not of the standard size of one of the test measures, the test is made as before, except that one of the measures must be filled more than once, or various measures and the graduate must be used and the error determined on the last amount added. For example, if a bottle is marked "One gallon," the quart must be filled and poured into the container four times, and the shortage, if any, determined on the last measure-full added.

Again, a bottle may be marked "1½ quarts." In this case the quart measure is filled and poured into the container, and then the pint is filled and poured in. In this case the amount remaining in the pint measure is the total shortage, and this is determined as before.

Fig. 8.—*Three bottles of extract (front and side views)*

This shows the impossibility of correctly estimating the quantity of contents from apparent size of the container. The bottle which is apparently smallest holds the most and vice versa.

A container may be marked "12 fluid ounces." As there are 16 fluid ounces in a pint, or 8 fluid ounces in a half-pint, the ½-pint test measure and the 4-ounce graduate may be employed, or the 4-ounce graduate may be filled three times.

(*g*) Use of graduates.—To avoid mistakes in reading cone graduates, it should be noted that these are sometimes more finely subdivided at the base than at the top. For example, a

4-ounce graduate may be subdivided to ½ dram for the first 2 drams, to 1 dram for the next 6 drams, to 2 drams for the remaining capacity up to 2 ounces, and to 4 drams, or half an ounce, for the interval between 2 and 4 ounces.

In filling the graduate to or reading it at any mark the graduate should be held level, and the readings should be made at the main surface of the liquid. The small amount of liquid which creeps up the sides of the glass to a point higher than the main surface of the liquid in the graduate should be disregarded.

(*h*) Receptacles used.—The size of a container or receptacle is of importance when a certain amount of liquid commodity in bulk is ordered from the merchant and there is sent to the store a receptacle in which this amount is to be placed. Such containers may not actually hold the amount ordered, yet often the container is filled and the amount *ordered* is charged for. "Gallon" and "half-gallon" oil cans, so-called, are often of a much smaller capacity. "Quart" bottles frequently hold only one-fifth of a gallon, or even less. Pails, demijohns, jugs, and other receptacles are not reliable as measures. Therefore, by means of the measures in the test set, determine the actual capacity of all receptacles that are to be used in buying. See that they contain at least the full amount to be purchased in them.

(*i*) Sale of dry commodities.[1]—Dry commodities, when sold in definite quantities, are commonly sold throughout the country in one of three ways, namely, by weight, by dry measure, or by numerical count. Since the method of sale in the last-mentioned way is usually legal when the commodities are such as are susceptible of sale in this manner, and since the method of buying and checking in retail sales is entirely obvious and presents no difficulties, no further mention will be made of it in the following pages. Sales by liquid measure, while common in some sections, are illegal and are therefore not considered here. It should also be noted that the sale of these commodities by guesswork methods, as by the "bag" or "sack," are also neglected as not being germane to the following discussion. It may be said generally that the

[1] Ordinarily the term "dry commodity" means anything not in liquid form which is bought and sold, but for the sake of conciseness and brevity the term will be used in this circular as limited to those dry products which are susceptible of measurement by dry capacity measures.

purchaser, for his own protection, should always demand some definite amount.

Formerly the more common practice was to sell potatoes, apples, onions, and other similar bulky commodities, as well as dried beans, seeds, and other small commodities, by measure. This was not universally true, since in the States of the Rocky Mountain and Pacific Coast sections such commodities have always been

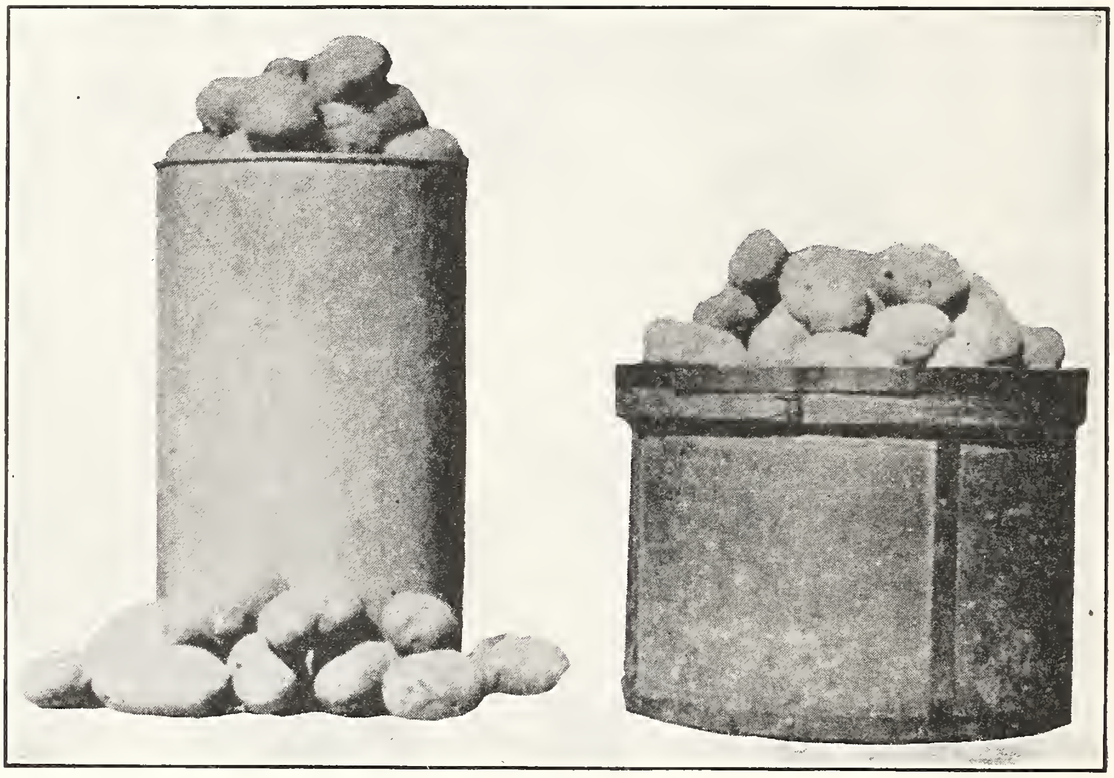


Fig. 9.—*Comparison of deliveries of "bottomless" type of measure and of the ordinary dry measure (both measures having the same capacity)*

The bottomless measure has so small a diameter that a proper heap can not be obtained. Moreover the small diameter causes stacking, which leaves large unfilled spaces in case of bulky commodities. When the potatoes in the right-hand measure (which contains the correct amount) are transferred to the "bottomless" measure on the left, the potatoes overflowing on the table represent the shortage in delivery of this measure.

sold exclusively by weight, and the growing tendency in the East and Middle West is to sell these commodities in this manner. Massachusetts, Ohio, Wisconsin, and Chicago, for example, have enacted legislation prescribing sales by weight. This is a long step forward, because the use of dry measures is very unsatisfactory and unreliable.

This Bureau strongly advises all purchasers to order dry commodities by weight and to insist that they be sold to them in this way. This method of dealing, it is believed, will be the prevailing method in the future, since the dry-measure method has always been unsatisfactory not only to the consumer but to the careful merchant as well.

In checking dry commodities by weight it will be necessary to have a list of the weights per bushel included in the laws of the State. These are given for the commoner commodities in Table 9.[2]

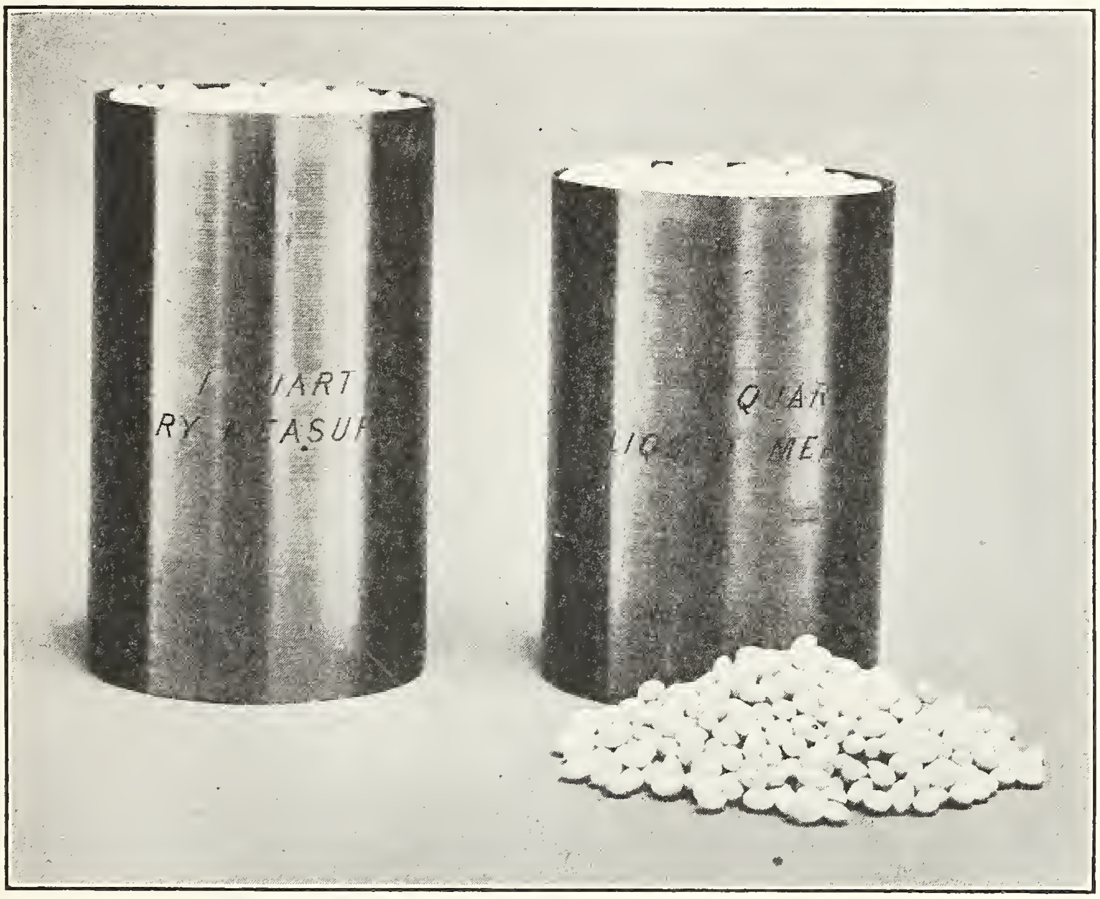


FIG. 10.—*Comparison of deliveries of liquid quart and of dry quart*

Dry commodities are often illegally sold by the smaller liquid measure. The beans on the table show the resulting shortage on a quart of commodity so measured.

One need, therefore, only check the weight of the commodity with the weight required by law.

Since it may not be possible in all cases to obtain dry commodities by weight, a set of dry measures is suggested in the household testing outfit. If it is practicable, however, these measures should be omitted.

---

[2] If a complete list of all commodities for which a legal weight is established by any State is desired, this can be procured from this Bureau upon request for Circular No. 10 of the Bureau of Standards. This circular is revised from time to time and changes made in the light of the latest legislation.

If dry commodities are obtainable only by dry measure, the buyer should understand what he is entitled to when buying in this manner. The majority of the States allowing sales by measure require by law that large or bulky commodities, when sold by measure, be sold by "heaped measure." This term is variously defined as "heaped in the form of a cone, the outside of the measure to be the base of the cone, and such cone to be as high as the article will admit," or "heaped as high as may be without special effort or design." The heaped bushel is usually considered under either of these definitions to be 1¼ "struck" bushels, i. e., in a heaped measure four-fifths of the whole amount of commodity will be contained up to the rim of the measure and one-fifth will be stacked in a conical form above the rim of the measure. Even a larger "heap" than this has been required. Therefore, in checking the delivery of bulky commodities by means of a dry measure, the measure should be well heaped up, since, if it is not, one is not receiving the full amount of commodity to which he is entitled. The term "bulky commodities" is in no case entirely itemized in the law, but includes potatoes, onions, beets, carrots, apples, pears, plums, peaches, Indian corn in the ear, cucumbers, parsnips, green peas unshelled, rutabagas, tomatoes, turnips, and some others. "Struck measure," however, is required for dried beans, peas, and shelled corn, berries and nuts of all kinds, seeds, wheat, oats, rice, and other cereals, etc.

6. State Laws Relating to Dry Commodities

In the matter of the sale of dry commodities, the laws of the various States differ. There is wide divergence in the wording employed in the various statutes, and many have never been interpreted by the higher courts. However, information is given below as to the force and effect which it is believed the legislatures intended to give to the statutes.

(*a*) States requiring sales by weight.—Some States have laws requiring that all dry commodities be sold by weight, while others require that those for which a legal weight has been established, be so sold. In the latter class when a unit of dry measure is called for, this must be determined by weight in accordance with the standard schedule of weights per bushel. In some of these

States a special contract may be made by the parties, specifying some other method of sale.

The list of States follows: Idaho, Iowa, Kansas, Massachusetts, Nevada, Ohio, Oregon, Utah, and Wisconsin.

In these States purchasers may demand that all orders be actually weighed before delivery, and that full weight as specified in the State law be delivered. It is desirable for purchasers to check the deliveries by weight and compare them with the standard legal weight.

(*b*) States requiring definite weights.—In the second class may be grouped a number of States having statutes similar to each other in wording and apparently similar in legal effect. These statutes read somewhat as follows: "The bushel shall consist of, or will mean, a stated weight," sometimes with the qualification, "When sold by the bushel." This list includes: Arizona, California, Delaware, Illinois,[3] Kentucky, Michigan, Minnesota, Missouri, Montana, New Mexico, New York, Oklahoma, Pennsylvania, South Dakota, Vermont, and Washington.

In these cases it appears to be the clear intent of the legislatures that the weights stated in the laws should be delivered by the dealers, whether the commodities in question are actually weighed or whether they are measured. Therefore, although the purchaser has no legal right to demand that the commodities be weighed by the dealer before delivery, it appears to be perfectly proper to check delivery by weight and to demand that the legal weight be delivered in all cases. As in the first group, some of these States allow the statute to be superseded by special agreement and, therefore, the purchaser should be careful to refrain from any action from which such agreement might be inferred.

(*c*) States establishing legal or standard weights.—The next group are those States which establish a legal or standard weight per bushel, usually without a provision for a special agreement clause: Alabama, Arkansas, Colorado, Connecticut, Florida, Georgia, Louisiana, Maine, Maryland, Nebraska, North Carolina, North Dakota, Rhode Island, South Carolina, Tennessee, Texas, and West Virginia.

---

[3] In some of the cities of Illinois, notably Chicago, the conditions given under the first class of States obtain, on account of a city ordinance to that effect.

This list is shown separately from that immediately preceding on account of the distinctive wording of the laws. The meaning is not essentially different and therefore the checking should be done in the same way as is suggested there.

(*d*) States requiring definite weights for sales by weight.—The States in the next list establish a legal weight for various commodities, but specifically limit it to apply to cases where the sale is actually made upon a basis of weight: District of Columbia,[4] Indiana, Mississippi, New Hampshire, New Jersey, and Virginia.

In these States if the purchaser has not demanded that the transaction be upon a weight basis, the purchase must be checked by the use of dry measures.

(*e*) States not regulating this matter.—Wyoming has no law establishing standard weights per bushel or requiring sales of dry commodities by weight.

While dry measures appear to be legal in this State, the usual practice is to sell dry commodities by weight and therefore they will usually be checked by weight.

(*f*) Checking dry commodities by dry measures.—In States of all the above classes if a legal weight for any dry commodity is not established and it is not provided that dry commodities be sold by weight only, the checking must be done by dry measures.

(*g*) Interpretation of State laws.—A legal question is presented whether many of the above laws require for fractional parts of the bushel, such as pecks, quarts, etc., the same fractional parts of the legal weight established. However, a reasonable view of the matter would be that such was the intention of the law. Therefore, when a peck, quart, or other fractional part of a bushel is purchased, the weight calculated by multiplying the legal bushel weight by the fractional part of the bushel purchased may be used for checking purposes.

7. Purchasing Commodities

(*a*) In general.—When a housewife makes her purchases in person she should watch carefully the manner of selling the commodities in the store, for here frauds can often be avoided, and complaints made at once will be very effective.

---

[4] The weight per bushel of potatoes only is established by law in the District.

The first precaution to be observed is always to order a definite amount of a commodity. When practicable, the buyer should avoid asking for a "basket," a "can," or a "pail," since these terms are not definite, or for "10 cents' worth," or a "quarter's worth," etc., since in many such cases he will not know to how much he is entitled, but rather he should specify a "pound," a "quart," a "peck," etc., as the case may be.

Next, the unit price of the commodity should be known, since lack of this knowledge will prevent ascertaining the accuracy of the price charged, even though full weight and measure is delivered.

Also it is businesslike to see that the exact amount in terms of weight or measure is recorded upon your sales slip or bill and not merely the kind of commodity and the total price of the amount delivered.

(*b*) BY WEIGHT.—In buying commodities by weight, the buyer should note that the scale is correctly balanced before the commodity is put upon it, since many errors or frauds result from scales set "fast."

While the commodity is being weighed the purchaser should read the scale. If it is an equal arm scale operated with loose weights, it must be brought to balance. It should be seen that the proper weights are on the pan. If the scale has a poise sliding over a graduated beam, the beam must balance correctly and the poise be in the proper notch. If the scale is automatic, having a pointer traveling over a reading face, or a graduated face revolving past a fixed point, the amount of weight indicated by the instrument after the pointer or chart has come to rest should be verified.

(*c*) BY LIQUID MEASURE.—In observing sales by liquid measure the buyer should see that the measures are clean, properly filled, and that the *full* amount of the contents is poured out.

(*d*) BY DRY MEASURE.—In observing sales by dry measure one should see that the measure actually holds its full apparent capacity; for example, that there is no false bottom in it. When the measure has been filled, take care that bulky commodities are not stacked into it in such a way that large spaces are left between the individual units and around the sides of the measure. Bulky commodities should be well heaped up and fine commodities fill the measure level full. Also one should make sure that all of the commodity in the measure is actually delivered.

79685°—21——3

(*e*) By linear measure.—In observing sales by linear measure the buyer must see that commodities like cloth are not unduly stretched, and if counter tacks are allowed in place of linear measure, that the proper tacks are employed and the measurement is not made from one end to an intermediate tack marking some fractional part of the full length purchased.

(*f*) Checking total price charged.—When the commodity has been weighed or measured, the total price should be checked by multiplying the amount purchased by the unit price so as to

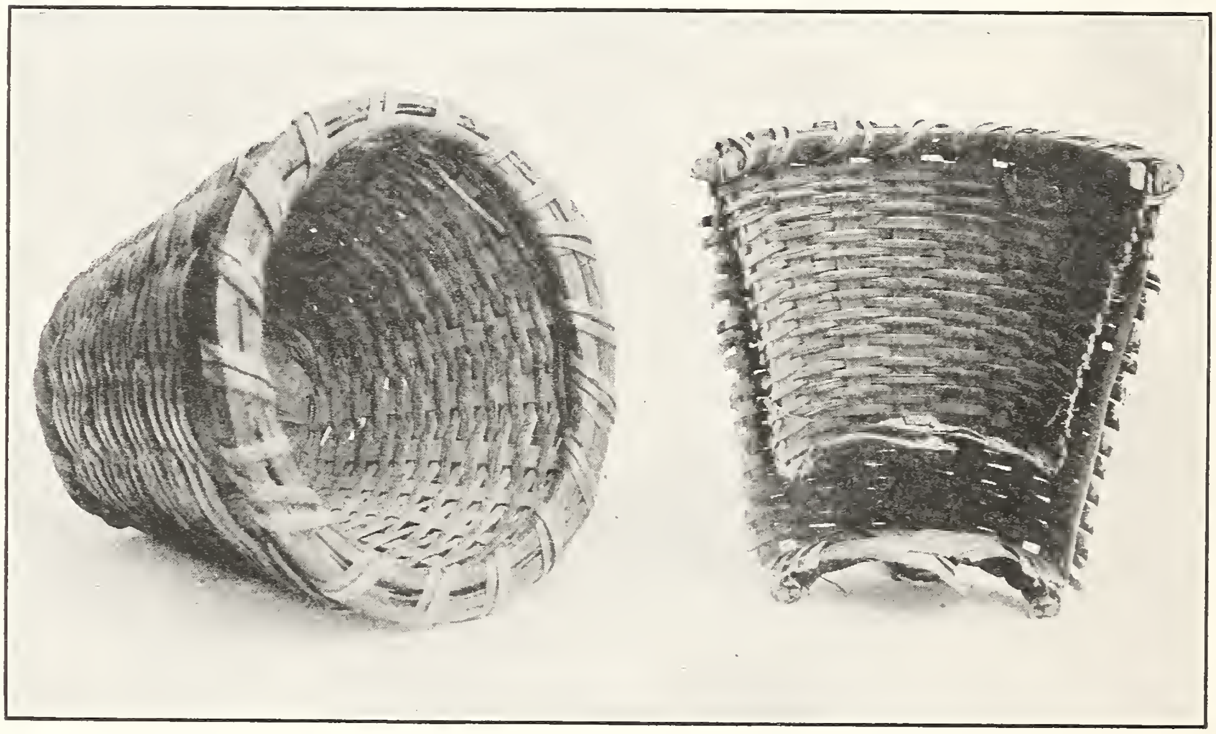


Fig. 11.—*Fraudulent basket (with side partially cut away exposing smaller basket woven inside, making false sides and bottom)*

The purchaser sees only the outside basket but the inside basket is the one that is filled—a delivery short by an amount equal to the difference in sizes resulting.

check any inaccuracy in the dealer's computation. In many sales, especially in the sale of meats, where even pounds are not often delivered, it is very easy for the dealer, either accidentally or with fraudulent intent, to overcharge a few cents on a purchase.

The above precautions are given to assist in preventing the delivery of short amounts, but should not be relied upon to the exclusion of the use of the test set of weights and measures in the home. For it should be remembered that even though the amounts delivered are correct according to the merchant's apparatus, still the accuracy of the latter may be uncertain.

8. Special Methods of Checking Certain Commodities and Containers

(*a*) Coal.—After coal has been delivered, its weight can be checked only roughly. If shortages are suspected, the details should be reported to the local inspector, who should be able to reweigh the coal furnished, or at any rate check the weight of the next delivery, if notified when this will occur. A weight ticket should be furnished by the seller, showing the net weight of the coal claimed to be delivered. The quantity of coal delivered may be roughly checked by ascertaining the amount in the bin, provided this is empty before the new coal is put in. If the bin is rectangular, with a level bottom and vertical sides, this is accomplished as follows: Measure the exact length and the exact width of the bin in feet and fractions of a foot. Then level off the top of the coal and measure its depth in the same unit. The product of the length and width of the bin, multiplied by the average depth of the coal will be the number of *cubic feet of coal* in the bin. Multiply this result by the *weight of the coal per cubic foot*, as given below, and the product will be the approximate number of *pounds* of coal in the bin. This evidence alone would not be accepted by a court, but it may be used to detect gross shortages and as a basis of complaint to the local sealer.

The average weight per cubic foot of anthracite (hard) coal varies with the size into which it is broken, and with the kind of coal or the vein from which the coal comes. The latter variation is nearly 10 per cent, but the figures given below are the average of several different kinds and will probably represent the average coal purchased within 2 or 3 per cent. Red-ash coal is somewhat lighter than that giving white ashes, hence, two sets of values are given below:

Average Weight of Anthracite Coal in Pounds per Cubic Foot

Size	White ash	Red ash
Egg	57.0	53.5
Stove	56.5	52.5
Nut	55.5	52.0
Pea	53.5	51.0
Buckwheat	53.0	50.5

The weight of bituminous (common soft) coal varies even more than that of anthracite, according to the locality from which the coal comes, and about the best figure that can be used is 47 to 55 pounds per cubic foot.

Example.—Find the number of pounds of a white ash anthracite coal of nut size in a bin 6 feet long and 4 feet 3 inches wide, with vertical sides, the coal filling the bin to an average depth of 2 feet 6 inches. Then, following directions and taking from the above table the weight of a cubic foot of white ash nut coal as 55.5 pounds:

Area of bottom = 6 feet by 4.25 feet = 25.5 square feet.

Volume of coal = 25.5 square feet by 2.5 feet = 63.75 cubic feet.

Weight of coal = 63.75 by 55.5 = 3538 pounds.

If in this case 2 tons of coal were charged for, and the measurements were accurately made, the purchaser may be fairly certain that full weight has not been delivered.

In a few localities, notably Maryland, District of Columbia, and Philadelphia, coal is required to be sold by the gross or long ton of 2240 pounds, while in others the net or short ton of 2000 pounds will ordinarily be employed.

(*b*) Wood in cords.—In purchasing wood by the cord one is entitled to and should receive for each cord, wood consisting of or equivalent to a pile, closely stacked, 8 feet in length, 4 feet in breadth, and 4 feet in height. This is true whether the wood is in 4-foot lengths or whether it has been sawed and split before purchasing. This latter point has been much misunderstood in the past, and because wood may shrink somewhat when the 4-foot wood is sawed and split, many dealers have assumed that a lesser amount of wood in this condition may be delivered for a cord. There is no authority for this contention, and it must be considered that a less amount of wood than 128 cubic feet, whatever be its condition at the time of sale and purchase, is not a cord.[5] If, however, one buys a cord of 4-foot wood, *to be sawed*

[5] This is not true in Minnesota, where the law provides as follows (Laws of 1913, chap. 560, sec. 5): "*Standard Measurement of Wood.*—In all contracts for sale of wood, the term 'cord' shall mean 128 cubic feet of wood, in 4 foot lengths; and if the sale is of 'sawed wood,' a cord shall mean 110 cubic feet when ranked, or 160 cubic feet when thrown irregularly or loosely into a conveyance for delivery to the purchaser; and if the sale is of 'sawed and split wood,' a cord shall mean 120 cubic feet, when ranked, and 175 cubic feet when thrown irregularly and loosely into a conveyance for delivery."

and split before delivery, he may only demand 128 cubic feet of 4-foot wood, and must bear whatever natural shrinkage occurs in the process of sawing and splitting.

To check the number of cubic feet of wood in any pile of the shape of a rectangular solid, measure the length, width, and height of the pile in feet and multiply these three dimensions together. The result is the number of cubic feet of wood in the pile. (When the ends of the sticks are beveled, only one-half of the length of the beveled part, usually known as the kerf or scarf, is to be included in the measurement of the width.)

(*c*) ICE.—In checking the weight of deliveries of ice, the best method of procedure is to weigh it immediately upon delivery. If the piece of ice purchased weighs more than the scale will indicate, a rough check can be obtained by multiplying the volume of the cake by the weight per unit of volume.

The weight of ice is 57.5 pounds per cubic foot; or, there are 30 cubic inches in a pound.

The volume of the ice is determined as follows: If the piece furnished is a rectangular solid, that is, having a square or rectangular base and vertical straight sides, accurately measure the length, width, and height of the ice in the same unit, and multiply these dimensions together. The result will be the volume of the ice.

Example.—Find the weight of a piece of ice in the shape of a rectangular solid 15 inches long, 10 inches wide, and 8 inches high. Then, following directions:

Volume, 15 by 10 by 8 inches $=1200$ cubic inches.
Weight $=1200 \div 30=40$ pounds.

(*d*) DETERMINING CAPACITY OF TANKS, BOILERS, SILOS, ETC.—If it is desired to measure the capacity of a tank an approximate result can be obtained by measuring the dimensions and computing from these the cubical contents. In the following the methods of determining the capacity of cylindrical and of rectangular tanks will be described. Care should be taken not to apply the formulas to tanks of other shapes, since the results obtained would be incorrect.

The measurements should always be of inside dimensions. If outside dimensions are the only ones which can be readily determined, and the thickness of the material is known, the inside dimensions can be obtained by subtracting the thickness of the walls from these outside dimensions.

(*e*) RECTANGULAR TANK.—In the case of a tank with a rectangular base and vertical straight sides, multiply the length by the width by the height, expressed in the same unit of length.

(*f*) CYLINDRICAL TANK.—In the case of a tank of the shape of a cylinder, the formula for computing the capacity is as follows:

$$\text{Capacity} = 0.785\ d^2h,$$

where d = the diameter and h = the height.

Having determined the diameter and the height of the tank in the same unit; for example, in feet: Square the diameter, that is, multiply it by itself, and multiply the result by the height. Multiply the product by 0.785 and the result is the capacity of the tank in terms of the cube of the unit of length; in this example, cubic feet. (If the circumference is more easily obtained than the diameter, the former may be measured and the diameter computed by means of the formula

$$d = \frac{c}{3.14}$$

where d = the diameter and c = the circumference.)

If the result is desired in gallons or in bushels, the result of the calculation may be reduced to these units as follows:

To reduce cubic inches to gallons divide by 231.

To reduce cubic feet to gallons multiply by 7.48.

To reduce cubic inches to struck bushels, divide by 2150. To reduce to heaped bushels divide by 2750. To reduce cubic feet to struck bushels divide by 1.244; to reduce to heaped bushels divide by 1.59.

(*g*) DETERMINING PERCENTAGE OF SHORTAGE.—The importance of the shortage in a delivery depends upon its amount compared with the total amount of commodity; or, in other words, the percentage of shortage. Thus, a shortage of 1 ounce on a total purchase of 10 pounds is often unimportant. An error of 1 ounce on each of ten 1-pound packages is, however, a serious one, since the shortage on the same total weight of 10 pounds is 10 ounces. The percentage of shortage is determined as follows: Divide the shortage by the total amount of commodity, *expressed in the same* *unit*. One hundred times this is the percentage of shortage. This percentage of shortage indicates the number of cents a buyer loses on the dollar by reason of the shortage.

To illustrate the percentage of shortage, consider a shortage of 1 ounce on 10 pounds. The shortage is given in ounces. Therefore, reduce the total amount to ounces, in order to have both figures in the same unit. There are 16 ounces in 1 pound. Therefore in 10 pounds there are 160 ounces. Divide 1 (the shortage) by 160 (the total amount) which gives 0.00625, or 0.625 per cent. Therefore, the total loss on a purchase of one dollar's worth is 0.62 or 5/8 of a cent. Similarly, a shortage of 1 ounce on a pound would be 6.2 per cent, or 6 cents on the dollar.

III. HEAT

1. What is Meant by Temperature and by Heat

The terms "heat" and "temperature," while often confused, have very different meanings. Temperature is familiar to all. Certain so-called *fixed* temperatures serve as starting points (reference points) for measurement. The most familiar of these is the *temperature of the body*, which is usually about 98½° F. Objects about us are said to be "warm," "hot," "cool," or "cold," compared with this temperature—not a very accurate or reliable standard, to be sure, but one which serves well enough for some purposes. This standard is, however, of little use for estimating temperatures of objects of very different materials, e. g., iron and wool. The better heat conductors, like iron, take heat from the hand much more rapidly than do poor conductors, like wool, and therefore feel colder (or warmer), even though at the same temperature. (See table of conductivities.) A bare floor feels much colder than a rug, although they are probably at the same temperature.

Neither is this standard of much service in estimating temperatures colder than that of melting ice or for those as hot as boiling water. There is often need to measure temperatures lower than that of ice and higher than that of steam, and with more certainty than can be done with the hand. Therefore, various kinds of thermometers are used, and temperatures are expressed by definite scales on which the *melting point of ice* and the *boiling point of water* have certain fixed numbers. On the Fahrenheit scale these are 32° and 212°; on the centigrade scale 0° and 100°, respectively.

A warm object differs from the *same* object when cold; it feels different to the hand; it is generally somewhat larger; and it will warm other objects placed near it. Thus, *temperature is a quality* or condition of objects and is measurable by means of thermometers. A certain definite amount of *heat* must be supplied to any object to warm it from one temperature to another, and this amount of heat must escape before the object can cool back to the former temperature. Heat is not measured directly by means of thermometers. It is only the effect of heat which is measured. When a pound weight falls a foot to the ground a foot-pound of work is lost and a definite amount of heat is produced. When a pound of coal or a cubic foot of gas is burned a definite amount of heat is produced, which depends upon the quality of the coal or of the gas. Therefore *heat is a measurable quantity* and can be expressed in "heat units." Thus, the "British thermal unit" (Btu) is that amount of heat which will warm 1 pound of water 1 degree Fahrenheit. The "calorie" is that amount of heat which will warm 1 gram of water 1 degree centigrade. If 1 Btu is supplied to 2 pounds of water, the temperature will rise only one-half degree Fahrenheit, etc. It is convenient to remember that 180 Btu will heat 1 pound (about a pint) of ice-cold water to the boiling point, or 100 kilo-calories (100 000 calories) will heat a kilogram (a little over a quart) of ice-cold water to the boiling point.

2. Thermometers

The familiar mercurial thermometer for household use is made somewhat as follows: A glass bulb is blown or sealed onto the end of a fine-bore glass tube or "stem." The bulb and part of the stem are then filled with mercury (quicksilver) and the top sealed after removing the air. This blank thermometer is placed in water at different known temperatures and the positions of the top of the mercury marked. A scale is then made, either on a separate strip of metal or on the glass, such that for a Fahrenheit thermometer the ice point will be 32°, the boiling point 212°, and the distance between will be divided into 180 equal degrees. On the centigrade scale the ice point is 0° and the boiling point 100°.

3. Convenient Tests for Thermometers

Household thermometers from reliable makers are usually correct to within 1 or 2 degrees at room temperature and below, although sometimes they are several degrees in error.

Any thermometer which has 32° F or 0° C on its scale may be easily tested at this point by scraping a tumbler full of *clear* ice, saturating this with ice-cold, pure water, and placing the thermometer bulb in this mixture until it reads as low as it will go. (See Fig. 12.) Clean snow saturated with water may also be used, but if the snow is left dry it may be much colder than 32° F. If the thermometer tested reads 32° F or 0° C, it is correct at this point. If higher or lower than this, it is too high or too low by the amount of the difference observed. Such a test is reliable to a tenth of a degree if carefully made.

For other temperatures there are no tests which are quite as convenient or reliable as for the ice point. The steam point, 212° F or 100° C, is used in the testing of thermometers in the laboratory, but the steam temperature depends upon the barometric reading, which varies with the weather, and with the altitude of the place where the water is boiled. For places within 500 feet of sea level the temperature shown by a thermometer immersed in a steam bath over briskly boiling water, or in the water itself if the same is pure, should be between 210 and 212° F, or between 99 and 100° C. For higher altitudes the temperature will be lower, as may be seen from Table 1. The temperatures given in this table are averages only and variations of 1° F or 0°.6 C may take place from day to day because of changes in the barometric pressure. Thus, at an altitude of 8000 feet the average barometer reading will be about 22.3 inches (566 millimeters) and the average temperature of steam will be 197°.6 F (92° C) but will vary from about 196°.6 to 198°.6 F at different times.

Fig. 12.—*Method of testing a thermometer at the freezing point*

Hold its bulb for a few minutes in scraped clear ice saturated with pure water. If the thermometer reads above or below 32° F or 0° C it is this amount too high or too low.

If a tested clinical thermometer is at hand, a fairly accurate test at about 100° F may be made as described under "Incubator thermometers" and illustrated in Fig. 20. A thermometer which is correct at the ice point and at about 100° F will probably be nearly correct at other temperatures.

