DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 70

MATERIALS FOR THE HOUSEHOLD

[1st Edition]
Issued December 5, 1917

PRICE, 25 CENTS
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MATERIALS FOR THE HOUSEHOLD

INTRODUCTION

Purpose and Scope

This circular describes the more common materials, other than foods and drugs, used in the home. A previous circular in this series described household measurements and a third circular (now in preparation) treats of household safety. The present circular relates to the quality and use of materials. While written primarily for the household, it may incidentally interest dealers in materials for the household, who should be in close touch with its needs, and teachers of home economics who are training future home makers in scientific home management.

The purpose of the circular is practical—(1) to stimulate the interest in household materials, (2) to explain the nature of their desirable properties, (3) to aid in their intelligent selection, and (4) to promote their effective use and preservation. A better utilization of materials will aid the efficient administration of the home and promote the health and comfort of the household. Home economics is of growing interest at this time. The subject is of universal and permanent concern, and when its importance is realized it must become a factor of primary importance to national well-being. The excellent instruction in the subject now given in high schools and colleges begins a new era in home management.

This circular is intended as a contribution to the growing literature in this field, prepared by the several departments of the Government. For each material the circular follows a general outline—composition and definition, sources, properties, uses, tests, preservation, hints as to selection and use, and references to the literature for those who desire further study. For convenience the materials are grouped according to subjects. The concluding chapter on "Quantity in the purchase and use of materials" is of special importance to the buyer.

Uses of Materials

The uses of materials are many: Paints preserve materials; building materials maintain structural shape; colorants and furnishings adorn the home; piping and wiring carry electricity, gas, and water; fuses and rods protect from fire and lightning; fuels and food are energy sources; flexible materials—textiles, rubber, and leather—serve as clothing; cleansers beautify and make sanitary the dwelling, attire, and person. Some materials are used for chemical effects—oxalic acid decolorizes inks; other materials for physical effects—blueing in laundry water whitens yellowed fabric, the blue and yellow blending as white. Again, color has economic value—cream walls and white ceilings diffuse light, and thus give brighter interiors without increase of cost. A given material has many properties, which we separate for study, but which act as a complex unit in practice. The economic value of any given property depends upon its relative effect on the net efficiency of the material for a given purpose. For a given need some properties are useful, others neutral or deleterious. Hence, most household materials are a compromise. Window glass is fragile as well as transparent and is used instead of celluloid, which is tough but has the fault of being combustible and less transparent.

The makers of household materials must (1) accurately gage household needs, (2) find properties to meet those needs, and (3) combine in convenient form materials having those properties. We need to light the fire, for example, and to meet this simple need men have brought the common match to its present effective size and make-up. To meet the household need for cleansing, soap is now made as liquid, paste, powder, or cake—forms easily handled—and of compositions effective for the purpose. The best combination of properties in a material viewed for a given purpose is found by test or trial.

Selecting Household Materials

The buyer rarely knows accurately how to select from available market supplies the best for a given need. He reads advertisements, false and true alike. If misled, he distrusts advertising and may regard the interested salesman as biased. The buyer thus may ignore printed data from reliable firms or disregard advice of experienced merchants. Under these conditions economic buying is a matter of chance, and expensiveness easily becomes the popular test of quality. This tendency is not discouraged by merchants, to whom it is a matter of business to encourage a pecuniary standard of quality, thus neutralizing the buyer's desire for economy. Expensiveness is often made the test even of good taste, which again sets up a false standard of value.

Standards of Quality for Household Materials

It must, then, be admitted that the average buyer can not select the "best value" in materials in return for the money available. In this circular some advice is given on the choice of materials for household use based upon their utility. Standards of quality which the ordinary buyer can specify in terms which admit of verifying exist in very few cases. Even the salesmen may lack data to assure the buyer of the quality. Again, some simple home tests of materials are given. As in the case of silk and wool, however, laboratory tests which would be convincing are not available to the casual buyer. The strength of thread may be found, roughly, on a spring balance, showing how many pounds it will support. The more complex quality of a cloth—its composition, durability, and the hue and fastness of color—is less easily tested. Adequate tests can be made only in the laboratory or by exposure to service conditions. If reliable home tests are not given, buying of local "reliable dealers" is an alternative. These must be learned from common repute or experience. The buyer also may buy reputable staple brands. This may not be economy, but it is some safeguard as to stability of quality. There is no certainty, however, that the quality will improve with the progress of the art. On the contrary, raw materials often become costly, and expense leads to lowered quality, as also to lowered quantity. "As good as ever" is of doubtful value as an advertising catchword in a time when technical progress is so rapid. As industry progresses with the application of labor-saving methods, more suitable materials, automatic machinery, and cheap power, the consumer should expect improved quality at lowered prices.

Attention is called to this situation to emphasize the growing need and demand among intelligent buyers and reputable manufacturers for genuine standards of quality so clearly specified and understood as to leave no incentive to misbrand. Clearly, official standards of quality recognized alike by the Government, manufacturers, dealers, and users would be a just basis to secure and maintain quality, prevent disputes, encourage the use of superior materials, and stimulate their steady improvement.

Properties of Materials

Materials are practically the vehicles of certain properties which make them useful. Many of the simpler properties are matters of common knowledge. The *sweetness* of sugar, *sourness* of acid, and the *fragrance* of flowers are examples. *Elastic* materials resist permanent change of form; glass and steel are as truly elastic as rubber. *Plastic* bodies lack elasticity. Soft clay is plastic, easily molded. *Rigidity* prevents change of shape, *mobility* permits easy change of shape, and *viscosity* permits only slower changes of shape. Iron is rigid, mercury mobile, molasses viscous. *Hardness* resists abrasion or indentation. A diamond because of its hardness can cut glass. The *malleability* of gold allows it to be beaten into sheets of foil. A *ductile* metal like copper may be drawn into fine wire. Many useful properties are complex and well known only to the specialist, such as magnetic permeability, elastic *hysteresis*, electrical and thermal *conductivity*, *reflectivity*, and *absorption*. Such complex properties are utilized by the specialist in providing for many of the household needs.

The varied uses of properties of materials is a matter of much interest to the student. The improvement in household articles and services is mainly through the scientific application of such properties. The efficient tungsten lamp was developed by selecting the most *refractory* of metals. Illuminating engineering takes into account the specific absorption and reflection of various colorants. The uses of other properties are more obvious. *Porosity* is essential to the porcelain filter. By *capillarity* a blotter absorbs ink and a lamp wick draws up oil. *Transparency* is applied in spectacle lenses, but *opacity* is used in a new kind of eyeglass which is made opaque to certain invisible and injurious parts of sunlight. Opacity is required for bottles to hold materials injured by light, and translucency is useful in lamp shades and skylights. *Divisibility* is needed when powdered consistency is desired, as in flour, talcum, and confectionery sugar. Lightness is often prized in food materials like whipped cream. *Lightness* is useful for portable utensils, *heaviness* for window weights; hence, aluminum is used for the one, iron for the other.

Making Up Household Materials

The householder's problem is the intelligent buying of materials or making them from specification or recipe. Both require some knowledge of the properties of materials. If such knowledge were complete, any given need could easily be met. In devising a recipe, for example, the final quality desired is built up by combining known properties, somewhat as a printer combines types from his case in setting a form. Each ingredient is added with a view to a characteristic desired in the finished material. It is well to know the effect of each ingredient, even in a ready-made article. Shoe blacking tends to become dry; glycerin will keep it moist. If polishing is difficult, wax will improve it. Such knowledge of the purpose of the ingredients will aid in using and keeping the article in good condition. Each ingredient has its function, either to add a useful property or neutralize an undesirable property in a necessary ingredient. The recipes in this circular are specially useful where an article costs too much or is not easily obtained and can be easily or cheaply made up. Many families must for economy do without certain materials or make them up in the home.

The subject of household materials is of added interest to the housewife and student from the fact that formerly many such materials were made up in the home. The making of soap, candles, yarns and fabrics, leather, sugar, alkali, wax, tallow, pens, and inks formed an interesting group of the old-time household industries. In fact, most modern industries are the outgrowth of what were originally household industries. The modern factory has replaced these home industries, and some social control over the quality and price of factory-made products is beginning to be felt through agencies such as the consumers' leagues, cooperative societies, publicity in the public press, misbranding laws, Government control, and the like.

The section on wood was furnished through the courtesy of the Forest Service. (See footnote on p. 28.)

The Bureau would welcome any suggestions which would be useful in revising the circular for the second edition. Progress is being made in many of the lines treated, and it is hoped to incorporate new material in later editions.

I. STRUCTURAL MATERIALS

1. CLAY PRODUCTS

Clay products constitute an important part of the home, both with reference to the dwelling proper and its furnishings. This has been so from the earliest times, when the housewife performed the work of the artisan, molding the crude clay by hand and burning the bowls in improvised kilns.

The strength of well-burned clay bricks, their durability, their fireproof quality, the ease with which they are laid up into walls, and their decorative qualities render them an exceedingly valuable building material. Other structural materials made from clay, such as terra cotta, roofing tiles, floor tiles, and wall tiles, contribute toward the attractiveness and individuality of the home. Modern sanitary requirements are satisfied by bathroom furnishings and other ceramic materials. For culinary purposes clay cooking ware is available and attractive to the housewife, since it appeals to her esthetic sense, and she has at her command a rich variety of tableware decorated in many ways and styles.

(*a*) Pottery

The housewife makes use of several kinds of clay utensils, both for utilitarian and decorative purposes. She uses cooking ware as well as tableware, flower pots, jardiniers, and art pottery of all kinds.

Porcelain.—Cooking ware consists essentially of a special type of stoneware body upon which a hard glaze is applied. It can only be examined by inspections for crazing, blisters, flaws, and similar defects. Slight defects like small pinholes are of no consequence. Like all good clay ware, it should give a clear sound when struck. After all, confidence must be placed in the name of the manufacturer, and the final proof of quality must be produced by service. Since a great deal of such ware is subjected to more or less abuse, failure under adverse conditions does not necessarily indicate poor quality. Cooking ware is not intended to be heated suddenly like metallic articles. It should always be heated up as gradually as possible before being subjected to the highest temperature. Likewise, heated ware of this sort should not be suddenly cooled in cold water, as this invariably leads to peeling of the glaze as well as cracking. Clay cooking ware is not used to such a great extent in the United States as it is in Europe, and hence its domestic importance is less.

WHITE TABLEWARE.—There are practically only two classes of white tableware—porcelain or china and white ware or earthenware. The difference between these two classes is to be sought in the fact that the porcelain is invariably vitreous, absorbs no water, and is translucent. White ware, on the other hand, possesses a porous body. When the glaze is chipped off, it will be found to absorb readliy ink or any other liquid. Likewise, it is not translucent. The property of nonabsorption and the translucency observed when a light is placed behind the article are therefore the two criteria of porcelain and china. The terms "semiporcelain" or "semichina," sometimes employed by dealers, have no meaning, since the kind of ware so designated is simply white or earthenware and has no claim to be considered a form of porcelain.

When a plate or similar article is chipped on the edge or broken, the housewife can readily apply a simple test by putting ink on the fracture. If the fluid is readily absorbed and the spot can not be washed off, the article is undoubtedly white ware. It will also be observed that the ink will then flow into the pores of the body beneath the glaze, so that a dark spot appears. But, of course, there are different porcelains, and there is also some difference, though not so marked, between various makes of white ware. As a general proposition it might be said that white ware is less fragile than porcelain and china, and hence stands up more sturdily under severe service, as in restaurants and hotels.

We may distinguish four types of porcelain—(*a*) American porcelain; (*b*) the English bone china; (*c*) the Austrian, Danish, French, German, and Swedish hard porcelains; and (*d*) the oriental porcelains.

The American type is a development of our white ware in which more fluxing material (feldspar) has been added, so that in the first firing the body burns to a hard, nonabsorbing, and translucent mass. The first burning, therefore, is carried high enough to perfect the body to its ultimate hardness and density. In the second firing the glaze is fused onto the ware, but the temperature is not carried so high as on the first burning.

The English bone china differs radically in composition from the American type, inasmuch as a large amount of finely ground calcined bone is added to the mixture. This type of porcelain is also fired to its finishing temperature in the first firing, and a comparatively very fusible glaze is fused on at a much lower temperature. Both the American and the English processes have this procedure in common, although in this country we employ a less fusible and harder glaze. The bone ash used in the British china imparts to the body a characteristic structure and a delicate creamish color admirably suited for decorating, especially with gold.

The method of firing the Austrian, French, German, and oriental porcelains differs radically from those mentioned before. The ware is first fired at a very low temperature (biscuited), and the glaze is fused on at the same temperature at which the body becomes dense and vitrified. At the same time the final temperature is very much higher than is the case with the American and English porcelains. As a result, the glaze used is exceedingly hard and becomes more or less a part of the body, fusing into the latter to a considerable degree. This, probably, is the main point of superiority of the European hard porcelains, since glazes as a rule are the harder the higher the temperature at which they are fused on to the body. This is the reason why ladies prefer to use European hard porcelain for overglaze decorating, since the glaze does not become "sticky" at the mild temperature of their ovens, as is apt to be the case with American and English porcelains. The highest kiln temperatures are employed in the manufacture of the Danish and Swedish porcelains, which are remarkable for the hardness of their body and glaze.

In firing the oriental porcelain a low biscuit and a high glazing temperature are employed, as in the case of the European continental porcelains, but the finishing temperature is considerably lower, since the body is made to vitrify at a lower temperature and the glaze is more fusible. It might be said that the Chinese and Japanese porcelains assume somewhat more the characteristic of a hard glass. As to the relative qualities of the four types of porcelain mentioned, it might be said at once that the English bone china and the typical oriental porcelain are the most fragile. In addition, the soft glaze of the English product causes it to be more susceptible to attack in being washed in hot water containing soda, which is present in most cleaning compounds, and to the wearing and abrading to which it is subjected in daily use. The comparatively high price, however, restricts it use to the more decorative function to which its beauty entitles it. One disadvantage under which the American porcelain labors as compared with the hard European porcelain is its softer glaze. In toughness of body and resistance to shocks the best American product is certainly not excelled by the highly vitrified ware of Europe. In color the European porcelain is somewhat superior, it being a bluish white, compared with the more creamish white of the American product. In part this is due to the more fusible glaze employed by American potters and in part to the method of firing. Our manufacturers, however, are progressing rapidly, and by changes in their glaze not difficult to make, they will soon produce ware the equal if not superior of the foreign pottery.

Art Ware.—With reference to the decoration of American porcelain, two methods must be distinguished—under and over glaze decoration. The former is applied directly upon the body of the ware and is burned in at the high temperature of the biscuit fire. The glaze is applied over the decoration and fused on in the second burn. Similarly, in European porcelain the decoration is applied on the soft burned biscuit and fixed in the high-temperature glaze fire. Underglazed decoration, being entirely covered by the glaze, results in softer, more subdued effects and seems to satisfy the modern demands for excellent tableware. Overglaze decoration, as the name implies, is applied over the glaze and necessitates a third burn at a low temperature. The decorating of china as practiced by ladies belongs to this category. Owing to the low firing temperature, a very rich scale of colors is available and makes possible also the use of relief decoration by means of pastes. It might be stated also that all gold decoration must be so applied, which invariably makes necessary the third firing when gold is used.

Two kinds of gold decoration must be recognized—the so-called matt and the liquid bright gold. The former consists of almost pure gold, which comes from the kiln brown in color and must be burnished to cause the gold to appear. It possesses invariably the rich yellow color characteristic of gold and is also the more lasting. The liquid bright gold does not contain so much of the pure metal but comes from the oven bright, requiring no burnishing. It may be recognized by its greenish hue and its greater transparency. It is not so durable as the matt gold.