TABLE 1

Boiling Point of Water and Average Barometer Readings for Different Altitudes

Altitude	Temperature of steam		Corrected barometer Average readings	
	°*F*	°*C*	*Inches*	*Millimeters*
Sea level	212.0	100.0	29.9	760
2000 feet	208.3	97.9	27.8	706
4000 feet	204.6	95.9	25.8	655
6000 feet	201.1	93.9	24.0	610
8000 feet	197.6	92.0	22.3	566
10 000 feet	194.0	90.0	20.7	526

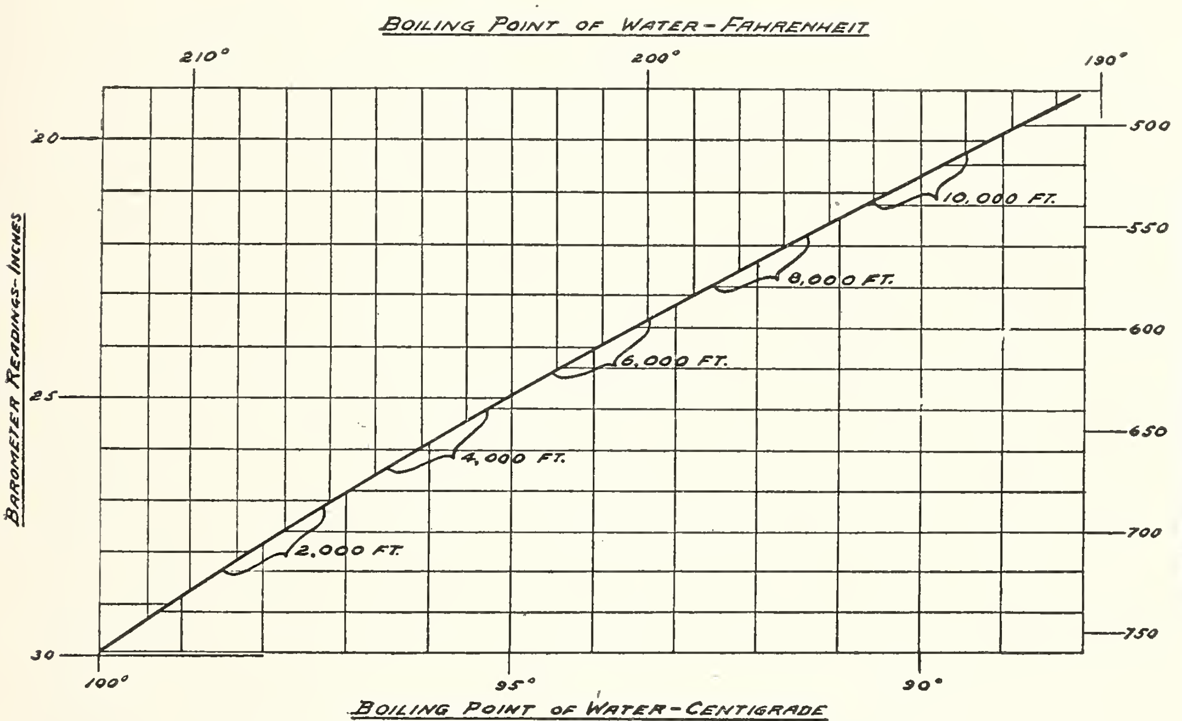


FIG. 13.—*Graphic diagram of data given in Table 1*

Boiling points of water at various altitudes (with barometer readings corresponding thereto).

4. Household Thermometers

Every household should possess some of the different kinds of thermometers described below.

(*a*) ROOM-TEMPERATURE THERMOMETERS.—A type of thermometer used for measuring the temperature of the air in rooms (or out of doors) is shown in Fig. 14. The air in some parts of a room is likely to be much warmer than in other parts. For instance, there may be as much as 10° or 15° F difference between floor and ceiling. If hung near a hot stove or steam radiator, a thermometer will read several degrees higher than elsewhere in the room, partly because of direct radiation from the hot object.

Room thermometers should be placed about 4 feet from the floor, away from stove, radiator, or ventilation flue and not on an outside wall. A thermometer brought from one room into another at a different temperature may not give the correct temperature until after 10 or 15 minutes. Thermometers mounted directly on heavy objects, such as are sometimes used for ornamental purposes, may require a much longer time than this before indicating the correct temperature.

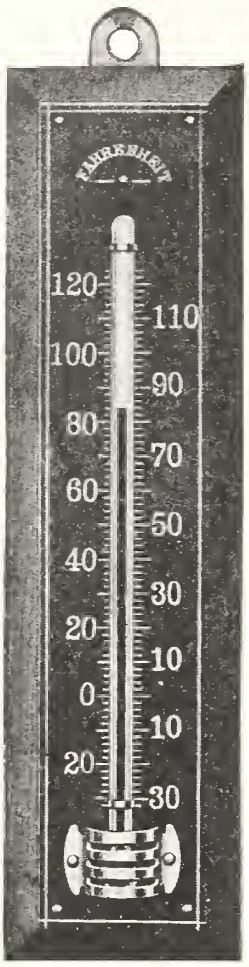
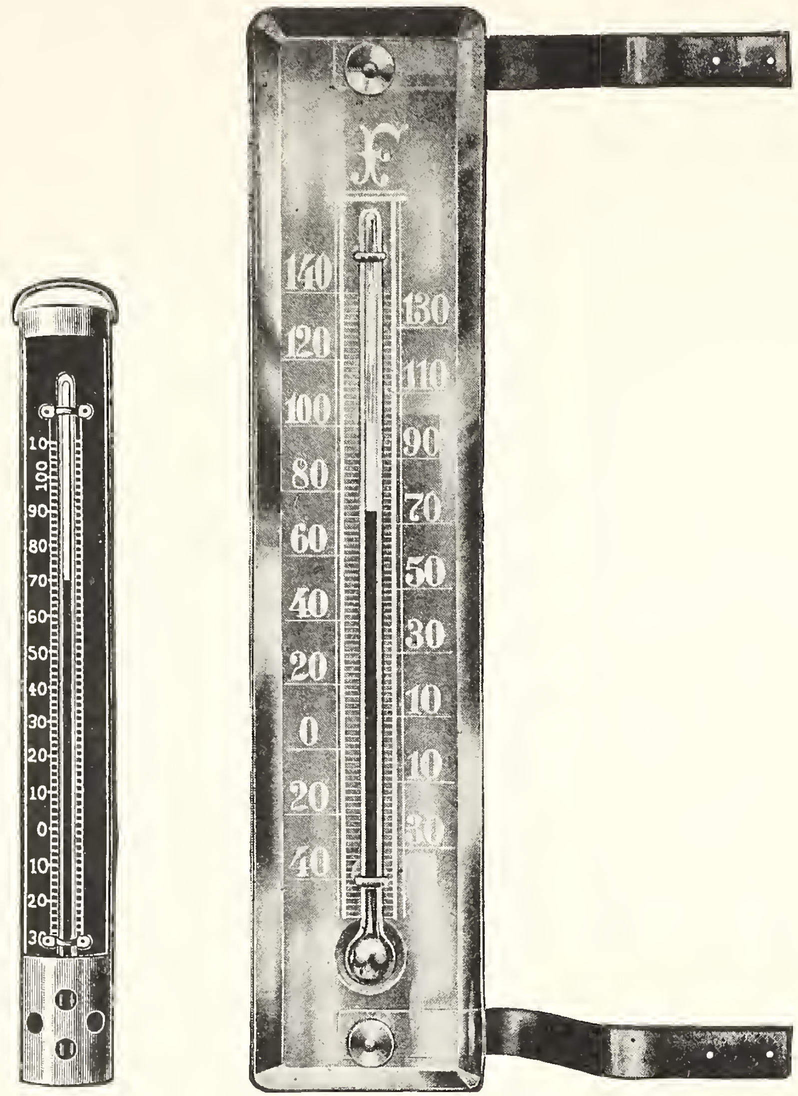


FIG. 14.—*A thermometer for measuring the temperature of rooms*

Such thermometers should be hung about 4 feet from the floor and away from cold outside walls, windows, or heating appliances.

(*b*) TEMPERATURE OUT OF DOORS.—Types of thermometers chiefly used outside the house for measuring the temperatures of the air are shown in Figs. 15 and 16. In order to find the real temperature of the air, as it is given in the weather reports, a thermometer must be mounted in a specially well-ventilated house or box 4 feet from the ground, and so built as to shield the thermometer entirely from direct sunlight. Nearly the same results may be had by placing a thermometer in an open, shady place, say at the north of a building, but several feet away from the walls and about 4 feet from the ground. Thermometers are sometimes mounted 2 or 3 inches outside windows for easy observations. Under these conditions they may read several degrees high in cold weather.

(*c*) CLINICAL OR "FEVER" THERMOMETERS.—Some types of thermometers for measuring the temperature of the human body, usually by being placed under the tongue, are shown in Fig. 17. The so-called "normal temperature" of the body is not a definite temperature, even for any one individual in normal health. It may vary by 2° F at different times of the day, being usually, under normal conditions of living, lowest in the morning (6 to 7 a. m.) and highest in the afternoon (5 to 7 p. m.). The temperature of



FIGS. 15 AND 16.—*Thermometers for use out of doors*

Such thermometers should be hung about 4 feet from the ground in the shade and not against the side of a building.

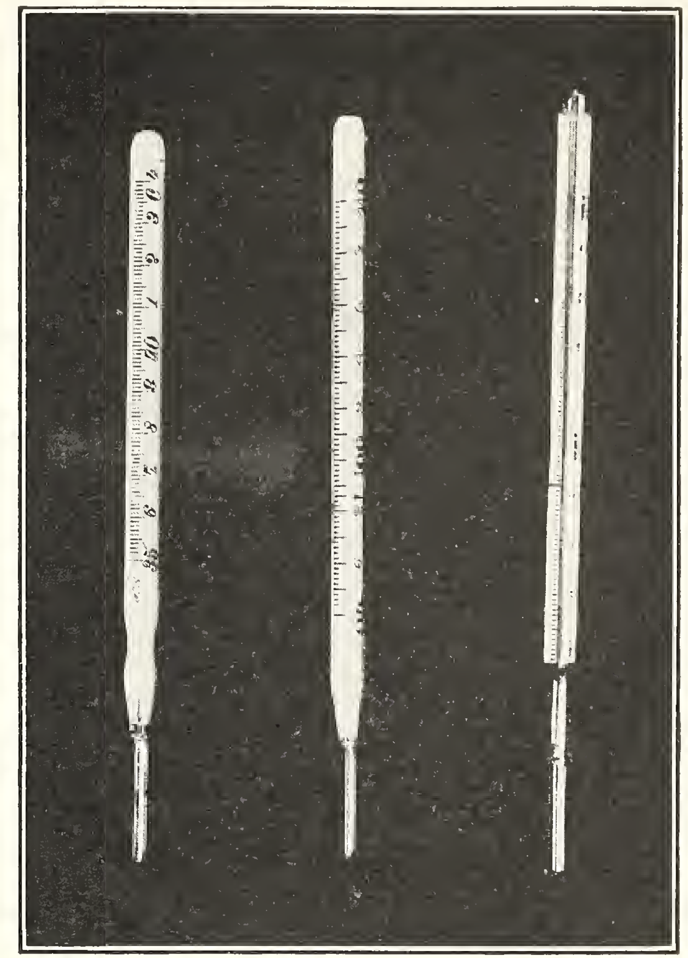


FIG. 17.—*Types of clinical thermometers*

These thermometers are used by physicians and nurses, and one should be owned by every family.

the body also depends upon many other factors, among which are age, sex, food, temperament, occupation, etc. The temperature very generally taken as normal is 98°6 F (37°0 C). *Clinical thermometers should be tested by a competent testing laboratory.* Many thousands of these thermometers are tested annually by the Bureau of Standards. A facsimile of a clinical certificate issued by the Bureau is shown in Fig. 18. Some dealers have sold clinical thermometers with certificates which did not come from this Bureau, but which look somewhat like the Bureau's certificates, even having the words "Bureau of Standards" printed prominently on the certificate. These certificates are evidently intended to deceive and are probably worthless. On the other hand, many reliable manufacturers test their own thermometers and issue their own certificates, which are, in general, reliable. The purchaser should, therefore, make sure that any certificate which appears to come from the Bureau of Standards is actually a Bureau of Standards certificate.

(*d*) Reading of clinical thermometers.—The usual clinical thermometer is a "maximum" thermometer, that is, the mercury in the stem registers the highest temperature reached and does not return when the thermometer is cooled, but must be shaken back before another temperature can be measured. For this reason the thermometer may be removed from the mouth and read later.

The usual type of "lens-front" thermometer is so made that the front of the glass tube acts as a lens magnifying the width of the mercury thread. To read such a thermometer, it should be held in the hand and turned until the mercury column suddenly appears magnified to considerable width. This will occur when the clear corner of the triangular tube is directly in front. The reading can then be made, remembering that the smallest divisions of the scale are usually 0°2. The mercury should then be shaken back into the bulb by holding the thermometer firmly between thumb and forefinger, bulb outward, and giving a few very brisk shakes from the wrist, or with the arm, and then seeing that the thermometer reads as low as 96° F or 35°5 C. The thermometer should never be tapped against a hard substance, as this is almost certain to break the bulb.

DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS

CERTIFICATE OF EXAMINATION
OF
REGISTERING CLINICAL THERMOMETER

Submitted by

Marked B. S. No.

This certifies that the above thermometer was found to have the following corrections at this date, compared with the official standards of this Bureau:

THERMOMETER READING	CORRECTIONS
96° F.	
100°	
104°	
108°	

NOTE.—When the correction is + it should be added to and when — subtracted from the reading.

Unless this thermometer has been suitably aged before testing, its indications are liable to change with time.

Washington, D. C.

S. W. Stratton
Director.

Form 35.

FIG. 18.—*A facsimile clinical thermometer certificate from the Bureau of Standards*

When purchasing a certified clinical thermometer, if a thermometer is wanted with a Bureau of Standards certificate, make sure that it has an *actual Bureau of Standards certificate,* not one which is made to *appear like* such a certificate.

(*e*) BATH THERMOMETERS.—Bath thermometers (see Fig. 19) usually have their scales printed on paper or milk glass contained in a large glass tube which incloses the thermometer capillary. They are often protected by a wooden cage to prevent breakage. When thus protected it may take some time to get the real temperature of the water unless the thermometer is kept moving. The temperatures in different parts of a tub of water may differ many degrees unless the water has been well mixed.

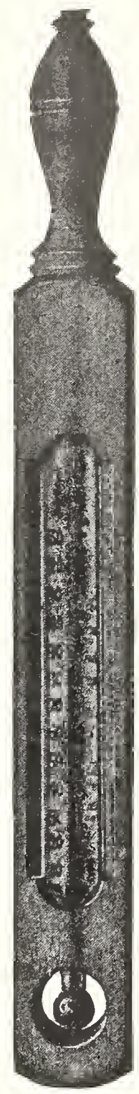


FIG. 19.—*One type of bath thermometer.*

Such thermometer must be read while the bulb is in the water, otherwise the readings will be incorrect.

A bath thermometer should be read *while it is in the water* because the readings will change very rapidly when the thermometer is taken out of warm water.

(*f*) INCUBATOR THERMOMETERS.—An incubator is essentially a well-insulated box supplied with some source of heat such as a lamp, and with a regulator for automatically keeping the temperature nearly constant by admitting more or less heat as the temperature falls or rises slightly.

It is of importance that an incubator thermometer be very nearly correct. If a tested clinical thermometer is available, the incubator thermometer can be tested by holding the two together as shown in Fig. 20 in a can or pail of well-stirred water at about 103° F. Stir the water well and bring it to a temperature of about 103°, as shown by the incubator thermometer. Then place the two thermometers together in the water, as shown in the figure, stirring slowly until the incubator thermometer stops rising. Read the incubator thermometer, immediately remove both thermometers from the water, and read the clinical. If the incubator thermometer reads higher or lower than the clinical, it is this amount too high or too low.

(*g*) MILK THERMOMETERS.—Fig. 21 shows types of thermometers which are useful in measuring the temperature of milk or cream, for the control of pasteurizing milk, churning cream, whipping

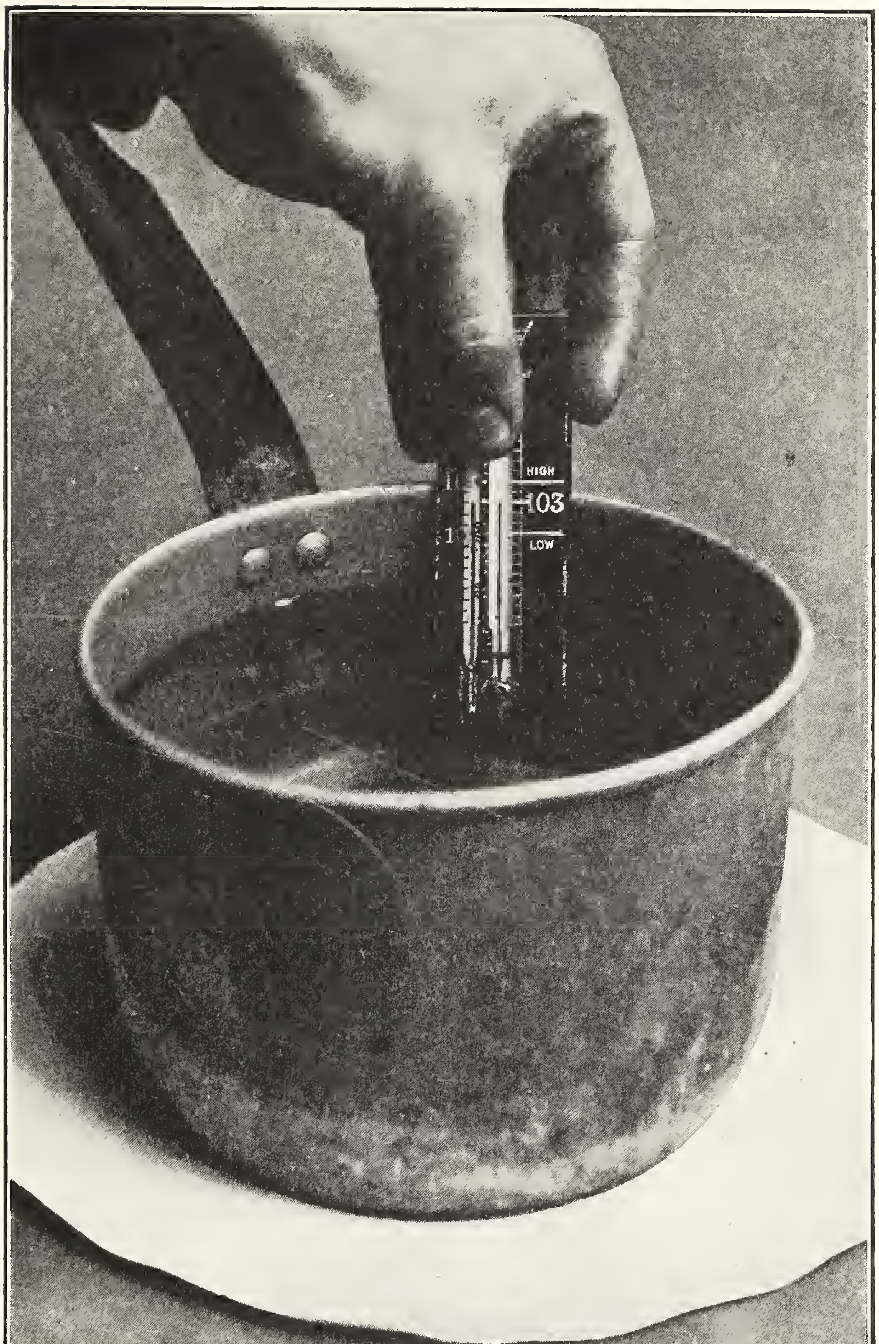


Fig. 20.—*A test of an incubator thermometer by means of a clinical thermometer*

This is accomplished as follows: Adjust the temperature of dish of water to about 103° F, using any convenient thermometer; stir this water for about one minute with the incubator thermometer and a tested clinical thermometer held together, read the incubator thermometer, then immediately remove both and read the clinical. The incubator thermometer should read the same as the clinical; if higher or lower it is incorrect by this amount.

79685°—21——4

cream, etc. These processes are best carried out at definite temperatures, some of which are noted in Table 5 and under "Refrigerator temperatures." Some of these milk thermometers are purposely made large and light so that they will float, making their use more convenient.

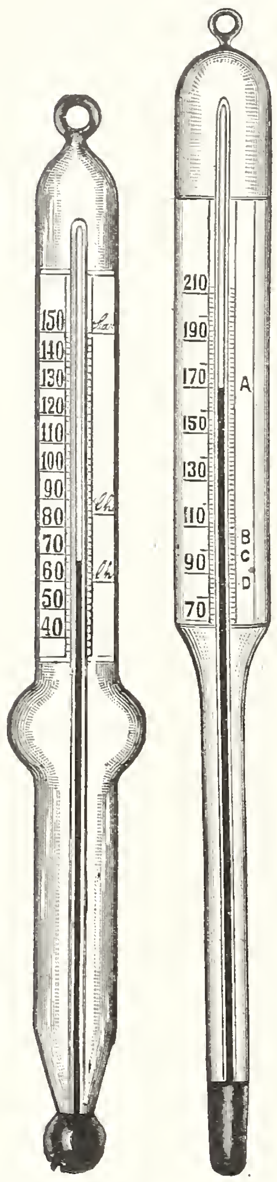


FIG. 21.—*Milk thermometers*

Types of thermometer useful for measuring the temperature of milk and other liquids. The one to the left floats in the liquid.

To *pasteurize milk* it should be heated to 145° F, kept at this temperature (within 2 or 3°) for half an hour, then quickly cooled to below 50°. After pasteurizing it should always be kept below 50°. See Bulletin of the Department of Agriculture, No. 85 (1914), "The cost of pasteurizing milk and cream."

(*h*) MAXIMUM AND MINIMUM THERMOMETERS.—Fig. 22 shows a maximum and minimum thermometer for registering the highest and lowest temperature reached since the last setting. This thermometer is one of several types of maximum and minimum thermometers in common use. When these thermometers are used to indicate the maximum and minimum temperature during each day they must be "set" or adjusted once a day or after each reading. The method of

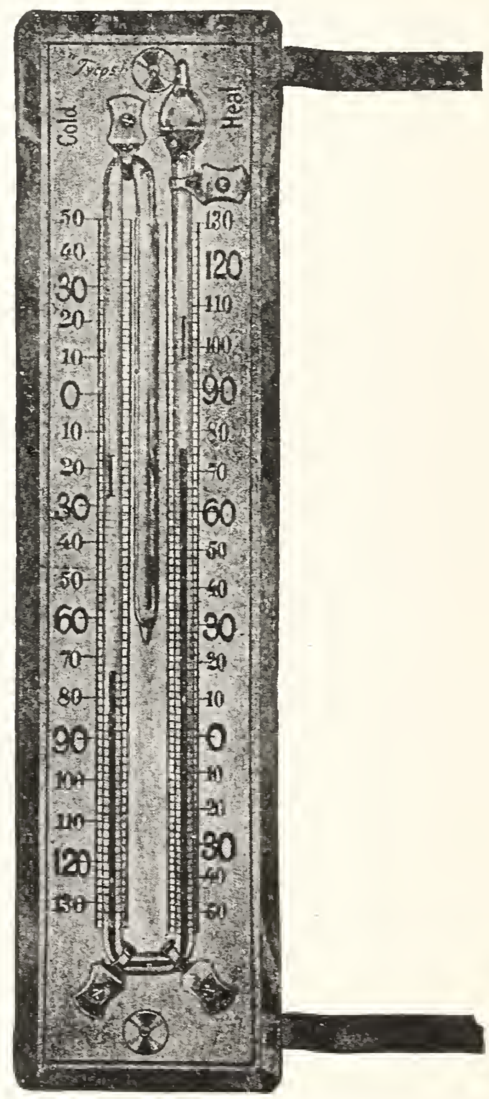


FIG. 22.—*A maximum and minimum thermometer*

Such thermometers are convenient for indicating the lowest and the highest temperatures reached during a given period, usually 24 hours.

doing this depends upon the type of thermometer, and directions should accompany each thermometer. When used out of doors such thermometers should be located as explained under "Temperatures out of doors," p. 42.

(*i*) CANDY-MAKING THERMOMETERS (Fig. 23).—These are thermometers for use in making candies, boiling sirups, etc. The most certain results in the making of candies and jellies can be had by the use of a good thermometer. The thermometer should not be too near the bottom nor the sides of the kettle, nor yet should it be at the point where boiling is most violent. Some of the temperatures at which boiling sirups should be removed from the fire to make different kinds of candies, as well as other useful information as to temperature, are given in Table 5 (p. 66).

(*j*) OVEN THERMOMETERS.—The results of careful study of the best oven temperatures for baking all sorts of foods [6] are summarized as follows: Slow, 250° to 350° F, custards, meringues; moderate, 350° to 400° F, bread, gingerbread, plain cake, cookies; hot or "quick," 400° to 450° F, Parkerhouse rolls, popovers, etc.; very hot, 450° to 550° F, biscuits and pastry. (See also Table 5.)

Various kinds of thermometers are used for reading oven temperatures. One kind is placed in the oven door and has a dial with a hand for indicating the temperatures. These thermometers may not indicate the true temperatures of the oven, because the door never gets as hot as the rest of the oven and often takes much longer than the rest of the oven in heating up. Yet, since temperatures sometimes need not be known better than 10° or 20°, such thermometers are useful and they are more convenient than

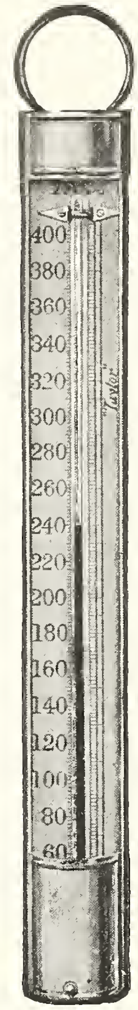


FIG. 23.—*A thermometer which is very useful in boiling candies, jellies, etc.*

Such a thermometer may be tested for accuracy as follows: First find the boiling point temperature for your altitude from Table 1 (thus at 2000 feet elevation the average temperature is 208° F or 98° C). Then hold the thermometer with its bulb well immersed in a dish of briskly boiling pure water and read the highest temperature reached. If this differs from that found in the table the thermometer is too high or too low by this difference.

[6] Journal of Home Economics, June, 1914.

thermometers which have to be hung inside the oven. The thermometer shown in Fig. 24, if made to read up to 550° F, is perhaps the best form of oven thermometer when it can be used; but a special opening must be made into which it can be screwed. A thermometer like Fig. 23, if made to read up to 550°, may be hung inside the oven, but in this case the door must be opened or a window provided in order to read it.

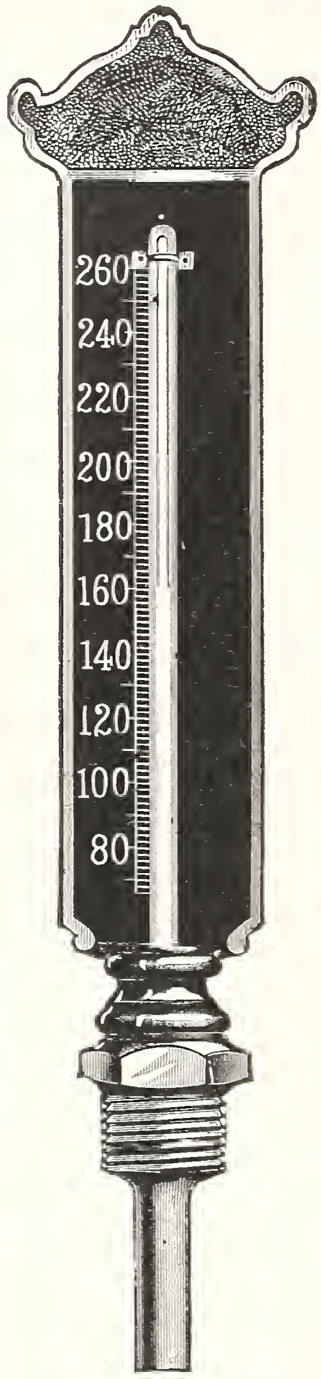


FIG. 24.—*Thermometer for measuring the temperature of water in hot water heating boiler*

A thermometer of this type reading to 550° F is used for measuring oven temperatures.

(*k*) REFRIGERATOR TEMPERATURES.—Almost any good household or bath thermometer may be used to measure temperatures inside the refrigerator. There are large differences between the temperature of air which is just entering the ice chamber at the top and that just leaving it at the bottom. (See Fig. 25.) Even the coldest air in the refrigerator will be found much warmer than most people suppose.

5. Refrigeration

As stated on page 39, heat is a quantity which may be measured in British thermal units or in calories. When heat is supplied to an object either its temperature is raised—that is, it becomes warmer—or else some other changes, such as melting or boiling, take place. Generally, much heat is needed to melt a solid and still more to boil away a liquid. It takes about 143 Btu to melt a pound of ice, 180 Btu to heat the pound of water thus formed to the boiling point, and then nearly 1000 Btu to convert it into steam. The heat used to melt or evaporate a substance is called "latent" heat because it does not change the *temperature* of the object, and so its effect is not shown by a thermometer.

In order to cool foods to 60° or 50° F and keep them at this temperature, a large amount of heat must be absorbed, and this is conveniently done in the household by letting the foods supply the latent heat necessary to melt a quantity of ice. When ice is melted an amount of heat equal to about 143 Btu is absorbed by each pound. Thus, if the price of ice is 35 cents per 100 pounds the cost of *absorbing* heat will be a little more than 10 times the cost of *producing* heat by burning city gas at $1 per thousand cubic feet. Unfortunately, the cooling effect of ice can not be turned off as a gas flame can; the ice goes on absorbing heat from everything warmer near it. This fact makes it important to prevent so far as possible heat from getting to the ice by inclosing it in a refrigerator or ice box having well insulated walls.

(*a*) Refrigerators.—The ordinary household refrigerator, even of the best make, is by no means as effective in the saving of ice as might be desired. The principles of operation are, briefly, as follows: A block of ice is placed in a compartment near the top of the refrigerator and having one or more openings at both top and bottom. The air next the ice becomes cool and sinks through the bottom openings of the ice chamber into the main part of the refrigerator, while warmer air from the upper part of the refrigerator enters the top of the ice chamber and is there cooled. There is thus a continuous circulation of air past the ice and through the food chamber. (See Fig. 25.) This circulation is important because it distributes the cooled air to all parts of the refrigerator, and also because on passing the ice the air loses some of the moisture and the odors which it has taken up from the food, especially that which is not yet cold. Therefore, anything which retards this circulation or stops up the openings to the ice chamber should be avoided.

Table 2 gives some results of tests on nine refrigerators of average quality or better, where the air in the refrigerator averages nearly as much *warmer* than the ice as it is *cooler* than the air outside; thus, with a room at about 90° the lowest temperatures inside the refrigerators range from 44° to 57° and the highest from 64° to 72°. It has been found (Bulletin No. 98 of United States Department of Agriculture) that in milk kept at 60° about 15 times as many bacteria will develop in one day as in milk kept at 50° F, and much the same is true of many other foods. *It is important, therefore, to find the coldest places in a refrigerator* (usually near where the air leaves the ice chamber) *and use these places for foods such as milk and meats which need to be kept as cool as possible to prevent spoiling.*

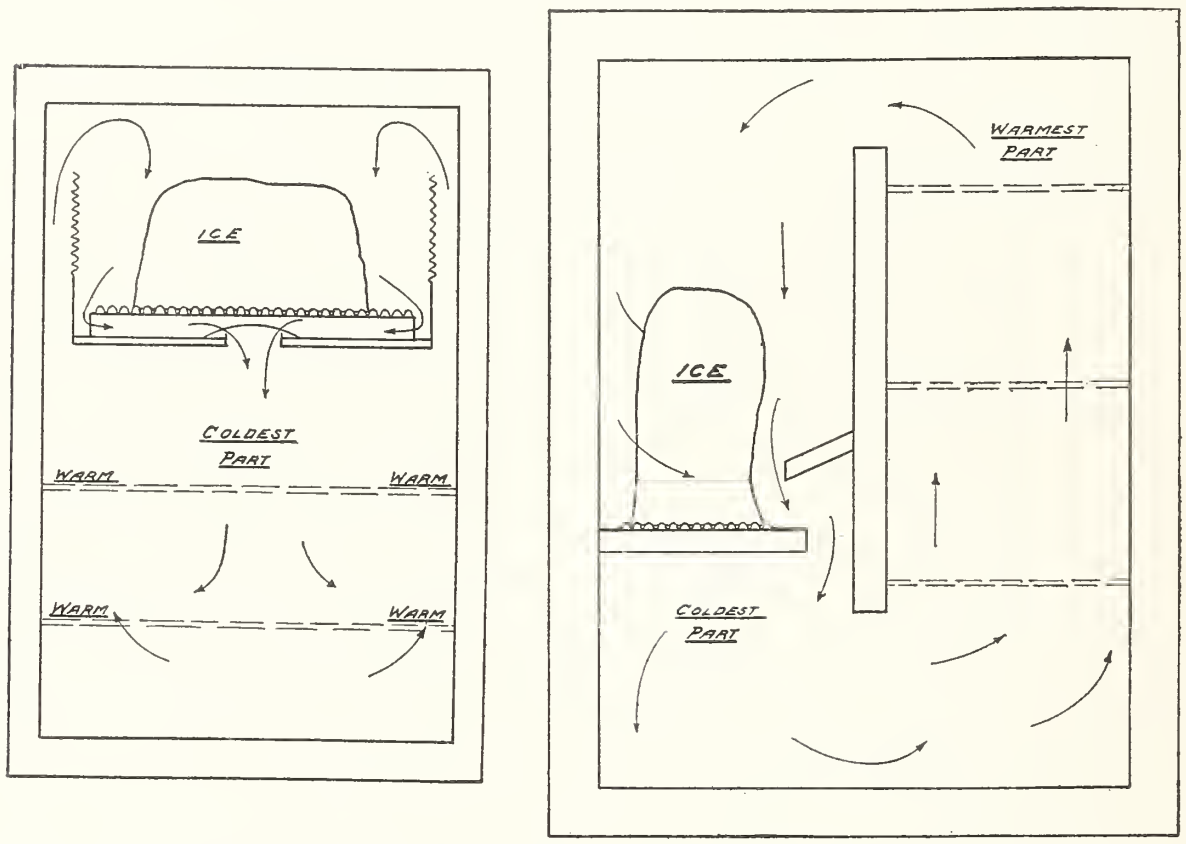


FIG. 25.—*Diagram showing the circulation of air in two usual types of refrigerators*

Air entering the ice chamber is freed from odors, cooled, and sinks through the bottom openings, drawing in the warmer air at the top. Butter, milk, and meats should occupy the coolest space, while food having a strong odor should be placed where the air is just about to enter the ice chamber.

The outside dimensions of the refrigerators listed in Table 2 averaged 24 inches deep, 40 inches wide, and 50 inches high.

The figures in the column headed "Heat transmission" give the amount of heat in British thermal units (Btu) that passes through every square foot of the outside surface of the refrigerator in an hour when the room temperature is 1° F higher than the average inside temperature of the refrigerator. If the room temperature were 10° higher than the inside of the refrigerator, ten times this amount of heat would pass through every square foot of the walls.

TABLE 2

Results of Tests of Refrigerators

Refrigerator number	Room temperature	Coldest inside temperature	Warmest inside temperature	Weight of ice melted per hour	Heat transmission per hour	Air circulation	Inside volume	Average weight of ice in box during test
	°F	*°F*	*°F*	*Lbs*	*Btu per sq. ft. per °F temp. diff.*	*Cu. ft. per minute at 60° F*	*Cu. ft.*	*Lbs.*
1	92.1	52.7	64.4	1.50	0.14	21.4	16.5	42.2
2	91.8	57.2	72.1	1.78	0.21	19.6	18.1	37.1
3	91.3	49.3	70.7	1.63	0.19	12.7	18.0	41.1
4	90.0	46.6	70.3	1.43	0.14	10.1	18.0	43.2
5	89.6	49.5	68.7	1.41	0.15	12.1	16.5	41.2
6	91.1	55.9	69.8	1.54	0.18	18.5	18.2	42.7
7	91.5	46.9	66.2	1.63	0.15	13.8	17.1	41.8
8	92.0	44.1	64.0	1.59	0.14	13.0	17.3	41.7
9	93.1	51.8	66.6	1.65	0.19	18.5	19.0	40.7

The sixth column of Table 2, headed "Heat transmission," illustrates the relative merits of the different refrigerators, since it tells directly how much cooling is wasted, that is, how much heat enters the refrigerator through the walls per hour for each square foot of wall and for each degree difference in temperature between the inside and outside. For instance, to hold the average temperature inside refrigerator No. 1, 30° below the temperature outside would require two-thirds as much ice as for No. 2. To be sure No. 2, though a much poorer refrigerator, used only about one-fifth more ice than did No. 1, but its inside temperature was not nearly so low and therefore it would not have kept food fresh so long as No. 1.

Slow melting of the ice does not necessarily indicate a good refrigerator. Unless the ice melts it can absorb no heat and is therefore of no use in a refrigerator. Protecting the ice in a refrigerator by covering it up is a good way to save ice but a *poor way to save food.* The only proper way to use less ice is by using a refrigerator with better insulated walls, and by opening the doors as seldom and for as short times as possible.

(*b*) OTHER COOLING DEVICES.—Another very useful device for keeping things cool, or hot, is the vacuum or "thermos" bottle. This is made up simply of one glass bottle within another with a space of from one-fourth to one-half inch between them, free from air and the surfaces silver plated on the vacuum side. Most of the heat which leaves or enters a hot or a cold object is carried by the circulation of air, called convection, and some also by direct radiation. Thus, when air is absent there is no convection and when the surfaces are good reflectors like bright silver there is very little radiation, and very little heat can enter or leave the inside of the thermos bottle. A bottle covered with a very thick layer of ground cork, feathers, cotton, wool, or other such material might retain heat about as well as a thermos bottle but would be less convenient to handle, as the insulating layer would need to be 2 or 3 inches thick instead of a quarter to half an inch.

The refrigerator and thermos bottle are by no means the only domestic cooling devices. There are several small refrigerating machines on the market, suitable for use in cooling the ordinary household refrigerator. Descriptions of these would be out of place here as they can be found in trade catalogs. Such machines all resemble the large mechanical refrigerating machines used for making artificial ice and for cooling cold-storage houses.

(*c*) Cooling by evaporation.—The natives of dry, hot climates have for centuries used cooling devices based on the cooling produced by the evaporation of water. As has been said before, to boil away or evaporate a pint of water requires about 1000 Btu of heat, whether the water boils in the ordinary way or evaporates into the air at ordinary temperatures (in fact it requires more heat to evaporate water at lower temperature). If the air is dry, evaporation is quite rapid even when water is cool. Thus, when water is placed in a slightly porous unglazed earthen vessel a small amount continually filters to the outside and evaporates, keeping the contents several degrees cooler than the surrounding air. This device in various forms has been used for hundreds and perhaps thousands of years.

(*d*) Frost.—White frost consists of small ice crystals frozen out of the air, often when the temperature of the air a few feet from the ground is as high as 40° F, namely, 8° above the freezing point. The temperature of the ice crystals and the leaves and other material on which they form must be as low as 32° F. This large difference in temperature in the air is caused by loss of heat by radiation from the earth to the sky. It is a familiar fact that hoar frost does not form when the sky is cloudy or hazy and seldom when there is wind. The haze or clouds in the sky prevent radiation while wind keeps the air so well mixed that no part can become much colder than another. The burning of fuel in fruit orchards, etc., protects from frost partly because of the heat of the fire and partly because the smoke acts as does a haze or clouds in preventing loss of heat by radiation. The covering of plants with papers and the covering of hotbeds and cold frames with mats prevents frost in much the same manner, i. e., by reducing the amount of heat radiated away.

Whenever on a clear, still night the temperature in the early part of the night, as shown by a thermometer 4 feet from the ground, goes lower than 40° F, there is danger of frost.

An article on "Frost Protection," by Humphreys, in the Monthly Weather Review, vol. 42, page 562, 1914, contains some interesting information.

6. Heating Value of Fuels

The heat required for heating, cooking, and other purposes may come from any one of several sources, and the one chosen should depend upon the cost and convenience of the heat supplied from these different sources. Table 3 gives the approximate amount of heat produced by burning several different kinds of fuel, also the number of gallons of water which could be heated from 32° to 212° F (0° to 100° C) for 1 cent, *if no heat were lost.*

These figures apply to the cost of the heat actually supplied to the water, but the true cost of any operation like heating a kettle of water or baking a loaf of bread will depend also upon what proportion of the heat is utilized, and this again depends upon the nature of the fuel. For instance, a coal fire must be kept burning for a long time in a stove of considerable size, so that much of the heat from the fuel is used in heating the stove and still more is radiated from the heated surface of the stove, while perhaps only a very little heat is actually used. A gas burner, on the other hand, may be lighted and turned out quickly, and there is no large amount of metal to heat, so that much less heat is wasted. For this reason gas, which costs six times as much as hard coal for each heat unit, may still be cheaper than coal to use when heat is needed for only a short time.

TABLE 3

Comparison of Fuels

Material	Heating value	Price	Gallons of water which could be heated from 32° to 212° F for 1 cent
	Btu per lb.		
Softwood	8000	$4 per cord (2 tons)	53.0
Hardwood	8000	$4 per cord (3 tons)	80.0
Soft coal	13 000	$4 per ton	43.0
Hard coal	13 000	$7 per ton	25.0
Coke	12 000	$5 per ton	32.0
Charcoal	16 000	$25 per ton	8.5
Fuel oil	18 000	$1.25 per barrel (50 gallons)	36.0
Kerosene	18 000	$0.10 per gallon	8.3
Alcohol	12 000	$0.50 per gallon	1.0
Gasoline	19 000	$0.20 per gallon	3.5
	Btu per cu. ft.		
Natural gas	1000	$0.40 per 1000 cubic feet	17.0
Manufactured gas	600	$1.00 per 1000 cubic feet	4.2
	Btu pir kw hr.		
Electricity	3400	$0.10 per kilowatthour	0.23
	Btu per lb.		
Ice (to absorb heat)	160	$0.35 per hundredweight	*0.32

* Water from 212° F to 32° F, gallons for 1 cent.

Note.—Ice in melting absorbs 143 Btu per lb., but the ice water thus formed also absorbs from 15 to 20 Btu additional before it leaves the refrigerator, making a total of about 160 Btu.

Hard coal when burned gives out about 13 000 Btu per pound, and if it costs $7 per ton, the last column shows that 25 gallons of water can be heated from 32° to 212° by burning 1 cent's worth of coal, provided none of the heat were lost; or kerosene supplies 18 000 Btu per pound and 1 cent's worth of it at 10 cents per gallon would heat 8.3 gallons of water from 32° to 212° F.

All fuels in burning require an amount of air many times the weight of the fuel. If enough air is not supplied, part of the fuel will not burn; if too much air is supplied, an unnecessary amount of heat is carried away in the smoke.

The economy of different fuels depends upon how completely they are burned. It is easy to see that coal is usually not entirely burned, since unburned pieces are found in the ashes. That gas, also, is not always entirely burned may not be so well known, because unburned gas is not visible. But partly burned gas is always dangerous, containing more or less of the poisonous gas carbon monoxide. This gas is produced when a burner "strikes back" or burns in the tube instead of from the proper openings. Some of it is also produced when an ordinary gas, oil, or gasoline flame plays upon a cold surface, as the bottom of a kettle of water. Partly burned gas can almost always be detected by a pungent odor. This is not the odor of carbon monoxide, but some of the latter is almost always present when there is such an odor. On account of the danger of this gas (carbon monoxide) all gas water heaters, and preferably gas and gasoline stoves as well, should be supplied with flues to carry off dangerous or partly burned gases.

Gas-stove burners should be adjusted so that the blue-green central part of the flame is about half the height of the whole flame. If the flame is very long and is bright yellow in parts, too little air is being admitted; if short and inclined to make a slight roaring noise, there is too much air. In the latter case the flame is liable to "strike back," under which condition much carbon monoxide is formed. In all gas burners the various openings should be kept clean. The amount of air supplied to gas burners is usually adjusted by means of a small damper or slide to be found at the base of the burner.

7. The Saving of Heat

Heat always tends to pass from warmer objects to cooler ones just as water always tends to flow downhill, but, unlike water, heat can never be entirely retained. If an object—for example, a flat-iron—is warmer than things around it, it loses heat partly by radiation, which can be felt by the hand held near but not directly above it, partly by air currents which may be felt if the hand is held above, and partly by conduction through any material in contact with it, as, for instance, a handle. Now, although this loss of heat can not be entirely prevented as long as surrounding objects are cooler than the iron, yet the heat passes much more readily through some substances than through others, and a knowledge of these substances is useful because it makes possible the saving of much heat which would otherwise be lost. (See Table 4.) The walls of steel passenger cars are lined with a layer of heat insulating material, since the steel itself is so good a heat conductor (that is, heat passes through it so readily) that such cars would otherwise waste too much heat and the sides would be uncomfortably cold even if the air were warm. Hot water, steam, and air heating pipes are often covered with insulating coverings of materials such as asbestos or hair felt in order to reduce the loss of heat from them.

The well-known fireless cooker is an extreme example of the conservation of heat. In this case a compartment, usually lined with sheet metal, is so thickly covered on all sides with some sort of insulating material that the contents once heated will stay hot for many hours.

8. Comparison of Heat Insulators

Table 4 gives the thermal conductivities of a number of common materials, also the number of Btu of heat which would pass in one hour through a sheet of the material 1 foot square and 1 inch thick, if the difference in temperature between the two faces were 1° F.

If the material were twice as thick, about half as much heat would pass through, or if the difference in temperature were 2°, twice as much heat would pass through.

Air which can not circulate and carry heat in that way (by convection) is one of the best heat insulators to be found. Cotton, wool, feathers, cork, etc., are good insulators because they contain a large amount of air in the cells or in the spaces between the fibers. Clothing keeps in the heat of the body chiefly because it contains air between the layers and in the meshes of the cloth. When the inclosed warm air is displaced and is replaced by colder air, as is the case in windy weather, the clothing no longer keeps one so warm. If clothing is close fitting, there is less room for an air layer between the layers of clothing and therefore it is less warm. To keep one warm in cold, windy weather the clothing should consist of loosely fitting garments, preferably of wool, with some outside wrap which is nearly wind proof, such as very close woven cloth, or even leather or rubber. A fur coat is very much warmer if the fur is on the inside, where the wind can not disturb the air which is held among the hairs, than if the fur is on the outside.

TABLE 4

Material	Thermal conductivity, metric units[7]	Transmission in Btu per hr., per sq. ft., per inch thickness for each degree F difference in temperature
1. Silver	1.0	2900.0
2. Copper	.9	2600.0
3. Aluminum	.5	1450.0
4. Iron	.14	400.0
5. Rock	.0025 to .009	0.7 to 26.0
6. Porcelain	.0025	7.2
7. Brick	.002 to .005	6.0 to 15.0
8. Glass (ordinary)	.0016	4.6
9. Water	.0014	4.0
10. Plaster (ordinary)	.001 to .0015	2.9 to 4.3
11. Wood (hard)	.0006	1.7
12. Asbestos paper	.00045	1.3
13. Asbestos felt	.00025	.7
14. Sawdust	.00018	.52
15. Wood (very soft)	.00015	.43
16. Paper	.00013	.38
17. Cork board	.00012	.34
18. Wool	.00010	.29
19. Hair felt	.00010	.29
20. Cotton wool	.00009	.26
21. Feathers	.000057	.16

[7] Thermal conductivity in metric units is the amount of heat in calories which will pass in one second through each square centimeter of a plate 1 centimeter thick, if the difference in temperature between the surfaces is 1° C.

In Table 4, second column, are given the *specific heat-conductivities* of a number of substances, i. e., the amount of heat in calories which will pass in one second through each square centimeter of a plate 1 centimeter thick when the two sides differ in temperature by 1 degree centigrade. Thus, about 18 000 times as much heat will pass through a silver plate as through a layer of feathers of the same thickness. Column 3 gives the amount of heat in English units.

9. Radiation

Hot objects, like stoves and steam pipes, lose much of their heat by radiation, and the blacker the object the more it will lose; hence, stoves and steam pipes should be black if they are intended to give out heat, but hot-air pipes, cooking utensils, etc., should be bright (for instance, tinned or nickeled) in order to lose as little heat as possible. A stove nickel plated all over will give out only about half as much heat as the same stove at the same temperature if black. Brightly tinned hot-air furnace pipes often lose less heat bare than they do when covered with one or two layers of asbestos paper, since the asbestos paper radiates heat so much more readily than the bright tin as to more than balance the insulating effect of the thin asbestos covering. Of course if the pipes were black to begin with, the covering would be useful, and if the insulating material were thick enough (say, 3/8 inch or more) it would save heat even on bright tin pipes.

A bright nickel or aluminum kettle will cool very much more slowly than a black kettle. On a coal or wood stove or directly over a coal or wood fire a kettle is heated largely by heat radiated from the stove or fire, therefore if the bottom is black the kettle will heat more rapidly than if bright. Over a gas, gasoline, or similar blue flame the condition of the bottom will not make so much difference, since here most of the heat is received by contact with the hot gases. The best kettle for general use is therefore one with the bottom black and the remainder polished, but for use on a gas stove it makes little difference whether the bottom is black or not.

10. Heat in the Household

(*a*) Heating of rooms.—The proper heating of a residence is a matter of the utmost importance, as upon it depend the comfort and health of the occupants. Two essentials are a supply of heat and a supply of fresh air. The supply of heat is usually given some attention, while the supply of air is often sadly neglected. Fortunately, few residences are so tightly built as to prevent some leakage of air from the outside, otherwise this neglect would be more serious than it is.

When fuel is burned in a furnace, stove, or grate for heating purposes, part of the fuel is usually left unburned, part of the heat produced passes off up the chimney, and part may be lost from hot water, steam, or air pipes running to the several rooms, and the remainder is utilized in heating the air in the room and in supplying the loss of heat through the walls, doors, and windows.

(*b*) The amount of heat required to warm fresh air.—A certain amount of heat is of course required to keep a house warm in cold weather even if no fresh air is admitted, and if cold fresh air is admitted heat is necessary also to warm this air, but the amount of heat needed for this purpose is not large. If the air outside is at a temperature of 32° F (freezing point) and is to be warmed to 70° F, it would require about 2 pounds of coal per day to heat an ample supply of air for one person (2000 cubic feet per hour). Thus, in heating residences an ample amount of fresh air can be allowed without greatly increasing the cost of heating.

(*c*) AMOUNT OF HEAT USED IN COOKING AND SOME OTHER HOUSEHOLD OPERATIONS.—In many household problems it may be of use to know how much heat is used. It takes about 180 Btu to heat a pound of water from freezing to boiling temperature, and it takes nearly 1000 Btu to boil away that amount of water. "A watched pot never boils" is a saying containing much truth, since *removing the cover* of a vessel in which water is being heated allows much heat to escape. Long before water begins to boil steam is leaving the surface of the water and each 5 drops of water thus taken away as steam absorbs enough heat to cool about a pound of water 1 degree. If a tight cover is kept in place, the escaping steam will mostly condense on the cover and much of the heat which it contains will be kept within. However, after the water begins to boil violently some of the steam will be driven out around the cover and the heat which it contains will be lost.

When water is kept boiling for cooking foods the object is to keep the food hot enough for cooking; that is, at the temperature of boiling water. But the water also prevents the food from getting too hot, because no matter how fast water boils it gets no hotter, and the cooking will proceed no faster. Whatever heat is used up in boiling away more water than necessary is entirely wasted, not to mention the disastrous effect of allowing all the water to boil entirely away. Therefore after boiling has begun, a gas or oil flame can be turned down considerably without delaying the cooking, provided the water keeps boiling. *To save heat, keep the cover on.*

But there are other processes where the boiling away of the water is the main object, as in the boiling down of sirups, the making of candies or jellies, etc. Here instead of saving heat by boiling slowly, heat may be saved by boiling briskly, since by so doing it will take less time, therefore less gas or coal, to boil away the required amount of water. Here no cover should be used since a cover would prevent the escape of some of the steam.

In baking and frying operations there is not much chance for the saving of heat, except in the selection of an oven. Baking in the ordinary oven is a very wasteful process, indeed, since more than 90 per cent of the heat supplied is usually lost through the sides of the oven. Such loss of heat could be made much smaller if the walls of all ovens were made with a thick layer of heat-insulating material. Electric ovens are usually well insulated, since without some means of saving heat the cost of baking by electricity would be altogether prohibitive in most places because of the relatively high cost of heat supplied by electricity.

(*d*) Regulation of stoves, ranges, and other heating appliances.—The air which enters cold below the fire in any stove or furnace passes up through the fire, producing combustion and absorbing the heat produced except that which escapes through the sides of the fire box. This heated air may then be utilized for heating in one of several ways, as by letting it pass around water tubes or through flues in a boiler, around air flues in hot-air furnaces, around the oven in a cooking range, or through a heating drum and length of pipe in the common heating stove. Whatever heat is left in the flue gas when it enters the chimney is useless except for increasing the draft. It is therefore important to utilize as large a proportion of the heat as possible before the gases reach the chimney. This can best be done by (1) having the gases as hot as possible, (2) allowing them to pass out as slowly as practicable, and (3) bringing them into the best possible contact with the flues, oven sides, or other heating surfaces.

Good contact between flue gases and the heating flues can only be obtained in any given stove or furnace by keeping the flues clean and free from soot and ashes. This is very much more important than most persons realize.

The gases will be hotter and will also pass more slowly the less their *amount;* therefore no more air should be admitted to the stove or furnace than is necessary. This applies particularly to air which might be admitted over the fire by opening the fire door or a draft in it, except under the following conditions:

When combustible gases are produced by the heating of fuels such as soft coal, or wood, it is sometimes necessary to admit air over the fire so as to permit the gases to burn. Therefore, with such fuels, some air should be admitted through the fire door or in some other manner immediately over the fire, so long as a bright flame is produced.

With hard coal, coke, and charcoal, as well as with wood or soft coal, after the flame has burned out, no air should be admitted over the fire.

In most cooking ranges and in some heating stoves and furnaces there is a damper which permits smoke from the firebox to pass directly to the chimney without passing through the heating flues. One should learn how any such damper operates and keep it closed, except possibly when first starting up the fire. Opening this damper will often make the fire burn more briskly, but most of the extra heat thus produced is usually lost up the chimney. In summer, however, when extra heat is not desired, this damper may be left open to allow heat to escape up the chimney.

This discussion suggests a few general rules for controlling heating and cooking fires.

1. To increase the amount of heat, open drafts which let air into the ash pit, and with *soft coal* and *wood* when fresh fuel has been added admit some air by draft immediately over the fire to help burn the combustible gases coming from the fresh fuel. For all fires burning without flame keep this draft closed.

2. To decrease the amount of heat close all drafts tight (being sure that ash-pit door and drafts particularly are tight and that the ash pit itself is free from air leaks), and if this is not sufficient open a check draft in the smoke pipe (*never the one in the fire door* or the door itself, as this practice is extremely wasteful of fuel).

3. To *insure economy* of fuel see that all flues and surfaces which the hot gases pass on their way to the chimney are cleaned every two or three weeks.

4. Be very careful in the use of the damper which closes off the smoke pipe, as such a damper is dangerous if closed too tightly

79685°—21——5

and can be left wide open or taken out entirely provided the ash pit is tight and the above directions are followed.

5. Keep the direct draft in a cooking stove or range closed except in hot weather, or when starting a fire.

A report on fuel tests and the issue of fuel by the War Department, 1914, contains considerable information as to the proper care of heating apparatus and the amounts of fuel used. Under average conditions, in detached residences, when the mean winter temperature is 45° F, about 1 long ton of coal (2240 pounds) is required per room for the season. The amount is less in houses built in rows; it is somewhat greater for smaller houses on account of the greater relative amount of outside wall space; it increases from 10 per cent to 15 per cent if the average winter temperature is 10° F lower.

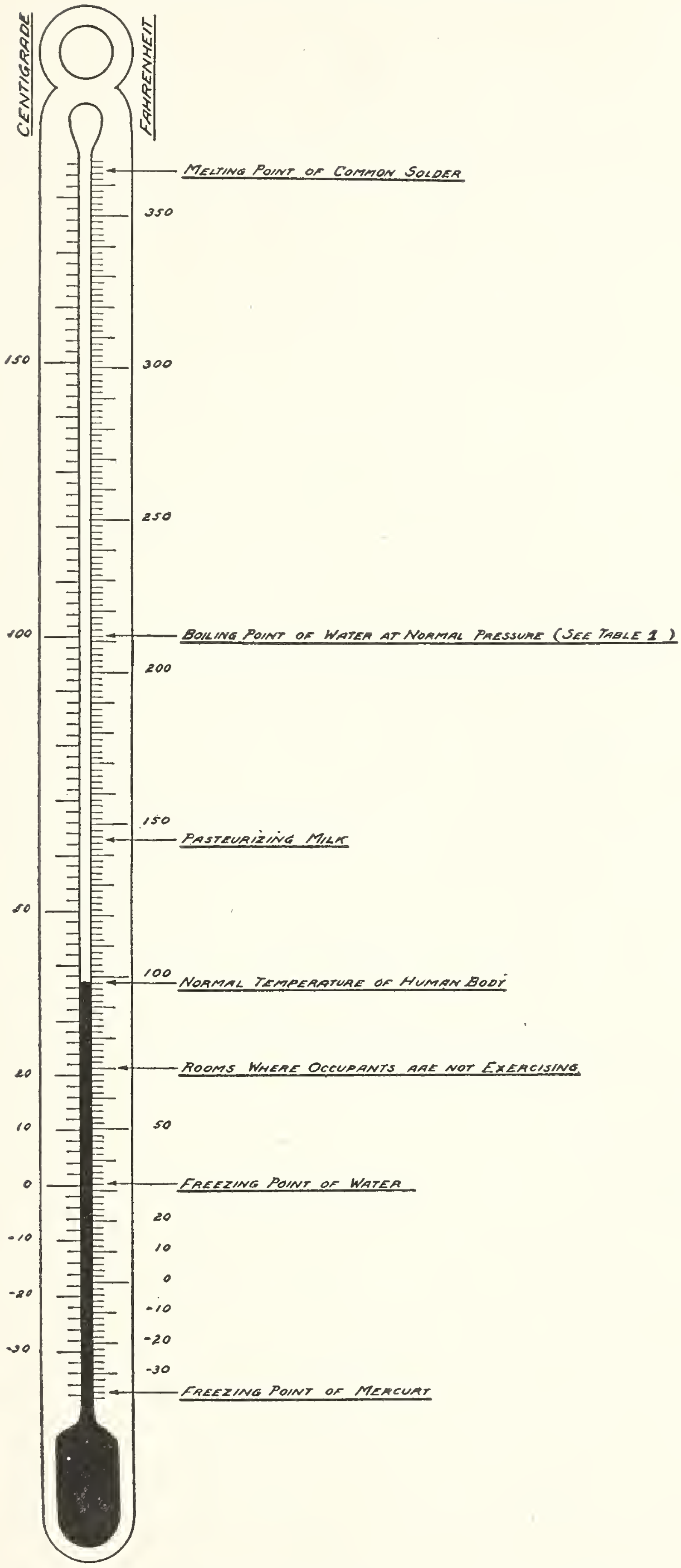


FIG. 26.—*Two common temperature scales, viz, Fahrenheit and centigrade*

On the centigrade scale the freezing point and normal boiling point of water are, respectively, 0° and 100°; on the Fahrenheit scale these points are 32° and 212°; thus 1° centigrade is equal to 1.8 Fahrenheit.

TABLE 5

(*e*) Table of Useful Temperatures

	Degrees centigrade	Degrees Fahrenheit
Mercury freezes	−39	−38
Freezing cold storage	−18 0	0 +32
Water freezes	0	32
Danger of frost	+ 4	39
Household refrigerator, proper temperature	7 13	45 55
Churning	11 17	52 62
Gymnasium, or rooms where occupants are actively engaged in physical work or exercise	13	55
Ripening of cream	18 21	65 70
Rooms where occupants are not exercising	20 21	68 70
Normal temperature of the human body determined by thermometer under the tongue	37	98.6
Incubator temperature	39.4	103
High fever, temperature measured as above	40.6	105
Pasteurizing milk	63	145
Pasteurizing milk (flash process)	71	160
Water boils at normal pressure. (See Table 1)	100	212
Plain sugar sirups:		
For sirup, 11 pounds to the gallon	104	219
For fondant candies	113 115	236 240
For fudge and other candies of like nature	115	240
For taffy and like hard candies to be pulled	149	300
For clear brittle candies, peanut brittle, etc	154	310
For almond and walnut brittle	157	315
Melting point of common soft solder	185	365
Oven temperatures for baking:		
Custards, meringues, pies, puddings, etc	121 177	250 350
Sponge cake, bread, gingerbread, plain cake, and cookies	177 204	350 400
Parker House rolls, popovers, and biscuits	204 232	400 450
Biscuit and pastry	232 287	450 550
Melting point of lead	327	621
Melting point of aluminum	659	1218

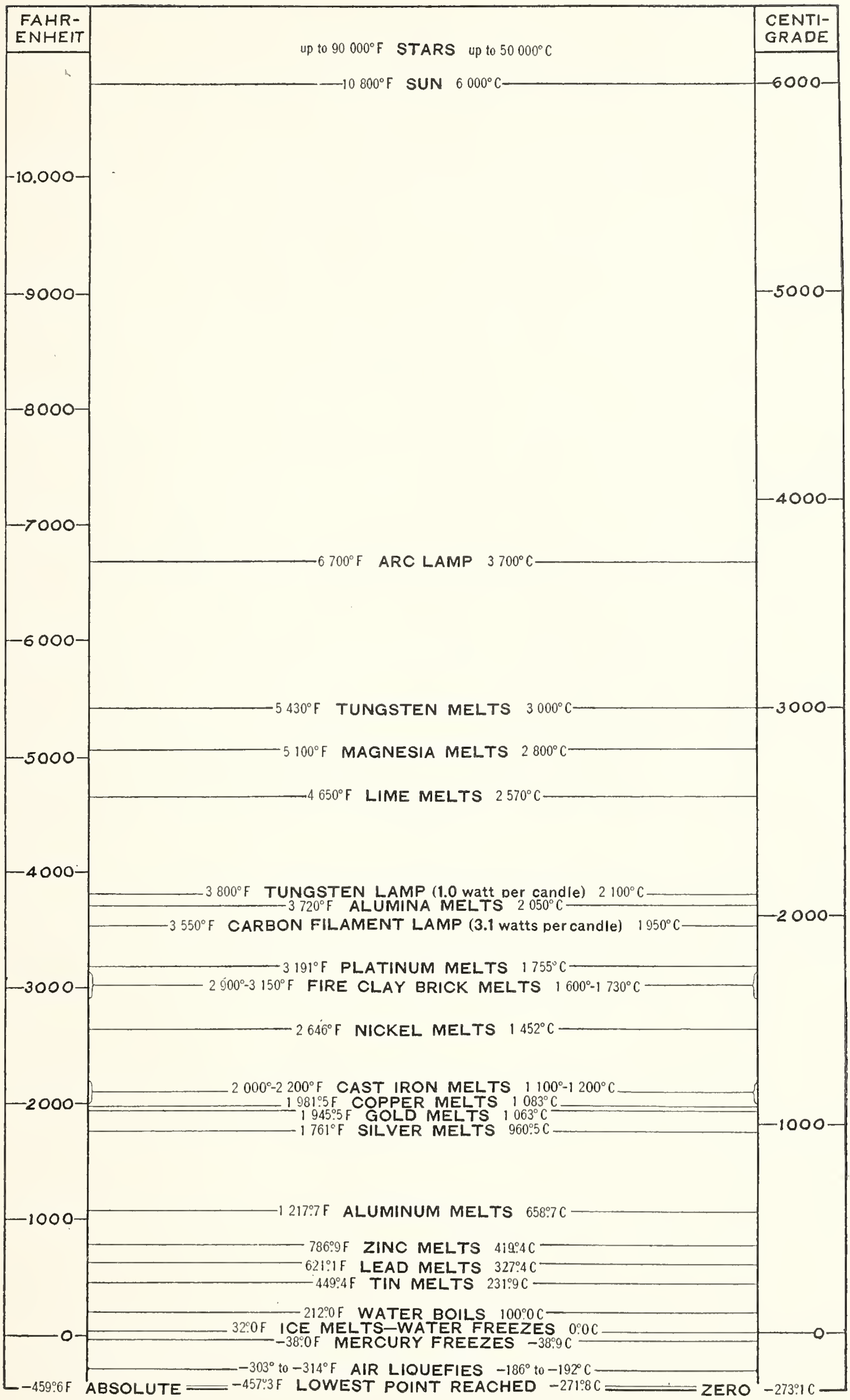


FIG. 27.—*Chart of various temperatures from the lowest attained to those of the stars, given on both the Fahrenheit and the centigrade scales*

IV. LIGHT

1. Units and Measurements

In measurements of lamps and of lighting or illumination two units are commonly used, the candle and the foot-candle. As the name "candle" indicates, this unit was taken originally as the average intensity of the light of a certain kind of candle. Results obtained with actual candles, however, are variable, and the unit called the candle is now maintained at the Bureau of Standards by electric lamps. All the important makers of lamps in this country use standards whose candlepower has been found by comparing them with these fundamental or primary standards kept at this Bureau. The candlepower of a lamp indicates the amount of light produced by it; that is, a 16-candle lamp gives 16 times as much light as a standard candle.[8]

Comparisons of candlepower are never made by looking at the lamps themselves, but always by letting the light from one lamp fall on a surface (usually white), and then comparing this surface with a similar one illuminated by another lamp. The light from the two lamps must strike the surfaces at the same angle. Then when the two surfaces are equally bright the candlepowers of the two lamps are in proportion to the squares of the distances of the surfaces from the respective lamps. An extremely simple light-measuring device, or photometer, can be improvised by placing a sheet of paper so that the light from two lamps falls on it at the same angle, and then holding a pencil or other small opaque object at a little distance from the paper so that it casts two shadows side by side. If the lamps are equally distant, the one of higher candlepower will cast the darker shadow; if the paper is moved so as to make the shadows equally dark, the more distant lamp is the more powerful in proportion to the squares of the distances.

---

[8] This statement is of course only approximately true unless allowance is made for the fact that a lamp usually has different candlepowers in different directions. The rating commonly given is the "mean horizontal candlepower." Different kinds of lamps having the same mean horizontal candlepower do not give exactly the same total amount of light, but the differences are usually small and will be disregarded in this circular.

In using light, as well as in measuring it, the important thing is the amount of light that falls on a given surface. When an object is set up at a distance of 1 foot from a 1-candle lamp, so that the light falls perpendicularly on its surface, the illumination received by the surface is called 1 foot-candle. If the 1-candle lamp is replaced by a more powerful one, the illumination is increased proportionately. For example, a 16-candle lamp would make the illumination 16 foot-candles. But if the distance is increased, the illumination decreases in proportion to the square of the distance; hence, at 2 feet the 1-candle lamp would give only $\frac{1}{4}$ foot-candle and the 16-candle lamp $\frac{16}{4}$ or 4 foot-candles. The reason for this "inverse square law" is easy to see. It is simply that the same amount of light is spread over a greater and greater surface as the distance is increased. The light which falls on 1 square inch at 1 foot distance must at 2 feet illuminate a surface which is 2 inches on a side—that is, 4 square inches; at 3 feet the same light is spread over 9 square inches; at 4 feet, over 16 square inches, and so on. The general rule, therefore, for finding the illumination on a surface which receives light directly from a lamp is to divide the candlepower of the lamp by the square of the distance in feet. For example, a 32-candle lamp at a distance of 4 feet gives an illumination of $\frac{32}{16}$ or 2 foot-candles. If the surface is turned so as to receive the light obliquely, a smaller amount of light is intercepted by the surface and the illumination of the surface is proportionately reduced.

2. Sources and Cost of Light

For the production of light a great variety of lamps are available, and in some kinds remarkable improvements have been made in the last few years. These improvements have made it possible in many cases either to improve the lighting of the home without increasing the cost or to reduce the cost. The cost of lighting by any method depends to some extent on local conditions, and the statements of cost given below will apply only approximately in any particular case. The cost will naturally depend on the candlepower of lamps used and the time the lamps burn. In order to make comparisons between different kinds of lamps it is convenient to consider a definite amount of lighting, which is obtained by multiplying the candlepower of the lamps burned by the number of hours they burn. For example, 1000 candle-hours of lighting may be obtained by burning a 10-candle lamp 100 hours or a 50-candle lamp 20 hours, but if the lamps are of the same kind the cost will be about the same. Calculations of the cost of producing 1000 candle-hours by different lamps are sometimes useful in choosing between lamps, but of course it does not necessarily follow that the lamp for which this cost is lowest is most

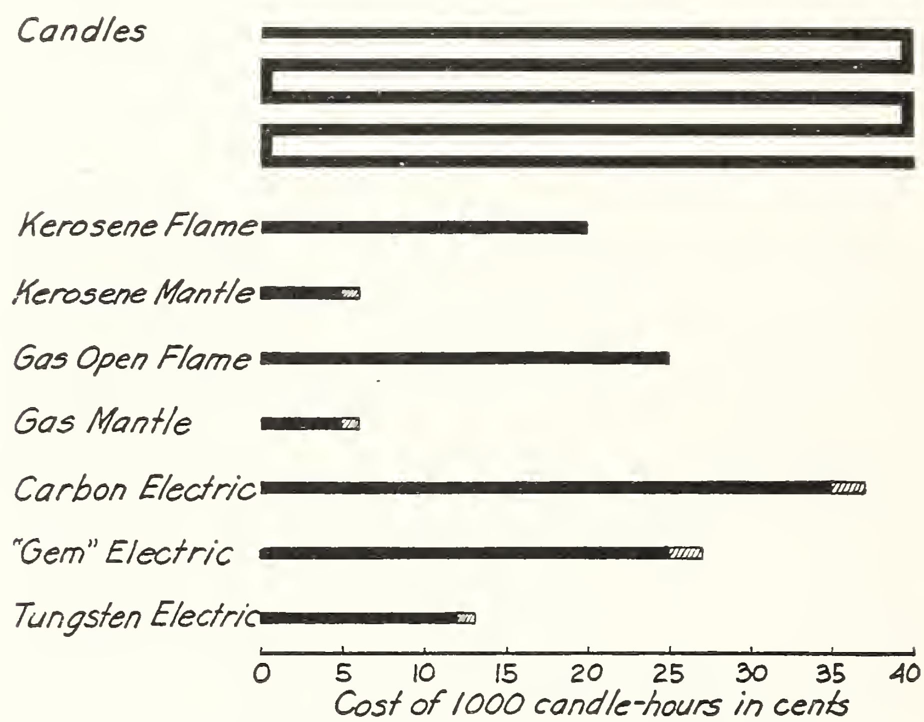


FIG. 28.—*Relative cost of producing a given amount of light by various illuminants at usual prices*

Costs are based on the following prices: Candles, 12 cents per pound; kerosene, 15 cents per gallon; gas, $1 per 1,000 cubic feet; electricity, 10 cents per kilowatthour. The solid lines represent cost of fuel or of current, the shaded parts the cost of the mantles and bulbs. Where prices are different from those given above, costs will be correspondingly different.

economical for household use. Data concerning relative costs of producing light by common methods usually employed in the house are given in Fig. 28.

(*a*) MISCELLANEOUS LAMPS.—Candles, the oldest form of illuminant we have, are still very widely used, but ordinarily they are used for decorative lighting, where cost and amount of light are not given much consideration. Candles are, in fact, very expensive when one considers the cost per unit of lighting, since 1000 candle-hours obtained from them costs about $2.

Kerosene oil lamps are much more economical, the cost for 1000 candle-hours being in the neighborhood of 20 cents. In other words, the cost of oil for a 10-candle lamp is about the same as the cost of burning a single candle for the same time. Kerosene lamps using incandescent mantles have been devised which give three or four times as much light for a given consumption of oil as the ordinary lamp, but their construction is usually rather complicated and their operation is not always satisfactory.

Various methods of lighting which are suitable for country houses or small villages, such as acetylene, air gas or carburetted air, and Blau gas, are in general more expensive than the gas or electricity available in larger towns. The cost of acetylene, for instance, is about 30 cents per 1000 candle hours.

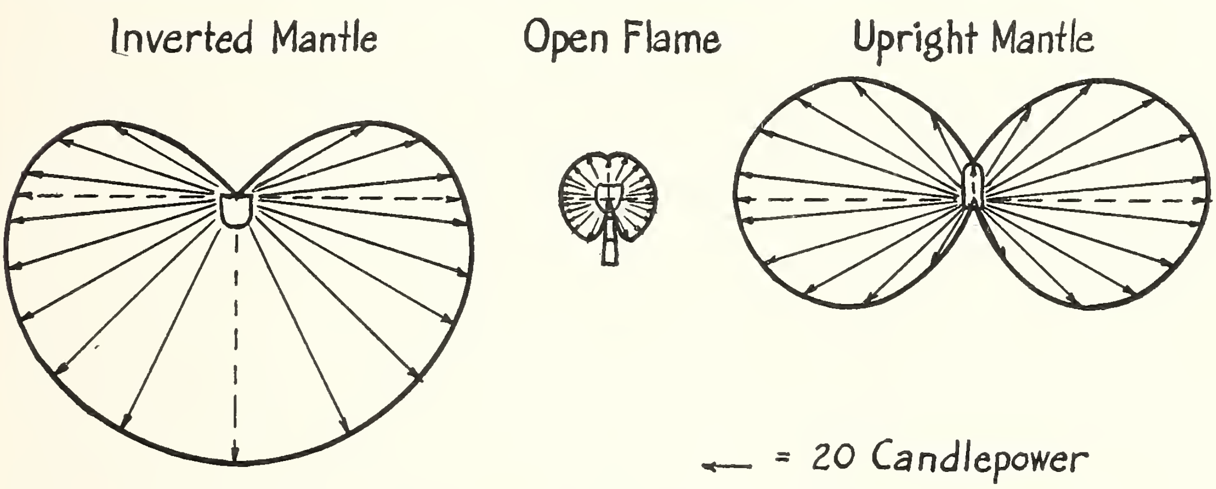


FIG. 29.—*Comparison of amount of light given by different gas lamps*

Each lamp is supposed to burn 5 cubic feet per hour, costing one-half cent if gas is $1 per 1000 cubic feet. Note that the mantle lamps give four or five times as much light as the open flame. The inverted mantle gives more light downward and less upward than the upright mantle.