Overglaze decoration burned on at too low a temperature or obtained with unsuitable colors may be detected by moistening the surface with a dilute muriatic-acid solution, which blurs and sometimes destroys the design.

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The decoration of American porcelain has made large strides within the last few years and has reached a state of perfection and dignity which makes it the equal of the imported pottery. Both as to general quality and beauty our domestic tableware occupies a high rank, and it is to be hoped that the custom of buying European pottery, simply because of its foreign trade-mark, will give way to a more patriotic pride in American achievements and products.

American white ware, the better grades of which are sometimes known as white granite ware, compared with European products of the same class is, without doubt, distinctly superior, since both its body and its glaze are harder than is the case with the English and German pottery. White ware, whatever its origin, is invariably fired to a higher temperature in the first or biscuit burn and to a lower temperature in the glaze burn.

In purchasing white-ware pottery it should be realized that a very porous body—say, one showing an absorption of 7 and more per cent—is undesirable, not only on account of its porous character but also because such ware is subject to hair cracking or crazing. White ware possessing an absorption of about 4 per cent would seem most desirable. It has been proposed to test white-ware pottery with reference to its tendency to craze by heating it gradually in an oven to a temperature of 360° F (182° C) and then plunging the piece in cold water. If upon five such quenchings no crazing develops after several days, the ware may be considered of good quality. This test has not been verified sufficiently to recommend its general adoption, since it has not yet been established whether the temperature given is a fair one for all cases. This much can be said, however, that any ware resisting this test gives promise of being a very satisfactory material. Besides the hair cracking of the glaze, such defects as peeling off of the glaze, blisters and bubbles, dull or roughened surfaces, blurred or discolored lines, lack of clearness of the glaze, dark specks in the body, and yellowish or grayish tinge of the glaze must be looked for. All good ware gives a clear, bell-like sound when struck.

With reference to such products as art ware, practically the same remarks apply which were made in the preceding paragraph. Obvious technical defects detract from the value of an artistic object. A crazed glaze is not desirable, no matter how beautiful the color or texture may be. It might be stated that some vases decorated with a matt, nonglassy glaze do not hold water. It is not advisable to allow certain types of matt glaze to come into contact with acids, such as vinegar, since they are apt to be attacked. The vast majority of glazes are unaffected by any common chemical agent. The quality of common flowerpots can readily be judged by inspection and by sound.

(*b*) **Enameled Ironware**

Much enameled cast sheet steel is now being used for cooking ware (granite ware) and enameled cast-iron for sanitary articles such as washbasins and bathtubs. Although the quality of the ware can be judged somewhat by the appearance; by the absence of roughness, blisters and bubbles, and bare spots; and by gloss and freedom from hair cracks and peeling, the real resisting quality can not be readily determined by the housewife except by use. Enameled ware readily roughened by the application of diluted vinegar should be under suspicion. The question as to whether the enamel sets free such injurious substances as lead and antimony can be determined only by the chemist. The use of either of the above metallic oxides should be prohibited for cooking ware, though allowable in sanitary ware. Care should be taken to prevent contact of acids of all kinds, including vinegar, with enameled surfaces. On no account should bathtubs and basins be cleaned with acids, but soda or alkaline cleaning compounds should invariably be used. A simple test of enameled ware consists in applying either black or red ink to the surface and allowing it to dry. Upon washing it off with clear water no faint stain should be left.

(*c*) **Structural Clay Products**

Brick.—Bricks are made from clays or pulverized shale by three principal methods. They may be made by pressing the soft clay by hand into wooden molds or by means of a machine closely imitating this procedure. This process is called the soft-clay method, because the clay thus molded contains a large percentage of water. The bricks so made are very porous and often can not be made dense even by hard burning. This, however, does not detract from their durability, as is evidenced by the remarkable resistance to weathering of medieval structures. The texture of soft molded bricks is pleasing and together with the characteristic red color contrasts pleasantly with the green of the landscape. The early colonial residences and churches of Virginia afford many fine examples of architecture in which the building material consists of hand-molded bricks.

The second process of brickmaking consists in forcing the clay in a stiff consistency through the die or opening of a machine resembling very closely the ordinary meat or sausage grinder. This machine forms a column of clay the width of which corresponds to the length of the bricks and the thickness to the width. By means of wires stretched between a frame this column is then cut into bricks. The amount of water used in this process is very much less than in the first case, and hence this mode of shaping is called the stiff-clay process. This process is especially used in the case of front bricks, since it can be made to produce a characteristic texture and removes the uniform, machine-made appearance which they would otherwise possess. Bricks so treated are brought on the market under numerous trade names, such as "tapestry," "devonshire," or "rug" bricks. When the color of the bricks is good, this texture undoubtedly contributes largely towards attaining beautiful effects.

The porosity of bricks made by the stiff-clay process is considerably less than for the soft-molded products, owing to the smaller amount of water used in tempering. Still, in spite of the greater density, it is more essential that stiff-molded bricks be burned hard than it is with the first class. Very porous, underburned stiff-molded bricks are more likely to succumb to frost action than the soft-molded products. At the same time a characteristic structure is produced by the action of the auger of the machine—a kind of twisting, resembling the strands of a rope—which is undesirable if it is excessive. Usually, however, it is not an important factor in such building bricks if they are burned sufficiently hard.

The third process of making bricks consists in grinding the raw material to a moist powder and shaping it into the desired form by means of powerful presses. This method is called the dry-press process. It results in perfectly shaped and finished bricks, which are compact and dense. In spite of their density they remain quite porous unless burned hard, owing to the fact that the structure consists of the separate clay grains, compacted simply by pressure but still leaving innumerable small pores between the grains. The amount of water used in this process is very small. If, however, the quantity of water is increased and the clay powder made quite moist, the density of the product is increased still more and at the same time the pore space decreased. This modification is called the semidry process and results in the maximum density it is possible to produce. Both the dry and semidry pressed bricks were in large demand up to 10 years ago, but in recent years the rough-texture stiff-clay products have largely replaced them. The mechanical perfection and finish of the dry-pressed bricks does not appeal to the modern architect, who objects to their smooth regularity and prefers the rough texture and variety of the other kinds of brick.

The bricks, after having been molded by any process, must be carefully dried to expel the water and, finally, must be subjected to the action of the fire in kilns. According to the kind of clay many colors and shades may be produced, Owing to the unavoidable difference in temperature in different parts of a kiln, some bricks remain softer and more porous than others.

The quality of building bricks must be considered from several standpoints. It must be kept in mind that the requirements are necessarily more severe in the case of front bricks than for the cheaper kind used for backing up in the wall. For the latter purpose comparatively soft and porous bricks, which would not be suitable for exposure to the weather, may be used.

Durability of Bricks.—The question of the weather and frost resistance of facing bricks is obviously the most important one. Fortunately it is a quality quite easy to estimate by the most simple means. A well-burned brick when struck with a hammer should give a clear sound, not deadened by soft burning, cracks, or weak structure. A little practice will enable anyone to judge the soundness of the bricks quite satisfactorily. The water absorption likewise may be used as a rough criterion of the quality of the bricks. This test is made in a very simple way, by drying a whole or half brick in an oven, weighing it on a scale, boiling it in water for five hours, allowing it to remain in the water until the latter has cooled to the temperature of the air, and then weighing it again. The absorption of water is then easily calculated by subtracting the weight of the dry brick from the wet weight, dividing this difference by the dry weight, and multiplying the result by 100. This will give the percentage of water absorption. For good facing bricks molded from soft clay the absorption should not exceed 15 per cent and for stiff-molded or dry-pressed bricks the same value should not greatly exceed 10 per cent. This, however, is not a hard-and-fast rule, as some clays, very high in sand or in carbonate of lime, may show higher absorptions and still produce durable bricks. It does, however, cover the majority of the materials of the country, with the exception of some southern and several northern districts. In any case the allowable leeway from the above values should not be more than 3 per cent.

Sometimes very impervious and hard bricks are specified under the term "vitrified bricks." Such materials are, of course, exceedingly durable and are destined to last for generations. All bricks bought as "vitrified" should show an absorption of not more than 4 per cent. Products of this kind bring a higher price on the market and they are worth it. Although the term "vitrification" in its dictionary meaning implies the idea of glassiness, it is ordinarily employed to indicate that the clay has reached a state of great density and imperviousness. The structure, while it may sometimes appear glassy, is usually more of a stony character. It is interesting to reflect how thus, by the agency of heat, the soft clay is again converted into an igneous stone. similar to some of the old plutonic rocks.

If doubt exists as to whether a brick is really weather resistant, a simple but drastic test can be used to determine its durability. This consists in first preparing a concentrated solution of Glauber's salt (sodium sulphate), which may be bought very cheaply. Such a solution is readily made by filling a pail with water at room temperature and placing in it a sufficient amount of the salt so that after standing for several hours, with occasional vigorous stirring, a certain amount of it still remains undissolved. Several half bricks are now dried by heating in any oven at a temperature over 212° F. for several hours and are then immersed in the solution for 12 hours or longer. They are then removed and again dried in the oven, the temperature of which is brought up to about the temperature required in the baking of bread. This drying requires several hours. If the bricks are still uninjured, they are put back into the Glauber's salt solution and allowed to remain there again for 12 hours or longer. After this time they are dried once more in the oven. If necessary this treatment should be repeated until it has been done five times. If the brick is still intact, showing no cracks or crumbling, it may with certainty be considered of good durability and frost resistance. A brick of weak structure will often go to pieces completely or break down to a crumbly mass. This test is very severe, in fact excessively so, but it errs on the safe side as far as the builder is concerned. It is apt to do injustice to some satisfactory but porous bricks. It should, of course, not be employed for common or backing-up bricks but only to those which are to be used as facing material. The test really is a kind of freezing, inasmuch as the dissolved Glauber's salt is absorbed with the liquid into the pores of the bricks and, upon drying out, crystallizes in the interior and at the same time exerts a considerable force tending to disrupt the body. Bricks which are underburned or are inherently weak will break down under this action.

The mechanical strength of bricks can, of course, be determined directly in the laboratory by means of the crushing and transverse tests, but this does not concern the average home builder. It might be said that no bricks, even those used for backing up, should possess a crushing strength below 2000 pounds per square inch, not because this resistance is actually needed, but because the strength is indicative of the desired quality. Well-burned bricks require as high a pressure as 25 000 pounds per square inch to crush them.

For the paving of driveways, hard, vitrified bricks should be employed, laid on a concrete foundation and well grouted with cement mortar. For foundation walls as hard bricks as can be secured should be used, even though their cost is somewhat higher than that of the ordinary run of kiln product. This will assure not only resistance to the destructive effects of the earth but will also prevent the rise of moisture from the ground to the walls of the house. The practice of using soft-burned bricks for chimneys is also very objectionable, as it has been found that the fire gases exert a very destructive action upon underfired material. Well-burned bricks should be used for this purpose.

Color.—The color of bricks may vary from pale to dark red and black or from a cream color to buff and brown. The kind of clay used naturally governs the color obtained, though even with the same clay different colors may be produced. Thus, most red-burning materials will give a dark red when well burned and black when burned very hard. Underburned bricks will usually show a pink or salmon color. Ordinarily buff-burning clays, such as are found in New Jersey, Pennsylvania, Ohio, Indiana, and Illinois, may by very hard burning and smoky firing be made to yield browns and golden shades, speckled with dark spots. Uniformity in color is no longer desired in front bricks, but within certain limits variation is demanded to give a lively appearance to the walls, especially where rough textures are employed.

Discolorations.—Some red bricks, unless they are burned very hard, show occasionally in service a very disagreeable white surface discoloration, called "white wash" (calcium sulphate). This annoying difficulty usually appears when the bricks are laid up in the wall and in very many cases is due to the mortar especially when the mortar contains cement. If it is due to the bricks, it may usually be traced to its source by placing a brick on edge in a pan containing about an inch of pure water, either distilled or rain water. As the brick absorbs the water, it will develop the white discolorations on the top surface after several days if it contains the soluble salts which give rise to the difficulty. Very hard-burned bricks will not discolor under any circumstances. Sometimes bricks show a light discoloration which is produced either in the drying or in the kiln. Such defects are permanent and, of course, readily seen before the bricks are used. The trouble of "white washing" may be entirely overcome by adding to clays subject to it a certain amount of barium carbonate. Owing to the comparatively high cost of this chemical, products so treated command a higher price but at the same time they offer assurance that the discoloration will not appear. Fortunately, in most cases the "white wash" will disappear in time, being washed away by the rains. This is especially true in the case of the white discoloration which appears when salt is mixed with the mortar, a practice which is employed in the winter time to prevent freezing of the mortar. The most common "white washing," that due to the mortar, is more difficult to combat. It may be reduced by waterproofing the joints around the window sills and between the foundation and the walls so that the absorption of moisture from rain and its rise from the ground is greatly diminished. The addition of about 2 per cent of barium carbonate to the cement tends to fix the soluble salts contained in the latter and to render them insoluble, thus tending to remove this cause of discoloration. Where the white efflorescence does appear, it may usually be removed by washing the wall with rain water containing a slight amount of muriatic (hydrochloric) acid and following this by washing again with clean rain water.

Hollow Tiles.—The use of hollow tiles for walls, either alone or in combination with a brick veneer, is growing rapidly in the favor of the building public. These tiles are being used both for bearing and nonbearing walls. In the case of the latter, represented principally by partition walls, hollow bricks also are frequently employed. For the former purpose none but hard-burned tile can be considered, while soft material is well suited for partitions. The tiles for outside walls should be true and straight and free from objectionable cracks and should be well burned, so that they do not absorb more than 10 per cent of their weight of water in the absorption test. No hollow tile should contain any void whose cross section, measured at right angles to the web, is more than 4 inches, and the vertical webs and shells of all tiles used for bearing walls should have a thickness of not less than 15 per cent of the measurements across the void inclosed by such shells or webs.

For a one-story building the thickness of the wall should be not less than 6 inches, for a two-story building 8 and 6 inches, for a three-story building 8, and beyond the second story 6 inches. The laying of tiles with vertical webs is greatly facilitated by the use of strips of wire screen on which the mortar is spread. The use of hollow tile either alone or in conjunction with bricks makes a very desirable residence construction, since the air spaces thus provided reduce very largely any dampness of walls and at the same time cause the house to be warmer in winter and cooler in summer. The combination of bricks for facing and tiles for backing up results in the most satisfactory construction and satisfies the esthetic taste, since it makes possible the use of the texture and color effects obtainable with bricks. Such effects can not be gotten with tiles, which usually require a stucco finish.

Where the considerations of permanency and durability, minimum cost of maintenance, fire and vermin proof qualities, and beauty are given prominence, an all-clay construction is bound to be the most satisfactory in the end. The cost of bricks and tiles in most localities is not high and is not nearly so important an item as is the cost of laying. Tiles are laid up somewhat more cheaply than bricks.

Terra Cotta.—The use of plain or enameled decorative terra cotta, such as is used in the construction of skyscrapers and other larger structures, has been applied to residences only to a small extent. This is due to the fact that the cost of such work seems high at the present time, in spite of the fact that in large structures terra cotta is furnished at remarkably low figures per square foot of surface. In terra-cotta buildings the designs and finish are nearly always original, at least to a large extent, and the plaster molds used in shaping the ware are destroyed after the completion of each job. If architects would cooperate with the manufacturers of terra cotta in standardizing a series of shapes and designs, it might be quite possible to employ this beautiful building material in residence construction and at the same time secure the variation which is desirable. The problems of design and color treatment are those of a skilful architect, and the subject must be handled with care in order to avoid unharmonious and "dowdy" effects. Terra cotta is essentially a kind of heavy tile provided with a ribbed web which can be inserted and fastened into the wall. The surface is either flat or decorated in relief and may be given any desired color, glaze, or enamel. The main essentials are hard burning and a surface not subject to attack by atmospheric agencies. The water absorption of the terra-cotta body should be not more than 12 per cent. Diluted muriatic acid applied on the surface of the enamel should not cause any visible destruction, indicated by roughening, and should bring about no whitish discoloration, which indicates dissolution of the coating. A piece of the terra cotta when tested with the Glauber's solution as described previously should stand up without showing any signs of breaking down.

Tiles.—Tiles, which are essentially thin-walled flat pieces of burned clay of various shapes, may be used in residence construction for many purposes, such as mantle decoration, flooring (especially for bath rooms), for walls, and as a roofing material.

Wall Tiles.—Under this heading come the well-known glazed tiles used in mantles and bathroom and kitchen walls. These are now made in a large variety of colors and textures, both glassy and matt. They afford an ideal aseptic surface, easily cleaned, durable, and resistant to the action of cleaning solutions. The main consideration in this connection is the quality of the glaze. It should be free from the fine hair cracks known as crazing and should have no tendency to show this defect, which sometimes develops after the tiles have been placed in position. This property may be tested by placing several tiles in a concentrated solution of common salt and boiling for three hours. The tiles should be removed from the solution while hot and then cooled. No cracking of the surface should be observed after several days.

Floor Tiles.—Two kinds of floor tiles may be employed—the vitreous kind, which is very hard and practically non-absorbent and is frequently used in the form of mosaics, and the semivitreous kind, usually put down in the form of larger tiles. The second class of tile is often made from a red-burning clay and is then known as quarry tile, which with its pleasing deep-red color lends itself so well to producing a decorative flooring which is agreeable to walk on. Where cleanness and aseptic qualities are essential, the first kind of tiles is the only one to be considered. The water absorption of these vitreous tiles should not exceed 0.5 per cent and that of the quarry tiles 8 per cent.

Roofing Tiles.—The products of this class should possess first of all the requisite weather-resisting qualities and should stand the Glauber's salt test. The water absorption should be not more than 10 per cent. The tiles should possess a clean color and should show no tendency to "whitewash," a point upon which a guaranty should be exacted from the manufacturer.

(*d*) **Sanitary Clay Ware**

With the development of modern sanitary conditions clay products in the form of washbasins, closets, and bathtubs have been introduced. Of this type of ware two types are to be distinguished—true porcelain and the so-called earthenware. The former is a white, thoroughly vitrified and practically nonabsorbent body, which would be translucent if the ware were thin enough. The glaze applied is a hard colorless glass. The second type consists of a porous, buff-colored fire-clay body, which is covered with a thin layer of an opaque porcelain, upon which again a transparent or semiopaque glaze is applied. The true porcelain when chipped will reveal the white, dense body characteristic of this type of ware. A drop of ink, for instance, when applied upon the fracture will not be absorbed but can be readily washed off. In the case of the earthenware goods chipping will show the buff or yellow body, which readily absorbs liquids. For sanitary reasons washbasins and closets should be of true porcelain. The same statement applies also to the linings of refrigerators. In the case of bathtubs the cost of making them of true porcelain is very high, and hence these articles are usually made from the porous-clay body well covered with a porcelain coating and the glaze. When well made, these are very satisfactory and are injured only by gross carelessness.

Sanitary porcelain is inspected principally for defects such as crazing, fine cracks in the body, flaws, blisters, and bare spots. As a rule, American porcelain of this type is extremely well made and is satisfactory and needs no further examination than that of visual inspection. When lightly struck, the article should give a clear and not a deadened sound. The water absorption of this kind of goods should not exceed 1 per cent. Obviously, this test can be made only where a fragment of the same type of ware is available. The above statement referring to visual inspection applies also to the earthenware type.

(*e*) Glass

Glass is used in the home in many shapes, from the common drinking glass to the most expensive cut glass. Here, again, the appearance of the glass, its smoothness, brilliancy, freedom from bubbles and cloudiness, its whiteness, and transparency are the main criteria of quality. Although the chemist has means of detecting inferiority as regards the resistance of the glass toward water and cleaning solutions, these can not be readily applied in the home. Although glass is apparently insoluble in water, this is, strictly speaking, not true. Delicate reagents such as iodeosin or phenolphtalein indicate that alkali is leached out from the glass. The more soluble a glass is, the more easily it becomes rough on contact with liquids. As a rule, alkaline substances like soda attack the glassware more readily than acids.

In the case of cut glass the so-called Weber test may give some information as to the resisting quality of the material. It consists in placing the piece of cut glass under a bell jar together with a small glass containing diluted muriatic acid. After standing for a week the fumes of the acid should not cause any iridescence or rainbow colors on the glass, as this is an indication of solubility.

Great differences exist also in glass as regards its resistance to sudden heating and cooling, depending on the manner of its annealing. Simple tests to determine this quality have not yet been worked out, and the present means of detecting any abnormal condition of the glass by optical means is entirely beyond the scope of home conditions. It is, unfortunately, true that most glass is subjected to very severe treatment in use, being heated and cooled too rapidly.

Fruit jars should be examined with particular reference to clearness and freedom from any dimming, since cheap products of this kind are sometimes not sufficiently insoluble. The alkali leached out from the glass by the juices is sometimes sufficient to interfere with the proper preservation of the canned material.

2. WOOD [1]

Wood has been and is still one of the chief materials used in the construction and furnishing of the home. It has had natural advantages because of the ease with which it can be worked and fastened, because it has sufficient strength and hardness for general purposes, because it is comparatively light in weight, because

[1] Prepared by Arthur Koehler, expert in wood identification, Forest Service, U. S. Department of Agriculture, Forest Products Laboratory, Madison, Wis.

it is a good protection against heat and cold, and because it is pleasing in appearance. These properties, which are due to its peculiar chemical nature and physical structure, have made wood unique among building materials.

An impression seems to be prevalent that the supply of wood is becoming so depleted that in the near future it can be used only for ornamental or special purposes. This is erroneous. We still have enough virgin timber in this country to last for several generations, and with the growing practice of forestry a certain supply will always be maintained, partly by increasing the yield of timber per acre and partly by checking the waste in using the timber. Although the centers of production are being removed farther and farther from the centers of population, freight rates do not make the shipment of lumber across several States prohibitive, wood being a comparatively light material.

(*a*) Structure and Classification of Wood

Cellular Structure.—Wood differs in structure from other materials largely used in the construction of the home in that it is composed of cells. These are minute, hollow, elongated tubes, grown together tightly and mostly closed at the ends, although in the hardwoods some are open at the ends to facilitate the conduction of sap. Many of the properties of wood can be attributed to this cellular structure. Since wood is a porous material, it can be cut with greater ease than if it were a homogeneous solid, and nails can be driven into it, thus affording a simple means of shaping and fastening pieces together. The empty cells act as dead air spaces and retard the conduction of heat and sound, thus making wood admirably fitted for building purposes and furniture. Because of its porous nature, preservatives can be forced into the wood and paint and other finishes will adhere to the surface readily, thus making it possible to prolong the natural life and to increase the beauty of wood.

In woods grown in a temperate climate the cells formed in the spring of the year are larger than those formed later in the season. This differentiates the season's growth into springwood and summerwood. The contrast between the summerwood of one year's growth and the springwood of the succeeding year defines the annual rings. (See Fig. 1.) These alternating concentric bands of springwood and summerwood are responsible for most of the figure in plain oak, chestnut, cypress, yellow pine, and Douglas fir lumber. In other woods, as birch, gum, yellow poplar, and white pine, there is little difference between the spring wood and summer wood (see Fig. 2), and the figure is not so pronounced, although some woods, such as maple and gum, may be figured from other causes.

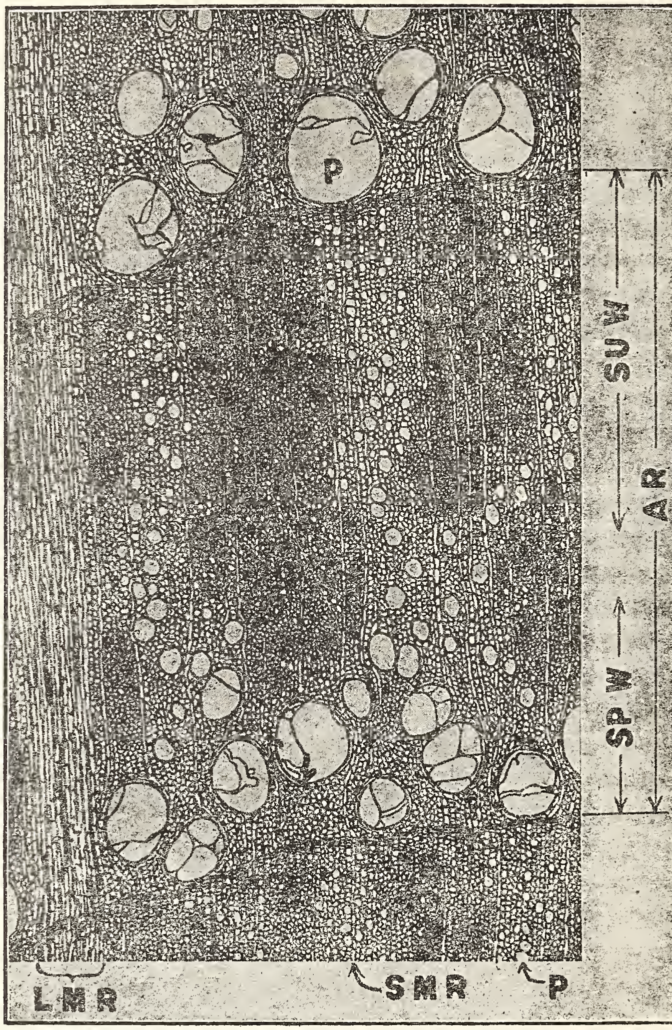

FIG. 1.—*Cross section of white oak*

A ring-porous wood showing *AR*, annual ring; *SPW*, springwood; *SUW*, summerwood; *P*, pores; *LMR*, large medullary ray; *SMR*, small medullary ray. The space not occupied by pores or rays is filled mostly with wood fibers

HEARTWOOD AND SAPWOOD.—Logs of most species show an inner, darker core—the heartwood—and an outer, lighter layer—the sapwood. This difference in color is not always pronounced, however, for in the spruces, true firs, hemlock, cottonwood, tupelo, basswood, and holly the heartwood is little, if any, darker than the sapwood. In some woods, especially the pines and red gum, the sapwood is often stained blue by a fungus which lives on the sap in the cells but does not attack the wood sufficiently to appreciably weaken it. This discoloration, which is known as sap stain, is considered a defect only in lumber used for finishing purposes.

The heartwood is usually preferred over the sapwood, either because it is more durable under conditions favorable for decay or because it is more decorative. For certain purposes, however, as interior trim and flooring, the white sapwood of maple, ash, and yellow pine is preferred. Sapwood, as a rule, dries out more quickly and also shrinks less than heartwood; conversely, sapwood absorbs liquids more easily, and, therefore, will take preservative treatment better in most woods, but is not as suitable for liquid containers as is heartwood.

There seems to be a common belief that heartwood is stronger than sapwood, but this is true only in old trees which have passed their period of best growth. Actual tests show that in young trees clear pieces of sapwood average as strong as clear pieces of heartwood.

STRUCTURE OF WOOD.—Our commercial woods are divided into two large classes—the hardwoods, or woods from broad-leaved trees, and the softwoods, or conifers, which are woods from trees with needle or scale-like leaves. There is a third class, represented by the palms and yuccas, but it is of minor importance. The terms "hardwood" and "softwood" give a wrong impression, however, for some so-called softwoods, as yellow pine and tamarack, are considerably harder than many hardwoods; and some so-called hardwoods—for example, cottonwood and basswood—are almost as soft as the softest conifers. These terms have been in use so long, however, that their meaning is well established.

Structure of Hardwoods.—The hardwoods differ essentially from the softwoods in having some cells which have a greater diameter than others (compare Figs. 1, 2, and 3) and have open ends, forming continuous tubes extending vertically in the tree trunk. These tubes are known as vessels or pores and are entirely absent in the softwoods. For this reason the hardwoods are also termed porous woods and the softwoods nonporous woods, although the word "porous," taken in the sense of containing small, empty spaces or of being permeable to liquids, would apply to both classes of woods.

The pores can readily be seen with the naked eye in some hardwoods of coarse texture, known as "open-grain" woods—for exam-

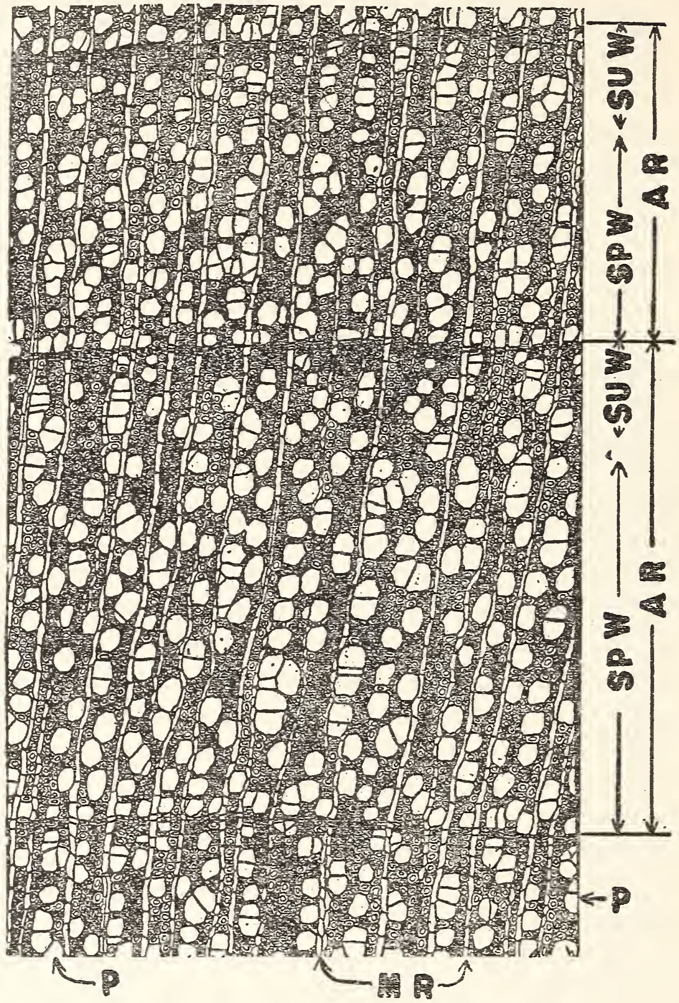

FIG. 2.—*Cross section of cotton gum*

A diffuse-porous wood showing *AR*, annual rings; *SPW*, springwood; *SUW*, summerwood (here not clearly defined); *P*, pores; *MR*, medullary rays. The space not occupied by pores or rays is filled mostly with wood fibers. Magnified 25 diameters

ple, oak, chestnut, and walnut, where they appear as small openings on the smoothly cut end surface or as dark lines or grooves on the longitudinal surface; but in finer-textured hardwoods, known as "close-grain" woods—as maple, yellow poplar, and red gum—they are visible only with the aid of a good hand lens. As a general rule, woods in which the pores can be seen with the naked eye require a filler in finishing in order to produce a smooth surface.