(*b*) GAS LAMPS.—For city gas a certain "candlepower" is commonly required by law. This usually means that a certain type of open-flame burner when using 5 cubic feet of gas per hour has the candlepower specified. Twenty-candle gas, therefore, means 4 candles for each cubic foot consumed per hour in an open-flame burner. At $1 per 1000 cubic feet this makes 1000 candle-hours cost 25 cents. If mantle lamps are used, the efficiency depends on the quality of the lamp and the care which is taken to keep it in good condition, but a good lamp in fair condition should give 20 candles per cubic foot per hour; that is, the mantle lamp will give five times as much light as the open flame, making the cost for 1000 candle-hours only 5 cents for the gas burned. (See Fig. 29.)

To balance against this very large saving in gas there is the cost of the lamp and of mantles. A better comparison can therefore be made if a year's use of the lamp is considered. The average open-flame burner takes more than 5 cubic feet per hour; 7 cubic feet is a fairer assumption. If the lamp is used 1000 hours in a year, this means 7000 cubic feet, or $7 for gas. Suppose that a mantle lamp using 4 cubic feet per hour is substituted, and that four mantles at 25 cents each are required during the year. The cost for gas and mantle is then $5. The saving would be more than sufficient to pay for a high-grade lamp equipped with the best kind of reflector or globe. The net result would be that the lamp would have more than paid for itself, while instead of a light of 25 to 30 candles one would have had 80, in addition to the very great advantages gained by using a lamp with a reflector.

If the burner happens to be located where the light of the open flame is sufficient, a still greater economy can be obtained by using one of the small mantle burners which cost only 10 cents for the fixture and 25 cents each for mantles. These will give as much light as an open flame and use about one-fourth as much gas.

In addition to the actual saving in gas the mantle burners have a great advantage in furnishing a steadier light. In some cases, also, there is a considerable reduction of the risk of fire, since the mantle burners are protected by chimneys, and hence inflammable objects are less likely to get into the flame. In short, there appears to be no good reason for continuing the use of open-flame burners in any place unless it be where there is some condition to cause excessive breakage of mantles.

(*c*) Electric lamps.—Of electric lamps three kinds are common in household use. These are the ordinary carbon, the metallized carbon or "Gem," and the tungsten lamp. Nearly all of the last kind sold in this country bear the trade name "Mazda." All three kinds are commonly marked with the number of watts (power) they take when used at the number of volts (electrical pressure) also marked on the lamp. When electricity is paid for at a certain rate per kilowatthour the cost of current for any lamp is easily calculated. The kilowatthour is 1000 watthours, and the number of watthours used by any electrical device is simply the watts times the number of hours burned. For example, a 50-watt lamp in 20 hours uses 1000 watthours or 1 kilowatthour; at 10 cents per kilowatthour current for such a lamp costs one-half cent per hour. This is true of any 50-watt lamp without regard to the kind of filament it has. The amounts of light produced by different kinds of filaments are, however, decidedly different. (See Fig. 30.)

If the voltage supplied is lower than the lamps are intended for, the watts taken by the lamps are reduced somewhat, but the light is reduced a great deal more. The amount of light obtained from a given amount of electric energy depends, therefore, on the voltage. Under fair conditions the amount of light and the cor-

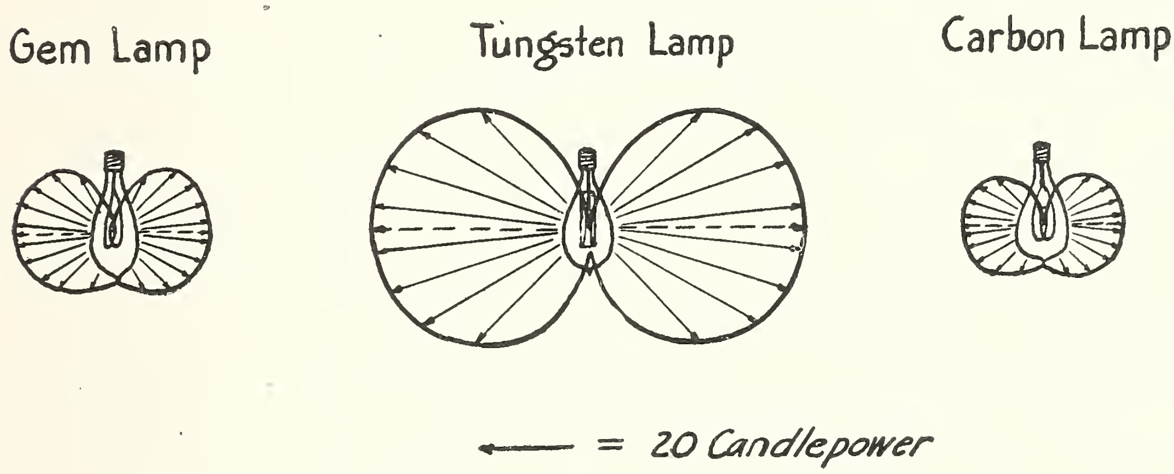


FIG. 30.—*Comparison of amount of light given by different electric lamps*

For comparison a consumption of 50 watts is assumed, although tungsten lamps are not usually made in this size. Fifty watts at 10 cents per kilowatthour costs one-half cent per hour, and gives 12 to 16 candles in a carbon lamp and 40 to 45 in a tungsten lamp. All lamps give different candlepower at different angles. Each arrow in the figure is proportional to the candlepower in its direction.

responding cost for current (at 10 cents per kilowatthour) would be about as follows:

Kind of lamp	Candles per watt	Cost for 1000 candle hours in cents
Carbon	0.25 to 0.33	30 to 40
Gem	About 0.40	25
Tungsten	0.80 to 1.00	10 to 12.5

From a 60-watt lamp, for example, the candlepower obtained is 15 to 20 for a carbon lamp, 24 for the Gem, and 56 for the tungsten.

In many places free renewals of carbon or Gem lamps are made by the power companies, while the consumer must furnish tungsten lamps at his own expense. This deters many people from using the better lamps, especially because the latter have the reputation of being very fragile. The early tungsten lamps were in fact easily broken and were comparatively expensive, but lamps are now very much cheaper and many times as strong as those made two or three years ago. Their durability is shown by their common use on street cars, for example. The average life required by the Government specifications for tungsten lamps is 1000 hours of burning, and most of the lamps last longer than this.

As an example of the economy to be obtained by using the more modern lamps, consider the cost of a year's use (say 1000 hours), at 10 cents per kilowatthour. A lamp commonly furnished by central stations is the 50-watt Gem, giving 20 candles. Fifty watts for 1000 hours make 50 kilowatthours, costing $5. If a 25-watt tungsten lamp (giving 22 candles) is substituted for the Gem lamp, the cost for current becomes $2.50; to balance against the saving of $2.50 there is the cost of the lamp, which is about 30 cents. Since a lamp may sometimes be broken and not last the 1000 hours, it may be interesting to calculate how long it must last to pay for itself. The reduction of 25 watts means a saving of one-fourth cent per hour; if the 30-cent lamp gives 120 hours of service, one has at least lost nothing by buying it.

These calculations have been based on a straight meter rate of charge for electric service because that method of charging is most common in this country. With other systems of charging, the saving to the user of better lamps will generally be less; in almost all cases, however, there will be some saving to the individual user. The total economic gain which is made possible by doubling the efficiency of production of light is almost incalculable. To consider only one item, it has been estimated by good authorities that the liberal use of the newer lamps might reduce the yearly consumption of coal in the United States by $8 000 000. The general tendency has been, however, not to reduce the amount of power used, but rather to use more light. The ability to produce so much more light without increasing the cost has encouraged the development of methods of lighting in which attention is given primarily to artistic appearance and to the comfort of the user rather than to getting as much light as possible out of a fixture.

3. Artificial Lighting

(*a*) General principles.—While the lamps that produce the light have been undergoing rapid improvement, methods of using light have also been studied and experimented with as they never were before. Many important questions remain unsettled, but there are certain simple rules on which there is general agreement.

One most important and fundamental principle is that things are seen by means of the light which they reflect *diffusely*. This means that, in order to see an object clearly, light from some source must fall upon it and must be reflected in such a way that no image of the lamp itself and no bright streaks or spots (which are really imperfect images of the lamp) appear.

A second principle is that excessive contrasts of brightness are to be avoided. Since an object is seen only by the light which comes from itself, it is desirable that no other part of the field shall be very much brighter than the object itself. If brighter things are in sight, there is a tendency to turn the eyes toward them, and the eyes, as a measure of protection to themselves, become adapted more nearly to the brightness of the more brilliant object. On the other hand, it is not well to have the thing on which one is working very much brighter than the surroundings. The eye seems to accommodate itself to a sort of average of the surrounding conditions, and the best results are obtained when there is a fairly even illumination.

For the amount of illumination needed—that is, the number of foot-candles—no general rule can be given. In fact, the eye can easily accommodate itself to a considerable range of intensity if the conditions are good. On dark-colored material, since it reflects only a small part of the light falling on it, naturally more light is needed than on lighter material. Similarly, in a room which has dark walls, a larger amount of light must be supplied for general illumination than is needed in a room which has a light finish.

(*b*) Special rules.—In amplification of these general principles the following rules may be helpful:

Do not work with a flickering light.—In such a light the eye is constantly being called upon to readjust itself, and is never properly adapted for the light it receives at any particular instant. Severe fatigue is the result.

Do not use unshaded lamps.—The bare flame, mantle, or filament is injuriously bright, and without shades one's glance is certain to fall upon the dazzling lamp more or less frequently. Moreover, diffuse light—that is, light from a considerable surface—usually gives more effective illumination than that from a small source.

Do not judge illumination by looking at the lamp.—The lamp is not meant chiefly to be seen but rather to enable you to see other things. The lamp which itself looks most brilliant may be for that very reason least effective. The light that comes directly from the lamp to the eye does no good and may interfere very seriously with the useful light which has gone from the lamp to surrounding objects and thence to the eye.

Do not face the light.—The old rule that the light should come from above and over the left shoulder is good. With the lamp so placed there is little likelihood of getting the brilliant reflection from table tops, smooth paper, or other shiny material which is so detrimental to good seeing; there is also little chance of letting the eyes fall upon the lamp itself. The common arrangement of lamps on library tables where the reader faces the lamp, while his book lies on the table, is very bad, unless the lamps are heavily shaded and the book lies at such a slope that the light regularly reflected from the page falls far away from the reader's eyes.

Avoid all brilliant reflections of the lamp like those mentioned above. In this connection school officials should be urged to choose text-books printed on dull-finished paper.[9] Most school books, especially those for smaller children, are now printed on glossy paper, which makes it very difficult to avoid such troublesome reflections even in a well-lighted room.

Do not put the lamp too close to your work, for this gives an excessive contrast between the work and surrounding objects, and the eye does not adapt itself properly to the intensity of light on the work. In factories it has been found that when

[9] An effort made by this Bureau to secure the use of suitable paper for this circular failed by reason of unforeseen circumstances, but it is hoped that future editions may not be faulty in this respect.

lamps are removed from individual machines and hung high enough to give a general illumination over the machines and their surroundings much better work can be done, and the total amount of light needed is often no greater. Similarly, tests have shown that when a desk lamp is used in a room otherwise unlighted the average person needs much more light to read on the desk than he does when the light is furnished by lamps which at the same time illuminate the whole room moderately.

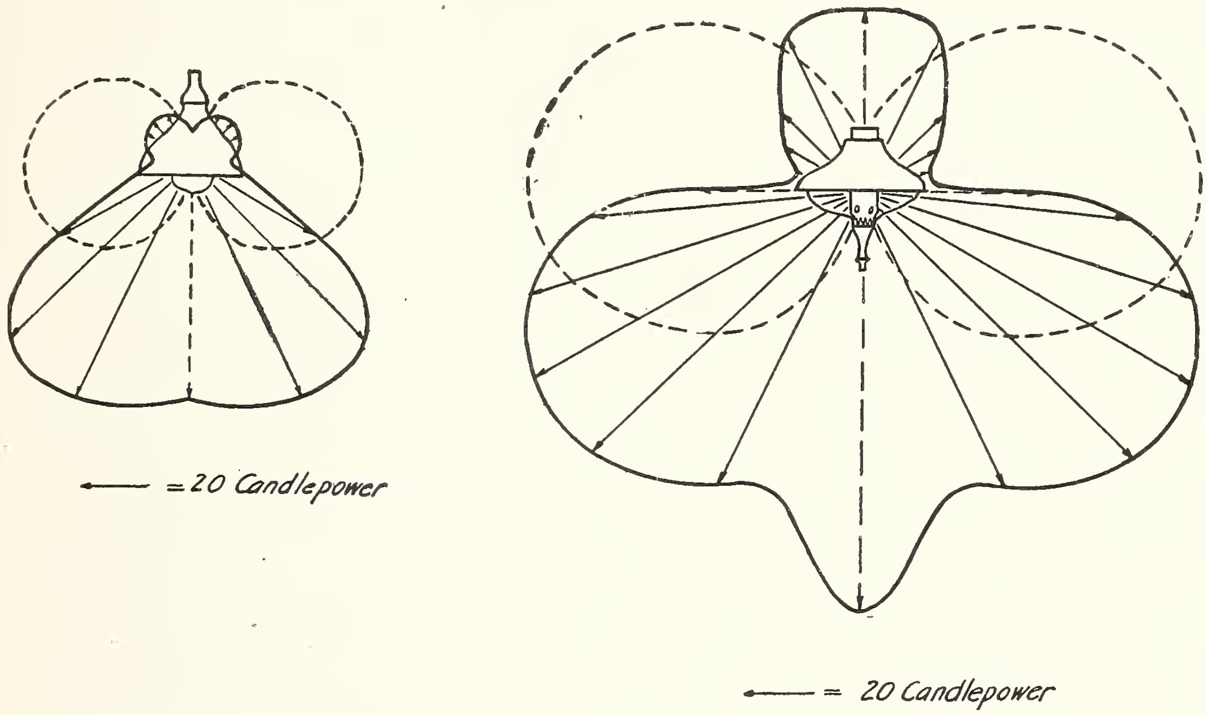


FIG. 31.—*Effects of reflectors in redirecting the light given out by lamps*

The dotted curves show the distribution of light given by the lamps without reflectors, while the solid curves and the arrows show the distribution with reflectors, the length of each arrow being proportional to the candlepower in its direction. Although some light is absorbed by the reflectors, the light received by objects below the lamps is very much increased.

The left-hand figure represents a tungsten lamp, the right-hand an upright mantle gas lamp, both with ordinary white opal-glass reflectors.

A special reading lamp, or other lamp for local lighting, is often useful, but is best used in connection with a soft general lighting.

(*c*) SHADES, REFLECTORS, AND DIFFUSING GLASSWARE.—Such a variety of lighting fixtures has been developed that one is likely to be bewildered in the attempt to choose among them. The advantages to be gained by using them are three. First, a reflector can be made to redirect the light so as to use it more effectively. (See Fig. 31.) Instead of allowing the light to go off from the lamp in all directions indiscriminately and be largely wasted on the walls and other places where little light is needed, the reflector can throw a large percentage in one particular direction where it will be most useful. Different types of reflectors are made to give different degrees of concentration, some being planned to light up brightly a small spot, while others spread the light over a considerable region. Second, a shade or a good reflector protects the eyes from the injurious brilliance of the bare mantle or filament; and finally, a well-chosen lighting fixture may have a decided artistic value and be a real ornament to a room by day as well as at night.

The relative importance of these three advantages depends on the place where the fixture is to be used. The great economy of light to be obtained by the use of reflectors was recognized at first, and for several years much stress was laid on the development of reflectors which should make effective use of the largest possible percentage of the light. It is now becoming more and more evident that the reduction of brilliance where it is not wanted is fully as important as the increase of light on the working space; and, especially for home use, the artistic possibilities of fixtures may often be more important than their engineering efficiency. Moreover, the great reduction in the cost of producing light has correspondingly reduced the importance of using all the light most economically. This reduction in cost, and the growing recognition of the fact that the arrangement which gives most light does not necessarily enable one to see best, have favored the use of various kinds of fixtures in which the redirecting action of reflectors is used either indirectly or not at all.

The extreme condition is reached in purely indirect lighting, where the lamp is hidden in an opaque reflector opening upward so that the ceiling is brightly lighted and becomes the source of light for the room. As a sort of compromise between this strictly indirect lighting and the use of ordinary reflectors, there are a multitude of globes and bowls of diffusing glass which are hung beneath or around the lamp. These reduce the brilliancy of the lamp very effectively, for the brightness of the globe or bowl is not likely to exceed two or three candles per square inch, while a lamp filament is likely to give 1000 candles per square inch and a gas mantle 30 or more. This advantage is gained at the expense of some loss of light by absorption in the globe, but in many special glasses developed in recent years these losses are comparatively small, and the illumination is really more effective than it would be if the globe were removed from the lamp.

With regard to the relative efficiency of direct, indirect, and "semi-indirect" systems of lighting there has been much argument. There can be no doubt that every time light is reflected or is transmitted through a diffusing medium part of the light is lost. In a properly planned direct-lighting equipment, most of the light is reflected only once or not at all before reaching the place where it is used. In indirect lighting the light undergoes at least one more reflection (at the ceiling), causing a loss which can hardly be less than 25 per cent and may be much more. The diffusing bowls used in so-called semi-indirect lighting throw a large part of the light to the ceiling, where it suffers a similar loss, while that part of the light which goes through the bowl is reduced considerably by absorption. Consequently, if we measure the efficiency of lighting by the fraction of the light which is finally thrown down upon the objects in the room, well-planned direct lighting will always be found most efficient. This advantage is accentuated if it is desired to light a particular spot (a table top, for example), for direct-lighting fixtures give most exact control of the distribution of the light, the other methods unavoidably giving a rather widely scattered light.

However, it has been intimated above that the quantity of light falling where it is wanted is not the only thing which determines whether one can see well. The proper diffusion of the light, the illumination of the surroundings, and the protection of the eye from excessive brightness are all of great importance, and in these respects a direct-lighting fixture is more likely than the other types to be faulty. Hence, it often happens that a poor direct-lighting equipment can be replaced by an indirect or semi-indirect one, giving a better illumination with no greater consumption of power.

Shallow reflectors not deep enough to cover the filament or mantle should be avoided. If they are used at all it should be only on lamps which are hung very high, and even on such lamps a deeper reflector usually gives a more effective distribution. The plain etched glass shades, which are commonly furnished on fix-

79685°—21——6

tures and through which the source of light can be plainly seen, are practically useless. They absorb more light than a good reflector and do no good in return, unless it be that they look somewhat better than the bare lamp. Ground glass, which shows the location of the lamp inside it by a bright spot, is one step better, but is by no means good.

Almost all electric fixtures except those made in recent years carry the lamps at an angle of 45°. In these fixtures, frosted lamps should be used. It is very difficult to use reflectors effectively or to screen the lamps from the eyes of persons who have to look toward the fixtures. Modern fixtures carry the lamps vertically, and old ones can often be much improved by being made to do so. Sometimes this can be accomplished without damage to the fixture by merely bending the tubes.

Many fixtures are equipped with shades, globes, or domes of colored glass or silk; these are almost always very inefficient in furnishing illumination, for whenever light is reflected from or transmitted through a colored material much more of the light is absorbed than would be absorbed in a similar material uncolored. The loss by absorption is especially large in the common type of colored shade which is little larger than the lamp bulb, and stops practically all the light except that given out by the lamp in the direction of its tip, which is the direction in which the lamp gives least light. Colored globes should not, however, be too hastily condemned, for they usually have the virtue of concealing the flame, mantle, or lamp filament very effectively, and hence are far better than clear glass or no shades at all. Furthermore, their decorative possibilities are almost unlimited.

It is possible to combine to some extent the efficiency of a white reflector with the advantage of a colored shade, as is done in some reflectors which are white inside and colored outside. So also a silk-shaded lamp may often be improved by mounting a glass reflector inside the shade so that it throws a large part of the light downward where it is useful, at the same time letting through enough light to illuminate the shade. The same arrangement is very effective in the domes which are so commonly hung over dining tables. The addition of a reflector in this way to a dome or reading lamp will often make it possible to use fewer or smaller lamps, so as to reduce the current used by one-half without reducing the useful light at all.

Dining-room domes are so often faulty that a word regarding them may be worth while. They should be hung high enough so that one's view of persons across the table is not obstructed, but should not be so high that the direct light of the lamp can fall in the faces of those seated at the table, as often happens. If a dome is so shallow that these two conditions can not be fulfilled, or if one has to make the best of a poor fixture already in place, the difficulty can often be satisfactorily met by hanging around the bottom of the dome a band of some material, which will harmonize with the glass and will screen off the direct rays of the lamp.

In conclusion of this subject it may be said that individuals differ considerably in the amount of light required, and tastes differ radically with regard to types and arrangements of lighting devices, but the general principle which applies to all cases and which should never be forgotten is that light is to be thrown on the things one wants to see and not into the eyes. Whether one uses candles, kerosene, acetylene, gas, or electric lamps no arrangement which lets the light shine directly into the eyes can be good for the eyes, satisfactory for seeing, or attractive in appearance. Hygiene, economy, and artistic taste agree in the demand that the unshaded lamp shall be banished.

V. ELECTRICITY

1. Electrical Units

The gas supplied to a house is consumed, and the products of combustion escape into the atmosphere. Electricity, however, is not consumed, but merely flows through the lamps or other appliances and passes back to the electric generator. The thing that is supplied by the electric company is the *energy* which the moving electricity possesses, and which it will give up in the form of light, heat, or power when it is allowed to flow through a lamp, a heating device, or a motor. A simple illustration will make this clear. Suppose a pump located in a central water-supply station to be operated so as to circulate water through pipes laid in the streets from which service pipes are run into buildings where power is needed. Assume that after the water has operated a water motor it is not allowed to run into the sewer, but is taken back through return pipes to the pump, which sends it out again. In other words, the same water is circulated continuously, and gives up its energy by passing through a motor which can perform work. The customer of such a company would not be supplied with the water itself, but with the energy (ability to do work) which the water possesses. This energy can not be measured simply by measuring the number of gallons which have passed through the customer's motor in a given time, because the energy depends also on the difference of pressure between the inlet and outlet of the motor. If the pressure varied from time to time, a correct "water-energy meter" would have to be so constructed as to take account of the rate of flow at each moment (in gallons per second), and also of the difference of pressure in pounds per square inch. If the pressure could be kept practically steady at all times, an ordinary water meter as now used would be sufficient, but its dials would have to be marked to read the energy of the water, not the quantity.

The case just described is very similar to the supply of electrical energy, and with the water illustration in mind, a table can be drawn up which will give an idea of the meaning of some of the commonly used electrical units.

	Water	Electricity
Quantity is measured in	Gallons	Coulombs.*
Rate of flow is measured in	Gallons per second	Amperes.
Pressure is measured in	Pounds per square inch.	Volts.
Rate of doing work (power) is measured in	Horsepower	Watts.
Energy is measured in	Horsepower-hours	Watthours.

*The coulomb is not used in commercial work; it is included in this table for completeness. The word "ampere" is a single term, which means "coulomb per second."

The units in which electrical energy is measured commercially are the watthour [10] and kilowatthour; the latter means simply 1000 watthours. For example, the same amount of electrical energy may be spoken of as 56 000 watthours, or as 56 kilowatthours. To illustrate the approximate size of these units, it may be stated that a 40-watt tungsten lamp will use 40 watthours of electrical energy per hour, or 1000 watthours (equal to 1 kilowatthour) in 25 hours. A 6-pound electric laundry iron, rated at 500 watts, will use a kilowatthour in about 2 hours, if connected to the circuit during the whole of this time.

2. Principle of the Watthour Meter

Electrical energy is measured (in this country) almost entirely by watthour meters.[11] A watthour meter is essentially a tiny electric motor driving a registering dial. The electric current used in the house flows through the motor. If only a single lamp is in use, the current is very small, and the motor revolves very slowly. If a larger number of lamps are turned on, the current is greater, and the motor will revolve more rapidly. An action similar to this is familiar to everyone who rides on electric cars. When the motorman leaves the controller handle on the first notch, only a small current is allowed to flow, and the motors move the car very slowly. When the controller handle is on the

[10] The energy required to lift a weight of 2650 pounds 1 foot from the ground is approximately a watthour. The work done by a fully loaded 1-horsepower motor in an hour is 746 watthours and the electric energy supplied to run it is about 1 kilowatthour or 1000 watthours (the difference being lost in heating).

[11] These meters have in the past been called wattmeters, recording wattmeters, or integrating wattmeters. These terms are going out of use.

second and higher notches, the current is greater and the motion more rapid. Another illustration is that of the electric fan, with a lever to vary its speed by varying the amount of current which flows through the motor.

3. Accuracy of the Watthour Meter

Generally speaking, the electric meter is a commercially accurate measuring device. It requires cleaning at certain intervals, just as a watch does, and like the watch, if neglected it usually tends to run slow. Under some circumstances a meter may be fast; that is, it may record in excess of the actual energy that has passed through it. Properly managed electric light companies do not want their meters to run either fast or slow, and they have a force of men whose work consists of testing, cleaning, and readjusting meters.

4. Causes of High Bills for Electricity

When the bill for electric current seems unduly high, the meter is often the first thing suspected. In reality it is usually the last thing to blame. Some of the reasons for higher bills are as follows:

1. Cloudy or rainy weather, requiring use of light in daylight hours.

2. Additional lamps may have been installed, or small lamps may have been replaced by larger ones.

3. Old dim lamps may be in use; in order to get sufficient illumination more of them must be lighted than would be necessary if lamps in good condition were used. A dim lamp takes practically as much current as a new one, and is a very wasteful thing to use. With lamps in good condition, the light will not be efficiently produced if the electric company allows the voltage to be low.

In this connection it may be well to state that the tungsten lamp has been improved in quality and reduced in price to such an extent that no customer can afford to use carbon lamps, even if he were paid a bonus on each lamp for so doing. Many householders cling to the use of carbon lamps because they are usually supplied free. The folly of this course may be realized from the following statement: The cost of a lamp is reckoned in cents, but the cost of the energy to operate it during its life is a matter of dollars. The energy cost for a tungsten lamp is only about one-third that of the carbon lamp.

4. Lamps are sometimes left burning for days in attics, closets, and other out of the way places.

5. Electric laundry irons, toasters, or other heating devices may have been placed in service or used more than in former months. Motor-driven devices may have been installed.

Many devices which are operated through flexible cord from a lamp socket take very much more power than any lamp which would be used in the household. It is often erroneously believed that because such devices can be operated from a socket they require no more power than a lamp. The extent of this error may be realized from the statement that a 6-pound laundry iron takes as much power as 20 tungsten lamps of about 20 candlepower each.

6. Defective wiring may allow current to flow when no lights or other devices are in use.

7. Where electric elevators or electrically driven machinery is used and not properly oiled and cared for, excessive friction may result, with a corresponding waste of power and increase in the bill for electric current.

8. An error may be made by the company's meter reader, so that the bill rendered is too high or too low. If it is too high, the bill for the following month will be low by the same amount, if the meter is then read correctly, so that the consumer will not usually lose anything in the long run. When a minimum monthly charge is made by the company, the consumer may lose in the long run. Hence, if an error has apparently been made by the meter reader, the company should be requested to investigate the matter and to render a corrected bill if an error is found.

5. Reading the Watthour Meter Dials

A view of the dials of a modern[12] electric meter is given in Fig. 32. The method of reading is similar to that of reading the dials of a gas meter as explained on page 94. The reading in Fig. 32 is 538 kilowatthours. In taking down these figures one should read the dials from right to left; that is, in the reverse of the usual

[12] There are older types of meters in service which have five dials, the one farthest to the right having 10 divisions, each equal to one-tenth of a kilowatthour, instead of 1 kilowatthour per division as in the standard dial herein described.

order of writing numbers. The pointer on the dial at the extreme right points to 8; the number 8 is written down as the figure in the units place. The index of the next dial to the left has passed the 3, but has not reached the 4, as shown by the fact that the units dial reads 8; the figure 3 is accordingly written in the tens

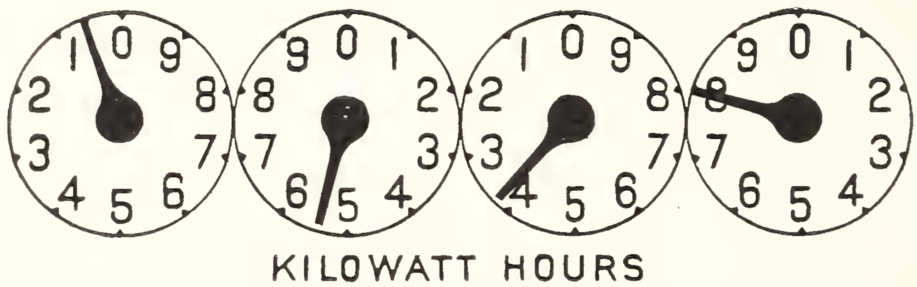


FIG. 32.—*Dial of a watthour meter*

In this dial the hands are correctly set on their shafts. The reading is 538 kilowatthours.

place. The index of the third dial has passed the 5, and this figure is to be written in the hundreds' place, giving 538 kilowatthours as the reading of the meter, since the index of the dial at the extreme left has not reached the figure 1.

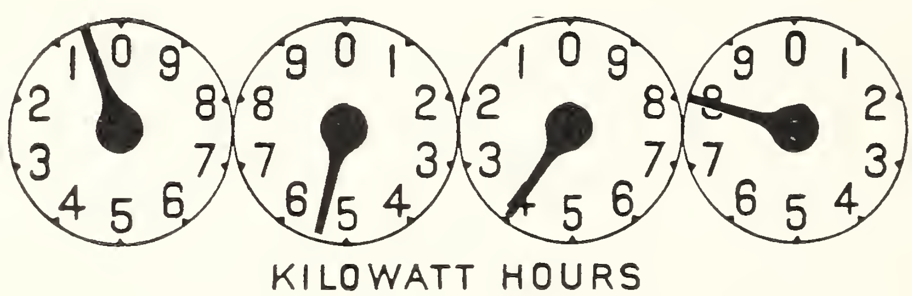


FIG. 33.—*Dial of a watthour meter*

In this dial the hand on the second circle from the right is slightly in advance of its proper position on its shaft. The reading is the same as in Fig. 32, namely, 538 kilowatthours, although at a glance it might be incorrectly read as 548 kilowatthours.

If the index hand of the second dial in Fig. 32 be turned slightly so as to point to (or even slightly past) the figure 4, it becomes more difficult to read the meter correctly, as a hasty inspection may result in the reading being made as 548 kilowatthours. However, the fact that the index of the units dial stands on the figure 8 shows that it has not quite completed a revolution, and hence that the index of the second dial (if it is properly set on its shaft) should be close to a division and about to reach it. Hence, it should be read as having passed the 3 and not having reached the 4. A view of a meter dial face having the second index to the left slightly displaced in this way is shown in Fig. 33.

When one dial hand points to 9, special care must be taken that the dial hand of the next higher dial is not read too high, as it may appear to have reached the next number, but will not have done so until the dial hand at 9 has come to 0. A simple illustration will make this matter clear. If the hour hand of a clock points to 10, as closely as can be read, and if the clock had no minute hand, the time would be read as 10 o'clock. If the minute hand, however, is pointing to the figure 11, the time is read as 9.55. Ten minutes later the hour hand may not have moved perceptibly, but the time is now read as 10.05. Similarly, in the electric meter, the reading of each dial must be interpreted by noting the reading of the next dial to the right.[13]

The dial hands on adjacent dials revolve in opposite directions, therefore a reading should always be checked after being written down, as it is easy to mistake the direction of rotation.

There are electric meters in use having marked on the dial "Multiply by ½" or "Multiply by 2," etc. In such cases the dials are to be read as usual, and the difference between the present reading and the reading of the previous month is to be multiplied as directed on the dial. This is an awkward arrangement which was adopted by the makers of early meters to avoid having to make slight variations in the gearing of the dials to suit different capacities of meters. Modern meters of small to moderate capacity read directly in kilowatthours; those of larger capacity use multipliers of 10, 100, 1000, etc., as required, and are of larger capacity than is needed in dwellings.

6. Checking the Watthour Meter by the Householder

The electric meter may be approximately checked by the householder without the use of electrical instruments. For this

[13] Experienced meter readers are able to read the dials from left to right almost at a glance, and with a very small liability of error. The method above described, however, is the best one to use, if one is not reading meters constantly.

purpose it is only necessary to note the reading of the meter, then turn on a number of lamps and note the time in hours required to cause the index of the dial farthest to the right to advance one division. It is necessary to use lamps which are rated in watts, as is done with most incandescent lamps now made. If the meter is a modern one, it will have a dial marked "kilowatthours," and one division on the dial farthest to the right is a kilowatthour, which means 1000 watthours. For example, if 10 lamps, each marked 25 watts, are lighted at a given time, the rate of using electrical energy is $10 \times 25 = 250$ watts. In 4 hours these lamps will use $4 \times 250 = 1000$ watthours, and this should cause the index of the dial farthest to the right to advance one division. As it is not possible to read a single division accurately, the lamps may be allowed to run until the index has moved over several divisions. If more lamps can be turned on, or larger lamps used, the time required for the test will be reduced.

The preceding test is an approximate one, but will settle the question of whether any large error exists in the meter. To make an accurate test requires portable watthour meters or other electrical apparatus which is suitable for use only by meter inspectors.

It is desirable for the householder to read the meter at the time it is read by the meter man, and to keep a record of the readings and the dates, in order to have the means of checking the bill rendered by the company. Many up-to-date electric light companies have meters on display in their public offices, and will explain the method of reading to customers who call and ask for this information.

On request of any customer, many companies instruct their meter readers to leave a card showing the position of the hands on the meter dials and the corresponding meter reading. This is done each time the meter is read.

7. How to Have a Watthour Meter Tested

Any user of electricity can usually have his watthour meter tested by making application at the office of the electric company. It is advisable to make such a request either by letter or by personal application at the office of the company, and not by asking the meter reader or bill collector.

Most electric light companies are much interested in keeping their meters accurate, and will usually make a test upon any meter in use by a customer upon his complaint and request, if not made too frequently. Well-managed companies to-day make it a practice to test all their meters at regular intervals, and in addition will make special tests, when circumstances warrant them, without charge, upon request of their customers.

In a number of cities customers of electric light companies may have watthour meters tested by making application to the city inspector of meters, and paying a small fee. Usually this fee will be refunded to the customer if the meter is found incorrect (in excess of the legal tolerance) to the prejudice of the customer, and will be collected from the company by the inspector. However, if the meter is found correct, or in error in favor of the customer—that is, is found to register "slow"—this fee must be paid by the customer.

In the cities of Charleston, S. C., Chicago, Cincinnati, Kansas City, Mo., Louisville, Memphis, Minneapolis, Norfolk, San Francisco, Sioux City, Iowa, and Topeka, Kans., and a few others, customers of electric companies may have meters tested upon application to the city meter inspector.

In the States of Arizona Connecticut, Illinois, Indiana, Massachusetts, Montana, Nevada, New Hampshire, New Jersey, New York, Oregon, Pennsylvania, Washington, West Virginia, Wisconsin, and the District of Columbia, the testing of meters is supervised by State commissions, known as Public Service, Public Utility, or Railroad Commissions, the name differing in the various States. Most of these commissions have published certain rules and regulations covering various meter tests and other matters with reference to electricity, gas, and water service, and all persons interested can get copies of such rules on written application to the Public Service Commission at the State capital.

The commission's meter inspectors in any State mentioned will make tests upon watthour meters upon the written application of any resident of the State, and the payment of a fee. All customers of gas and electric companies should get the service rules issued by their State Public Service Commission. In many other States Public Service Commissions have power to make tests, but have not yet organized their work.

8. Tolerance Allowed for Watthour Meters

No measuring device can be made which is absolutely accurate. The amount by which it may deviate from strict accuracy and still be considered "commercially correct" is called the tolerance. The usual tolerance for watthour meters is 4 per cent; that is, a meter which registers 96 to 104 per cent of the energy passed through it is considered correct. This does not mean that a meter 4 per cent in error would be left in that condition, as the practice of well-managed meter departments is to have their meter testers adjust meters found fast or slow until they are within 1 per cent either way.

VI. GAS

The gas used in the household is usually measured on the premises by a gas meter. In the United States and parts of Europe, the so-called dry gas meter is most commonly used for this purpose.

There are a number of different types of dry gas meters in use, which, while differing considerably in external appearance and design of parts, operate on the same general principles. These general principles of operation would be understood from a description of any one of the types and therefore only one of the most commonly used will be described.

1. Description of a Gas Meter

The external appearance of the meter (see Fig. 34) is well known. The interior is shown in Fig. 35, with the front and top of the meter and the top of the valve chamber removed. Essentially the meter consists of four chambers, which are filled and emptied of gas by the action of the meter mechanism. The number of times this filling and emptying of the measuring chambers is repeated is indicated on the dial in cubic feet. Two of the measuring chambers are shown in the figure. One is the space between the disk (201) with attached leather diaphragm (203) and the middle partition (the plate just behind the diaphragm) of the meter. The other is the space between this same disk and diaphragm and the outside walls of the meter. The other two measuring chambers are like the two described, and are situated symmetrically to them on the opposite side of the middle partition. The filling and emptying of the measuring chambers is effected by the backward and forward movement of the disks. These disks operate in conjunction with the valves and recording mechanism (see Fig. 35) above the measuring chambers. Each set of two measuring chambers thus constitutes a kind of double-acting bellows, the number of times these are filled and emptied being a measure of the amount of gas passed through them. The power for operating this very simple and effective instrument is

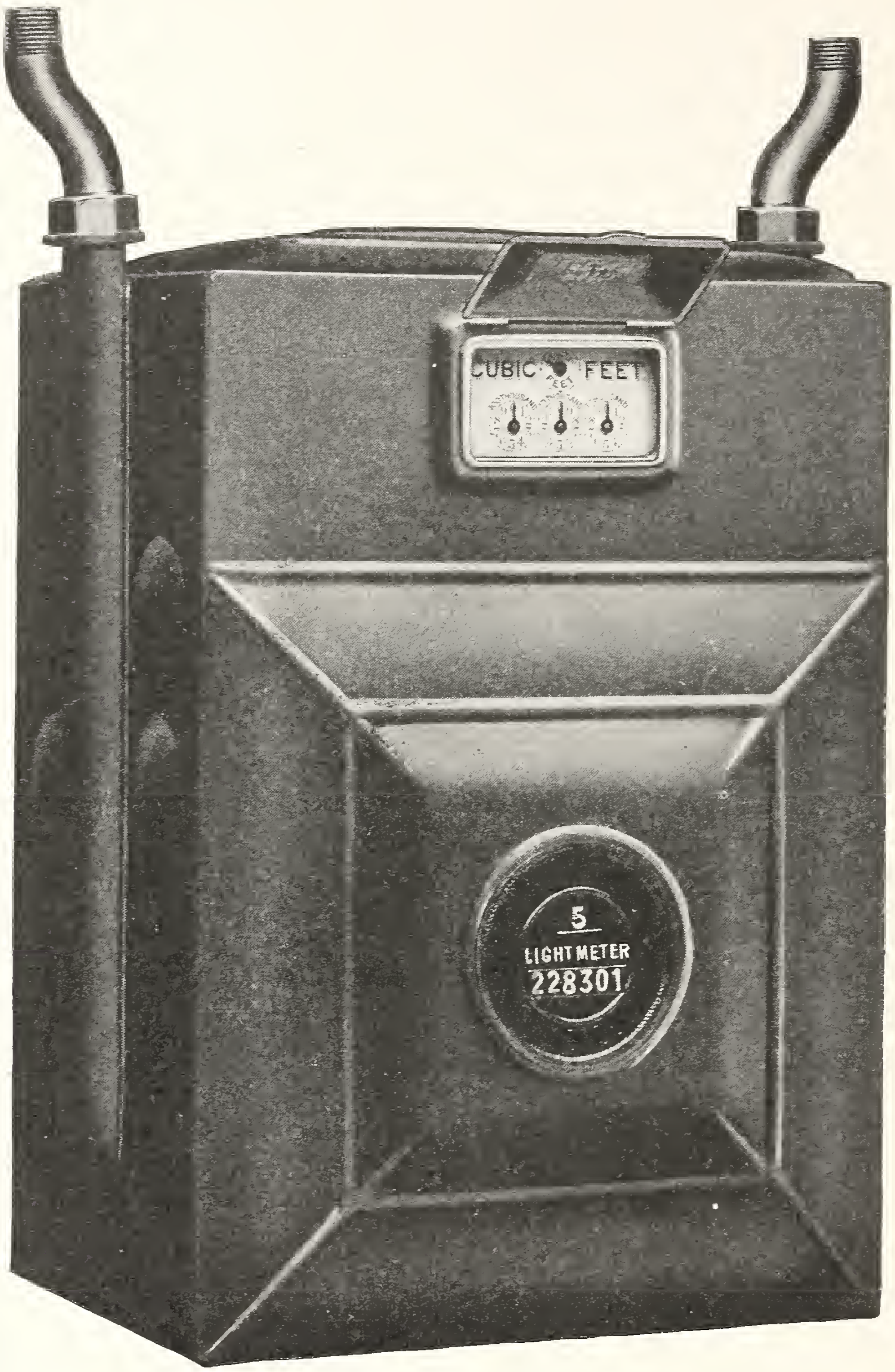


FIG. 34.—*Exterior of dry gas meter*

There are a number of different types of dry gas meters in use, which, while differing considerably in external appearance and design of parts, operate on the same general principles. The above figure illustrates the exterior appearance of one of the so-called "tin gas meters" which are extensively used in this country.

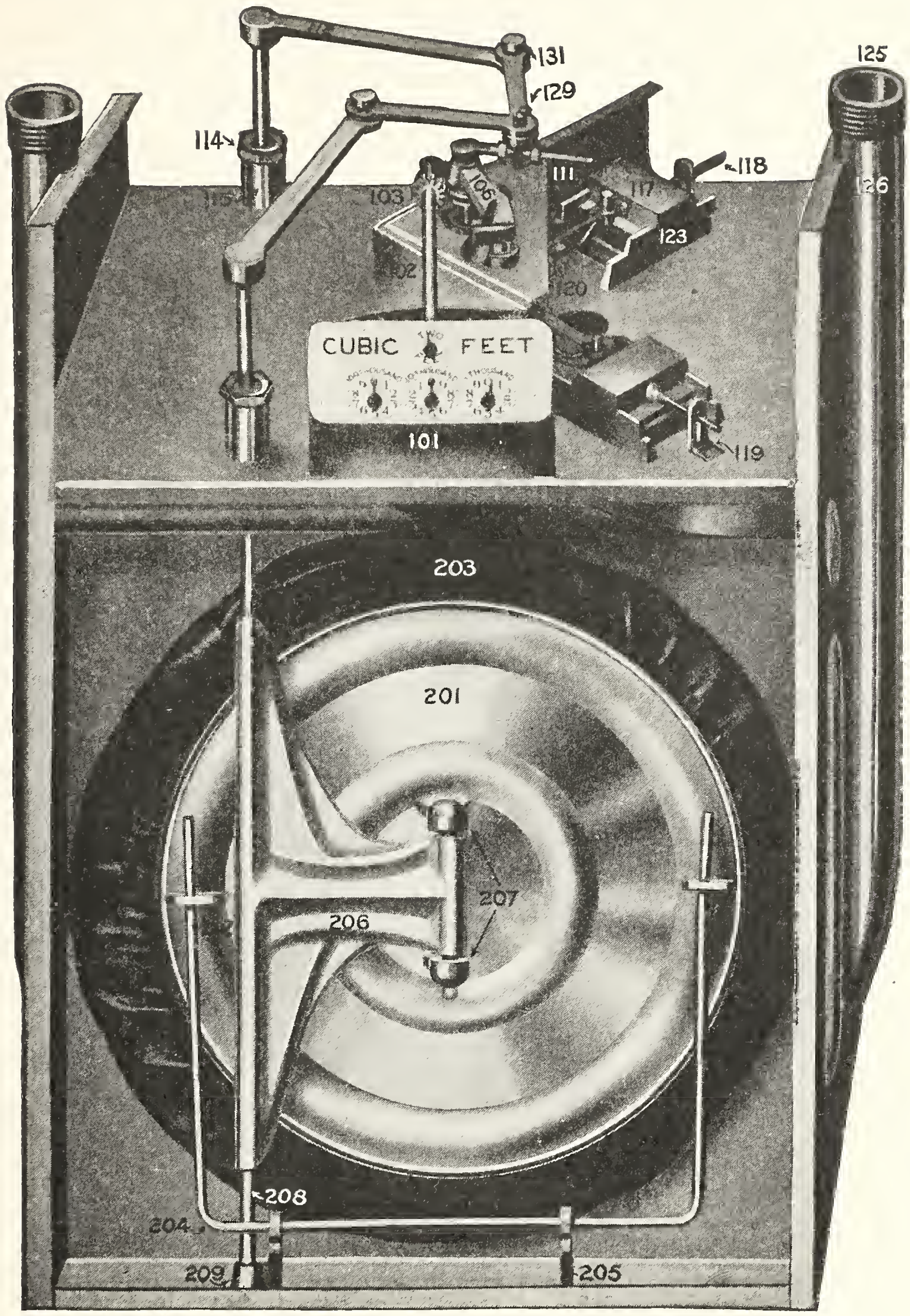


FIG. 35.—*Interior of dry gas meter*

The meter, the external appearance of which is shown in Fig. 34, would appear as above if the front, top, and top of valve chamber had been removed. Essentially the meter consists of four chambers which are filled and emptied of gas by the action of the meter mechanism. The number of times this filling and emptying of the measuring chambers is repeated is indicated on the dial in cubic feet.

furnished by the pressure of the gas itself which acts upon the disks, pushing them back and forth just as the power to operate the steam engine is furnished by the steam which presses upon the sides of the piston. The index (101) upon which the volume of gas passed is recorded, is connected to the other mechanism by means of the shaft (102) and gear wheel (103).

2. The Gas Meter Index and How to Read It

Fig. 36 illustrates the index of an ordinary gas meter which is similar to that of an electric meter or a water meter. The smaller top dial, which is marked "Two feet" inside of the circle, is generally called the "testing circle" or "proving head," and is used

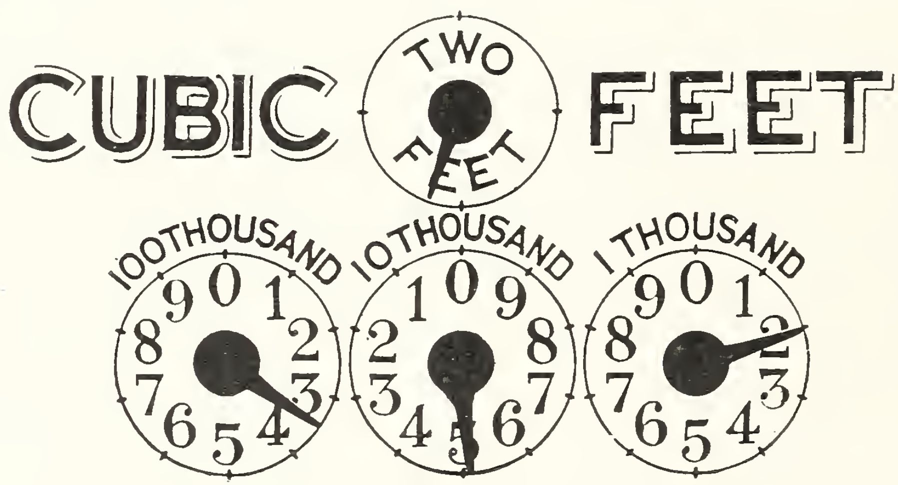


Fig. 36.—*The index of a gas meter*

Each dial is marked with the volume of gas passed per revolution. The smaller top dial, which is marked "Two Feet" inside of the circle, is generally called the "testing circle" or "proving head" and is used principally in testing the meter.

principally in testing the meter. One revolution of the hand of the testing circle indicates that 2 cubic feet of gas have passed through the meter. In some meters one revolution of the hand of the testing circle represents more or less than 2 cubic feet of gas and the testing circles are correspondingly marked. The indication of the hand of the testing circle is ignored in the ordinary reading of the meter.

Of the large dials the first one at the right is usually marked "1 thousand." This means that during one complete *revolution* of the hand 1000 cubic feet of gas has passed through the meter. This dial is divided into 10 equal parts so that the passage of the hand over each part indicates the passage of one-tenth of 1000 cubic feet, or 100 cubic feet. For most meters, it may be said of the other dials that the complete revolution of each hand indicates the passage of 10 times as much gas as one revolution of the hand of the dial of next lower denomination (usually the one to the right). The figure representing the number of cubic feet discharged during one revolution of the hand is written over each dial. Thus if the first dial is marked "1 thousand," the second dial will be marked "10 thousand," the third "100 thousand," and so on.

The reading of the index, as illustrated in Fig. 36 is as follows:

Reading of "1 thousand" dial....................	200	cubic feet
Reading of "10 thousand" dial....................	5 000	" "
Reading of "100 thousand" dial....................	30 000	" "
Complete reading of the meter................	35 200	" "

It is not necessary to write down separately the reading of each dial, but it is much shorter to set down from *right* to *left* the figure

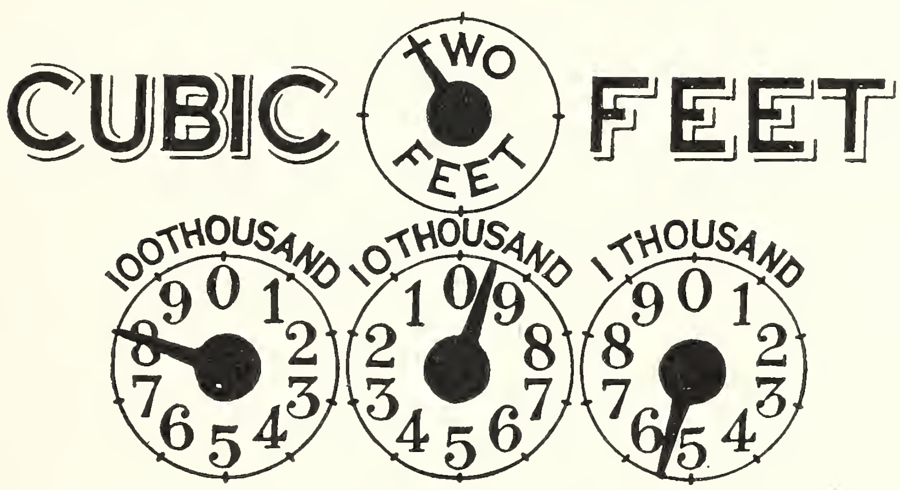


FIG. 37.—*Gas-meter index reading 79 500 cubic feet*

last passed by the hand of each dial, commencing with the dial of lowest denomination and then—if the dial of lowest denomination is marked "1 thousand"—appending two zeros to the resulting figures. To illustrate further the method of reading meters, illustrations of several settings of a meter index are given with the correct readings in Figs. 37 to 40, inclusive.

If a hand is very nearly over one of the figures on a dial, it is impossible to tell without consulting the dial of next lower denomination whether the figure under the hand or that just previously passed by the hand should be read. For example, in Fig. 37 the hand of the "100 thousand" dial is over 8, and considering this dial alone the reading might be taken as 8; but it is seen that the reading of the "100 thousand" dial can not have

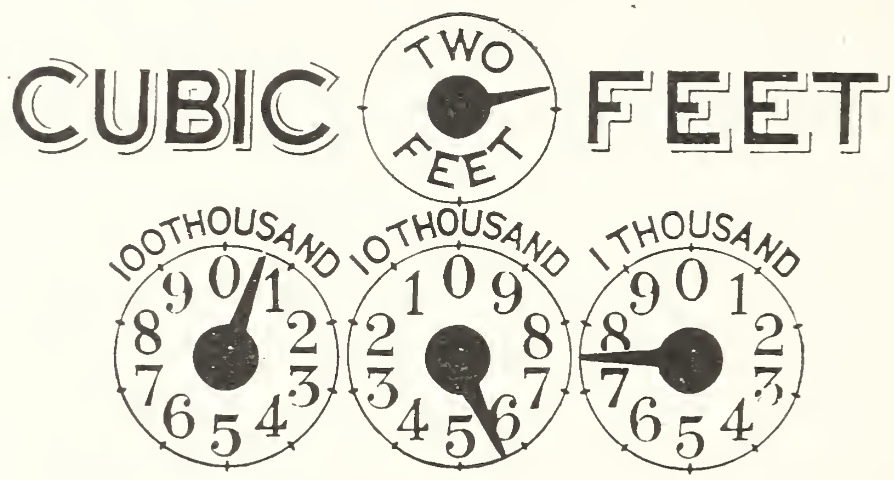


FIG. 38.—*Gas-meter index reading 5700 cubic feet*

reached 8, since the hand of the dial to the right (the "10 thousand" dial) has not reached zero. The reading of the "100 thousand" dial is therefore 7, and the correct reading of the entire index is 79 500 cubic feet.

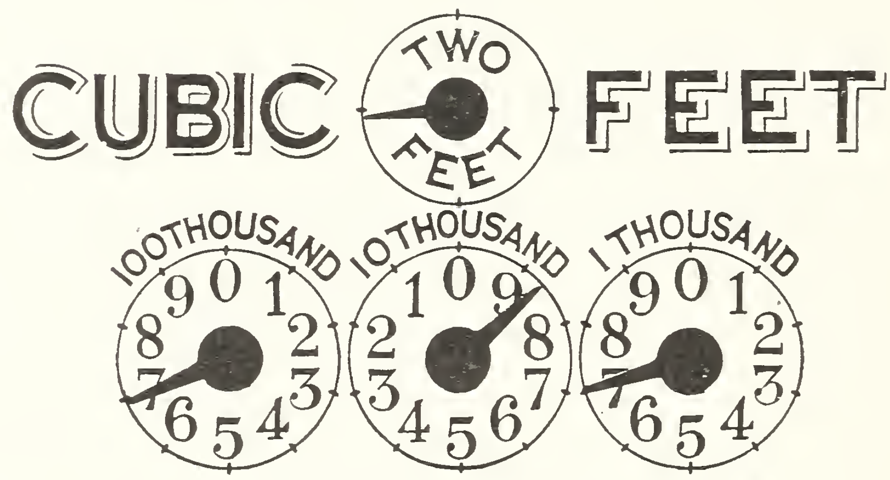


FIG. 39.—*Gas-meter index reading 68 700 cubic feet*

3. Cost of Gas Consumed per Hour in Appliances

With only a little trouble one can determine the cost per hour of operating a gas light, heater, or other gas-consuming appliance. To do this, have in operation the appliance in question and have all other gas appliances supplied through this meter shut off. Then, by observing the "testing circle" of the meter, determine the time in seconds required for 1, 2, or more cubic feet of gas to pass. The number of cubic feet of gas used per hour is then determined in the following manner: (1) Divide the number of cubic feet burned during the test by the number of seconds, thus determining the number of cubic feet of gas used per second, and (2) multiply the result by 3600 (the number of seconds in an hour).

Example.—It is observed that with a gas water heater in operation the meter indicates the passage of 2 cubic feet of gas in 1 minute and 40 seconds. Applying the above rule, 2 (cubic feet) is divided by 100 (seconds) (the equivalent of 1 minute and 40 seconds), which gives $\frac{2}{100}$; $\frac{2}{100}$ is multiplied by 3600, giving $\frac{7200}{100}$, or 72. The water heater is therefore using 72 cubic feet of gas per hour.

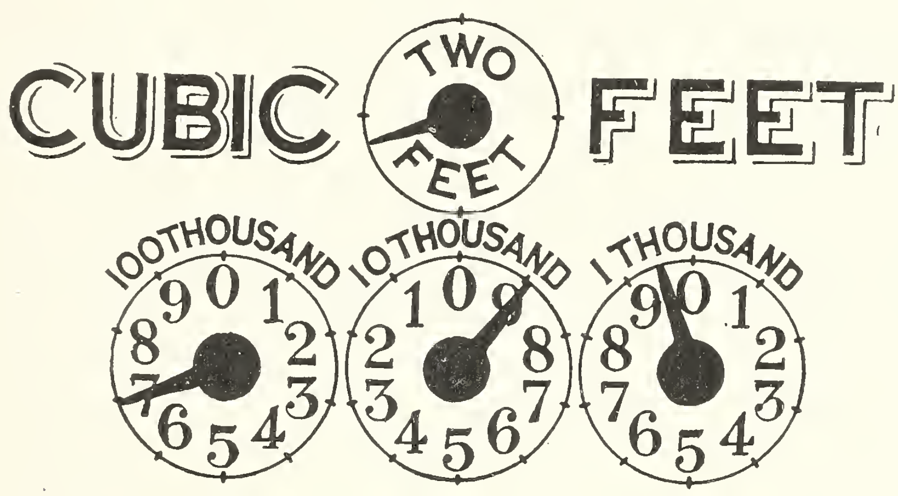


FIG. 40.—*Gas-meter index reading 68 900 cubic feet*

Knowing the cost of gas per 1000 cubic feet, one can easily calculate the cost per hour for gas used in the heater; for example, if gas were $1 per 1000 cubic feet, the 72 cubic feet would cost 72 times $\frac{1}{1000}$ of $1, or 7.2 cents, which is the cost per hour for gas.

Fig. 41 shows graphically the approximate average gross cost of operating various appliances utilizing gas for producing light.

4. Prepayment Meters

A special type of the gas meter, known as the prepayment gas meter, is extensively used in some places. These meters are so constructed that one can insert a coin and thereby receive a certain amount of gas; after this is used the meter will automatically cut off the supply of gas until another coin is inserted.

NUMERALS REFER TO COST PER HOUR IN MILLS (TENTHS OF A CENT).

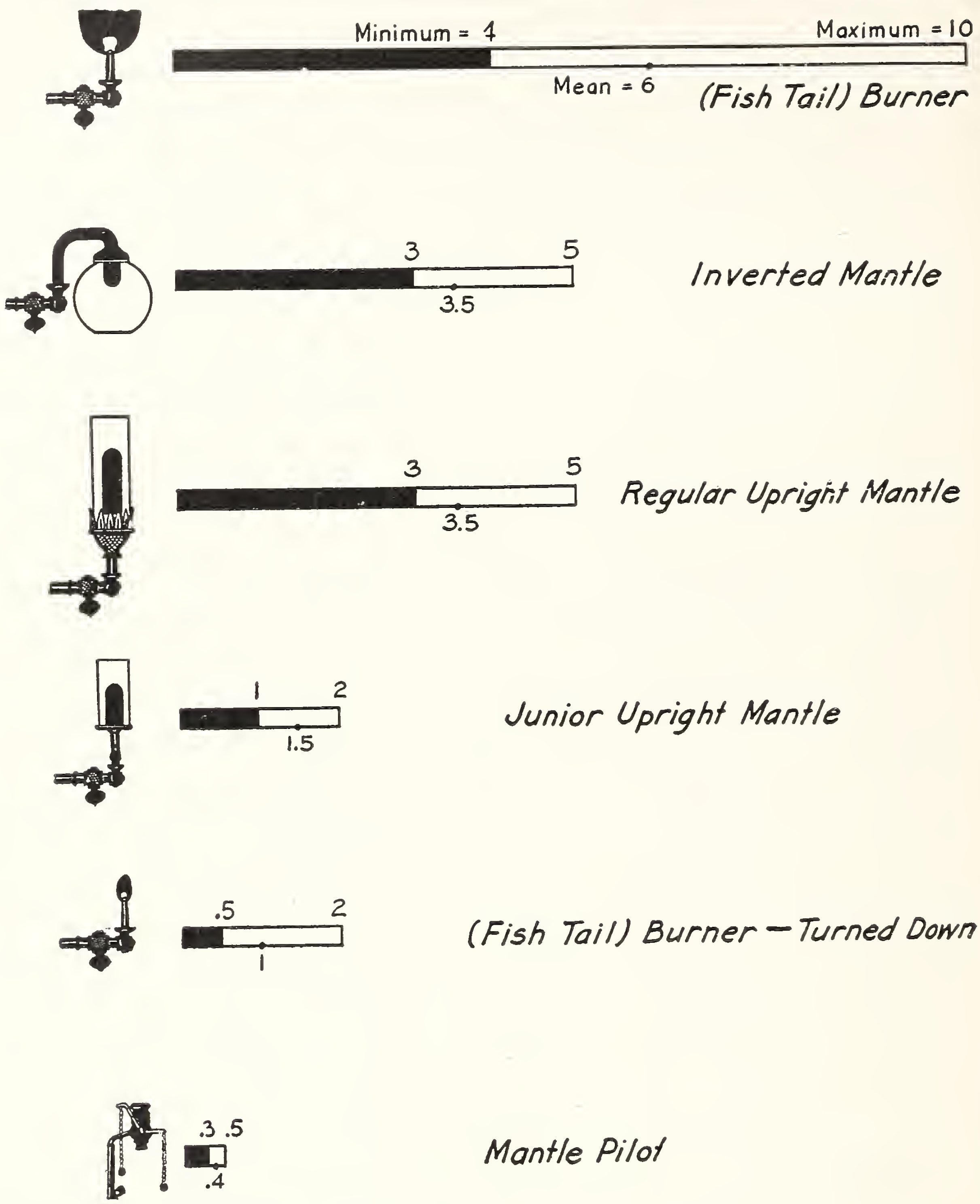


FIG. 41.—*Cost of gas used per hour in some common gas appliances*

The cost per hour is calculated on the basis of gas at $1 per 1000 cubic feet. The large difference between maximum and minimum costs is due to difference in size of burners and difference in the pressure of the gas supply. The mean value represents the cost under average conditions.

For a water heater of ordinary household size the gas would cost from 3 to 8 cents per hour. For larger automatic water heaters gas would cost from 10 to 25 cents per hour for the period that the heater is in operation. The pilot-flame gas for these heaters would amount to one-tenth of a cent per hour. Room heaters require 5 to 12 cents worth of gas per hour.

Since a match costs only one-tenth mill or less, it is usually economical to turn off the gas when not in use, except for short intervals.

Most prepayment meters are so constructed that when the gas paid for is nearly used the supply of gas will be gradually shut off, thus giving the consumer a chance to insert another coin before his supply of gas fails entirely. The sudden shutting off of the gas supply would be not only inconvenient, but dangerous, for if one should forget to turn off his burner when the meter shuts off the supply, the insertion of another coin into the meter would allow gas to escape into his apartments. Even when the meter does shut off the supply of gas gradually, cases arise (as when one leaves a light burning during his absence) in which the valves of appliances may be left open when the meter has shut off the supply. In such instances care must be taken that all gas outlets be closed before inserting another coin into the meter. The number of accidents which result from neglect of this precaution indicates its importance and shows that there is a considerable element of danger in the use of prepayment gas meters.

5. Errors of Gas Meters

When a meter registers more gas than is actually passed, it is said to be "fast," and the consumer's bill will therefore be too large. When a meter registers less gas than is actually passed, it is said to be "slow," and the bill will be too small.

Gas companies are allowed to have meters in operation which are fast or slow by not more than a definite small amount. This allowed variation from absolute accuracy is called a "tolerance" and usually varies from 1 per cent fast or slow to 3 per cent fast or slow. A tolerance is reasonable and necessary, since absolute accuracy is obviously unattainable in any type of measuring apparatus. If meters are as often slow as fast, neither producer nor consumer ultimately loses any large amount. A gas company will generally try to have its meters correct within 1 per cent when they are installed. It is probable that the great majority of the meters of a well-conducted company are in error by less than 2 per cent or 3 per cent. However, serious errors in gas meters do occasionally occur, especially in those districts without the services of a good inspection department, and it is well for the consumer to be aware of this possibility.

To satisfy one's self that the gas company does not make a mistake in reading the meter, it is well for the consumer, occasionally at least, to read his meter at as nearly as possible the same time that the gas company reads it. Usually the gas company's bill will state the meter readings on the dates between which the bill applies, so that checking meter readings will be easy. If the meter readings are not given on the bill, the consumer can determine what the amount of his bill should be if he knows the meter readings and the price of gas per thousand cubic feet. Should the consumer take one meter reading at the proper time and then miss the next one or two, it is obvious that he can still check up the gas bills by taking a reading at the next convenient time when the company's reader calls, calculating the cost of gas used between the dates of his readings and comparing this cost with the sum of the amounts of the bills rendered for gas between the same dates.

If a consumer's gas bill for a certain period greatly exceeds that of the previous period, it is due to one or more of the following causes:

(*a*) *An increased consumption of gas.*—A careful consideration of the use made of gas during the period covered by the bill will very often reveal the fact that an unusual amount of gas has been consumed. Baking, canning of fruit, entertaining, the coming of long winter evenings, etc., are a common cause of increased gas consumption resulting in larger bills than usual. Leaks in the gas pipes of the house may produce the same results.

(*b*) *An error of the gas company in reading the meter or in office work.*—If the consumer reads his own meter and checks the bill, the question as to whether this cause is operative can be quickly ascertained.

(*c*) *A fast meter.*—If causes (*a*) and (*b*) apparently do not exist, the consumer will naturally consider that his meter is fast.

The best procedure for the consumer who thinks that his meter is incorrect varies with the locality. Many of the larger cities are provided with meter-inspection departments, under the supervision of the city or State, and the consumer can have his meter tested by this department. If his meter is found to be fast in excess of the established tolerance, the company usually pays the fee for the test and refunds to the consumer a certain amount, depending upon the magnitude of the error of the meter and the probable length of time that the consumer has been thereby overcharged. If the meter is found to be within the tolerance, or "slow," the consumer usually pays the fee (about $1), and may have to pay the gas company for the probable amount he has been undercharged.

The fact that it is so difficult for a consumer to know when his meter registers correctly, since he can not check up the amount of gas delivered to him as he can check up the amount of groceries bought, makes it especially evident that every community of gas consumers should have a meter-inspection service available, where meters may be tested by or under the supervision of a public official.

VII. WATER

1. Measurement of Household Water Supply

Water, when not sold at a flat rate without direct measurement, is usually sold at so many cents per thousand gallons, and the quantity used by each consumer is measured by meter. The water meter is located in the supply line from the water main to the consumer's premises and is either placed indoors where the service enters the house or outside underground in front of the consumer's house in a box or manhole provided with a cover at the ground level for easy access. No water can reach the consumer except by passing through the meter, and all water passing through the meter is recorded whether it be used or wasted through leaks or otherwise.

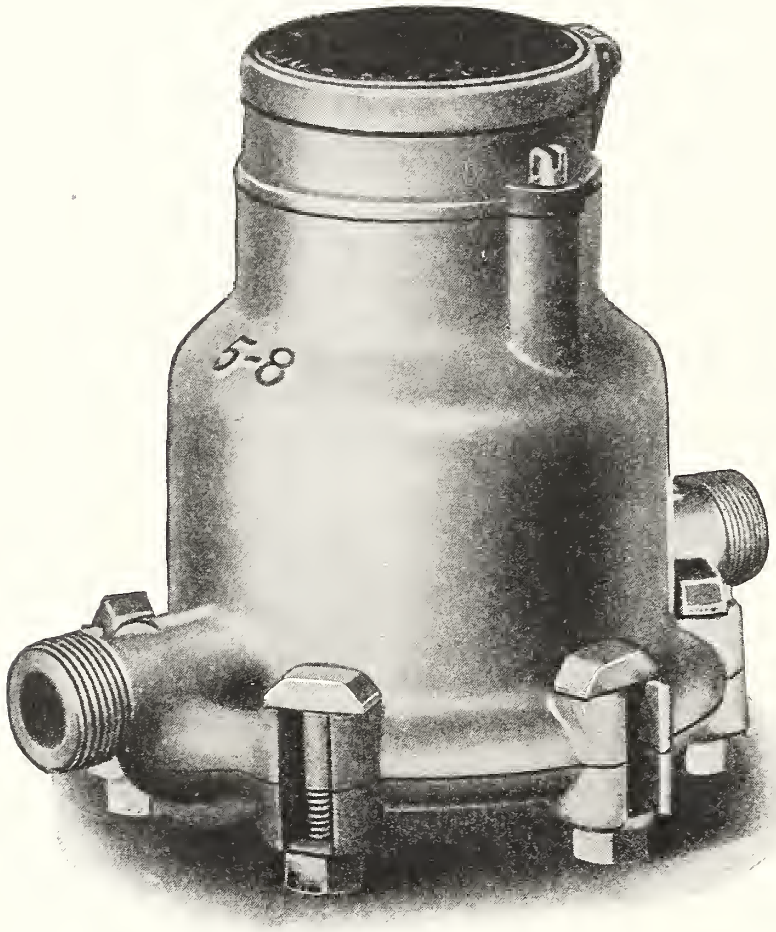


FIG. 42.—*Exterior view of a water meter*

2. Water Meters

The principle is very similar to that of gas meters, described above. An example of the commonest type of meter for measuring water for domestic use, the disk type, is illustrated in Fig. 42. Fig. 43 shows a water meter cut in two so as to show the working parts, and Fig. 44 shows the part of the meter which actually does the measuring, called the measuring chamber, separately, with the cover removed so as to show the disk in position and the circular chamber in which it moves.

The interior of the meter case (see Fig. 43) is divided into three compartments, one at the top, which the water can not reach, containing the register or mechanical counter, provided with a dial (see Figs. 45 and 46) facing upward, which is read from the top by lifting back the little cover at the top; one at the bottom, containing the moving piston; and one between the two containing some small gear wheels, whose only use is to reduce the motion of the piston in the lower chamber and communicate it to the counter above.

The left-hand threaded end is the inlet, and to it is screwed the pipe from the water main; the right-hand end is the outlet and leads to the consumer's service pipe. The course of the water through the meter is indicated by the arrow, entering at the left, passing upward through a screen intended to keep dirt and scale from the working parts, to the middle compartment, then downward around the measuring chamber and out at the right.

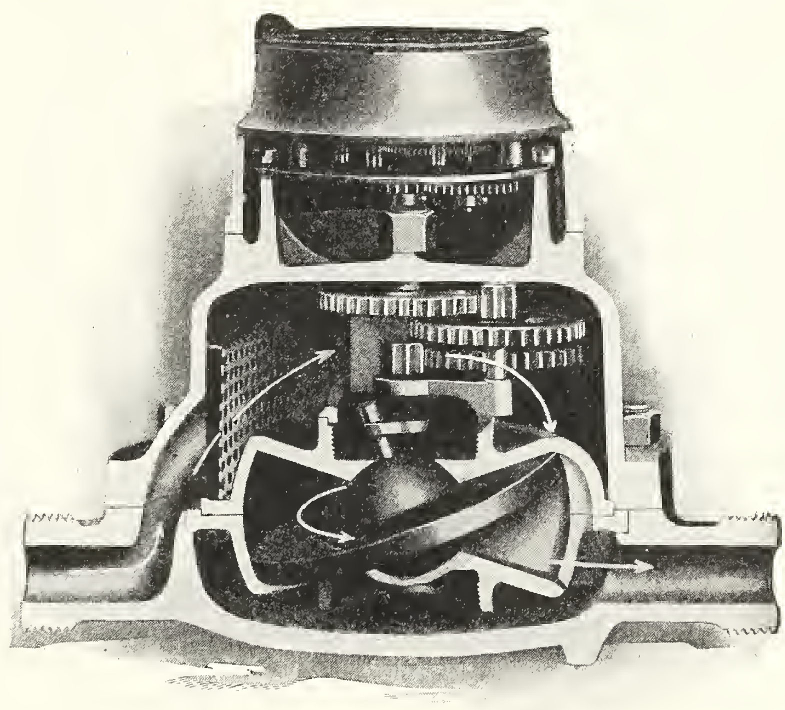


FIG. 43.—*Interior view of a water meter, showing working parts*

The way the meter operates is more clearly seen from Fig. 44. The disk of rubber composition is mounted on a ball working in sockets at the top and bottom of the chamber and just touches the sides of the chamber all the way round, dividing it into an upper and lower compartment. On one side is a thin partition extending halfway across and passing through a slot in the disk.

The disk does not rotate, but has a motion similar to that of a coin which has been spun on edge and is coming to rest, tilting around its edge.