The size and arrangement of the pores, as seen on the smoothly cut end surface, is a valuable aid in distinguishing the different hardwoods. In oak, chestnut, ash, hickory, and elm the pores in the spring wood of each annual ring are comparatively large, forming a distinct porous ring. Such woods are known as ring-porous woods. (See Fig. 1.) In other hardwoods, as birch, beech, maple, basswood, yellow poplar, cotton gum, red gum, and cherry, the pores are of more uniform size throughout the annual ring. Such woods are known as diffuse-porous woods. (See Fig. 2.) The size, number, and arrangement of the small pores in the summer wood of ring-porous woods varies greatly, producing characteristic patterns on the end surface of each annual ring. For instance, in oak and chestnut these small pores are arranged in irregular rows across the annual rings—i. e., radially in the tree, as in Fig. 1; in elm they are in conspicuous wavy bands, extending in the direction of the annual rings—i. e., tangentially; and in ash and hickory they are few and isolated. It must be borne in mind that in order to see the structure of wood clearly and to the best advantage, in order to identify it or judge its quality, it should be cut smoothly with a sharp knife across the end surface. The cut need not be large—a quarter of an inch square is sufficient—but it must be clean and sharp, leaving no knife marks.

The area between the pores is occupied mostly by wood fibers (see Fig. 2), which are comparatively thick-walled cells of very small diameter. Usually they are not visible individually except with a compound microscope. The wood fibers serve primarily to give strength to the tree trunk.

Narrow strips of cells known as medullary rays extend radially in the tree—that is, from the bark toward the center—thus facilitating the conduction of sap from the bark to the wood and vice versa. (See Figs. 1, 2, and 3.) In the oaks some of these rays are very distinct as heavy lines on the end surface. In oak lumber which is cut radially—that is, quarter-sawed—the rays appear on the surface as lighter-colored patches, giving to the finished wood its beautiful figure. Plain oak is cut across the rays, more or less at right angles to them, and does not show these lighter patches or "silver grain." In sycamore and beech the rays are also very distinct, but not as much so as in oak. Sycamore is occasionally

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quarter-sawed. In other hardwoods the rays are less distinct, being barely visible, or even invisible without a lens on the end surface and very obscure on the radial surface; for example, chestnut, ash, elm, walnut, cottonwood, birch, and cotton gum.

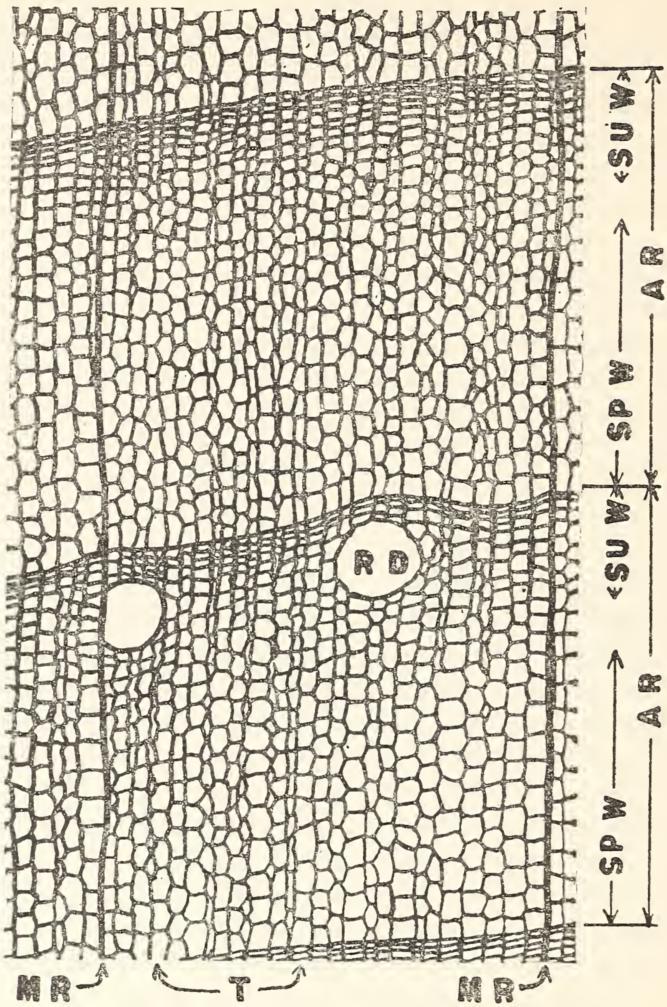

FIG. 3.—*Cross section of sugar pine*

A nonporous wood showing *AR*, annual rings; *SPW*, springwood; *SUW*, summerwood; *T*, tracheids; *RD*, resin ducts; *MR*, medullary rays. Magnified 25 diameters

Structure of Softwoods.—The cells in all the softwoods are so small that they can not be seen individually on the end surface without a lens. They are arranged in uniform radial rows, as seen under a hand lens, which together with the absence of true pores distinguishes the softwoods as a class from the hardwoods.

(See Fig. 3.) The special name of tracheids has been given to these cells, since they are neither vessels nor true wood fibers, but serve the combined purpose of conducting sap and giving strength to the tree.

In the pines, spruces, larches, and Douglas fir canals for the conduction of resin extend vertically and radially among the tracheids. These resin ducts, as they are called, are visible in some woods, especially pine, without a lens, but are much less numerous and serve an entirely different purpose than the pores in hardwoods, with which they should not be confused. It follows that other softwoods, as hemlock, the balsam firs, cedars, cypress, and redwood, which have no resin ducts, never show exudation of resin or "pitch" on the surface, even when subjected to heat, as near a radiator or above furnaces. A test for the presence of resin ducts, if not directly visible, is to trim the end surface of a piece of wood fairly smoothly and place it in a warm oven for 5 to 10 minutes. If resin ducts are present, resin will exude and appear as specks on the end surface to a conspicuous extent in the pines and least in the spruces. The resin ducts often appear as brownish lines on the longitudinal surface of most pines after exposure to the air for some time. This is especially characteristic of sugar pine but occurs in others also.

While the cedars, junipers, cypress, and redwood do not have resin ducts, they contain an appreciable amount of resin of a different nature, which makes the durability of these woods rank above the average.

Identification of Wood.—The number of woods commonly used in the construction and furnishing of dwellings is limited, and there is no reason why the housewife or home builder should not be able to distinguish most of them. It is the purpose of the following paragraphs to point out certain characteristics of the more common woods that will aid in their identification. Some woods can be distinguished by their color alone, but in others the color is not distinct enough to permit of accurate description; therefore, the structure is also taken into consideration. It will be repeated here that the hardwoods can be distinguished from the softwoods by the presence of numerous larger cells or pores scattered more or less abundantly throughout the annual ring but not constituting the entire bulk of the wood. These pores should be looked for only on a smoothly cut end surface, and they may not be visible without a hand lens.

Hardwoods.—The oaks are commonly divided into two groups in the lumber trade—the white-oak group and the red-oak group. Each group contains a dozen or more botanical species generally not separately distinguished in the market. Where resistance to decay without preservative treatment is essential, the white oaks are more desirable, because they have a greater natural durability than the red oaks; but where strength or beauty of figure only are concerned, the red oaks are equally serviceable.

All oaks are characterized by having very distinct medullary rays and (except evergreen or live oak) in being conspicuously ring-porous. (See Fig. 1.) The distinction between the white-oak and red-oak groups involves careful examination but is absolutely reliable. In the white oaks the pores in the outer portion of each annual ring are very numerous and very small, thus making it difficult to count them or even see them individually with a good hand lens on a carefully smoothed surface. (See Fig. 1.) In the red oaks the pores in the summerwood are larger and less numerous and can be counted easily with the aid of an ordinary magnifying glass. The red oaks usually have a slight reddish hue, and the large pores in the springwood are more open, making the wood appear more porous, but exceptions occur in which this distinction does not hold.

Ash is another ring-porous wood. The pores in the summerwood are few and small; the rays are not distinct without a lens. The color of the heartwood is grayish brown, the black ash being darker than the white ask.

Chestnut resembles ash superficially. It has a similar color, is decidedly ring-porous, and has inconspicuous rays. The pores in the summerwood are very numerous, however, and arranged in irregular radial rows.

Elm is used comparatively little in the building trades, for it is liable to become rough from wear in the course of time, but its toughness makes it well fitted for bent chair backs, and it is used in other parts of cheap furniture. The wood is light reddish brown in color. Usually the annual rings contain only one row of large pores, but the smaller pores are very numerous and arranged in characteristic wavy bands extending in the same direction as the rings.

Black walnut can usually be recognized by its chocolate-brown color. The pores are scallered promiscuously throughout the annual rings and decrease in size very little toward the end of each year's growth; i. e., the wood is diffuse-porous. The pores are readily visible to the unaided eye, but the rays are indistinct.

Butternut, like black walnut, is diffuse-porous with plainly visible pores. It is lighter colored than the walnut and softer and weaker.

Mahogany has a reddish-brown color, varying greatly in the unstained wood from light to dark shades. The color gradually becomes darker on exposure to the air and light. The wood is diffuse-porous. The pores are visible without magnification, which distinguishes it from cherry, which is of approximately the same color, and from red gum stained to imitate it. Birch furniture is sometimes so effectively stained that it is difficult to distinguish it from real mahogany, but a small cut which can usually be made in some inconspicuous place will show a white interior, while mahogany is dark throughout. The growth rings of mahogany, which often are very irregular in the same piece, are marked by narrow light-colored lines, which distinguishes American mahogany from the closely related African mahogany, in which these lines are absent. Most other so-called mahoganies, as Philippine mahogany (*Shorea sp.*), are no more related to the American species of mahogany (*Swietenia mahagoni*) than maple is to oak.

Birch lumber is derived mostly from two botanical species—the yellow birch (*Betula lutea*) and the sweet or cherry birch (*Betula lenta*), which are very much alike. It is sold as "red" birch and "white" or "yellow" birch, the heartwood of both species being the "red" birch and the sapwood the "white" or "yellow" birch. The heartwood is light to moderately dark reddish brown in color, and the sapwood is almost white. Birch wood has a very uniform texture, the pores being distributed uniformly and the annual rings not conspicuously defined. The pores are barely visible with the unaided eye in good light, thus distinguishing birch from maple, in which the pores are much smaller. The rays, on the other hand, are not distinct in birch but quite conspicuous in maple.

Maple is classed as hard and soft maple. The former is obtained from sugar maple (*Acer saccharum*) and the latter from the silver maple (*Acer saccharinum*) and the red maple (*Acer rubrum*). A good rough test for distinguishing the two groups is by cutting the wood across the grain. The hard maple offers considerable resistance, while the soft maples cut rather easily. "White maple" is sapwood and may be from any species of maple. The chief distinguishing characteristics of the maples are white to pale reddish-brown color, very small pores scattered uniformly, rays as wide as the largest pores, and a thin reddish-brown layer at the end of each annual ring. Oregon maple, as the name indicates, is a western species. It ranks in quality between the eastern hard and soft maples.

Beech is occasionally used as flooring but more often in the hidden parts of furniture. It resembles maple somewhat, but some of the rays are considerably broader and more conspicuous; in fact, they are two or three times as wide as the largest pores and up to one-fourth inch in height, thus giving somewhat of a speckled appearance to the radial surface.

Sycamore can be identified by its conspicuous medullary rays, which are very close together on the end surface and about one-fourth inch high on the radial surface. It resembles beech, except that the rays are more numerous and more conspicuous.

Cherry can usually be identified by its lustrous reddish-brown color. The pores are not distinct without magnification, but the rays are very distinct.

Red gum, or sweet gum, also has a reddish-brown color but is lighter than cherry, often with blackish streaks. It has a very uniform structure. The pores are very small under a lens, and rays and annual rings are barely distinguishable with the unaided eye. On account of the streaks in red gum, it resembles Circassian walnut, but the walnut can be distinguished by the larger pores, visible as dark lines on the longitudinal surface.

Yellow poplar, or tulip poplar (*Liriodendron tulipifera*), is one of the softer of the hardwoods. It varies from white to light greenish-yellow in color. The texture is very uniform and the grain is straight, which makes it a very desirable wood where strength and hardness are not essential. The pores of yellow poplar are not visible without a lens, but the rays are distinct and the annual rings are limited by a narrow whitish layer. The sapwood of yellow poplar is sold as "whitewood," but the same name is also applied to basswood and cottonwood.

Cotton gum (tupelo) (*Nyssa aquatica*) is a grayish-white wood practically without any figure. The annual rings are indistinct, the pores are very small and evenly distributed and, like the rays, can not be seen without a lens. The wood is without distinct odor or taste and moderately light to moderately heavy in weight.

Cottonwood (*Populus sp.*), which, though often called poplar, is entirely distinct from yellow poplar, is found occasionally around the home. It is the wood commonly used for the sides of cracker boxes and light egg cases. In building it is occasionally used for interior trim and siding. Its chief characteristics are light weight, white to pale-gray color, very numerous and uniformly distributed pores, barely visible with the naked eye in good light, and very fine rays.

Basswood is creamy-white in color, rather light and soft, and without figure. Although the rays are distinct to the unaided eye, the pores are exceedingly small. It has a slight odor, which helps to identify it, but for practical purposes it is considered odorless and tasteless.

Softwoods.—The white pines are a distinct botanical group, with soft, slightly resinous wood of very uniform texture. The white pine of the Northeastern and Lake States, the western or Idaho white pine, and the sugar pine of California are the principal species of this group. Soft grades of western yellow pine, especially the white, narrow-ringed sapwood, are sometines marketed as "white pine." The wood of the white pine, as a rule, has a creamy-white to light reddish-brown color. The annual rings are marked by narrow, inconspicuous bands of summer wood, thus distinguishing the white pines from the hard or yellow pines, which have wider and denser summer wood. The resin ducts are usually quite distinct as brownish lines on dressed surfaces, especially in sugar pine, and are visible on a smoothly cut end surface as small openings. (See Fig. 3.)

The yellow or hard pines as a class are harder, stronger, and more resinous than the white pines, but show great variation in these properties. Some half a dozen species of yellow pine are cut in commercial quantities, but no hard and fast line of distinction can be made between all of these woods. Tests made at the Forest Products Laboratory show the following average weights in pounds per cubic foot of oven-dry wood, based on the volume when green: Western yellow pine, 24 pounds; Norway or red pine, 28 pounds; shortleaf pine (sold as Arkansas soft pine or North Carolina pine), 31 pounds; loblolly pine, 31 pounds; longleaf pine (known as Georgia pine), 34 pounds; and Cuban or slash pine, 36 pounds. These weights are indicative of the relative hardness and strength of these species, but it must be remembered that wood is variable, and some pieces of shortleaf pine are as heavy as the average longleaf pine and some longleaf pine is as light as the heavier grades of Norway pine. The western yellow pine averages about the same in weight as the white pines. As a rule, it contains a very small proportion of the summer wood, which, although it may be very narrow, is always denser and more glistening than in the white pines.

Douglas fir, also known as red spruce, Oregon fir, and Oregon pine, can usually be distinguished by its distinct reddish hue, although the outer parts of old trees are often yellowish. It is a resinous wood, but, on the average, not as much so as the hard pines. Slight exudations of resin are often noticeable, especially on the ends, or can be made to appear by warming the wood. This test distinguishes Douglas fir from hemlock and redwood, with which it is often associated, but does not distinguish it from the pines or larches, which, however, have more of an orange-brown to russet-brown color.

The larches or tamaracks are heavy, somewhat resinous woods, russet-brown in color. The resin ducts are inconspicuous and difficult to see even under the most favorable conditions. Any indication of resin, however, serves to distinguish the larches from hemlock; the lack of the cherry-red tinge usually is sufficient to distinguish them from Douglas fir; and they are less resinous than the pines, which have distinct resin ducts and are orange to reddish brown in color. The western larch (*Larix occidentalis*) has narrower rings, as a rule, than the eastern tamarack (*Larix laricinia*) and, therefore, is not as coarse and is more suitable for finish and flooring.

The spruces are important lumber trees, producing light-colored wood of soft, uniform texture. The Sitka spruce of the west coast has a pale reddish hue, but most of the other spruces are almost white, making it impossible to distinguish between heartwood and sapwood in most cases. The spruces (*Picea*) resemble the true firs (*Abies*), except that the former contain resin ducts, although exudations of resin on spruce lumber are rare. Heating the wood, as previously described, may cause sufficient exudation of resin from the resin ducts to make them appear as specks on a smoothly cut end surface.

Hemlock is a nonresinous [2] softwood. No sharp color distinction exists between heartwood and sapwood, both being pale brown with reddish tinge. The wood is odorless and tasteless or with a slight soured odor when fresh. The eastern hemlock (*Tsuga canadensis*) is coarser, more slivery, and more subject to shakes

[2] "Nonresinous" as here used means that no exudations of resin normally occur, although more or less resin may be contained in the wood.

(splits along the annual rings) than the western hemlock (*Tsuga heterophylla*).

Redwood can usually be identified by its dark reddish-brown color. Dark pieces of western red cedar are sometimes confused with redwood, but can be distinguished by their characteristic cedar odor and slightly bitter taste, the redwood being practically odorless and tasteless.

Cypress varies greatly in color and weight. It is without characteristic taste, but has a somewhat rancid odor which is easy to remember if a person once becomes familiar with it. In order to detect the odors in woods, they should be whittled so that fresh surfaces are exposed or, better yet, the sawdust should be held to the nostrils. Other characteristics of cypress are a greasy or waxy surface, most pronounced in the darker grades, and irregular annual rings with very narrow but dense summer wood.

Northern white cedar is pale brown in color, very soft and light. It has a characteristic cedar odor and somewhat bitter-tasting heartwood, which distinguishes it from cypress. The western red cedar (*Thuja plicata*) is very similar to white cedar (*Thuja occidentalis*) in odor and other properties, except that it has a distinct reddish hue.

The true firs (*Abies sp.*), of which there are several species commonly known as balsam fir, white fir, noble fir, and red fir (the latter name is also applied to Douglas fir (*Pseudotsuga taxifolia*)), are rather light, nonresinous woods. They vary in color from almost white to pale reddish brown, the heartwood being practically of the same color as the sapwood. The noble fir (*Abies nobilis*) of the West resembels the western hemlock so closely that it is often impossible to distinguish the two woods when dry except with a compound microscope. In short, the firs have the same general characteristics as the hemlocks, except that they are mostly lighter in color and not as heavy.

Grain, Texture, and Figure.—The word "grain" is applied in a number of different ways in respect to lumber. Wood is said to be "coarse-grained" when the annual rings are wide and conspicuous, and "fine-grained" when the rings are narrow, but woods with very fine pores or cells and indistinct annual rings are always classed as "fine-grained" no matter how wide the rings may be. The painter classes woods with large pores as "open-grained," and hardwoods with small pores and softwoods are classed as "close-grained."

When the fibers in a piece of lumber run parallel to the surfaces, as can be determined by splitting, it is termed "straight-grained," but when they are not parallel the wood is said to have "diagonal grain" or "cross grain." The latter term is used also when the fibers in the same piece do not all run in the same direction but some slant some way and some another way, this making it exceedingly hard to split the wood. "Bird's-eye grain" and "curly grain" are due to slight elevations and depressions in the annual rings which appear as smaller or larger circlets or figures when cut through, as in plain sawed wood. "Wavy grain" is due to undulations in the fibers seen best on the radial or "quartered" surfaces. These irregularities in the direction of the fibers cause differences in the reflection of light to the eye, even when smoothly surfaced, and hence produce the beautiful play of figure seen in such woods when tilted back and forth in the light.

"Texture" is often used in place of "grain" when the size and arrangement of the different wood cells are concerned, as "coarse texture" (oak, chestnut) and "fine texture" (maple and cedars). If there is a decided difference in the hardness of the spring wood and summer wood, the timber is said to have an "uneven texture" (oak and yellow pine); when there is practically no difference between spring wood and summer wood, the wood is said to have "even texture" (white pine and red gum.)

"Figure" is the pattern produced on the surface of a board, whether by the annual rings, cross grain, undulations on the fibers, or irregular colorations.

Commercial Classification and Measurement of Lumber.—In the market lumber is classified not only according to the kind of tree from which it was cut but also by standard grades (of the same kinds). The grades are determined by the size of the piece and the character of the defects in it. The sizes usually run in standard lengths, widths, and thicknesses. Softwoods are cut into standard lengths of even feet beginning at 4 feet and widths of even inches, beginning at 4 inches, for such material as boards, joists, and timbers, and into lengths of even and odd feet for such material as flooring, siding, and casing. Hardwoods are cut in lengths of even and odd feet, beginning at 4 feet, except for flooring, which may be shorter, and in all widths, beginning at 2 inches, and sold to the nearest inch in width. In general, the lower grades comprise more defective lumber or are narrower and shorter than the upper grades. The standard thickness of lumber is highly variable, depending on the purpose for which it is to be used.

Recognized defects that may occur in lumber are knots, shakes, checks, splits, pitch pockets and streaks, wane, rot, stain, warp, cupping, so-called mineral streaks, pith on the face of the board, wormholes, and the like. In certain woods, where the heartwood is the principal product, sapwood is considered a defect if it comprises over a certain proportion of the individual piece of lumber. Many grades of lumber are manufactured from each kind of wood, some of which are intended for special purposes, such as the manufacture of doors, wagon boxes, or railway cars. In the construction of dwelling houses the best two grades are commonly used for interior and exterior finish. These grades are variously designated as "clears" and "selects," or "firsts" and "seconds," or "A" and "B," or "No. 1" and "No. 2" for the best and next best quality, respectively, depending on the association which formulated the grading rules. The lumber used for rough construction—as joists, studding, rafters, subfloors, and sheathing—is usually not as good quality as that used for finish. The better grades for rough construction are designated as "No. 1 common" and "No. 2 common." "No. 3 common" and poorer are used only for cheap or temporary construction.

Lumber is sold either by the board-foot—e. g., boards, flooring, joists, and studs—or by the lineal foot—e. g., moldings—or by the number of pieces, each piece being of standard size—e. g., lath and shingles. Theoretically, a board-foot contains 144 cubic inches of wood. It may be in the form of a board 1 foot square and 1 inch thick or of other dimensions. In practice, however, the actual dimensions of a piece of lumber are often less than the selling or nominal dimensions. This is due in rough stock to scant manufacture and to shrinkage of the lumber after drying out and in dressed stock to the custom of basing the nominal dimensions on the size of the rough piece of lumber required to produce the desired finished stock. Thus "2 by 8" hemlock joists surfaced on one side and one edge measure 1¾ by 7¾ inches, and "2 by 8" yellow-pine joists surfaced on one side and one edge measure 1⅝ by 7½ inches. This fact should be taken into consideration in figuring the strength of structural material and in computing the thickness of walls, floors, and other construction where actual measurements are essential. In flooring the difference between actual dimension and nominal dimension is still more pronounced. For instance, a "1 by 3" Douglas fir or oak flooring has a surface width of only 2¼ inches and a thickness of $^{13}/_{16}$ inch. This decrease in the width of the surface is necessary in order to produce the "tongue" which fits into the "groove" of the next piece of flooring. The actual thickness of dressed stock is highly variable but practically is always computed as inch material when an inch or less in thickness. The lengths of lumber are full measure.

(*b*) Important Properties that Influence the Use of Wood

The most important properties affecting the use of wood include: Moisture absorption, shrinking, and swelling; weight or density; thermal and acoustic conductivity; taste and odor; strength; hardness; resistance to decay; and fuel value.

MOISTURE CONTENT AND DRYING OF LUMBER.—Green lumber contains a considerable quantity of moisture, a large part of which must be removed before the lumber is put into use. The water in green wood may form from one-fifth to two-thirds of its total weight. The chief reasons for drying lumber are: To reduce subsequent shrinkage and "working," to make the conditions of decay less favorable, and to reduce the shipping weight. If wood is to be given a preservative treatment, it should also be thoroughly seasoned beforehand.

Lumber is dried either by stacking it so as to be exposed to the air from several months to over a year, or even several years, or by placing it in a dry kiln for several days or weeks. Much lumber is first air-dried and then kiln-dried. When lumber is thoroughly air-dried in the open but protected from rain, it still contains from 12 to 18 per cent of moisture, the percentage being based on its oven-dry weight. Lumber in this condition resists decay fairly well and is fit for such purposes as rough construction, sheathing, siding, studding, subfloors, and other structures in which subsequent shrinkage, if any should take place, would not be a serious factor; in fact, the framework of buildings is often constructed of lumber only partially air-dried. When used in the interior of heated buildings, especially in places where considerable shrinkage would be evident, as in finish, flooring, and furniture, lumber must be dried still more, so that no drying and resulting shrinkage will occur after the wood is in place. Wood used for interiors should contain preferably from 5 to 8 per cent of moisture. If the wood is drier it will swell by absorbing moisture from the atmosphere, thereby causing floors to bulge and doors to stick, and if it contains more moisture it will dry out and open up as soon as the rooms are heated. This is a very important consideration for the home builder, and he should insist that all interior finish, doors, sash, flooring, etc., be made of properly kiln-dried stock.

The moisture content of lumber may be determined with sufficient accuracy by cutting a number of pieces ¼ inch in length with the grain, but not at the very ends of boards. These pieces should be carefully weighed as soon as cut and then placed in an oven heated to about the boiling point of water (212° F) for several hours. If pieces more than ¼ inch in length are used, the time of drying must be increased. The pieces are then taken out and weighed. The loss in weight represents the loss in moisture, which, divided by the oven-dry weight and multiplied by 100, gives the per cent of moisture in the lumber. Thus, if the lumber before drying weighed 125½ ounces and after drying 110 ounces, it would have lost 15½ ounces. Dividing 15½ by 110 and multiplying by 100 shows that the wood had slightly over 14 per cent moisture based on the dry weight. This is too high a moisture content for interior work.

Moisture Absorption, Shrinking, and Swelling of Wood.—Thoroughly kiln-dried or air-dried wood will absorb moisture from moist objects with which it comes in contact and from the air during damp weather. The moisture enters the cell walls and causes them to expand, thus swelling the whole piece. As the surroundings become drier, this absorbed moisture evaporates and the wood shrinks. This shrinking and swelling of wood is commonly called "working." It can not be overcome entirely, but kiln-drying reduces the capacity of wood to absorb moisture from the air, hence kiln-dried wood will not "work" as much as wood which has not been kiln-dried. The ordinary "working" of lumber is not a serious factor, for allowance is usually made for it in the fitting of drawers, doors, and windows, and joints in furniture are glued together so that they can not open up. It is of great importance, however, to have the lumber thoroughly dried before being put into place, otherwise it will check or pull apart when it finally dries out.

Wood shrinks very little longitudinally, in fact, so little that the shrinkage is negligible for all ordinary construction. The shrinkage is greatest crosswise in the direction of the annual rings; that is, tangentially. The shrinkage across the annual rings—that is, radially—is somewhat less; consequently, quarter-sawed lumber shrinks and swells less than plain-sawed lumber of the same species.

Warping of lumber, after it leaves the pile or dry-kiln, indicates that it was not properly dried or that its location is such that one part absorbs more moisture than another, e. g., near sinks or water pipes that "sweat."

WEIGHT OF WOOD.—Wood used about the household is not usually selected with regard to its weight, although very light or very heavy furniture or utensils would not be as desirable as those of medium weight. The weight of dry lumber indicates the relative strength and hardness of wood. In general, heavy woods are stronger and harder than light pieces, whether of the same kind or different kinds. Light woods, as a rule, shrink and swell less than heavy woods, but there are some notable exceptions. Light woods also conduct less heat than heavy woods under the same conditions.

The weight of each kind of wood is quite variable. Mahogany, cotton gum, oak, and cypress are some of the most variable woods, the denser pieces of some of these species being fully twice as heavy as the lighter pieces.

The following table indicates the average weights of the principal native woods:

Average Weight of Air-Dry Wood of Different Species

Kind of wood	Pounds per cubic foot at 12 to 15 per cent moisture [a]	Estimated shipping weight in pounds per 1000 board feet of rough lumber 1 inch or more in thickness [b]
Very light: Northern white cedar	Below 22	Below 2300.
Light: Western red cedar, cottonwood, buckeye, balsam fir, redwood	22 to 26	2300 to 2600.
Moderately light: Basswood, white pine, sugar pine, butternut, western white pine, western yellow pine, spruce, yellow poplar, noble fir, hemlock, chestnut	26 to 31	2600 to 3000.
Moderately heavy: Cotton gum, cypress, white elm, Norway pine, black ash, sycamore, Douglas fir, red gum, soft maple, Oregon maple, black cherry, shortleaf pine, mahogany, western larch	31 to 37	3000 to 35000.
Heavy: Paper birch, tamarack, black walnut, white ash, longleaf pine, light oak, beech, hard maple	37 to 45	3500 to 4000.
Very Heavy: Yellow birch, sweet birch, oak, hickory	45 to 56	4000 to 4500.
Heaviest commercial woods: Heavy oak and hickory	56 and over	4500 and over.

[a] The average weight of a cubic foot of kiln-dried wood at 8 per cent moisture is about 1 pound less than that of the same species air-dried to 14 per cent moisture.

[b] Wood considered "air-dry," but the moisture content, therefore the weight, may vary considerably.

CONDUCTIVITY OF HEAT AND SOUND IN WOOD.—One of the principal properties that makes wood desirable in the household is its comparatively low heat conductivity. The use of wood for handles, furniture, refrigerators, fireless cookers, floors, and walls is governed largely by the fact that heat passes through it slowly. A marble-topped table or a tile floor in a room not sufficiently heated would be unpleasant to the touch, as would an iron handle on a hot teakettle.

The rate with which heat passes through dry wood depends on its density and on the direction of the grain. Wood conducts from two to three times as much heat with the grain as across it, other conditions being the same.

Heavy woods conduct heat more rapidly than light woods; therefore, for the lining of refrigerators and fireless cookers as light wood as is practical should be used. Oak conducts about twice as much heat as spruce under the same conditions. This is due to the fact that in light woods a larger volume is occupied by air spaces than in heavy woods, and air is a poorer conductor of heat than is wood substance. Dead-air spaces in a wall are more effective in retarding the passage of heat than walls of solid wood.

The heat conductivity of wood is much less than that of other structural materials, such as stone, brick, and concrete. Broadly speaking, the conductivity of heat through stone and concrete is from 10 to 30 times as great as through wood across the grain. other conditions being the same.

Wood is a fairly good conductor of sound along the fiber, in which respect it ranks with brick and stone, but across the fiber sound will travel only about one-third as well as with the fiber. Materials of looser construction, as cork and felts, and even air spaces are still poorer conductors of sound and should be used for "deadening" walls and floors.