In the position shown in Fig. 43 the water will enter from above, as shown by arrow at one side of the partition (shown at the right in Fig. 43), flow under the disk, tilting the back edge of the disk upward as it moves around and the opposite edge

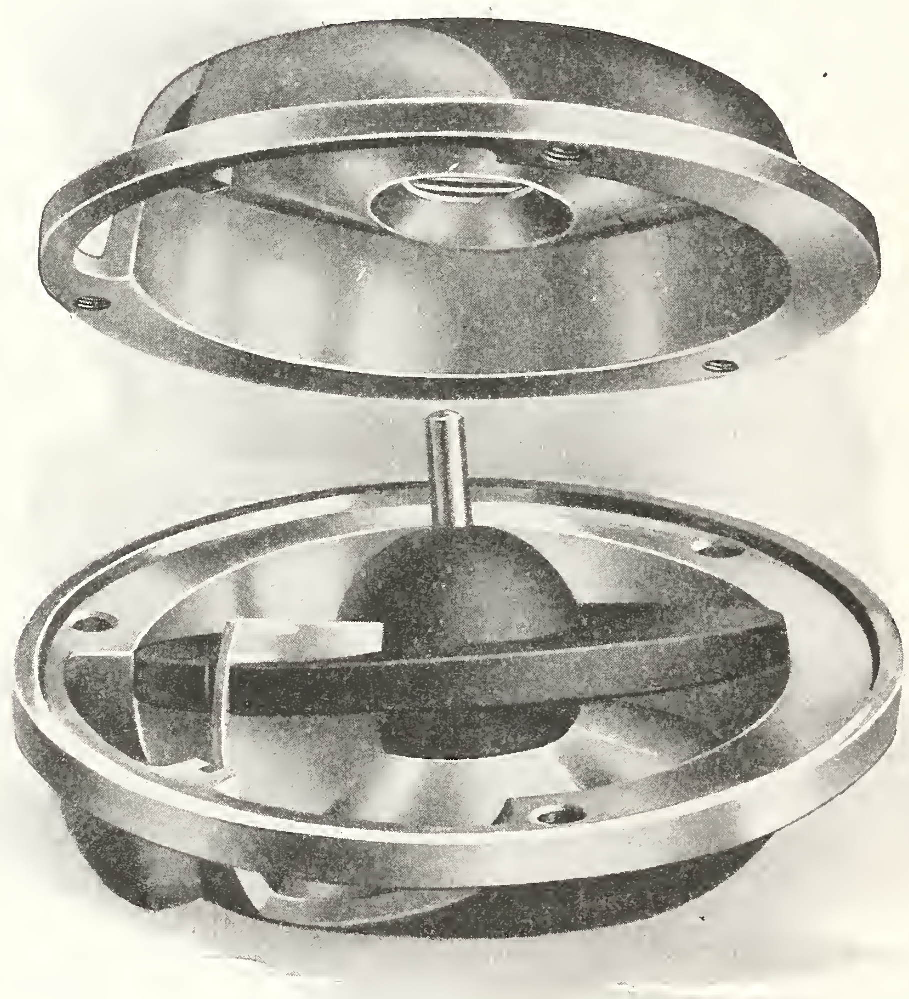


FIG. 44.—*Measuring chamber of a water meter*

downward, forcing water out through the lower opening at the rear side of the partition, as shown by the arrow. Water enters above the disk in a similar manner; while one compartment is filling another is emptying, making the flow continuous. The end of the spindle projecting upward from the disk is given a circular motion. In revolving it pushes around a little lever (Fig. 43) attached to the spindle of the gears in the middle compartment, which in turn moves the hands on the register dial. Each complete movement corresponds to filling the measuring chamber once. The number of times this is done is recorded by the dials. The process is analogous to measuring the water with a cup and automatically counting the cupfuls.

3. Accuracy of Water Meters

Water meters are commercially accurate instruments. Cases of meters which register correctly when installed and overregister after being in service are very rare. Any derangement of the meter from dirt entering the working parts or from other causes is likely to slow the meter down and cause it to underregister. There is a small amount of unavoidable leakage through the meter which causes it to underregister when very small quantities of water are passing.

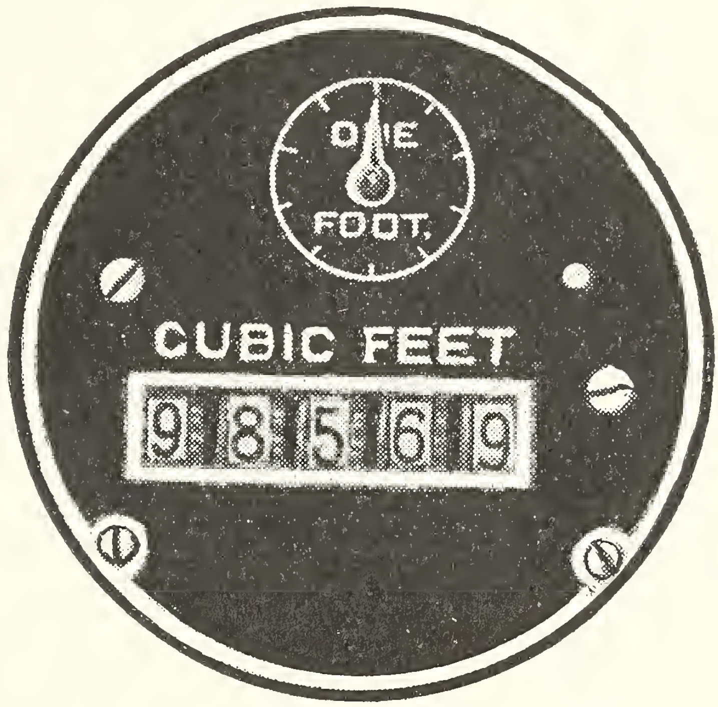


FIG. 45.—*Form of direct-reading water-meter dial*

Meters for measuring water for domestic use are usually graduated in cubic feet—sometimes in gallons. One cubic foot is taken commercially as equal to 7½ gallons. Hence, to reduce a meter reading in cubic feet to gallons, multiply the number of cubic feet by 7½.

4. Reading of Water Meters

The ordinary form of dial is shown in Fig. 46. In Fig. 45 is shown a special form of register which is more convenient to read. It is known as a straight-line register and gives cubic feet or gallons directly.

In Fig. 46 the unit is cubic feet and is plainly marked on the dial. If the unit were gallons, the method of reading would be the same.

The hands revolve around circles, each divided into 10 numbered divisions. The number on the outside of each circle indicates the number of cubic feet for one complete revolution of the hand. The divisions of the circles are numbered alternately in the counter clockwise and clockwise direction. Thus, the first dial (at the bottom) is marked 10 and one division measures 1 cubic foot, the second 100 and one division measures 10 cubic feet, the next is marked 1000 and one division measures 100 cubic feet, and similarly for the rest. The small dial at the left measuring 1 cubic foot for a complete revolution is disregarded in reading the meter, being used for test purposes. One division of a circle is equal to a complete revolution of the hand on the next lower circle. When a hand is between two figures the lesser is to be taken. If a hand is very near a figure, whether that figure or the next lower is to be taken can be determined by observing the hand in the next lower circle. Unless the hand on this circle has reached or just passed 0, the lesser figure is to be taken. The best method of reading is from low to high, that is from right to left. For example, reading the dial shown in Fig. 46 and setting down the figures successively from right to left, we have 7 for units place, 6 for tens place, 8 for hundreds place, and 1 for thousands place and for ten-thousands place, or 11 867 cubic feet.

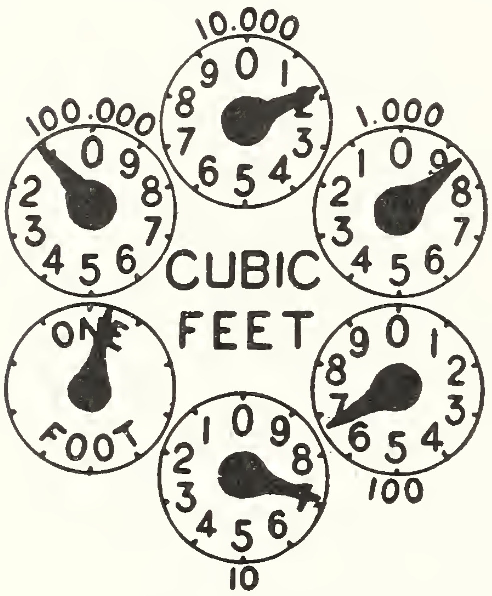


Fig. 46.—*Ordinary form of water-meter dial*

Reading 11 867 cubic feet.

The circles on different makes of dial may be differently located on the dial, but the method of reading is the same as given.

In meters larger than those ordinarily used for household measurement the lowest graduated circle, the one marked 10, corresponding to units place in the reading, is sometimes omitted, the lowest circle being then the one marked 100. In this case the meter is read exactly as described above, and a zero added in the units place.

The dial after reading can not be set back to zero. The record is continuous. The amount of water which has passed through the meter in a given time is therefore obtained by subtracting the first reading from the last. For example, if the meter were read the 30th day of June and again the 30th day of July, the June reading is to be subtracted from that taken in July.

5. Using the Water Meter as a Measuring Appliance

The amount of water required for a particular use—for example, in watering a lawn—may be determined by first turning off all other outlets and allowing the hose to run, say, half an hour, reading the meter at the beginning and end of the period and subtracting the first reading from the second.

Since the meter can only register when water is passing through, should the hands move when all outlets are closed, water is being wasted through some leak. This can be most easily detected by observing the circle marked "one foot," referred to above as being provided for purposes of test.

VIII. ATMOSPHERIC HUMIDITY

1. Effects of Humidity

The need for measuring the moisture in the air arises from the fact that this moisture plays a rather larger rôle than is generally appreciated in comfort and health, and also in the physical condition and behavior of wood, cloth, etc. The drying out of furniture and woodwork often causes considerable damage, while excessive moisture may cause almost as much trouble. The latter is favorable to the formation of rust and mold in basements. Many of the conspicuous effects of the moisture of the air are, however, caused by the changes rather than by the particular degree of humidity. Also there is good reason for believing that the extremely low humidity (very dry air) commonly met with in heated houses in winter is distinctly injurious to health.

2. Proper Humidity for Houses

The effect of humidity on personal comfort and health is extremely complicated, but one general principle is well established, namely, that extremes, either of heat or cold, are felt less and are less injurious when the humidity is very low, or, as it is commonly expressed, when the air is very dry.

As a rule, in the house, humidities of from 50 to 70 per cent are desirable.[14] For equal comfort, the higher humidity permits temperatures several degrees lower than does the lower humidity. These figures must be taken as rough approximations only, because there has not been enough careful work done on the subject to warrant a more definite statement. Moreover, these figures may be changed by personal peculiarities or by the fact that the general climate of a place is very dry or very moist.

3. Regulation of Humidity

The measurement and regulation of humidity in the winter is of considerable importance, and is more feasible and less expen-

---

[14] From a letter by the U. S. Public Health Service, Apr. 16, 1914.

sive than is sometimes thought. In summer this regulation is generally of much less importance, but is practicable and important under certain conditions.

In case of sickness, when the temperature and humidity are both high, it may be of great value to reduce the humidity of the sick room. A slight reduction in humidity will then make a great increase in comfort, even though the temperature is changed very little. This can be done readily by an electric fan blowing the air rapidly over a large cake of ice, or even very cold water. If there is doubt as to whether the water is cold enough, this question may be decided by noting whether dew is deposited on a glass or thin pitcher filled with the water. If dew forms freely the air can be blown directly onto the surface of the water, since the condensation will far exceed any evaporation from the water. Too large a supply of outside air must not be admitted, since it might not be possible to dry it sufficiently.

A detailed discussion of methods of securing sufficient moisture in winter is beyond the scope of this circular. Only a few general suggestions can be made. With stoves it is often possible to keep some sort of kettle in a place where the water will boil slowly, or at least keep warm enough to evaporate rapidly. The speed of evaporation can be regulated, roughly, by the temperature or the amount of surface of the water that is exposed. With hot-air furnaces water pans are generally supplied, but they are sure to be utterly inadequate unless placed where the water is heated considerably. In severely cold weather the opening that admits fresh air from outdoors may be partly closed and air returned to the furnace from the interior of the house. This will greatly reduce the amount of water needed. With hot water or steam heat it is generally much more difficult to secure a sufficient rate of evaporation. There are on the market pans that can be hung behind the radiators. The surface of the water in these is small, however, and the evaporation will be correspondingly slow, so that they are likely to be as inadequate as the water pans commonly put in hot-air furnaces.

When the heating is done by a combination of steam or hot water with hot air, the humidification can be accomplished by moistening the hot air.

Automatic regulation of humidity is more difficult than automatic regulation of temperature, and has received very little attention except as applied to large buildings, such as textile mills. At present small equipments are expensive, but with increasing demand and increasing attention it should be possible to reduce the cost a great deal.

4. Amount of Water Needed in Cold Weather

When air near the freezing point or below is raised to the ordinary indoor temperature its relative humidity is reduced to 20 per cent or less, even if it were saturated before being heated.

To maintain a proper humidity arrangements must therefore be made to evaporate a considerable amount of water. If fresh air enough for only one person is supplied, and air from out of doors at the freezing point and saturated with moisture is raised to 72° and a relative humidity of 60 per cent, it would require about an ordinary pailful (10 or 12 quarts) of water each day. Much more air than this is generally supplied in cold, windy weather, though it is doubtless true that too little ventilation is generally provided in mild weather or when several persons are gathered in a room somewhat shut off from the rest of the house. If a house is heated by hot air, all of which is taken directly from out of doors, there may be hundreds of times as much air supplied in severe weather as is needed for ventilation alone, and it is impracticable to supply enough water to raise the humidity to a reasonable amount.

These illustrations show that much more water is required than is often supposed. However, if the full amount can not be supplied, it should be borne in mind that the most important requirement is to avoid such extremely low humidities as 10 per cent or less. It is therefore the first comparatively small addition of water that accomplishes the most good.

5. How Humidity is Expressed

The actual amount of water vapor in a unit volume of air is called the absolute humidity. In metric units it is commonly measured in grams per cubic meter. It is also measured in pounds per cubic foot, or, since it is only a few hundredths or thousandths of a pound, in grains per cubic foot.

The effects of humidity on personal comfort and health and also the rate at which things "dry" depend on the "relative humidity." At a temperature of 32° F (0° C) a space having 2.1 grains of water vapor per cubic foot (4.8 grams per cubic meter) has all the water vapor that can be put into it; in it water would not evaporate, and if more water vapor were forced in the excess would condense to liquid water. The "relative humidity" is 100 per cent. But at 72° F (22.°2 C) a space containing the same amount of water vapor would be called very dry, because at this temperature 8.5 grains per cubic foot (19.5 grams per cubic meter) could be put into it before evaporation would cease. The "relative humidity" in this case is therefore approximately 25 per cent, because there is about one-fourth as much water vapor in the air as there could be.

Relative humidity may be defined as the ratio of the amount of water vapor actually present in a given space to the amount that would be present if it were saturated at the same temperature. It is commonly expressed in per cent, as in the illustration above.

The relative humidity may also be taken as the ratio of the pressure of the water vapor actually present to the pressure it would have if saturated at the same temperature.

For clear and accurate thinking it should be understood that there is no absorption of the water vapor by the air.[15] Nor is it the air that becomes saturated; it is the water vapor itself. In fact, the water vapor acts practically as though there were no air present. This does not mean that a wind has no effect in hastening evaporation, but its effect is merely to brush away the vapor already formed and thus give the water a better chance to evaporate.

6. Measurement of Humidity

(*a*) Hygroscopes.—For general household use the instrument need not be very accurate; 10 per cent difference in relative humidity would seldom be of more importance than 1° or 2° in temperature.

The most convenient instruments are unfortunately the most unreliable. Most of them depend on the hygroscopic properties

[15] The word "air" as used here refers to the other ingredients besides the water vapor. The word is often used to refer to the total contents of the atmosphere, including the water vapor.

79685°—21——8

of hair (see Fig. 47) or of thin, flat strips of various materials that are generally made up into spiral coils. (See Fig. 48.) These

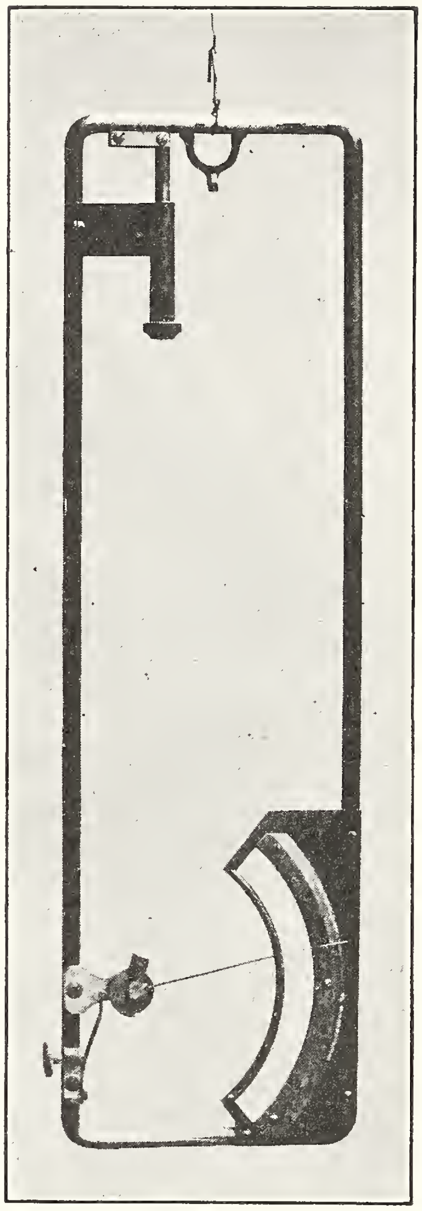


Fig. 47.—*A simple hair hygroscope*

The hair expands and contracts with changes in the relative humidity. In this type a single hair is used and is attached to the half circle at the left end of the pointer. A spiral spring keeps the hair under a very slight tension. Very sensitive and convenient, and may be kept sufficiently accurate by checking it occasionally. See p. 114.

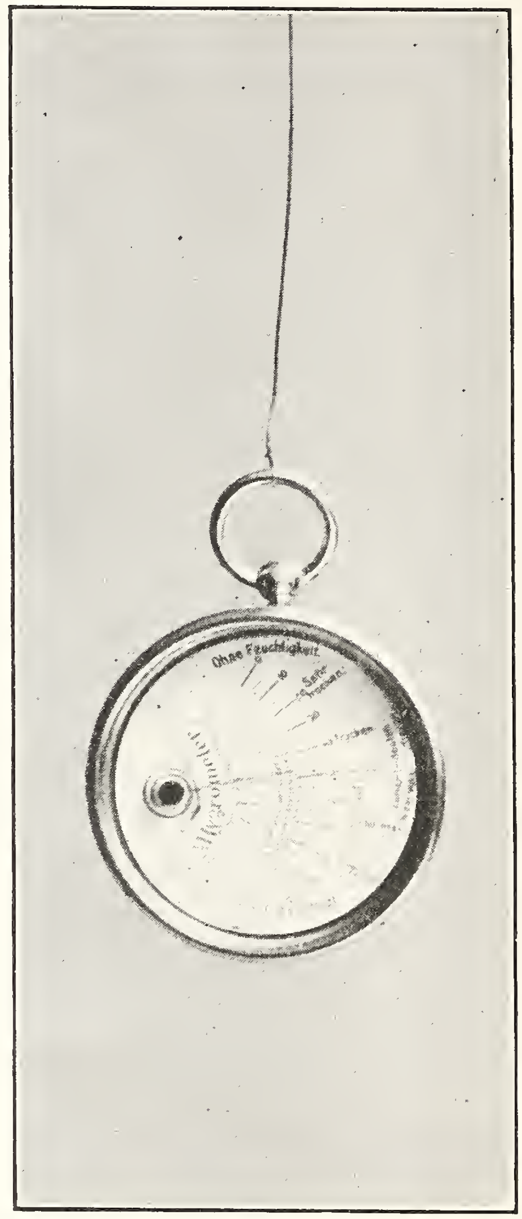


Fig. 48.—*Spiral coil, or film hygroscope*

A spiral of very thin metal is coated with a material that expands and contracts with changes in the relative humidity. This makes the coil open and close slightly and thus moves the pointer attached to its free end. Generally less reliable than the hair hygroscopes and may be worthless unless checked by a reliable instrument.

instruments may read directly in relative humidity, and they generally have the words "dry," "moist," etc., added to the scale. Because of their convenience, it is sometimes worth while to use them, checking them up occasionally to see how nearly

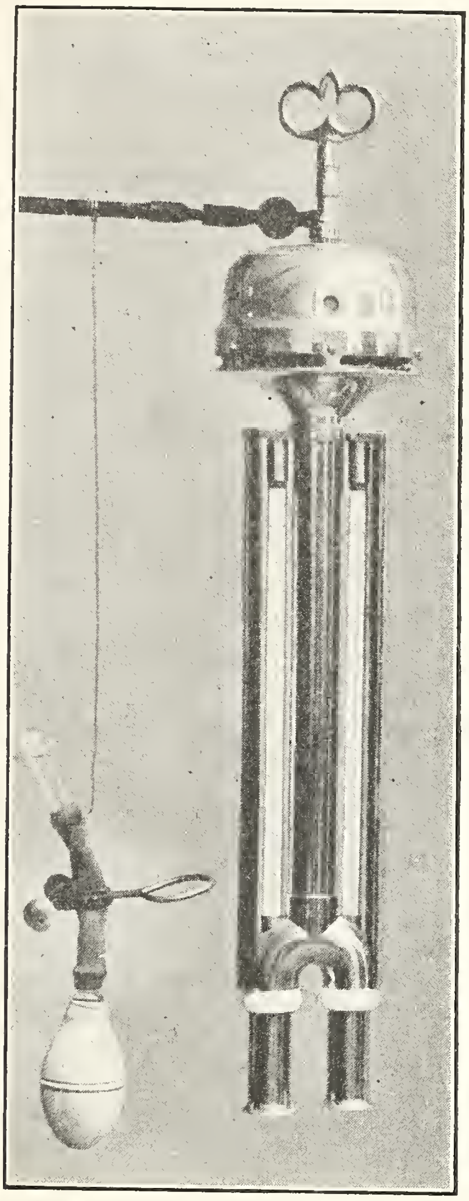


FIG. 49.—*Aspiration psychrometer*

A very reliable instrument for precise measurement of humidity. A fan at the top draws air up through the tubes that surround the thermometer bulbs. Water is applied to the wet bulb by the tube shown at the left. The double polished tubes that surround the thermometer bulbs shield them from heat radiated from warmer objects in the neighborhood.

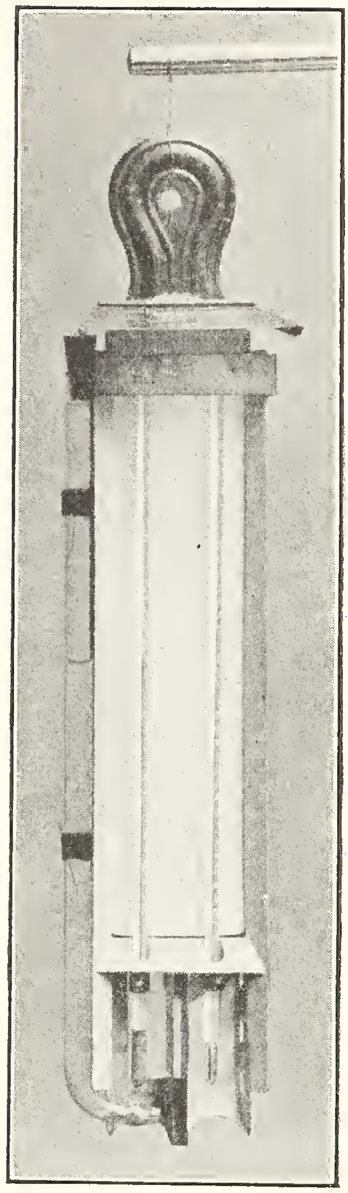


FIG. 50.—*A simple wet and dry bulb hygrometer*

The wet bulb is kept moist by the water in the reservoir at the side. Its temperature depends on the rate of evaporation and therefore on the relative humidity. The humidity may be found from Fig. 53 or Fig. 52. The screens between the two thermometer bulbs and between the water tank and the thermometer are good features.

correct they are. The saturation point (100 per cent relative humidity) is sometimes checked by wrapping the instrument in

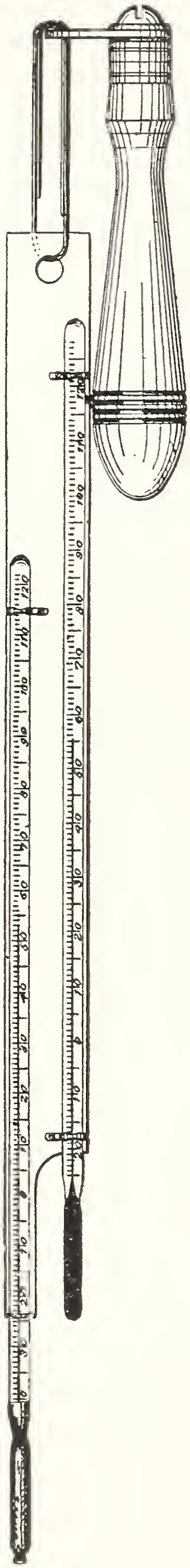


Fig. 51.—*Sling psychrometer*

Ventilation is secured by whirling the whole instrument. Care and some skill are needed to read the wet bulb quickly enough. One or two revolutions per second is a satisfactory speed. This is one of the reliable instruments and has been much used in careful meteorological work.

wet cloth (taking care not to wet the sensitive part). This is not recommended, however, because most of such instruments will not read accurately at the lower humidities for many days after this treatment, and may be permanently changed by it. A better method is to use or improvise a wet and dry bulb hygrometer. This can be done very easily with a fair degree of accuracy even with one thermometer. To do it the real temperature of the air is first read, and the bulb of the thermometer is then carefully wrapped with a single layer of thin cloth and thoroughly wetted. With this the "wet-bulb" reading is then obtained and the relative humidity found, as described below. Extra or heavy cloth is objectionable. It holds extra water; the bulb cools off more slowly, and may not cool to quite the proper reading.

(*b*) Psychrometers.—The wet and dry bulb hygrometer, also called psychrometer, is the simplest of the reliable instruments. In its simplest form it consists merely of two thermometers, one of which gives the true temperature of the air, while the other is covered with a wet cloth and gives a temperature that varies with the rate of evaporation. This "wet bulb" is generally kept moist by a wick that dips into a reservoir of water. (See Fig. 50.)

If the air about the psychrometer is quiet, the relative humidity may be found directly from the psychrometer chart for still air. (See Fig. 53.) The horizontal line corresponding to the real temperature of the air (dry-bulb reading) is found from the scale along the left-hand edge of the chart, and the vertical line representing the wet-bulb temperature is found from the scale along the top. These lines are then traced to the point where they intersect. If this point is on one of the "diagonal" lines, the relative humidity is the per cent marked on that line. If the point lies between two of these "humidity lines," the nearer one may be taken; or for closer reading it is sufficiently accurate to estimate the per cent by the distance of the point from the humidity lines on each side.

Psychrometers are on the market with charts or tables attached, but such charts or tables are usually intended for instruments having rapid forced ventilation. The errors are therefore sometimes 10 to 20 per cent unless special ventilation is provided, as noted below.

The "unventilated" instrument is accurate enough for general household use, provided the air is really still. If the air is not still, however, artificial ventilation can easily be supplied by vigorous fanning, and the correct results can then be read from the chart for "rapid ventilation." (See Fig. 52.)

More accurate results can be obtained with the "ventilated" instruments because slight currents of air have a relatively large effect on the reading of the wet bulb, while the rate of ventilation makes no difference so long as it is kept above a certain amount (about 10 feet per second). There are two types of instruments specially designed for rapid ventilation. The cheaper forms called "sling psychrometers" (Fig. 51), have the two thermometers on a rather narrow backing arranged so that the whole instrument can be whirled. Other forms have a fan, driven by clockwork or an electric motor, for drawing the air over the thermometers. (See Fig. 49.) These instruments generally do not read continuously, and the wet bulb must be wetted each time a reading is taken.

If rain water or distilled water can be obtained readily, it should be used on any type of psychrometer. Practically all water has material dissolved in it. This gradually gathers on the cloth on the wet bulb, closes the pores, and prevents the cloth from being saturated with water. When this happens the cloth should be removed and cleaned or replaced by a new one. If clean rain water or distilled water is used, the cloth will last very much longer before it needs to be removed.

PSYCHROMETER CHART
FOR
RAPID FORCED VENTILATION

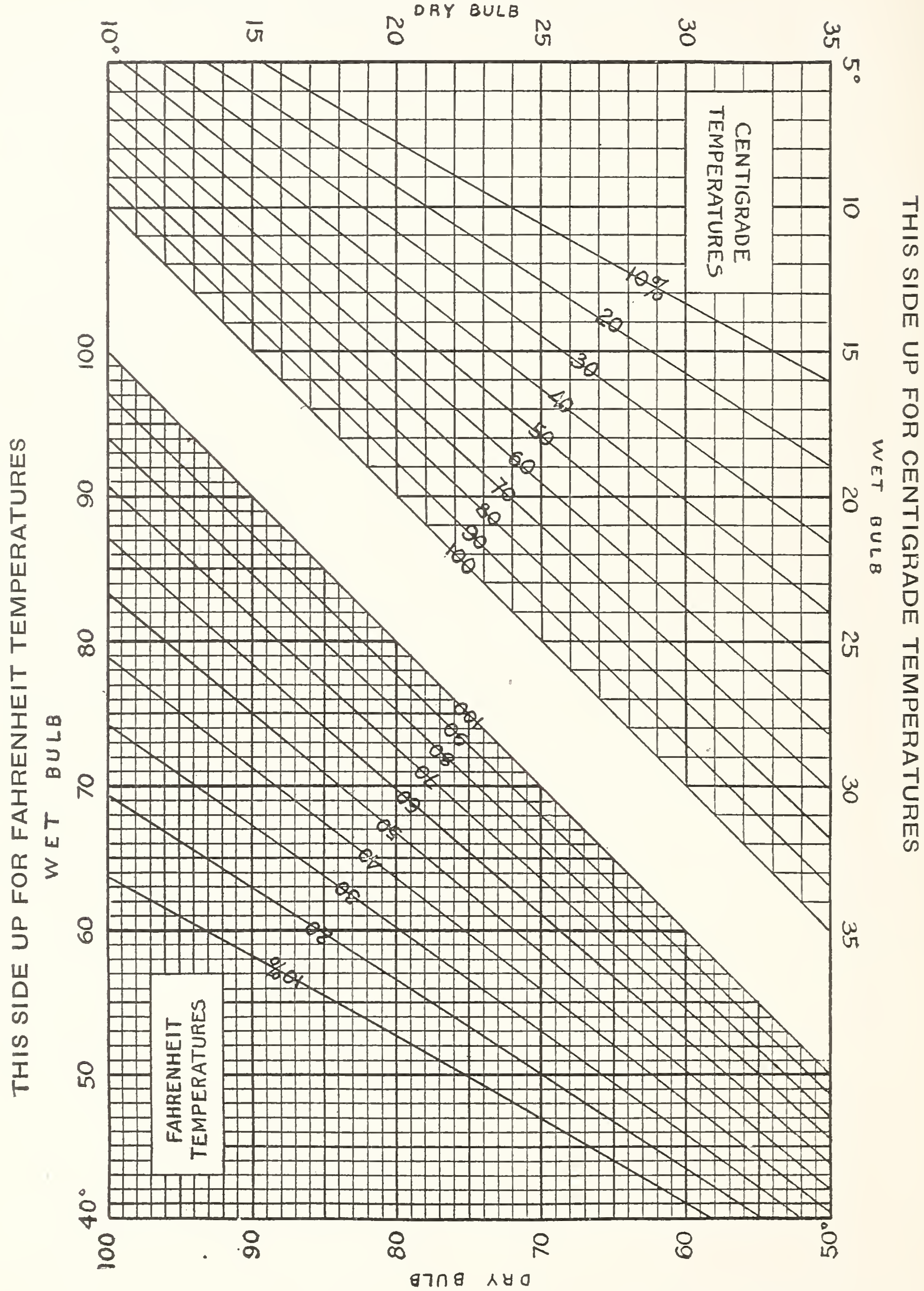


Fig. 52.—*Psychrometer chart, giving relative humidity from readings of wet and dry bulb hygrometers with rapid forced ventilation*

Calculated for a barometer height of 755 mm. At altitudes of 6000 feet or over the reduction in barometric pressure will cause an error of 5 per cent or over at very low humidities.

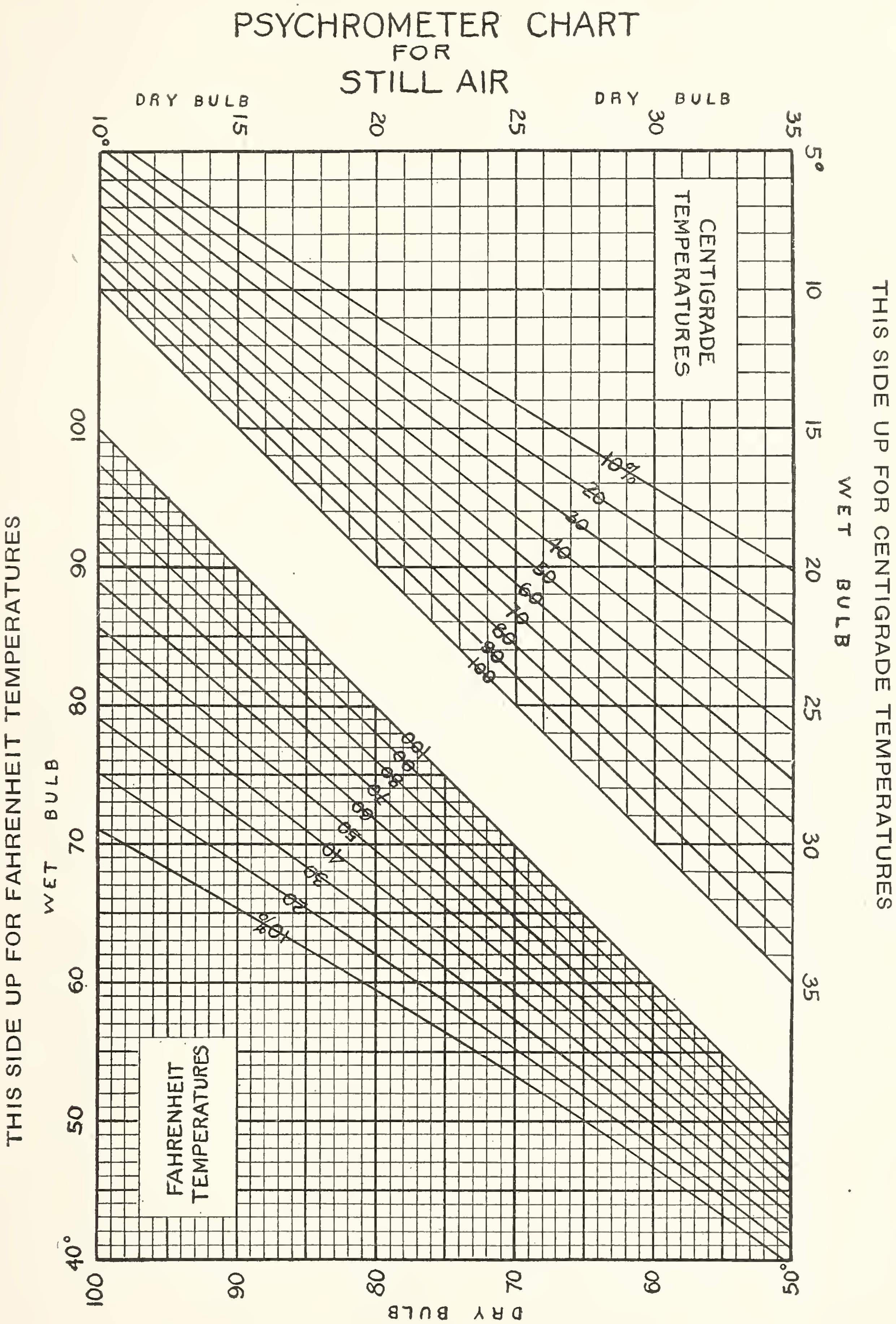


FIG. 53.—*Psychrometer chart, giving relative humidity from readings of the wet and dry bulb hygrometer in still air*

Calculated for a barometer height of 755 mm. At altitudes of 6000 feet or over the reduction in barometric pressure will cause an error of 5 per cent or over at very low humidities.

IX. ATMOSPHERIC PRESSURE

1. Uses of Aneroid Barometers

Among other purposes aneroid barometers (see Fig. 54) are used for altitude determination in aviation and in mountain climbing, and for weather observations at sea and in the household.