Taste and Odor of Wood.—Most of our native woods are without pronounced odor or taste. A few have characteristic odors, but in none of the woods cut into lumber is the odor of such nature as to make the wood unfit for general use. Care must be taken, however, in selecting woods for making food containers, such as refrigerators, cupboards, and shipping boxes, since some foods, especially butter, take up ordors readily. Woods of the laurel family, of which sassafras and California laurel or myrtle are representatives, have a distinct spicy odor and taste. Port Orford cedar of the Pacific coast has a very spicy, resinous odor; other cedars have a more aromatic odor, especially the pencil cedar or juniper. Hemlock has a slightly sour odor, cypress a somewhat rancid odor, and cottonwood a faint, disagreeable odor. Except in cedars and junipers these odors are rarely strong enough to taint food, unless the food is brought in direct contact with the wood, as in butter tubs and butter boxes. For wooden pie plates, butter dishes, bowls, buckets, candy pails, kegs, and barrels only woods which are without taste can be used. Buckets and tanks are sometimes made of cedar, since after they have been in use for some time the wood no longer imparts its characteristic taste to the contents.

Strength of Wood and Factors Affecting It.—In the construction of a dwelling house the strength of its timbers, joists, and studding is an important consideration. No definite rule can be laid down, however, as to the necessary size of each piece, for this varies with the size of the building, the type of construction, the length of the span, and the distance the supporting members are apart. The selection of proper dimensions is an engineering problem and should be left to a competent architect. A few suggestions, however, may be of value to the owner in inspecting his building or building material.

The strength of structural timbers—whether bending strength, as in joists and rafters; the side-crushing strength, as in sills and the end of joists; or the end-crushing strength, as in studding—is influenced by several factors. The density of the wood, as indicated by its dry weight, is a good indication of its strength. Heavy woods like oak, yellow pine, and Douglas fir are much stronger than lighter woods, as white spruce and white pine. The density of the softwoods, and also the oaks and other ring-porous hardwoods, can be judged by the percentage of dense summer wood as seen on the smoothly cut end surface. For the softwoods, like yellow pine, tamarack, hemlock, and Douglas fir, the densest wood is usually found in pieces showing neither very slow growth nor very rapid growth. In the southern yellow pines and Douglas fir an average of six rings per inch, with an average of one-third of each ring summer wood, indicates excellent quality so far as strength is concerned. In general, for ring-porous hardwoods, as oak, ash, and chestnut, the wider the rings the stronger the wood. The home builder should be particularly careful that those timbers which have heavy loads to support be not of very wide or of extremely narrow-ringed softwoods, or very narrow-ringed hardwoods, unless they are larger than would be necessary for timbers of average rate of growth.

Whether a stick of timber contains much or little sapwood has no direct bearing on the strength. Other things being equal, sapwood is as strong as heartwood. Sapwood, as a rule, is less durable than heartwood, and, consequently, under conditions favoring decay it may soom be destroyed, weakening the structure correspondingly. If the wood is to be given a preservative treatment, sapwood is not objectionable, for it absorbs preservatives more readily than heartwood.

The direction of the grain should be parallel to the sides of a stick in order to afford maximum strength. Diagonal grain greatly reduces the strength of wood. The direction of the grain can easily be determined by trying to split a sliver off one or two corners of the stick or by noting the direction of seasoning checks on the longitudinal surfaces.

Moisture in wood reduces its strength, but in timbers the increase in the strength of the wood fiber due to drying is offset by checks and shakes which are the natural result of seasoning. The influence of moisture on shrinkage and durability is far more important than its influence on strength in the construction of dwelling houses.

The presence of knots and large checks may seriously affect the cross-breaking strength of wood, their seriousness depending on their size and location. Knots in the lower portion of a beam near the middle have considerably more weakening effect than in other portions. Joists with knots on one edge should be placed with the knots up. Knots, provided they are sound, do not seriously weaken the wood in compression. The weakening influence of checks, which are radial cracks due to seasoning, and shakes, which are cracks following the annual rings, depends on their size and location. The weakening is least if they are located near the upper or lower edge of a timber and becomes greater as they approach the horizontal plane halfway between the upper and lower edges.

HARDNESS.—The hardness of wood governs its wearing qualities in floors and thresholds and its resistance to indentation when struck by another object. Most of the flooring on the market now has sufficient wearing qualities for all practical purposes in the home, and the choice is between appearances rather than between grades of hardness. It might be said that in "flat grain" or "plain" flooring the surface shows wider strips of soft spring wood alternating with dense summer wood than in "edge grain" or "quartered" flooring, and consequently would show greater tendency to uneven wear. Soft-textured woods, as white pine and yellow poplar, while having certain characteristics which make them desirable for doors and interior trim, are more easily indented by careless handling of furniture than harder woods.

RESISTANCE TO DECAY.—The length of time wood will remain free from decay (rot) depends on the conditions under which it is

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placed and on the kind of wood. Wood will not decay if kept thoroughly air-dry or if thoroughly saturated with water. Specimens have been taken from buildings several hundreds of years old in which the wood showed no signs of deterioration. Similarly, woods taken from the bottom of lakes or from old wells have been found sound after hundreds of years of submergence. Decay takes place most rapidly in wood kept damp and warm.

The sapwood of practically all woods is not durable and should never be used under conditions favorable for decay. In speaking of the relative durability of woods, the heartwood only should be considered. Woods in which the heartwood can not easily be differentiated from the sapwood, on account of the light color of the heartwood, usually show relatively little durability, although Port Orford cedar is a notable exception. The following lists indicate the relative durability of common woods and should be an aid to the builder in selecting the more durable species for posts, sills, sidewalks, and other structures subject to decay. It must be remembered, however, that woods vary in durability as they do in other properties, and exceptions may be found which, apparently, are not consistent with this classification.

Relative Durability of Common Woods

CONIFERS

Very durable	Durable	Intermediate	Nondurable
Cedar, northern white. Cedar, western red. Cypress. Redwood.	Fir, Douglas. Tamarack. Larch, western. Pine, longleaf. Pine, eastern white.	Hemlock, eastern. Hemlock, western. Pine, loblolly. Pine, Norway. Pine, shortleaf. Pine, sugar. Pine, western white. Pine, western yellow.	Firs, true. Spruces.

HARDWOODS

Very durable	Durable	Intermediate	Nondurable
Chestnut. Walnut, black. Locust, black.	Cherry, black. Oaks, white.	Ash, white. Butternut. Gum, red. Poplar, yellow. Oaks, red.	Basswood. Beech. Birch. Buckeye. Cottonwood. Elm, white. Maple, hard. Maple, Oregon. Maple, soft. Sycamore. Cotton gum.

Fuel Value of Wood.—Equal weights of dry, nonresinous woods give off practically the same amount of heat in burning; that is, a ton of dry cottonwood will give off as much heat on burning as a ton of white oak. Highly resinous woods, like some of the pines and Douglas fir, have an appreciably greater heating value per ton, because a pound of resin gives off about twice as much heat during combustion as a pound of wood.

When buying wood by the cord, it must be remembered that different species vary greatly in weight per cubic foot, so that a cord of hickory has considerably more fuel value than a cord of soft maple. Some species, especially the conifers, produce straighter sticks and thereby also increase the volume of wood per cord. Furthermore, the smaller the sticks are in cross section the less wood per cord. A cord of split wood would not measure a cord if the same amount had been left unsplit. The shorter the pieces, the greater the volume per standard cord of 128 cubic feet, because short pieces can be piled closer together than long pieces. It must be remembered, however, that firewood shorter than 4 feet is often sold on the basis of a cord being 4 feet high and 8 feet long, irrespective of the length of the stick. A cord of seasoned wood contains more wood than a cord of green wood, because of the shrinkage which takes place in seasoning.

The amount of moisture in firewood influences not only the vigor with which it burns but also the amount of heat actually given off to the surroundings. The heat required to drive out the water and send it up the chimney in the form of steam is considerable.

Therefore, to obtain a standard cord of wood of the greatest fuel value, thoroughly dry wood of the heaviest kind, straight in growth, cut into short lengths, but with the largest diameters, should be selected. Other factors, however, must be taken into consideration in buying firewood, such as price, the rapidity and completeness of combustion, quickness of heating, or uniform heating, depending on the particular results desired. As a rule, the softwoods burn more readily than the hardwoods and the lighter woods burn more readily than heavier ones.

In comparing the heating value of coal and wood, 1 pound of good coal may be taken as the equivalent of 2 pounds of seasoned wood. Allowing 80 solid cubic feet of wood to an average cord of wood, and assuming the sticks to be well seasoned, a cord of hickory or other heavy woods is equivalent in heat value to 1 ton of coal. For the lighter woods, as cedar, poplar, spruce, and white pine, 2 cords are equivalent to 1 ton of coal.

(c) Woods Commonly Used in the Construction and Furnishing of the Home

The table on pages 60–62 shows which woods are commonly used in constructing the various parts of a house and its furnishings. Of course, the species indicated for each purpose are not all equally desirable, and it may be found to be of advantage locally to use other woods. The controlling factors in selecting the kind of wood to be used for any particular purpose are the properties required, whether mainly strength or durability or appearance, or a combination of these and other properties, and the price.

The letters after each species in the table refer to the regions similarly lettered in the map on page 53 and indicate the part of the country in which the species is principally cut.

Rough Construction.—The woods used for the framework of dwellings are mostly those kinds that are fairly abundant and reasonably strong. The softwoods usually fulfill these requirements, the stronger and more durable kinds being most desirable, but others are also taken. In the Central States hardwoods are often used for the framework of buildings. If the sills are in contact with the ground, or the posts are in a damp cellar, or if any part of the frame for other reasons is liable to remain damp, only woods with great natural durability should be selected. Timbers with a large proportion of sapwood should never be used in damp places unless they have been given some treatment to retard decay.

Sheathing, Roof Boards, and Subfloors.—For these purposes the cheaper and more abundant softwoods are usually selected. In certain localities rough hardwood lumber of low grade is used for roof boards, and occasionally even better grades are used for sheathing or subfloors. Durability is not an essential feature, since the lumber thus used is protected from the weather.

Shingles.—Shingles demand a very durable wood because they are usually exposed to the weather without paint covering or preservative treatment. The cedars, cypress, and redwood shingles give excellent results, although pine shingles have been known to last many years. Fresh redwood shingles discolor the rainwater that passes over them and the cedars give it a disagreeable taste, but after several rains leaching ceases and the shingles no longer impart objectionable properties to the soft water for the cistern.

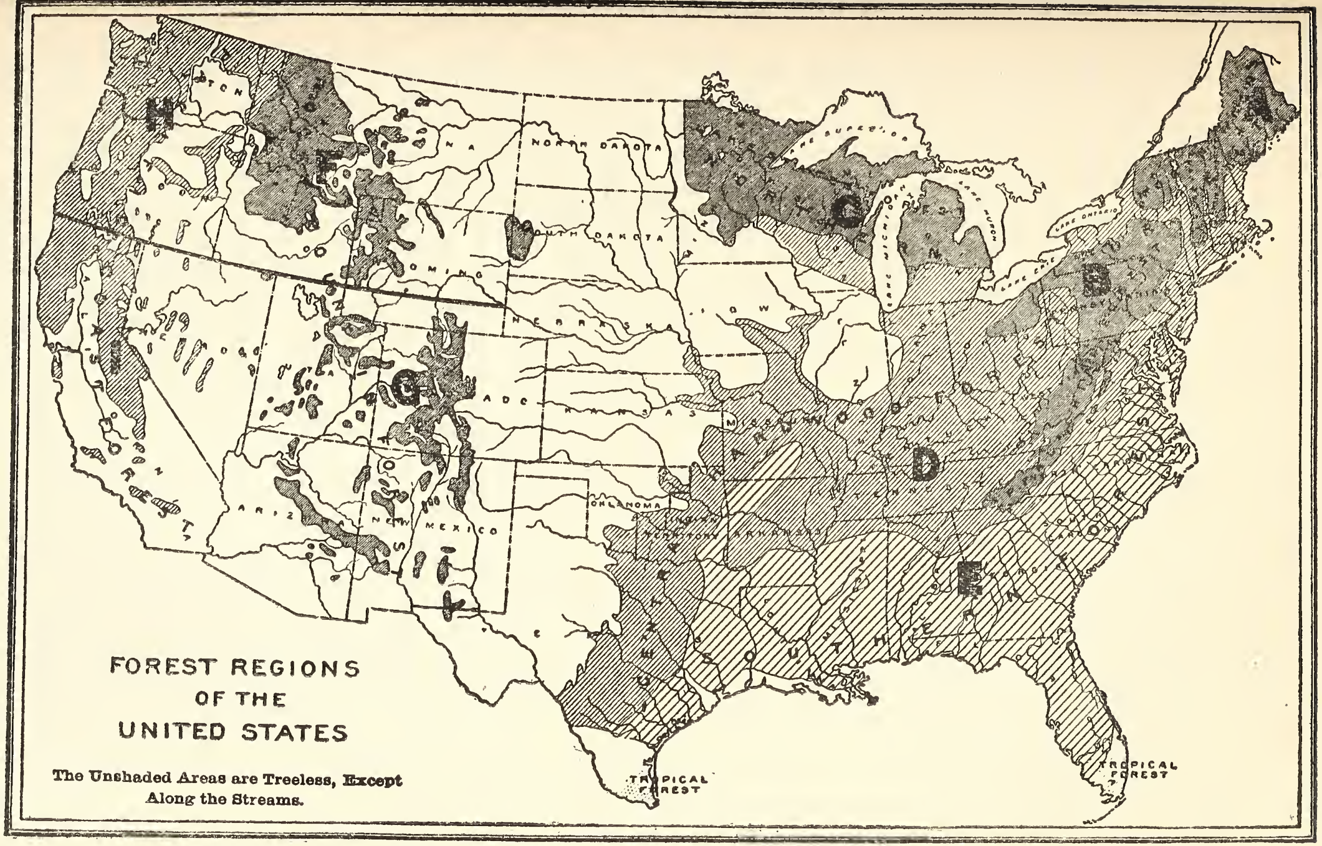

FIG. 4.—*Map showing forest regions of the United States*

The Pacific coast and Rocky Mountain forests are divided into northern and southern sections by the heavy line passing along the southern boundary of Oregon and Idaho

Lath.—Laths are mostly cut from slabs and other waste material and many species contribute to the supply. Coniferous woods are chiefly used, but softer hardwoods are used to some extent. The chief requirements of laths are softness and freedom from warping.

Siding and Exterior Trim.—Comparative freedom from warping and checking and easy nailing with little splitting, together with fair durability, are the properties especially desirable in woods used for siding and outside finish. Some woods with low resistance to decay, as cottonwood, basswood, cotton gum, buckeye, and spruce, are also used, but special care must be taken to keep such woods well painted and free from moisture to retard decay.

Porch Columns.—Porch columns are of two kinds, solid and built up. Solid columns, if they contain the pith or center of the tree, are very liable to check and split unless they are bored through the center, leaving only an outer shell. Small solid columns should be made of heartwood not containing the pith. Since porch columns are subject to decay, especially at the base, durable woods are highly desirable for their construction. Built-up porch columns give the most satisfactory service, but the lumber should be thoroughly kiln dried before being put into the columns so that the joints will not open up. The columns should be installed in such a way as to exclude moisture from the interior.

Flooring.—The chief qualities required of flooring are hardness, even wearing, and freedom from slivers. The hardwoods as a class fulfill these requirements better than the softwoods, but owing to the fact that softwoods are cheaper, as a rule, much flooring is made of yellow pine, Douglas fir, and other conifers. Although white pine and spruce are occasionally used for flooring, they are not recommended when subject to considerable wear. Yellow-pine and Douglas-fir flooring is divided into two classes; namely, "flat grain," in which the annual rings are almost parallel with the surface, and "edge grain," in which the annual rings run at right angles, or nearly so, to the surface. "Edge-grain" flooring is more desirable because it wears more evenly and is not as apt to sliver as the "flat-grain" flooring. Furthermore, the "edge-grain" flooring being quarter-sawn will not shrink and swell as much as the "flat-grain" flooring. Oak flooring is also classed as "plain" and "quartered." In oak, however, the choice is not so dependent on wearing qualities as on the decorative effect produced. Maple is excellent for floors in which hardness and smoothness are desired. Maple has a very compact structure, absorbing liquids slowly, which, together with its hardness and light color, makes it admirably suited for kitchen floors.