Aneroids should always be read in the same position; for example, hung up on a hook in a vertical position; and tapped sharply just before reading. Care should be taken not to suddenly heat or cool the instrument or to press too heavily on the dial, otherwise changes will be produced which are not really due to air pressure.

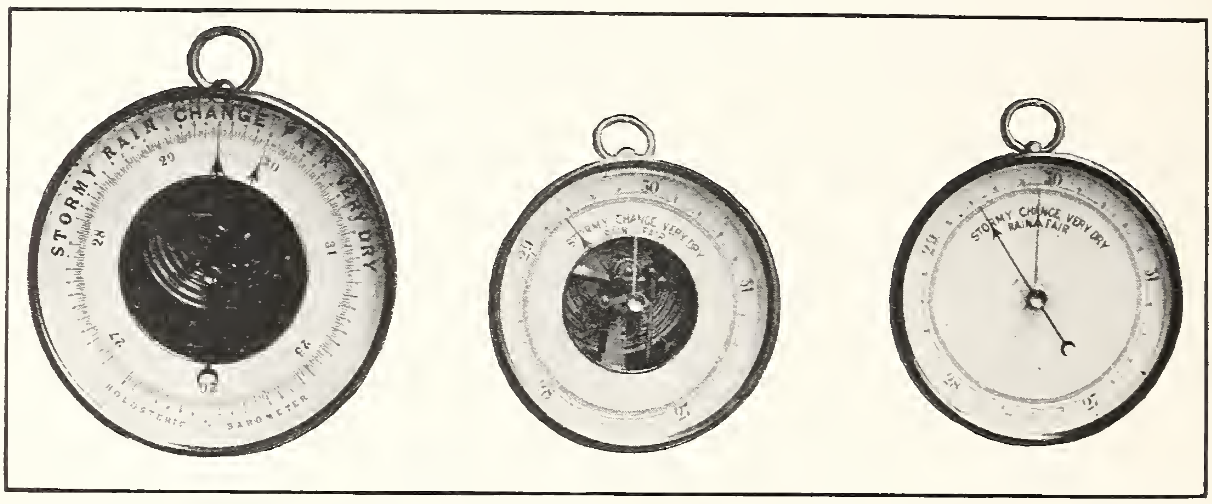


Fig. 54.—*Household type of aneroid barometers*

This type is distinctly different from those used in aviation and in surveying, and is intended for household weather observations.

A relatively rapid fall of pressure if continued for some hours will probably be followed by stormy weather, but the barometer can not be relied upon to indicate forthcoming weather. The scale of a common household aneroid is graduated to read "inches" of pressure. The figures "28, 29, 30, 31" are usually on the dial, the top of the dial coming between 29 and 30, and the space between each of these numbers is divided into 10 or more subdivisions. The normal pressure at sea level in fair weather is about 29.9 inches. (At higher altitudes the pressure will be less—for example, in Denver about 25 inches.) If, now, the pointer falls below the normal value of the locality (which may well be marked on the dial or indicated by the dummy brass pointer), that is a sign that the weight of the air column pressing down on the aneroid has for some reason diminished. This may be due either to the air becoming damper and hence lighter, or to the approach of a

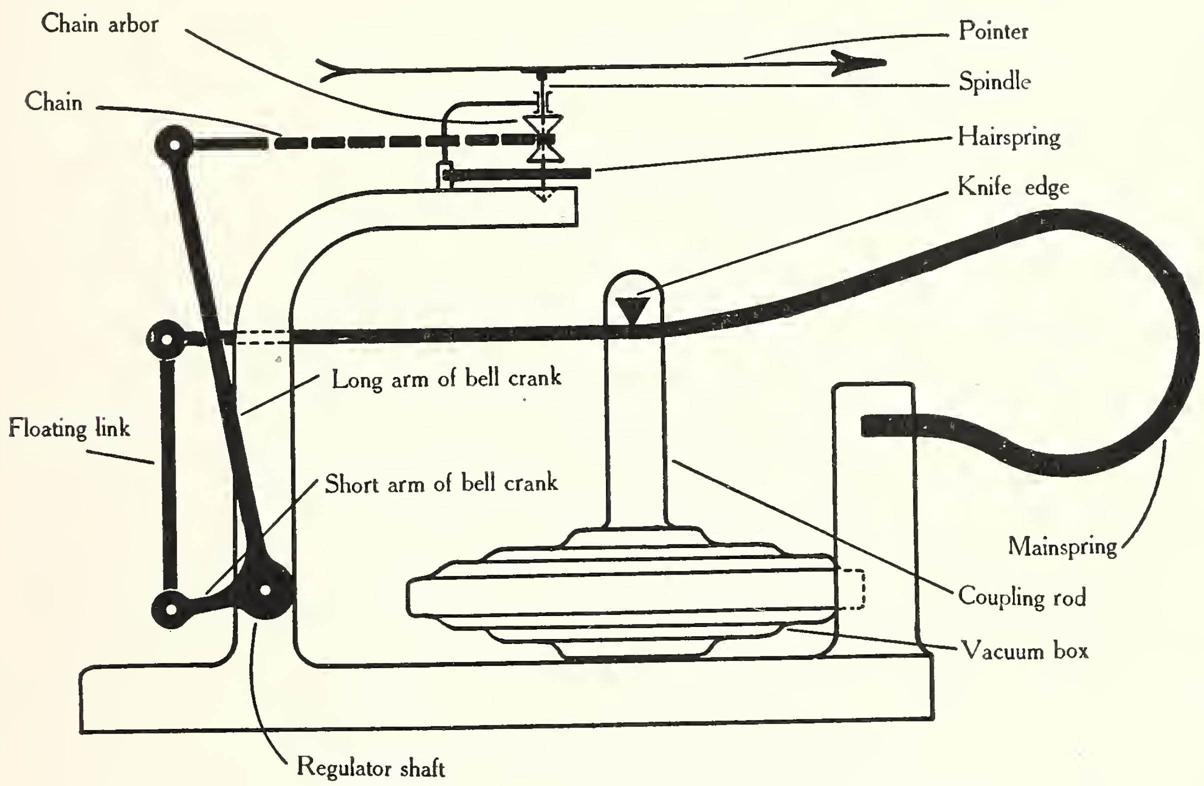


FIG. 55.—*Diagram showing principle of operation of aneroid barometers*

Increasing air pressure on vacuum box pulls mainspring down, actuates the connecting mechanism, and turns pointer.

large portion of the atmosphere having a low barometric pressure. The effect will be most pronounced if the observer is directly in the line of progress of such a storm, the passage of which may be accompanied by pressure changes of half an inch or more.

2. How Aneroids Work

A reading of 30 inches on the dial of an aneroid means simply that the pressure of the air is great enough to support a column of mercury 30 inches high in an ordinary mercurial barometer.

Instruments of the latter type are used as standards in testing aneroids at this Bureau. But the aneroid, as its name implies, contains no liquid. It is essentially a spring balance. (See Figs. 55 and 56.) Imagine such a balance with a horizontal disk, 2 or 3 inches in diameter, hung on it for a scale pan. If the air pressure

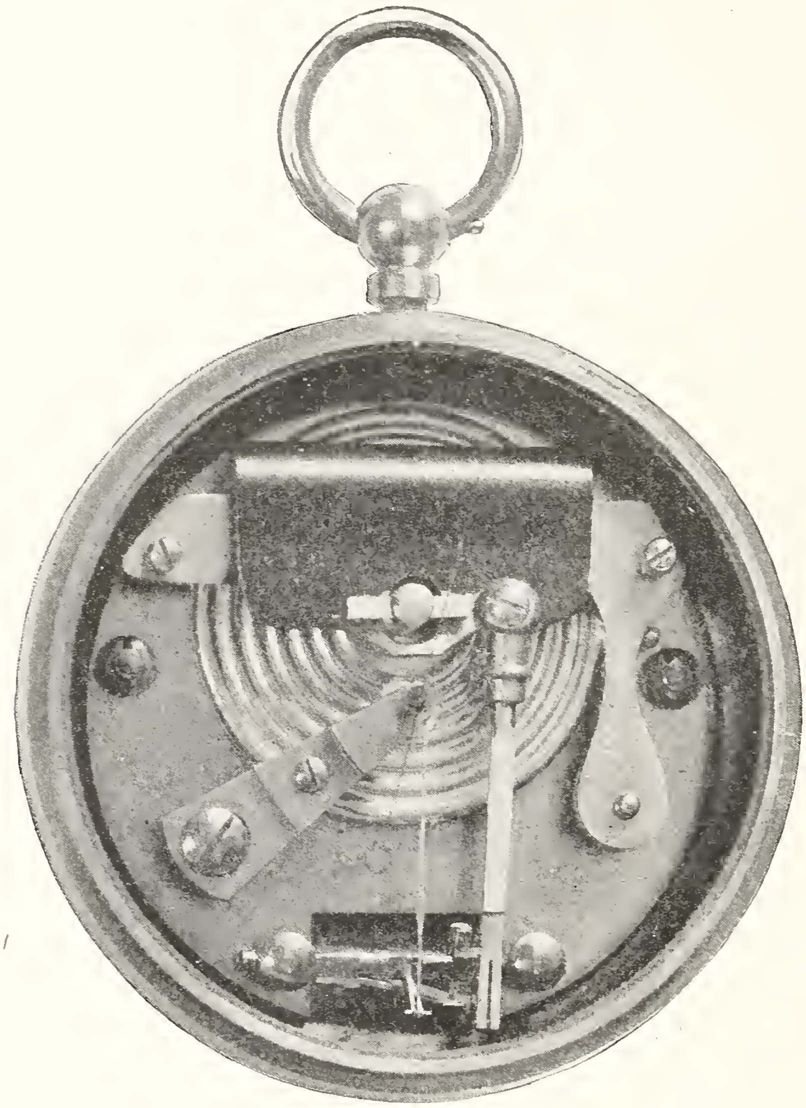


Fig. 56.—*Mechanism of an aneroid barometer*

The broad black mainspring and corrugated vacuum box may be readily recognized and compared with the diagrammatic side view in Fig. 55.

could be prevented from acting upward on the bottom of that pan such a device would evidently serve to give the true weight of the entire column of air supported on the pan and extending vertically up to the sky. In the aneroid barometer this is actually done. The air is prevented from acting on the bottom of the disk by letting that disk form the top of a box from which the air has been pumped out. The works of an aneroid thus consist of a "vacuum box," the top of which is hooked onto a very stiff steel spring, together with suitable levers for connecting the spring to the pointer and greatly magnifying the deflections which the spring undergoes whenever the air pressure on the top of the vacuum box changes. As the top of the vacuum box also moves (only the rim being rigid) it is made of very thin corrugated metal so as to resist the necessary movement of the spring as little as possible.

3. Some Common Defects to Be Avoided

(*a*) FRICTION AND LOOSENESS IN THE MECHANISM.—As a consequence the position of the pointer is unsteady and uncertain, and the aneroid will not respond quickly to any pressure change; or may not respond at all unless the change is a large one.

(*b*) INADEQUATE COMPENSATION AGAINST THE EFFECT OF TEMPERATURE CHANGES.—Aneroids are examined for these and other possible defects when submitted to the Bureau for test. (See Bureau of Standards Circular No. 46.)

X. DENSITY OF LIQUIDS

1. Uses and Definition of Specific Gravity

A knowledge of the density or specific gravity of a liquid is usually of value in the household only as an index of some other physical property or quality of the liquid. For example, in the preparation of sirups, jellies, and other food products of that nature, a measurement of specific gravity is a convenient means of determining when the process of evaporation or "boiling down" has been carried far enough. Also, the quality or fat content of milk may be determined by measuring its specific gravity.

Specific gravity is the ratio of the weight of any volume of a substance to the weight of an equal volume of water. Milk has a specific gravity of 1.03, since the weight of any volume of milk is 3 per cent more than that of an equal volume of water. The densities given in Table 6 are stated in grams per cubic centimeter, and are numerically the same as specific gravity in terms of water at 4° C as unity.

2. Determination of Specific Gravity

The specific gravity of a liquid may be most readily determined by means of a small glass instrument known as the hydrometer. This instrument floats in the liquid to be examined and the specific gravity of the liquid is determined by noting the point on the stem to which the instrument sinks in the liquid. Since a floating body sinks in a liquid to such a point that the weight of the liquid displaced by the body is equal to the weight of the body, the hydrometer, when provided with a suitable scale, indicates directly the specific gravity of the liquid.

3. Classes of Hydrometers

Hydrometers in general use may be divided into three classes with reference to their indication.

(*a*) Specific gravity hydrometers.
(*b*) Per cent hydrometers.
(*c*) Arbitrary scale hydrometers.

(*a*) Specific gravity hydrometers indicate the ratio of the weight of a given volume of the substance to the weight of the same volume of some standard substance. The standard substance is usually water at a definite temperature.

(*b*) Per cent hydrometers indicate the percentage of a substance, either by weight or by volume, in a mixture or solution of the substance in water.

(*c*) Arbitrary scale hydrometers indicate the concentration or strength of a substance in terms of some arbitrarily defined scale. Lactometers and Baumé hydrometers are examples of this class.

TABLE 6

Densities of Some Household Materials

Substance	Temperature in degrees centigrade	Density in grams per cubic centimeter
Air, dry	20 (68° F)	0.001205
Air (of 50 per cent humidity)	20	0.001195
Brine (5 parts by weight of salt in 100 parts of brine)	15	1.035
Brine (25 parts by weight of salt in 100 parts of brine)	15	1.191
Butter		0.86 to 0.87
Cider vinegar		1.013 to 1.015
Cream [16] (18 per cent butter fat)	20	1.01
Cream (40 per cent butter fat)	20	0.99
Gasoline	20	0.70 to 0.74
Ice		0.92
Kerosene	20	0.78 to 0.82
Lard		0.92
Linseed oil	20	0.92 to 0.93
Milk	20	1.028 to 1.032
Olive oil	20	0.91
Sea water	15	1.023 to 1.025
Sirup, maple [17]	17.5	1.32 to 1.34
Tallow		0.91 to 0.97
Turpentine	20	0.86 to 0.87

[16] Minimum butter fat content for cream (definition of Bureau of Chemistry).

[17] The density of maple sirup varies from 1.32 with 35 per cent of water to 1.34 with 32 per cent of water.

4. Choice of a Hydrometer

The hydrometer to be chosen for household use will depend upon the purpose for which it is intended, the degree of accuracy required, and to some extent upon the personal preference of the user. The specific gravity hydrometer (see paragraph (*a*) above) is recommended for most purposes.

For use in making sirups, preserves, etc., an instrument indicating specific gravity in terms of water at 60° F, or one reading in Baumé degrees will be found convenient. The hydrometer should have a range of about 1.00 to 1.50 in specific gravity or 1 to 50 in Baumé degrees, and should be so graduated that the readings can be conveniently made.

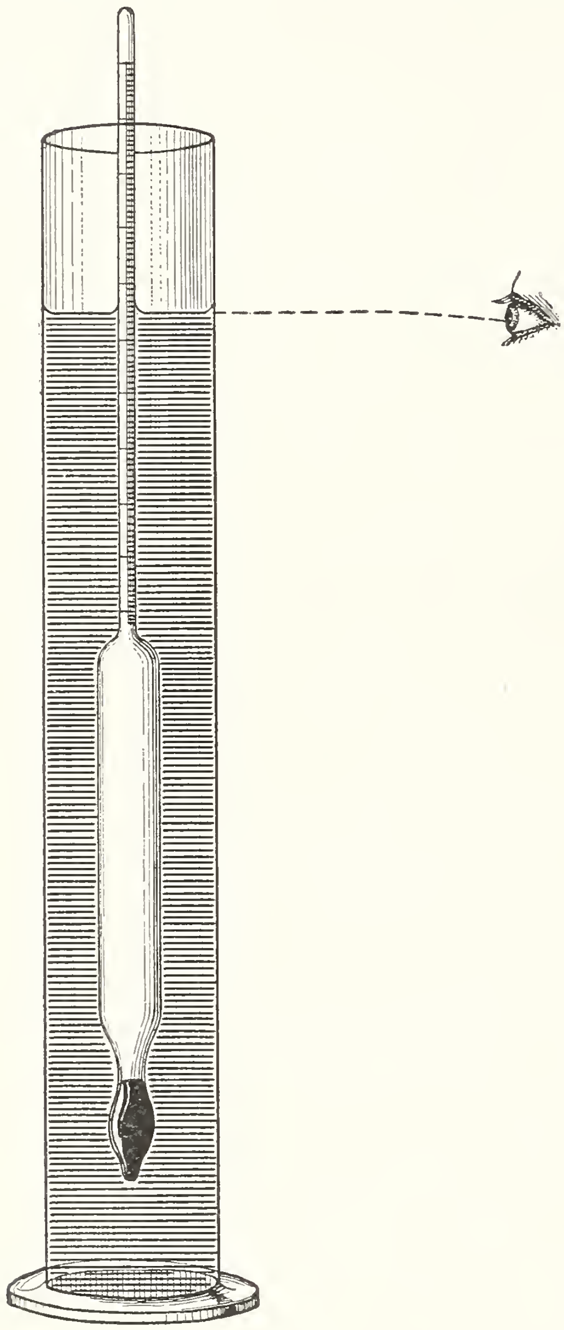


FIG. 57.—*Hydrometer floating in liquid, showing proper position of the eye for reading the scale*

5. Use of the Hydrometer

In using the hydrometer a portion of the liquid whose specific gravity is to be measured should be placed in a glass cylinder of such a size that the hydrometer when placed in the cylinder will be free to move up and down without coming in contact with the walls of the vessel.

The liquid should be well stirred. For specially accurate work, the temperature of the liquid should be observed by means of a thermometer placed directly in the liquid; when the temperature has become fairly constant the readings on the hydrometer may be taken.

6. Method of Reading

The eye should be placed on a level with the surface of the liquid, as shown in Fig. 57, and the line where the surface of the liquid appears to cut the stem of the hydrometer should be taken as the reading of the hydrometer.

In case the liquid is not sufficiently transparent to allow the scale of the hydrometer to be read through the liquid, the reading can not be made as indicated above. It is then necessary to read as accurately as possible above the surface of the liquid. If the readings in a dark-colored liquid are always made in the same way, the resulting error will not be great, and successive readings will be comparable.

7. Influence of Temperature

When the temperature of a liquid changes, its specific gravity also changes and the indication of a hydrometer in the liquid will therefore be different at different temperatures. All hydrometers should be marked with the temperature at which they are intended to be correct.

In actual practice, however, it is not always necessary that the hydrometer be used at its standard temperature, but if readings are to be compared, they must all be made at the same temperature. For example, in practice it may be found by experience that a certain sirup has the proper consistency when cool, if the reading on the hydrometer is 1.36 at 80° F. The standard temperature of the instrument may be 60° F, but if experience has shown that a certain reading of the hydrometer at some other temperature gives satisfactory results, it is not necessary to wait for the liquid to cool to the standard temperature of the instrument.

XI. TIME

1. Types of Household Clocks

The usual clocks found in the home may be divided into two classes, the mantel or wall clock type, which has a pendulum, and the common alarm-clock type, in which the movement is controlled by the vibrations of a balance wheel, as in a watch. The second variety is quite portable and will usually run in any position, but the pendulum clock must be kept fixed in an upright position and must be adjusted every time it is moved.

2. Moving a Pendulum Clock

The pendulum clock usually has its pendulum suspended by a thin flat spring, and to avoid breaking this spring when the clock is to be moved from one place to another it is best either to unhook the bob from the pendulum rod or to secure the pendulum tightly to the clock works or case so that it can not swing. In setting up such a clock after removal it is necessary to put the clock "in beat"; that is, to make the successive vibrations of the pendulum, or the time between successive ticks of the clock, of equal length. This must be done by carefully leveling the clock on its support (unless the clock is provided with adjusting thumbscrews at the top of the pendulum by the movement of which one way or the other it can be made to beat uniformly).

3. Setting a Clock

The setting of a pendulum clock is usually best done by turning the minute hand *forward*, several revolutions if necessary, to bring the hour hand to the correct hour. If the clock does not have a striking mechanism, the hour hand, which is usually held on its slightly conical shaft by friction, may be moved forward a sufficient number of hours, and the minute hand adjusted to the correct minute. As the hour hand may have become loosened on its shaft by this procedure, however, it should be pressed tightly into place after it is set correctly. In some clocks with a striking mechanism the minute hand should not be moved backward across a striking point, although it can, without injury, be moved back short distances in other parts of the dial to set it correctly.

4. Regulating a Clock

Few clocks of either the pendulum type or the alarm-clock type are made with devices to compensate for changes in temperature, and as changes in temperature will change the rate it is desirable to keep the clock in the part of a room where its temperature will be most constant. Even with the best conditions in this respect it will be necessary to regulate the clock's rate frequently on account of the changes of temperature with season or with the conditions of heating or cooling of the room. A rise of temperature will lengthen the pendulum rod and make the clock run more slowly. It will be necessary, therefore, to raise the pendulum bob by turning the supporting nut, unless an adjustment device is provided by which a contact point on the suspension spring at the top of the pendulum can be changed. This is done by turning a key to right or left in a small keyhole in the face of the clock, usually near the upper part of the dial. This has the effect of shortening or lengthening the pendulum.

In the alarm-clock type the regulation is done by moving a small lever, usually at the back of the clock, which engages with the hairspring on the balance wheel, and so decreases or increases the effective length of the spring, thus controlling the time of a vibration of the balance. The lever should be moved toward the letter "S" when one wishes to make the clock run slower and toward "F" when it should run faster. The same rule applies in the regulation of a watch.

When regulating a pendulum clock (see Fig. 58) by the key device, the key should be turned overhand toward the letter "S" or "F" according as one wishes to make the clock run slower or faster. If there are no indicating letters ("F" and "S") provided, the usual rule is to turn the key in the direction the hands move to make it go faster or counterclockwise to make it run slower.

The amount of movement required to correct the rate must generally be found by trial. Thus, if the clock gains five minutes a day, and one turns the key of the regulator two revolutions toward

"S," or moves the lever of an alarm clock two divisions toward "S," and the clock then loses three minutes a day, one can obtain nearly zero rate by turning the key three-quarters of a revolution back toward "F" or by moving the lever three-quarters of a division back toward "F." In some pendulum clocks there may be some motion lost in reversing the regulation, and this should be taken into account in estimating the amount to move the regulator.

5. To Correct the Striking of a Clock

While some clocks of a more recent type have the hour and minute pinions and the striking mechanism so geared together that it is almost impossible for the clock to strike wrongly, this frequently happens with other types of clocks. This difficulty can be easily remedied in the latter case by several methods. One method, which can be used in case the hour hand is held in position on its shaft by friction only, is to move the hour hand backward or forward an hour or more as may be necessary to make the hour indicated by the clock face agree with the striking mechanism, pressing the hour hand tight on its shaft afterwards, as described above. Then set the clock to correct time by moving the minute hand around the dial the necessary number of times, allowing the clock to strike the full amount each time the hand passes the XII point before approaching that point again. This method is especially convenient when the clock strikes one or two strokes less than it should. When it strikes more strokes than it should, the same method can be used, or the minute hand can be turned ahead rapidly so that it will again pass through the XII point while the clock is still striking for the previous hour. By so doing the striking mechanism is not released to strike the following hour, and thus an hour is gained in the face indication of the clock compared with the striking. This can be repeated as many times as the number of strokes by which the striking mechanism was in error. The clock can then be set to correct time in the usual way, allowing it to strike the full amount on each passage of the XII point, or the clock can be stopped for as many hours as it is fast, until it again indicates the correct hour, when it can be started and set correct without the necessity of striking all the 9, 10, or 11 hours that may have intervened.

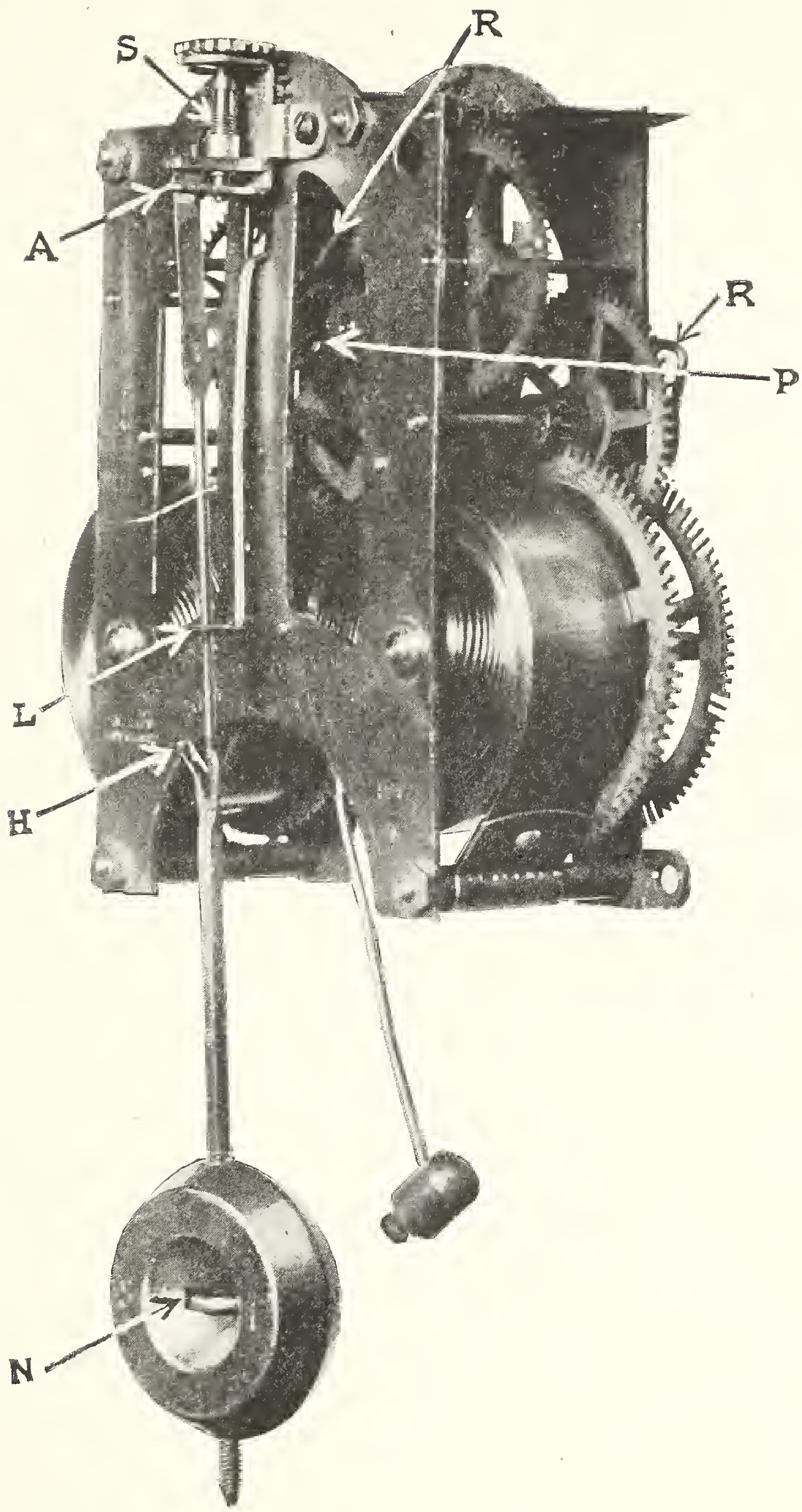


FIG. 58.—*Rear view of a common pendulum clock movement*

Showing the hook H at which the pendulum bob may be unhooked for transportation, and the loop L through which the pendulum rod passes and in which the rod should be adjusted when the clock is set up if the loop is not closed. The nut N when turned to the right or left raises or lowers the bob and makes the clock go faster or slower. The adjusting device A is lowered or raised along the thin piece of steel below by means of the screw S operated from the front of the clock by a key and effects the fine adjustment of the rate of the clock. The striking mechanism can be released by raising the pin P or by lifting the rods at the points marked R, by doing which the clock can be made to strike correctly.

Some clocks have a lever in the movement—an extension of the striking mechanism release arm or shaft—which can be moved up or down to release the striking mechanism and allow it to strike as many hours as are necessary to bring it into agreement with the indication of the hands. Or, if a special lever for the purpose is not provided, it is sometimes easy, on opening the door to the works of the clock, to find the release arm itself and by raising it accomplish the same thing.

6. Correct Time

In practically all towns in the United States the so-called *correct* time is the standard time of the *standard time section* in which the town is located. This country is divided into four standard time sections, designated by the names Eastern, Central, Mountain, and Pacific sections, or by the meridians of longitude which are nominally the middle of the sections, namely, the seventy-fifth, ninetieth, one hundred and fifth, and one hundred and twentieth. Each section is thus theoretically 15 degrees of longitude in width, the section central about the seventy-fifth meridian extending from longitude 67° 30′ to 82° 30′, the ninetieth meridian section extending from 82° 30′ to 97° 30′, etc. Practically, however, the boundaries of the sections are irregular, broken lines connecting the terminal or division points at which the various railroads change their time in passing from one section to another. Thus, the boundary between the Eastern and Central time sections extends, roughly, from Sault Ste. Marie, Mich., through Lake Huron to Detroit, Mich., thence through Lake Erie to Buffalo and then southward through western Pennsylvania to Atlanta and Savannah, Ga.

All the clocks in any one time section would read the same if they were *correct*, and the clock time indicated by them would differ from that of the adjoining time sections by just one hour, the time of the section to the west being one hour slower, and that of the section to the east one hour faster, for each time section uses the mean solar time of its central meridian.

Mean solar time has as its unit the average length of time between successive passages of the sun across the north and south line or meridian through any place throughout the year. Because the path of the earth around the sun is not a circle but an ellipse, the time between successive passages of the sun across a meridian differs throughout the year, and hence the average of the apparent lengths of all the days in the year is taken as the unit, and the average time at which the sun crosses the meridian is taken as the noon of mean solar time. This noon of mean solar time differs from the apparent time of noon by as much as 16 minutes at certain times of the year. Hence, the time as kept by a clock running on mean solar time will differ from the indications of a sundial by 16 minutes at those periods in the year.

Mean *local* time of any place is the mean solar time reckoned from the noon of the meridian passing through the point in question. Hence, the mean local time of every place in this country would differ from that of every other place except the points actually on the north and south line through the place. The *mean local time* of a point a fifth of a mile west of a given point would be a second slower than that of the eastern point, while at a point one-fifth of a mile east of the given point it would be one second faster (lat. 45°). Thus, the *true local time* in different parts of some large cities might differ by nearly a minute. To avoid all this confusion the standard time sections were established and each point in the section instead of reckoning its time from its own local noon, uses instead the mean solar time counted from the mean time noon of the central meridian, the seventy-fifth, ninetieth, one hundred and fifth, or one hundred and twentieth.

As the 15 degrees of difference between these meridians is equal to one twenty-fourth of a rotation of the earth, the time in the successive sections differs by just one hour. Hence, the time as sent out daily at noon and 10 p. m. of seventy-fifth meridian time from the United States Naval Observatory can be taken as the *correct* time of 11 a. m. and 9 p. m. in the ninetieth meridian section, and as 10 a. m. and 8 p. m. in the one hundred and fifth meridian or Mountain section, and 9 a. m. and 7 p. m. in the one hundred and twentieth meridian or Pacific section. On account of the difficulty of transmitting such time signals by telegraph or radio (wireless) across the continent, similar signals are also sent out from the Mare Island Observatory, Cal., every day at noon and 10 p. m. of one hundred and twentieth meridian time.

These time signals from both observatories consist of the tapping of all the seconds of the five minutes preceding noon and 10 p. m., except that the twenty-ninth and fifty-fourth to fifty-ninth seconds of each minute are omitted. In the last minute the last 10 seconds are omitted instead of the last five, and on the sixtieth second just at noon or 10 p. m. the key is held down for a whole second. The series of signals is illustrated in Fig. 59. The last contact is used in several cities to automatically drop a time ball and also to set to correct time a master clock usually located in the telegraph office.

In many large cities this master clock is used throughout the day to automatically set other public clocks in the city to correct time every hour. The accuracy of this system of master clock and secondaries depends, therefore, upon the uniformity of rate of the master clock throughout the day, and upon the regularity of its operation of the secondaries. Where they receive careful attention they can be depended upon to give practically correct time at any time of day.

Most tables of the time of rising and setting of the sun and moon are made out for mean local time. To find the corresponding standard time for these events, it is necessary to know by how much the longitude of one's locality differs from the central meridian of that time section and dividing the degrees, minutes, and seconds of arc by 15 to obtain their equivalent in hours, minutes, and seconds of time, this difference must be added to the time of sunrise, sunset, etc., given in the table to obtain the standard time for these events if the locality is west of the central meridian of the section, or the difference in time must be subtracted if the locality is east of the meridian, seventy-fifth, ninetieth, one hundred and fifth, or one hundred and twentieth, as the case may be.

7. Care of Timepieces

Precautions should be taken not only with clocks but also with watches to keep them at a constant temperature if one wishes to obtain the best results with them. If possible a watch should be kept at as nearly the same temperature at night as during the day. The variations with the drop in temperature at night will affect the rate of the alarm clock uncompensated for temperature much more than that of a watch, which is usually compensated for high and low temperatures.

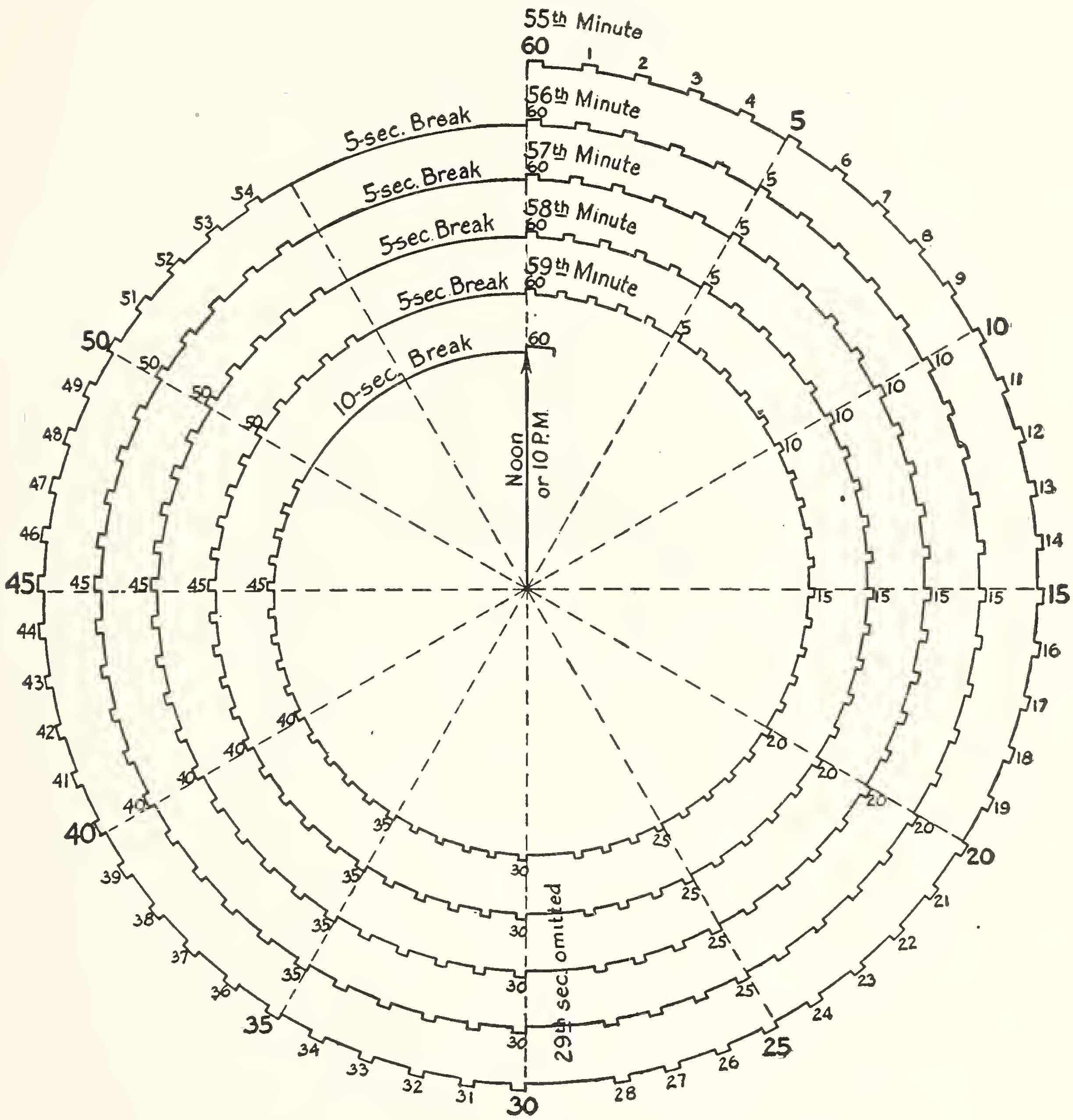


FIG. 59.—*Illustrating the time signals as sent out by telegraph and radio (wireless) for five minutes preceding noon and 10 p. m. from the United States Naval Observatory, Washington, and the Mare Island Observatory, Cal., for 75th and 120th meridian standard time.*

The careful handling of a timepiece of the balance-wheel type—clock or watch—is also important, because of the effect on the adjustment and rate. All sudden changes of motion should be avoided, and a fall is liable to bend some of the pivots and seriously change the rate. The position in which it is kept also makes a large difference in its rate, especially with the unadjusted cheaper types. Both the watch and the clock should best be kept in an upright position, both day and night, as uniformity of practice is the chief essential. All timepieces should, of course, be kept protected from dust and dirt. They should be wound regularly. It is perhaps better to wind a watch twice a day than once a day, if it is done regularly, and the last part of the winding should be done slowly to avoid injury to the mechanism.

8. Use of a Timepiece in the Kitchen

Many operations in the kitchen may be judged most easily and accurately by means of the elapsed time, especially where the operation is carried out under uniform conditions, as, for example, the boiling of food or even of baking where the heat supplied is continuous and uniform in its rate of application.

The most familiar case is, of course, the boiling of eggs. With a little experience and the keeping of a record of results, the same principle can be applied to cooking other foods to the most palatable condition. Such records will also be valuable in determining for future use the time necessary for the preparation of food materials.

Even if interest in such methods is lacking, an alarm clock may be made very useful in giving a warning of the necessity of inspecting a given process which otherwise might be overlooked, and where food materials are frequently spoiled in preparation from lack of attention, the use of an alarm clock will soon save its cost.

In using the alarm feature of an alarm clock, the setting mechanism should be turned in one direction only, for the same reason as in the case of setting a clock with striking mechanism to correct time, to avoid locking or breaking the setting device. Occasionally the indicating hand of the alarm will not be placed correctly on its pinion and the alarm will sound at a different time from that expected. This error will be a constant one, however, and its amount having been once learned, allowance may be made for it in setting the hand; or a watch repairer can correct the fault very quickly. Many alarm clocks have the dial for setting the alarm of very small diameter, making it difficult to make accurate settings of the hand. For this use it is desirable to secure a clock with as large an alarm-hand dial as possible, preferably one having the alarm hand set on the central pinion with the hour and minute hands. With such a clock the alarm can be set quite accurately for giving a signal at short intervals of time and can be used to give warnings of the time to inspect certain processes of the kitchen, for the taking of medicine at regular intervals, etc.

Sand glasses having the two sections of rather long, cylindrical-shaped glass tubes and mounted on a board or card on which are indications of the elapsed time corresponding to different heights of the sand in the tube are also useful for keeping track of short-time intervals, such as the time of boiling of eggs or other cooking processes.

XII. KITCHEN MEASURES

1. Kitchen Measuring Appliances

In the kitchen more accurate weights and measures are gradually coming into common use as the units used are becoming better defined. Domestic science departments of schools and colleges are largely responsible for this advance.

The basis of the kitchen system of weights and measures is the standard cup, a measure holding 8 fluid ounces—that is, one-half liquid pint—and used to measure either dry or liquid commodities.

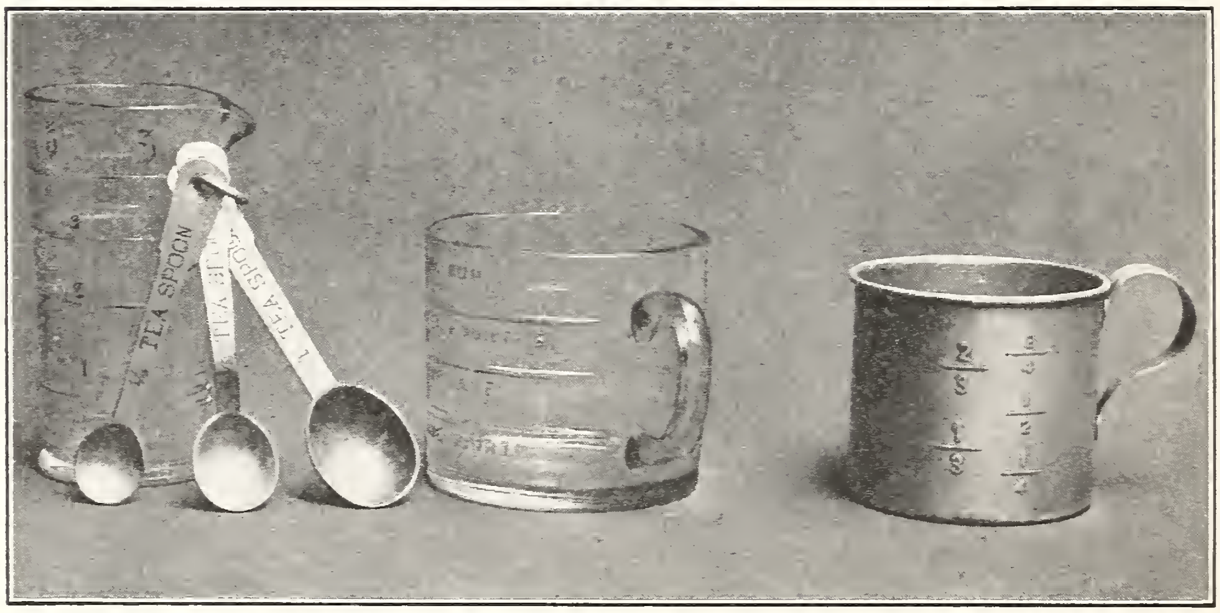


FIG. 60.—*Measures used in the kitchen*

For cooking and other purposes in the kitchen, the following capacity measures are useful: A four-ounce glass graduate, a teaspoon measure (with half and quarter fractions), and a cup measure (of glass or metal). The cup measures shown have the same capacity (8 fluid ounces), although the thinner walls of the aluminum measure make it smaller in appearance.

One of these cups, subdivided into thirds, fourths, or both, should be procured, since the ordinary china cups vary greatly in size. A special set of spoon measures (from one-fourth teaspoonful up) will be found convenient, since ordinary spoons also vary in size. Moreover, neither the ordinary cup or spoon is adapted to measuring of fractions of their capacity.

2. Equivalents of Capacity Units Used in the Kitchen

The measures of capacity used in the kitchen are based upon the standard cup, as follows.

3 teaspoonfuls	=	1 tablespoonful = 4 drams
4 tablespoonfuls	=	1/4 cupful = 2 fluid ounces
1/2 cupful	=	1 gill = 4 fluid ounces
2 gills	=	1 cupful = 8 fluid ounces
1 cupful	=	8 fluid ounces
2 cupfuls	=	16 fluid ounces
16 fluid ounces	=	1 pint
4 cupfuls	=	1 quart

In the above table all measures are level full. The equivalents given will permit the use of the large glass graduate for measuring liquids in cooking.

In Table 7 are given equivalents of units commonly used in cooking and for other household purposes.

TABLE 7

2. Equivalents of the Common Capacity Units Used in the Kitchen

Units	Fluid drams	Tea-spoonfuls	Table-spoonfuls	Fluid ounces	1/4 cupfuls	Gills (1/2 cupfuls)	Cupfuls	Liquid pints	Liquid quarts	Cubic centimeters	Liters	Units
1 fluid dram equals...	1	3/4	1/4	1/8	1/16	1/32	1/64	1/128	1/256	3.7	0.004	Equals 1 fluid dram
1 teaspoonful equals...	1 1/3	1	1/3	1/6	1/12	1/24	1/48	1/96	1/192	4.9	0.005	Equals 1 teaspoonful
1 tablespoonful equals.	4	3	1	1/2	1/4	1/8	1/16	1/32	1/64	15	0.015	Equals 1 tablespoonful
1 fluid ounce equals...	8	6	2	1	1/2	1/4	1/8	1/16	1/32	30	0.030	Equals 1 fluid ounce
1/4 cupful equals......	16	12	4	2	1	1/2	1/4	1/8	1/16	59	0.059	Equals 1/4 cupful
1 gill (1/2 cupful) equals	32	24	8	4	2	1	1/2	1/4	1/8	118	0.118	Equals 1 gill (1/2 cupful)
1 cupful equals	64	48	16	8	4	2	1	1/2	1/4	237	0.237	Equals 1 cupful
1 liquid pint equals....	128	96	32	16	8	4	2	1	1/2	473	0.473	Equals 1 liquid pint
1 liquid quart equals..	256	192	64	32	16	8	4	2	1	946	0.946	Equals 1 liquid quart
1 cubic centimeter equals	0.27	0.20	0.068	0.034	0.017	0.0084	0.0042	0.0021	0.0011	1	1/1000	Equals 1 cubic centimeter
1 liter equals	270	203	67.6	33.8	16.9	8.45	4.23	2.11	1.06	1000	1	Equals 1 liter

APPENDIXES

APPENDIX 1

THE BUREAU OF STANDARDS' RELATION TO THE WEIGHTS AND MEASURES OF TRADE

Ever since its inception in 1901 the Bureau of Standards has taken the greatest interest in the elimination of fraud in commercial transactions. It has done all in its power to assist in establishing proper State and local inspection services over the weights and measures used in trade.

As early as 1902 local investigations of the efficiency of the inspection service in the city of New York were conducted by the Bureau. In 1904 the Bureau conceived the plan of inviting officials, having the custody of the State standards, to meet in Washington to study the weights and measures situation, and the first meeting was held at the Bureau in 1905. A meeting has been held each year since, which is known as the Annual Conference on the Weights and Measures of the United States. These meetings are very largely attended by weights and measures officials, by manufacturers, by representatives of commercial organizations, and other persons interested, and are an important factor in standardizing the laws and practices in relation to weights and measures throughout the country.

In 1909 the Bureau of Standards was authorized by Congress to undertake an investigation of the general condition of the weights and measures in commercial use throughout the United States. Through this investigation deplorable conditions were discovered. Only two or three States and a few of the larger cities maintained at that time any efficient inspection service, and negligence in this regard was costing the consuming public large sums of money and putting a premium on dishonesty in competition. Shortage in weights and measures was found to be a common condition. While there are many manufacturers and merchants who are honest in their dealings, there is another class, who, either through fraud, carelessness, or ignorance, fail to deliver honest weight and measure to the consumer. The inaccuracy of scales and measures in use, and the weights of packages ready for delivery or already delivered confirm this view. The investigation mentioned above showed that every State in the Union was suffering in this respect, conditions being especially bad in those States which were entirely neglecting the subject.

TABLE 8

Summary of Apparatus Examined by Inspectors of Weights and Measures, Bureau of Standards

	Articles tested	Percentage correct or incorrect
Total number of scales tested	10 034	....
Correct	5 535	55.2
Incorrect	4 499	44.8
Total number of weights tested (partly estimated)	12 211	....
Correct	9 792	80.0
Incorrect	2 419	20.0
Total number of dry measures tested	5 656	....
Correct	2 935	51.9
Incorrect	2 721	48.1
Total number of liquid measures tested	2 407	....
Correct	1 761	73.2
Incorrect	646	26.8
Total apparatus of all kinds inspected	30 500	....

Total number of stores visited, 3220

The Bureau's investigation showed that nearly 45 per cent of all the scales tested were 3 or more per cent in error, and when the rapidity with which a tradesman sells his wares is considered, even 3 per cent is a very important consideration; and when it reaches 12, as it did in a number of cases, the loss to the purchaser is a serious one. The honest dealer, as well as the purchaser, suffers from the existence of such fraud, since the possessor of such a fraudulent scale can apparently undersell him and yet actually receive more for his goods.

As an example, it was estimated that the consumers of the country lost annually more than $8 000 000 on short-weight deliveries of one staple article of food.

By framing a model State law and a model city ordinance, by interviewing governors, State legislators, and others on the general subject, and by issuing reports on the conditions found, the keenest interest was aroused. Since that time a large majority of the States and many important cities have passed weights and measures laws and ordinances and as a result of these enactments now have an increasingly efficient inspection service to enforce honesty in weight and measure.

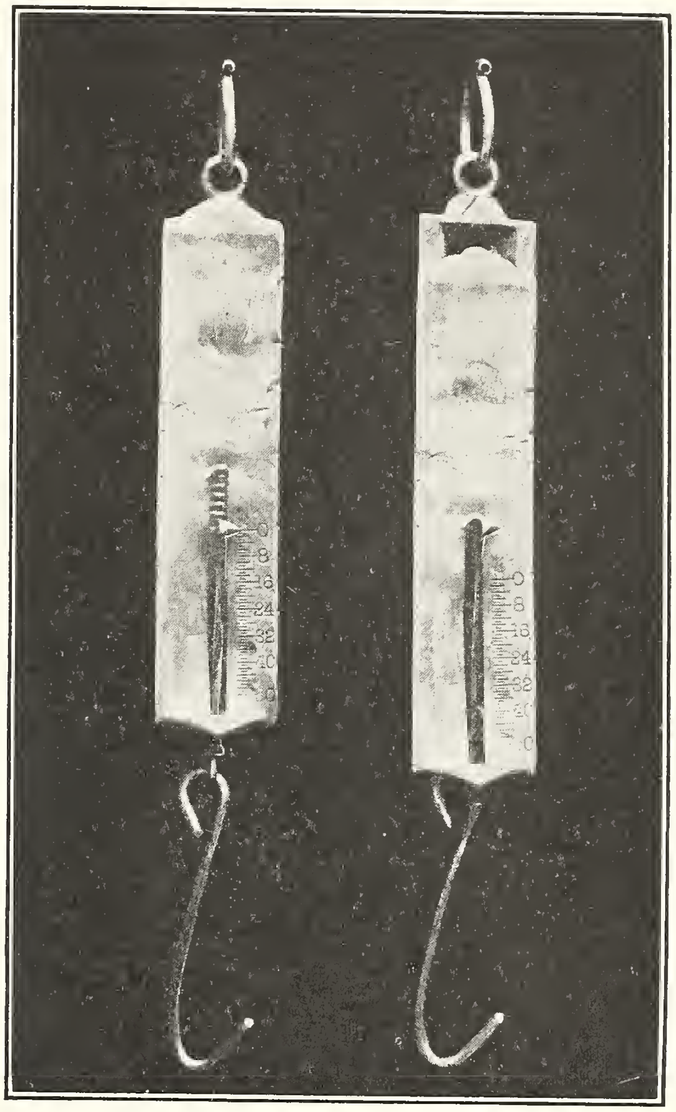


FIG. 61.—*Straight-face spring scale with fraudulent sliding face*

This is used in buying. During the process of weighing the buyer slides the face downward, thus greatly decreasing the indicated weight and defrauding the seller.

The efficient officials of the States and cities realize that the best results can not be expected from the inspection services unless the persons whom they are appointed to protect understand what should be accomplished, and assist and cooperate in revealing bad conditions, and in thus obtaining competent enforcement of the laws. Therefore, any person having evidence of shortage in the weight or measure of commodities purchased should communicate with the local sealer or inspector of weights and measures, where there is such an officer. If it is found that the State or city has not taken an advanced stand in this matter and has no official to take charge of and investigate proper complaints, or has an official who is not inclined to take proper notice of the matters which arise, then a protest against this lack of protection should be lodged with the government of the city or State, coupled with a request that the matter be investigated and steps taken to remedy the condition. The most efficient way to obtain protection is, and should be, by the force of public opinion, and with a sufficient volume of protest, remedial legislation is practically assured.

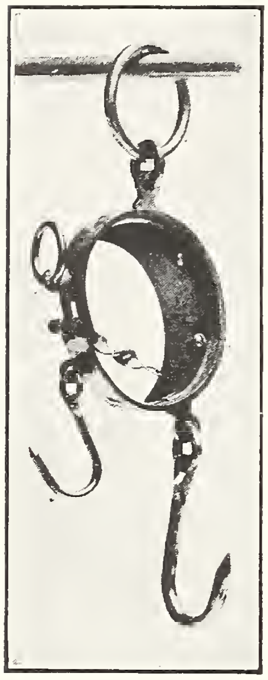


FIG. 62.—"*Crab*" *or "handcuff" scale.*

The large ring, the large hook, and the larger capacity face and the small ring, small hook, and the smaller capacity face, are intended to be used together. By combining these parts incorrectly, results very greatly in error are obtained, the most common method of use resulting in shortages of 25 per cent.

The investigation by the Bureau of Standards and by others has clearly shown that some losses are likely to result from the improper, but not fraudulent, use of some types of relatively correct apparatus such as would be found in first-class stores. By far the larger individual losses, however, are those resulting from the use of false weights and measures and by intentional cheating, either with false or comparatively correct apparatus.

The methods of cheating and the types of false apparatus exhibit great variety. (See Figs. 7, 9, 11, 61, 62.) Among the different types of false capacity measures may be mentioned those having movable or false bottoms; measures having a portion of the height cut away from either the top or bottom; measures with staves removed and the hoops and bottom adjusted accordingly; "bottomless" measures which have relatively small diameters and high sides, and which—although they may contain the proper number of cubic inches—give incorrect quantities as they do not permit a proper heap; measures with false interiors, such as have been found in milk cans and measures for selling gasoline; and liquid measures used for dry commodities. This last practice is found in use to some extent in practically all parts of the country and results in a shortage of about 14 per cent. It is one of those practices which has come into use largely through "trade custom."

The use of correct scales of high quality is not always in itself a guarantee that correct amounts will be given, for it is possible for the user of correct scales to manipulate them to his own advantage, but fraud is more often committed with apparatus that readily lends itself to that purpose. A type of scale which was formerly common among certain classes of dealers is the straight-face spring scale, designed to be held in the hand, with the graduated face made movable so that the dealer might lower or raise it so as to make the pointer indicate an amount less or greater than the true weight, according to whether he was buying or selling. Some even-arm balances of inferior construction may be made to indicate falsely by placing the weights and commodities in certain positions on the pans. This is done in an apparently unintentional manner by the dealer and would not be noticed by the customer unless he were familiar with the action of such scales. Counter beam scales with a removable scoop and counterpoise may very easily be used fraudulently by omitting the counterpoise when the scoop is in place. These are a few of many ways in which short weights or measures may be given even with apparatus which, upon a casual examination, may appear correct.

False apparatus is sometimes very crude in construction and this may easily be detected upon examination. The users of such apparatus depend to escape detection upon the unsuspecting attitude of the purchaser and their own dexterity in handling the apparatus. In the majority of instances, however, tests with standards are necessary.

79685°—21——10

APPENDIX 2

LEGAL WEIGHTS PER BUSHEL FOR VARIOUS COMMODITIES

On the following pages is given an abbreviated list of the weights per bushel established by law of the various States, and those established by the United States for customs purposes only. A complete list is printed in Circular No. 10 of the Bureau of Standards, only those being given here which are of more common use in the everyday transactions of the household. This list is correct, as established by law, including those passed at the sessions of the various legislatures up to the summer of 1914. Information concerning later revisions of laws as to bushel equivalents may be obtained from State authorities or from a revision of this circular or Circular No. 10. Inquiries directed to the Bureau on this and other related subjects will receive attention.

TABLE 9

Selected List of Legal Weights (in Pounds) of the Bushel of Various Commodities

	Apples									Corn [1]									
	Apples [2]	Dried apples	Barley	Beans [2]	Beets	Blue-grass seed	Buckwheat	Carrots	Clover seed	Corn [2]	Shelled corn	Corn meal [2]	Cotton seed [2]	Cranberries	Cucumbers	Flaxseed (linseed)	Hemp seed	Hungarian grass seed	Indian corn or maize
United States			[3] 48				[3] 42			[3] 56		[3] 48				[3] 56			
Alabama		24	47	60							56		32						
Arizona			45	55						54									
Arkansas	[4] 50	24	48	60		14	52		60		56	48	33⅓			56			
California			50				40												52
Colorado			48	60		14	52		60			50					44		56
Connecticut	48	25	48	60	[5] 60		48	50	60			50	[6] 44			55			56
Delaware												[7] 44							56
District Columbia																			
Florida	[4] 48	24	48	[8] 60							56	48	[9] 32						
Georgia		24	47	[10] 60		14	52		60		56	48	30			56	44		
Hawaii			48																56
Idaho	[4] 48	24	48	60	56	[11] 14	50	50	60		56					56	44	50	[15] 70
Illinois	[4] 50	24	48	[10] 60	60	14	52	50	60		56	[12] 48	32	33	48	56	44	50	56
Indiana		25	48	60		14	50		60		56	50		33			44		
Iowa	48	24	48	[13] 60	56	14	48	50	60	[14] 50	56	48			48	56	44	50	
Kansas	[4] 48	24	48	60	56	[11] 14	50	50	60		56					56	44	50	[15] 70
Kentucky		24	47	[10] 60		14	56		60		56	50				56	44	50	
Louisiana			48							56									
Maine	44		48	60	60		48	50		56		50							
Maryland	[4] 50	28	48	60		14	48	50	60		56	48				56	44	50	
Massachusetts	48	25	48	60	60		48	50	60		[17] 50	50	[6] 44	32		55			56
Michigan	48	22	48	60		14	48		60		56	50		40		56	44	50	
Minnesota	[4] 50	28	48	60	50	14	50	45	60		56			36			50	48	
Mississippi		26	48	[10] 60		14	48		60		56	44	[6] 32			56	44	50	
Missouri	48	24	48	60		14	52	50	60		56	50	33		48	56	44	48	
Montana	45		48	60	50	14	52	50	60		56	50				56	44	50	
Nebraska	[4] 48	24	48	[10] 60	56	[11] 14	50	50	60		56	50				56	44	50	[15] 70
Nevada	[4] 48	24	48	60	56	[11] 14	50	50	60		56	48				56	48	50	[15] 70
New Hampshire	48	25	48	[16] 60	60		48	50	60	[17] 50		50		32		56			56
New Jersey	50	25	48	60	60		50	50	64							55			56
New Mexico	45	24	48	60	56	14	52	50	60		56	50	32		48	56	44	50	56
New York	48	25	48	60			48	50	60			50	[6] 44			55			56
North Carolina	[4] 48		48	[18] 60		14	50		60			48	[19] 30			55	44		56
North Dakota	50		48	60	60		42		60		56					56			
Ohio	48	24	48	60	56		50	50	60		56	48				56	44	50	[15] 68
Oklahoma	48	24	48	60	60	14	52	50	60		56	50	32		48	56	44		
Oregon	45	28	46				42		60										56
Pennsylvania	50	25	47	[13] 60	60	14	48	50	60	58	56	50		40	50	56	44	50	56
Rhode Island	48	25	48	60	50		48	50	60		56	50	[6] 44			56	44	50	
South Carolina												[20] 48	[21] 30						
South Dakota	48	24	48	60	56	14	52	50	60		56	50			48	56	44	50	
Tennessee	[4] 50	24	48	[13] 60	50	14	50	50	[22] 50		56	[7] 50	28		48	56	44	48	
Texas	45	28	48	[10] 60			42		60		56		32			56	44	48	
Utah																			
Vermont	48		48	60	60		48	50	60		56	50		32	48	55		50	56
Virginia		28	48	[10] 60		14	52		60		56	50	32			56	44	48	
Washington	[4] 45	28	48				42		60							56			56
West Virginia		25	48	60			52		60	56			[6] 44			56			
Wisconsin	50	25	48	60	50		50	50	60			50			[23] 50	56	44	48	56
Wyoming																			

1 See also "Indian corn."
2 Not defined.
3 For customs purposes only.
4 Green apples.
5 Sugar beets and mangel-wurzel.
6 Sea-island cotton seed; upland cotton seed, 30 pounds.
7 Bolted; unbolted, 48 pounds.
8 Shelled.
9 Sea-island cotton seed, 46 pounds.
10 White beans.
11 Native blue-grass seed; English blue-grass seed, 22 pounds.
12 Unbolted, 48 pounds.
13 Dried beans.
14 Sweet corn.
15 Indian corn in ear.
16 Small white beans.
17 Cracked corn.
18 Soy beans.
19 Sea-island cotton seed, 44 pounds.
20 Bolted or unbolted.
21 Seed of long-staple cotton, 42 pounds.
22 Red and white.
23 Green.

TABLE 9—Continued

	Millet	Oats	Onions		Orchard grass seed	Parsnips	Peaches[1]	Peanuts (or "ground peas" *)	Pears[1]	Peas		Potatoes		Red top	Rye	Timothy seed	Tomatoes	Turnips[1]	Wheat
			Onions[1]	Onion sets						Green peas, unshelled	Peas[1]	Potatoes	Sweet potatoes						
United States	....	[2] 32	....	....	....	....	....	....	....	....	[2] 60	[2] 60	....	....	[2] 56	....	....	....	[2] 60
Alabama	....	32	....	....	....	....	....	....	....	....	60	60	55	....	56	....	....	55	60
Arizona	....	32	....	....	....	....	....	....	....	....	....	....	....	....	56	....	....	....	60
Arkansas	50	32	57	....	14	....	....	....	....	....	60	60	50	14	56	60	....	57	60
California	....	32	....	....	....	....	....	....	....	....	....	....	....	....	54	....	....	....	60
Colorado	....	32	57	....	....	....	....	....	....	....	....	60	....	....	56	45	....	....	60
Connecticut	....	32	52	....	....	45	....	....	....	....	60	60	54	....	56	....	....	[3] 50	60
Delaware	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	60
District of Columbia	....	....	....	....	....	....	....	....	....	....	....	60	....	....	....	....	....	....	....
Florida	50	32	56	....	....	....	[4] 54	22	60	....	....	60	60	....	56	....	....	54	60
Georgia	....	32	57	....	....	....	....	*25	....	....	60	60	55	....	56	45	....	55	60
Hawaii	....	32	....	....	....	....	....	....	....	....	....	....	....	....	56	....	....	....	60
Idaho	50	32	57	....	....	50	48	....	....	....	[5] 60	60	50	....	56	45	56	55	60
Illinois	50	32	57	[6] 30	14	50	48	[7] 20	58	32	[8] 60	60	50	14	56	45	56	55	60
Indiana	50	32	48	....	14	55	....	....	....	....	....	60	55	....	56	45	....	55	60
Iowa	50	32	52	[6] 28	14	45	48	22	45	50	[8] 60	60	50	14	56	45	50	55	60
Kansas	50	32	57	....	....	52	48	....	....	....	[5] 60	60	50	....	56	45	56	55	60
Kentucky	50	32	57	[9] 36	14	....	....	*24	....	....	60	[10] 60	55	....	56	45	....	60	60
Louisiana	....	....	....	....	....	....	....	....	....	....	....	....	....	....	56	....	....	....	60
Maine	....	32	52	....	....	45	....	....	....	....	60	60	....	....	50	....	....	[3] 50	60
Maryland	[11] 50	32	54	....	14	....	[12] 40	22	....	....	[13] 60	60	60	14	56	45	60	60	60
Massachusetts	....	32	52	....	....	45	48	[7] 20	58	28	[14] 60	60	54	....	56	45	56	55	60
Michigan	50	32	54	....	14	....	....	....	....	....	60	60	56	14	56	45	....	58	60
Minnesota	48	32	52	....	14	42	....	....	....	....	60	60	55	14	56	45	....	....	60
Mississippi	50	32	57	....	....	....	....	*24	....	....	60	[10] 60	54	....	56	45	....	55	60
Missouri	50	32	57	[15] 28	14	44	48	....	48	56	[16] 60	60	56	14	56	45	45	[3] 42	60
Montana	....	32	57	....	....	50	....	....	45	....	60	60	....	....	56	45	....	50	60
Nebraska	50	32	57	25	....	50	48	....	....	....	[5] 60	60	50	....	56	45	56	55	60
Nevada	50	32	57	....	....	50	48	....	....	....	[5] 60	60	50	....	56	45	56	56	60
New Hampshire	....	32	52	....	....	45	48	[7] 20	58	....	60	[10] 60	54	....	56	45	56	55	60
New Jersey	....	30	57	....	....	....	50	....	....	....	60	60	54	....	56	45	....	....	60
New Mexico	50	32	57	[6] 30	14	42	48	22	48	....	60	60	50	....	56	45	50	56	60
New York	....	32	57	....	....	....	....	....	....	....	60	60	54	....	56	45	....	....	60
North Carolina	50	32	57	....	14	....	....	22	....	....	60	[10] 56	56	14	56	45	....	50	60
North Dakota	50	32	52	....	....	....	....	....	....	....	60	60	46	....	56	45	....	60	60
Ohio	50	32	56	28	....	50	48	....	....	....	60	[10] 60	50	....	56	45	56	60	60
Oklahoma	50	32	57	[15] 28	14	44	48	22	48	56	60	60	55	14	56	45	45	[17] 60	60
Oregon	....	32	....	....	....	....	....	....	45	....	....	60	....	....	56	....	....	....	60
Pennsylvania	50	32	50	28	14	50	48	22	50	56	60	60	54	14	56	45	60	60	60
Rhode Island	50	32	50	....	....	50	48	....	....	....	[18] 60	60	54	....	56	45	56	50	60
South Carolina	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
South Dakota	50	32	57	[6] 32	14	42	48	20	....	50	60	60	46	14	56	45	50	55	60
Tennessee	[19] 50	32	[20] 56	[21] 28	14	50	[22] 50	23	[23] 56	30	60	60	50	14	56	45	56	50	60
Texas	50	32	57	....	....	....	50	....	....	....	....	60	55	....	56	45	55	55	60
Utah	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Vermont	50	32	52	....	....	45	48	[7] 20	58	48	60	60	54	14	56	45	56	60	60
Virginia	50	30	57	28	14	....	....	22	....	....	[24] 60	56	56	12	56	45	....	55	60
Washington	....	32	....	....	....	....	....	....	[18] 45	....	....	60	....	....	56	....	....	....	60
West Virginia	....	32	....	....	....	....	....	....	....	....	....	60	....	....	56	45	....	....	60
Wisconsin	50	32	57	....	....	44	....	....	....	....	60	60	54	....	56	45	....	42	60
Wyoming	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

1 Not defined.
2 For customs purposes only.
3 Common English turnips.
4 Green peaches.
5 Shelled, dry.
6 Top sets; bottom sets, 32 pounds.
7 Roasted; green, 22 pounds.
8 Dried.
9 Bottom onion sets.
10 Irish potatoes.
11 German and American.
12 Peaches (peeled); unpeeled, 32 pounds.
13 Cowpeas; dried peas, 60 pounds.
14 Smooth; wrinkled, 56 pounds.
15 Top onion sets.
16 Including split peas.
17 Common English turnips, 42 pounds.
18 Green.
19 German, Missouri, and Tennessee millet seeds.
20 Matured onions.
21 Bottom onion sets, 32 pounds.
22 Matured.
23 Matured pears, 56 pounds; dried pears, 26 pounds.
24 Black-eyed peas.

APPENDIX 3

TABLES OF WEIGHTS AND MEASURES

Apothecaries' Fluid Measure

60 minims = 1 fluid dram
8 fluid drams = 1 fluid ounce
16 fluid ounces = 1 liquid pint
8 liquid pints = 1 gallon
(British measures differ from above)

Apothecaries' Weight

20 grains = 1 scruple
3 scruples = 1 dram
8 drams = 1 ounce
12 ounces = 1 pound

Avoirdupois Weight

27 11/32 grains = 1 dram
16 drams = 1 ounce
16 ounces = 1 pound
25 pounds = 1 short quarter
28 pounds = 1 long quarter
4 quarters = 1 hundredweight {short hundredweight = 100 pounds; long hundredweight = 112 pounds}
20 hundredweight = 1 ton {short ton = 2000 pounds; long ton = 2240 pounds}

Circular Measure

60 seconds = 1 minute
60 minutes = 1 degree
90 degrees = 1 quadrant
4 quadrants = 1 circle or circumference

Cubic Measure

1728 cubic inches = 1 cubic foot
27 cubic feet = 1 cubic yard
144 cubic inches = 1 board foot
128 cubic feet = 1 cord

Dry Measure

2 pints = 1 quart
8 quarts = 1 peck
4 pecks = 1 bushel
1 barrel (for fruit, vegetables, and other dry commodities) = 7056 cubic inches = 105 dry quarts

Kitchen measures. See Section 12, pages 137–138

Linear Measure

12 inches = 1 foot
3 feet = 1 yard
5 1/2 yards = 1 rod or pole
40 rods = 1 furlong
8 furlongs = 1 statute mile (1760 yards, or 5280 feet)
3 miles = 1 league

Linear Measures (special)

1000 mils	=1 inch
72 points	=1 inch
4 inches	=1 hand
7.92 inches	=1 surveyor's link
9 inches	=1 span
6 feet	=1 fathom
40 yards	=1 bolt (cloth)
10 chains	=1 furlong
6080.20 feet	=1 nautical mile=1.1516 statute miles

Liquid Measure

4 gills	=1 pint
2 pints	=1 quart
4 quarts	=1 gallon
31 1/2 gallons	=1 barrel
2 barrels	=1 hogshead

Paper Measure

For small papers the old measure is still in use:

24 sheets	=1 quire
20 quires	=1 ream (480 sheets)

For papers put up in cases, bundles, or frames the following measure is now used:

25 sheets	=1 quire
20 quires	=1 standard ream (500 sheets)

Square Measure

144 square inches	=1 square foot
9 square feet	=1 square yard
30 1/4 square yards	=1 square rod or perch
160 square rods	=1 acre
640 acres	=1 square mile
36 square miles	=1 township (6 miles square)

Surveyor's Measure

7.92 inches	=1 link (Gunter's or surveyor's)
100 links	=1 chain (=66 feet)
80 chains	=1 mile

Surveyor's Area Measure

625 square links	=1 (square) pole or square rod
16 (square) poles	=1 square chain (surveyor's)
10 square chains or 160 square rods	=1 acre
640 acres	=1 square mile
36 square miles	=1 township

Time Measure

60 seconds	=1 minute
60 minutes	=1 hour
24 hours	=1 day
7 days	=1 week
365 days	=1 year
366 days	=1 leap year

Troy weight

24 grains	=1 pennyweight
20 pennyweights	=1 ounce
12 ounces	=1 pound (Troy)

Carat (for precious stones)=200 milligrams. The carat was formerly an ambiguous term having many values in various countries.

Karat (fineness of gold)=1/24 (by weight) gold. For example, 24 karats fine=pure gold; 18 karats fine=18/24 pure gold.

International Metric System

In the international metric system the fundamental unit is the meter—the unit of length. From this the units of capacity (liter) and of weight (gram) were derived. All other units are the decimal subdivisions or multiples of these. These three units are simply related; e. g., for all practical purposes 1 cubic decimeter equals 1 liter and 1 liter of water weighs 1 kilogram. The metric tables are formed by combining the words "meter," "gram," and "liter" with the six numerical prefixes, as in the following tables:

Prefixes			Meaning		Units
milli-	=	one thousandth	$\frac{1}{1000}$	0.001	"meter"[a] for length
centi-	=	one hundredth	$\frac{1}{100}$	.01	
deci-	=	one tenth	$\frac{1}{10}$	.1	
Unit	=	one		1	" gram "[a] for weight or mass
deka-	=	ten		10	
hecto-	=	one hundred		100	
kilo-	=	one thousand		1000	"liter"[a] for capacity

[a] One meter=39.37 inches; 1 liter=1.0567 liquid quarts: 1 gram=0.035 avoirdupois ounce.

UNITS OF LENGTH			UNITS OF CAPACITY			UNITS OF WEIGHT (OR MASS)		
millimeter=	0.001	meter	milliliter=	0.001	liter	milligram=	0.001	gram
centimeter=	.01	"	centiliter=	.01	"	centigram=	.01	"
decimeter=	.1	"	deciliter=	.1	"	decigram=	.1	"
METER=	1	"	LITER=	1	"	GRAM=	1	"
dekameter=	10	"	dekaliter=	10	"	dekagram=	10	"
hectometer=	100	"	hectoliter=	100	"	hectogram=	100	"
kilometer=	1000	"	kiloliter=	1000	"	kilogram=	1000	"

UNITS OF AREA

The table of areas is formed by squaring the length measures, as in our common system. For land measure 10 meters square is called an "ARE" (meaning "area"). The side of one are is about 33 feet. The hectare is 100 meters square, and, as its name indicates, is 100 ares, or about 2 1/2 acres.