Door and Window Frames.—Many woods can be used for this purpose, although a moderate amount of natural durability is desirable, for moisture from the outside may find its way into the hidden parts of frames and produce conditions favorable to decay. This applies especially to the sills of windows. The hardwoods, as a class, are more liable to warp under changes in moisture conditions and, therefore, in general, are not as desirable for this purpose as the softwoods.

Doors.—The choice of wood for doors depends largely on the taste of the builder, the price and finished appearance being the principal considerations. If the doors are to be veneered, the home builder has the choice of many hardwoods and softwoods which are cut into veneer. The cores of veneered doors, and doors which are not veneered, should be made of woods that will not warp and check easily, for often radically different conditions of humidity and temperature exist on the two sides of a door. Soft pine is one of the best woods for veneer cores. The hardwoods as a class, except possibly yellow poplar, are not as desirable for doors (except as a veneer covering) as the softwoods, principally because they are more liable to warp, and also because they are heavier and shrink and swell more.

Sash and Blinds.—Sash and blinds require a fairly durable wood that works easily and will not check and warp when exposed to the weather. Yellow-pine sapwood used for sash has been known to rot out in a few years. White-pine heartwood is one of the best woods for this purpose. While soft maple, birch, basswood, and buckeye are used because of their uniform texture and easy working qualities, they are not durable and should be kept well painted wherever used for sash and blinds.

Interior Finish.—A list of woods used for interior finish includes practically all commercial woods. Durability, as a rule, need not be considered, for all interior finish is supposed to have so low a moisture content that decay-producing organisms can not thrive in it. Some of the hardwoods, especially those that are usually cross-grained, as sycamore, cotton gum, and red gum, are liable to warp if not properly dried previously, but when properly dried they make excellent finishing material. The large choice of woods makes possible the selection of finish with pronounced figure, as in quarter-sawed oak and all ring-porous woods and softwoods with dense bands of summerwood; or others with milder figure, as redwood, maple, birch, and mahogany; or others of uniform, fine texture and light color, especially for enameling, as white pine, spruce, yellow poplar, basswood, cotton gum, and buckeye.

FURNITURE.—The same qualities desired in interior finish also apply to furniture. The softer woods are not as desirable as the harder woods, because they are easily indented by careless handling in moving.

Lawn furniture should be made of durable wood, the stronger kinds being preferred. Elm, which is little used in house construction, finds a place in lawn swings and seats, but should be kept painted.

CUPBOARDS, CABINETS, AND REFRIGERATORS.—One essential of woods used in compartments for storing food is the absence of strong odors. The cedars are not recommended for this use, although painting would retard the effusion of the odor. Other woods, as hemlock, pine, cypress, and cottonwood, also have distinct odors, but not sufficient to impair the quality of the food, unless placed in direct contact with the wood.

Woods used for refrigerators meet with extremely trying conditions. Light woods conform to the requirements better than the heavier and denser woods but do not afford the beauty of finish possible with oak, ash, and birch. Elm is used largely in refrigerators because it stands the moisture conditions well and is not affected by repeated scrubbing.

WOODENWARE.—Many woods are used in the manufacture of tubs and pails, but light, white woods are preferred. For kegs and barrels the white oaks are used almost exclusively; red oaks can not be used, for they are not sufficiently impervious to liquids.

For kitchen utensils, such as chopping bowls, wooden spoons, wooden forks, ladles, and mashers, dense woods which will not absorb moisture readily and in which the surfaces do not roughen easily are preferred. Maple, beech, black gum, and cotton gum answer the purpose well. For flat surfaces, as bread boards and kitchen-table tops, a soft, white wood, preferably basswood, is used, because the soft woods do not warp as easily when wet and white woods are neater in appearance. Elm is excellent for drain boards because it will endure repeated soaking and scrubbing, although cypress and some other woods are also satisfactory for the purpose.

Wooden Tanks.—Wooden storage tanks for water are common in dwelling houses. They are usually built up of staves but may be in box form. The woods used must be impervious to liquids and must possess great natural durability. Cedar, cypress, and redwood are specially recommended. If cedar is used, the staves must be allowed to leach for some time if the water is to be used for drinking purposes, because the fresh cedar imparts a taste to liquids in contact with it. Redwood staves will impart a red color to the water for some time, but eventually this will cease. Dense, resinous yellow pine, the larches, and also the white pines make satisfactory tanks but do not possess as great durability as cypress, redwood, or cedar. White oak is satisfactory but usually too expensive.

(*d*) Care and Preservation of Woodwork

Outside woodwork in dwelling houses is subject principally to two forms of deterioration—weathering and decay. The former is by far the least damaging and assumes importance only in regions subject to severe sand storms. The fine particles of sand driven about by the wind wear away exposed wood to an appreciable extent in the course of time. The planting of windbreaks is probably the most effective remedy.

Shingles have been known to be worn out by weathering before they suffered seriously from decay, but in such cases they have given service from 25 to 35 years, and such deterioration is not a drawback to their use.

Decay takes place only in woods which are fairly moist but not saturated. Dry wood or thoroughly soaked wood will not decay if kept in that condition. Decay in wood is not confined to the outer covering, but it is often more prevalent in the hidden parts which are not exposed to the drying influence of the air. In dwellings decay is most common in posts set on the ground; beams in damp cellars; sills in contact with the soil; the base of porch columns; the backs of window and door frames; the unexposed portion of siding; wood underneath leaks in roofs, drains, water pipes, or around pipes and tanks that "sweat"; and other places where moisture is liable to accumulate, but where it can not readily evaporate.

The chief means of checking decay is to use well-seasoned, durable woods in situations favorable to decay and keep conditions such that they will be as dry as possible. Timbers to be placed in situations where they can not dry out, or at most would dry very slowly, should be seasoned thoroughly from one to two years, the time depending on the size of the piece and the climate. Sapwood and nondurable woods in general (see p. 31) should never be used in damp places. The making of window sash of sapwood should be condemned. Sills should be kept at least a foot above ground by supporting them on piers or walls of masonry. Posts in cellars should be set on a footing of stone or concrete masonry extending several inches above the floor.

The builder is warned against the use of lumber which has been stored in crowded, insanitary lumber yards, where the free circulation of air underneath and through the piles of lumber is impossible and where decayed lumber is scattered about the yard. Under such conditions decay may be well started in the wood before it is put into use.

Keeping exterior woodwork well painted, especially the joints where two pieces meet, is an effective means of preventing the rapid absorption of rain and resultant decay, although woods constantly in moist situations will ultimately absorb as much moisture when painted as when unpainted.

The preservative treatment of woods used in dwelling-house construction is not generally practiced because of the expense entailed. Furthermore, creosote, which is one of the best and most commonly used preservatives, has a strong, penetrating odor, usually considered objectionable. It is advisable, however, to apply with a brush two coats of hot coal-tar creosote to the base of posts in cellars and to sill and porch timbers which must be placed in contact with or near to the ground or which for other reasons are liable to become moist.[3] The application of water-soluble preservatives, as zinc chloride and sodium fluoride, with a brush is not sufficiently effective in retarding decay to make it worth while. The more expensive method of dipping timbers in the preservative or injecting the preservative under pressure is not usually practicable for ordinary dwelling-house construction.

Termites [4] or "white ants" are very destructive to wood in certain sections of the country, especially the South Atlantic and

[3] For a more detailed discussion of decay and methods of preventing it the reader is referred to United States Department of Agriculture Farmers' Bulletin No. 744, "The Preservative Treatment of Farm Timbers."

[4] For a discussion of the habits of termites and methods of guarding against them see United States Department of Agriculture Farmers' Bulletin No. 759, "White Ants as Pests in the United States and Methods of Preventing their Damage."

Gulf States. They live in wood which is in contact with or can be reached from the ground, often completely riddling it with their galleries, leaving only a thin shell. Their ravages can largely be prevented by keeping all wood free from contact with the soil. If this is not practical, timbers impregnated with creosote should be used. In no case should untreated timber be completely surrounded by masonry, for such conditions prevent the drying of the timber and increases the liability of decay and attack by "white ants."

Woods Commonly Used in the Construction and Furnishing of the Home

Use.	Southern yellow pine (E)	Western yellow pine (F, G, H, I)	Norway pine (A, C)	Eastern white pine (A, B, C)	Western white pine (F, H, I)	Sugar pine (I)	Douglas fir (F, G, H, I)	Eastern larch or tamarack (A, C)	Western larch (F, H)	Eastern hemlock (A, B, C)	Western hemlock (H)	Redwood (I)	Cypress (E)	Western red cedar (H)	Northern white cedar (A, B, C)	Eastern spruces (A, B, C)	Western spruces (F, G, H)	Balsam fir (A, B, C)	Western true firs (not Douglas fir) (F, G, H, I)	White-oak group (A, B, C, D, E)
House sills	X	X	X	......	......	X	X	X	X	X	X	X	X	......	......	X	......	......	......	X
Beams and girders	X	X	X	......	......	X	X	X	X	X	X	X	X	......	......	X	......	......	......	X
Posts	X	X	X	......	......	......	X	X	X	X	X	X	X	X	X	X	......	......	......	X
Joists	X	X	X	......	......	X	X	X	X	X	X	X	X	......	......	X	X	......	X	X
Studding	X	X	X	X	X	X	X	X	X	X	X	X	X	......	......	X	X	......	X	X
Rafters	X	X	X	X	X	X	X	X	X	X	X	X	X	......	......	X	X	......	X	X
Sheathing, roof boards, and subfloors	X	X	X	X	X	X	X	X	X	X	X	X	X	X	......	X	X	X	X	X
Shingles and shakes	X	X	X	X	X	X	......	X	......	X	......	X	X	X	X	X	......	......	......	......
Lath	X	X	X	X	X	X	X	X	X	X	X	......	X	......	......	X	X	X	X	......
Siding	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	......	X	......
Exterior trim	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	......	X	......
Porch columns	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	......	X	X
Flooring	X	X	X	......	X	......	X	X	X	X	X	......	X	......	......	X	X	......	......	X
Outside door and window frames	X	X	X	X	X	X	X	X	X	X	X	X	X	X	......	X	X	......	X	X
Doors	X	X	X	X	X	X	X	X	X	X	X	X	X	X	......	X	X	X	X	X
Sash and blinds	X	X	X	X	X	X	X	......	X	......	X	X	X	X	X	X	X	......	......	......
Interior finish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	......	X	X	X	X	X
Furniture, high grade, exposed parts	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	X
Furniture, medium grade, and hidden parts	X	X	X	X	X	X	X	X	X	X	X	......	X	X	......	X	X	X	X	X

Furniture, lawn	X	......	......	......	......	......	X	......	X	......	......	......	X	......	......	......	......	......	......	X
Cupboards, cabinets, and refrigerators	X	X	X	X	X	X	X	X	X	X	X	X	X	......	......	X	X	X	X	X
Woodenware, as pails, tubs, and kitchen utensils	X	X	X	X	......	X	X	......	X	X	X	X	X	......	......	X	X	X	X	X
Wooden tanks	X	......	......	X	X	......	X	X	X	......	......	X	X	X	X	......	......	......	......	X

Woods Commonly Used in the Construction and Furnishing of the Home—Continued

Use.	Red-oak group (A, B, C, D, E)	Hard maple (A, B, C, D, E)	Soft maple (A, B, C, D, E)	Oregon maple (H, I)	Red gum (B, D, E)	Birch (A, B, C, D, E)	Beech (A, B, C, D, E)	Chestnut (B, D)	Elm (A, B, C, D, E)	Ash (A, B, C, D, E)	Yellow poplar (B, D, E)	Basswood (A, B, C, D, E)	Cottonwood (A, B, C, D, E, F, H, I)	Cotton gum (tupelo) (E)	Buckeye (D)	Black walnut (B, D, E)	Butternut (A, B, D)	Sycamore (B, D, E)	Cherry (A, B, C, D, E)	Mahogany (imported)
House sills	X							X												
Beams and girders	X							X												
Posts	X							X												
Joists	X						X	X												
Studding	X						X	X	X									X		
Rafters	X						X	X	X									X		
Sheathing, roof boards, and subfloors	X	X	X		X	X	X	X	X	X	X	X	X	X				X		
Shingles and shakes								X												
Siding								X			X	X	X	X	X					
Exterior trim						X		X			X				X					
Porch columns	X					X		X			X			X	X					
Flooring	X	X	X	X		X	X	X		X				X		X		X	X	
Outside door and window frames	X							X	X	X	X									
Doors	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Sash and blinds											X	X			X					
Interior finish	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X
Furniture, high grade, exposed parts	X	X	X	X	X	X	X	X	X							X	X	X	X	X
Furniture, medium grade, hidden parts	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	
Furniture, lawn	X	X	X			X	X	X	X	X	X									
Cupboards, cabinets, and refrigerators	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Woodenware, as pails, tubs, and kitchen utensils		X	X	X		X	X		X	X	X	X	X	X	X			X	X	

3. METALS

A. METALS FOR STRUCTURAL PURPOSES

The householder uses a wide variety of metals, but since his facilities will not permit him to actually test many of the materials, it is necessary for him to depend almost entirely on the dealer to supply him with suitable material. It is desirable, however, that he should have some knowledge of the characteristics of metals used and a very general idea as to how they are produced. The most important group of metals is what is generally known as iron; it is further divided broadly into cast iron, steel, and wrought iron. These terms are used in a rather broad way, and one class may merge into another so that it is impossible to give a strict definition for each class.

(*a*) Cast Iron

Cast iron is produced from pig iron, which is made in the blast furnace by charging iron ore, coke, coal or charcoal, and limestone into the furnace. Air is forced in near the bottom of the furnace, and the heat produced by the combustion of the fuel causes the ore to be reduced by the excess of carbon present. The limestone carries off the foreign matter of the ore, and the molten metal is run out and cast as ingots in suitable molds. These ingots are called "pigs" on account of the original resemblance of the casting bed with its main channel and smaller lateral troughs to a sow and a litter of suckling pigs.

The resulting pig iron always contains several per cent, often 5 to 6 altogether, of carbon, silicon, manganese, phosphorus, and sulphur. Under certain conditions part of the carbon will be present in the uncombined form as flakes of graphite. Such metal, known as gray iron, can be readily machined and is fairly tough. Under other conditions the carbon will be all combined chemically with the iron and evenly distributed throughout the metal, causing the metal, known as white iron, to be so hard and brittle that it can not be easily machined. Mottled irons are grades between these extremes. Suitable proportions of these grades of iron, with or without other additions, are melted with coal or coke in the cupola furnace (much like a small blast furnace) and cast into the form desired. Machine castings—i. e., those which have to be machined—where strength is essential, are made from gray iron.

Phosphorus when present to the amount of 1 per cent or over causes the metal to be more fluid when melted, and for that reason its presence is desired in iron used for many of the intricate thin or small castings used about the house, such as stove parts, hot-air registers, large-size water and sewer pipes, and steam and hot-water radiators, which do not require special strength. Many of the cheap tools sold at the 10-cent stores are made from cast iron and are very unreliable. While cast iron serves many uses satisfactorily and has high compressive strength, it should not be used when subjected to severe transverse strains or shock, as it is liable to fail under such conditions. Cast-iron articles can usually be detected by inspection.

(*b*) **Malleable Cast Iron**

Many small articles which are frequently made of cast iron are much improved if made of what is termed "malleable cast iron," often called "semisteel." Articles of this kind are given a long annealing at a high temperature after being cast. By this process the metal is rendered much more ductile than the ordinary cast iron. Samples properly treated will withstand being bent double without cracking. Such castings are consequently much more resistant to shock than is common cast iron. Pipe fittings are nearly always made, or should be, of this material. While malleable cast iron is much more reliable than ordinary cast iron and has a proper and legitimate use, it is frequently sold as steel or semisteel or by other trade names. Many cheap tools, particularly hammers, are made in this way. An inspection of the surface finish and marking of any articles sold as semisteel will usually show that the piece has been cast to shape. While many articles made in this way answer their purpose admirably and as well as if made of the more expensive steel, they should not be sold under a name the evident purpose of which is to suggest that the material is much better than it really is.

(*c*) **Steel**

Ordinary steel is chiefly made by refining pig iron in either the Bessemer convertor or open-hearth furnace, from which it is cast into the ingot and finally rolled or forged into the finished form. It varies in its character from a hard steel, containing 1 per cent or more of carbon and having an ultimate tensile strength of over 100 000 pounds per square inch, to soft steel, containing less than 0.1 per cent carbon and having an ultimate strength of about 55 000 pounds per square inch. The former may be hardened by heating and quenching in water and is hence used for keen cutting articles, such as razors, knives, etc., while the latter is not materially hardened by heating and quenching but can be readily welded and worked and formed cold like wrought iron. Between the extremes we have a wide range of products, differing chiefly in the carbon content, which serve to meet all of our ordinary needs. For razors, surgical instruments, watch springs, etc., where a very high-grade steel is required, crucible steel is usually employed. A high grade is produced by heating wrought iron in a crucible with charcoal until the proper carbon content is obtained, melting to eliminate slag, and casting into ingots which are forged to the desired shape.

The usual householder rarely has the facilities to fabricate the suitable steel into the finished form, so he must depend on a reputable dealer to supply his needs; even then he runs a risk that his knife will be so hard that it will nick or that his razor will be so soft that it will not hold its edge. This is usually not so much the fault of the dealer as of the manufacturer, who either does not use the proper steel or does not control the temperature of heating, quenching, and drawing the metal to insure the proper "temper" of his product.

Structural steel such as is used in house construction is usually a medium carbon steel (about 0.3 per cent carbon) made by the Bessemer process and having an ultimate strength of about 70,000 pounds per square inch, which is ample for the usual designs of construction.

(*d*) **Wrought Iron**

Wrought iron is produced by melting pig iron with scrap iron and a flux in a puddling furnace out of contact with the fuel. As the impurities are removed, in the form of slag or cinder, the fluid molten metal becomes pasty and is worked into a ball on the hearth of the furnace. It is then removed from the furnace, most of the slag is eliminated by squeezing or forging, and the metal is rolled into "blooms." These blooms are cut into short lengths, piled together, reheated to a welding temperature, and rolled into "muck bars," which are finally rolled or forged to the finished form. Due to the fact that it is not cast into the bloom, it always contains filaments of slag, which give it a so-called fibrous structure. Wrought iron is soft and malleable, can be welded, and is not materially hardened by heating and quenching.

Since soft low-carbon steel has most of the characteristics of wrought iron and can be produced at less cost, it has largely replaced it in general use. Wrought iron is, however, still used for

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certain purposes, such as stay bolts in boiler construction, where it is believed its fibrous structure makes it stand alternating strains better than ordinary steel.

(*e*) Coated Metals

Galvanized Iron.—The term "galvanized iron" is applied to any form of iron or steel coated with zinc. The zinc may be applied by the "hot dip" process, the "Sherardizing" process, or the "electrolytic" process. In any of these methods it is necessary that the base metal—i. e., the iron—be cleaned by pickling in acid to remove scale or oxide from its surface.

Hot-Dip Process.—In the hot-dip galvanizing process the sheets of mild steel or wrought iron, after pickling in acid, are passed through a bath of molten zinc, which forms an alloy with the base metal on the surface of the sheets and a final coating of pure zinc on the outside. The thickness of the coating depends on the temperature of the bath, the speed of passing, and extent to which the sheets are wiped after coating. Pipe and wire are coated in a somewhat similar manner, and irregular-shaped articles are also coated by dipping.

Electrolytic Process.—The electrolytic process is usually applied to relatively small irregular-shaped articles. As the name implies, the coating is obtained by depositing the zinc from a solution by means of an electric current.

Sherardizing Process.—The Sherardizing process, which is also usually applied to small irregular-shaped articles, depends on heating the articles in an iron drum with powdered zinc. The zinc is volatilized and deposited on the iron base so as to form a firm adherent coating conforming sharply to the original line of the object being coated.

Nearly all sheet metal and pipe are coated by the hot-dip process. It is essential that the coating be adherent, continuous, free from "pinholes" or bare spots, and be of the thickness which will stand bending without cracking or peeling. For ordinary service the coating should amount to 1 ounce per square foot of surface (2 ounces per square foot of sheets, considering both sides). The average thickness, however, can be determined only by chemical or metallographic analysis. Surface imperfections can usually be detected by careful inspection, the adherence of the coating can be approximately measured by bending the sheet, and a general indication of the thickness of the coating can be obtained by scraping through the coating and examining with a hand magnifier. The coating produced by the electrolytic or Sherardizing process can be examined in a similar way.

The zinc coating forms an excellent protection to iron, since the iron will not rust so long as the zinc coating remains. It should be painted, however, as directed on page 120, not only for the sake of appearance but also to furnish additional protection. Galvanized iron can be readily soldered, but it will not stand sharp bending without cracking. Much of the failure of the galvanized products is due to lack of sufficient coating, and hence this point should be kept in mind when purchasing or inspecting such material. Tables of gauge of sheets (weights per square foot, etc.) can be obtained from the dealer where material is bought.

(*f*) **Roofing Terneplate**

This material is usually known in the trade as tin plate or roofing tin. It is not, however, true or bright tin plate, but is an alloy of about 75 per cent lead and 25 per cent tin applied to a base of soft steel, or rarely wrought iron, in much the same manner as zinc is applied by the hot-dip process.

The coating is more adherent than zinc, will stand bending without cracking, and can be readily soldered. It does not, however, protect the base metal against rusting so well as zinc, and unless well painted, as directed on page 120, the base metal will rust when exposed. Neither terneplate nor galvanized iron should be walked upon, as this may cause leaks. The general remarks on galvanized metal will apply to terneplate. Standard roofing terneplate should weigh about 10 ounces to the square foot and should carry at least 1.3 ounces of coating to both sides of a square foot of area. The sheets are produced in different weights of base and quantity of coating and are sold in boxes of 112 sheets of 20 by 28 inches or made up from such sheets into rolls soldered together. Tables of weight, gauge mark, quantity of coating, etc., can be furnished by the dealer. Owing to the high cost of copper and its great expansion upon heating, copper sheet is being superseded by terneplate.

Before deciding on the roofing to be used, it would be wise to consider other forms of roofing material, such as canvas (see p. 134) or prepared roofing felt (see p. 136), as these types possess certain advantages.

(*g*) **Hardware**

Under this heading are included the metal articles used about the home, such as hinges, locks, knobs, window and shutter catches, exposed plumbing, and electric and gas fixtures.

These articles are usually of cast iron, steel, brass, or bronze. Since all iron or steel parts are liable to corrode, many of them are given a thin coating of brass or bronze and frequently are then represented by unscrupulous dealers as brass or bronze fittings. The actual metal used can be readily determined by scratching the surface at some unexposed part. In general, far better protection will be afforded by some form of zinc coating, if consideration of appearance will permit. If, however, a bronze or brass coating is desired, it should be of sufficient thickness to actually afford protection and not a thin wash intended only to keep the objects bright while on the shelves of the dealer. A good grade of baked japan is better than such a thin wash.

It is undoubtedly true that solid brass and bronze are far more permanent than either bare or coated steel, but as they usually cost from two to three times as much as steel or iron, true economy may not permit their use.

(*h*) Brass and Bronze

Brass is essentially an alloy of copper and zinc having a yellowish color, and bronze is an alloy of copper and tin with a whiter color. Other elements, such as lead, iron, manganese, nickel, phosphorus, etc., frequently present in small amounts, affect the quality of the alloy. Bronze is usually stronger and is considered a better material than brass, but this is only a general statement, since the composition, method of casting, and annealing have a pronounced effect on the character of the material. In rolling such materials into sheets, bars, etc., the metal is strained, and unless these strains are removed by annealing cracks may develop on standing. The character of the metal can only be determined by chemical analysis and physical tests, so the user must consider cost and character of service required and depend on a reputable dealer to furnish the material best suited to his needs.

(*i*) Plumbing Parts

Bathroom fittings are usually made of brass coated with nickel. Such surfaces when properly nickel-plated remain bright with minimum attention. The articles should be carefully inspected for surface imperfections, and the thickness of the coating should be judged by scratching through to the base. Kitchen and laundry plumbing fixtures are generally solid brass and can usually be bought on reputation.

Electric-light and gas fixtures are usually iron or steel coated with paint or washed or coated with brass, or less frequently are solid brass. The same general remarks made regarding hardware apply to these materials, except that as they are not subject to much wear a bronze or brass coating protected by lacquer will usually afford adequate protection.

B. METAL UTENSILS AND WARE

Under this head will be considered the metal utensils and ware used in the kitchen and dining room and about the house. It includes the iron pots and pans; tin-plated ware; aluminum, copper, and brass utensils; pewter, steel, and silver-plated knives, forks, and cutlery used in the dining room; and buckets, pails, metal utensils, and tools.

There are certain fundamental principles which must govern in all considerations of household efficiency and economy which can be called "proportional value." This point can be best illustrated by a comparison of the value of cheap and expensive articles, such as cheap tinware and the more expensive aluminum articles used in the kitchen. This ware has many advantages. It is light, clean, and sanitary, transmits heat readily, does not chip, remains reasonably bright, is unattacked by food in the process of cooking, and is not poisonous; but it requires care to keep it in proper condition, will not stand careless heating, and is attacked by the alkaline cleaning compounds frequently used. If it can be given proper attention, it is believed to be an economical investment in spite of its relatively high initial cost. On the other hand, if the housekeeper is forced to use inefficient service and for adequate reasons is unable to give strict attention to the details of the kitchen, the use of cheap tin ware renewed when necessary would undoubtedly be better economy.

The description and characteristics of the utensils will, it is believed, enable one to select that which is best fitted to the individual requirement.

(*a*) Kitchen Utensils

Cast Iron.—Under the older general conditions and present rural conditions where the kitchen stove is kept going most of the time, the old-fashioned iron pots and pans serve a useful purpose. Cast-iron utensils are practically indestructible, and owing to the mass of metal they maintain an even temperature, but they are heavy and cumbersome, difficult to keep clean, the dark surface causes high radiation loss of heat, and on the modern gas range they require high consumption of fuel to heat the mass of metal.

Tinware.—Tinware consists of a sheet iron or steel base coated with pure tin. The article is pressed into shape or made up with soldered joints. The pressed article is to be preferred when the shape permits, as it possesses a smooth surface, whereas soldered joints are objectionable owing to the presence of lead in the solder. As the coating may be injured in the stamping, the better class of tinware is retinned after forming by passing the formed article through a bath of molten tin. Such retinned articles will be found to have smooth rounded corners. As originally made and still obtainable, when coated with a heavy layer of pure tin on a heavy base, tinware is very serviceable but should not be used to cook foods which contain or may become acid, such as tomatoes and rhubarb. It is light in weight, can readily be kept bright and clean, and holds up well in service. Much of the modern tinware is so light in weight and has such a thin coating of tin on the surface that its life is extremely short, so that in spite of its very low initial cost thinly coated tinware, except in special cases, can not be considered economical. Care should be taken that empty vessels are not overheated, as the tin coating melts at a low temperature (231° C or 448° F)—far below the temperature of the flame of the modern gas or blue-flame oil stove.

Pinholes in the coating of tin, through which the steel backing is exposed to the action of any corroding agent, largely determines the life of tinware, provided that the coating has not been otherwise injured or misused. Retinned ware is comparatively free from imperfections. The presence of tin will accelerate rather than retard the corrosion of the iron base if the latter is exposed. It is important that tinware be kept clean and dry when not in use.

Copper and Brass.—Copper and brass metals have long been held in high esteem, and while they both tarnish readily and require constant burnishing to be kept bright the tarnish is superficial, and with reasonable care they will last indefinitely.

Copper is used largely as the bottom of tin wash boilers and teakettles, as it conducts heat readily and is not corroded by the water. While both copper and brass have been largely used abroad, even by the poorer class, by whom such utensils are treasured and handed down from one generation to the next, they have but a limited use in this country, confined more especially to hotels and kitchens of the larger homes.

Brass has many of the characteristics of copper. Its use has been largely superseded by the enameled ware described in the section on ceramics. (See p. 14.)

Both of these metals are ideal for most cooking vessels, so far as durability, heat conductivity, etc., are concerned. If the vessels are carefully tinned on the inside, an undesirable corrosion of the metal from atmospheric or accidental causes while not in use is thereby prevented. The exterior is also most easily kept clean and in a sanitary condition if it is electroplated with nickel or some similar metal and polished.

Zinc.—The use of zinc in the form of sheets and drawn and swaged forms is not as well known as that of many other metals. Its slight corrodibility renders it very desirable for articles used in damp or wet places. Its uses are numerous. Eyelets made from zinc for any portion of the clothing will not rust and discolor the cloth as do those of steel; the same is true of shoe nails. Covers for fruit jars, washing tanks and draining racks of various kinds, the facing of washboards, and metal weather strips are also made from sheet zinc and illustrate uses of the desirable properties of the metal. Zinc is becoming more widely used especially where noncorrodibility is of prime importance rather than mere strength. The strength of the metal is much improved as the metal is worked and rolled into sheets, so that it compares very favorably in this respect with other metals often used for similar purposes.

Aluminum.—The noncorrodibility of this metal by atmospheric agencies, its high conductivity for heat, and its excellent wearing properties make aluminum very desirable for cooking utensils. Its longer life in service offsets the higher initial cost as compared with other cooking utensils.

It is shaped for use in several different ways. A few forms—e. g., griddles, ladles, some teakettles, etc.—are cast to shape. For this purpose the metal is hardened by the addition of from 6 to 8 per cent of copper. Cast vessels are not to be preferred, however, to the same forms prepared by other means.

The usual methods of shaping the metal are stamping and spinning. In the latter case a sheet of very soft metal is used, and by the aid of proper forms the sheet may be "spun" into the desired shape while it is being rotated upon a lathe. Although the metal is hardened considerably by the working it receives during the spinning, it usually remains comparatively soft. The stamped pieces are produced by a series of stampings from sheet metal, each succeeding step approximating more and more the finished article in shape. After the last stamping the article is finished by buffing and polishing. In this method a comparatively hard sheet metal may be used at the start. This, together with the hardening the metal receives during the stamping, insures a much harder and durable finished article than that which has been spun. Differences of hardness, great enough to be detected quite easily by pressure of the thumb and finger, often exist. The relatively low melting point of aluminum as compared with some other metals renders it necessary to take precaution in heating an empty aluminum dish over a very hot flame to avoid melting out the bottom. The melting point of copper is 1080° C (1981.5° F); that of aluminum is 656° C (1218° F). Iron melts at 1530° C (2754° F) and steel at a somewhat lower temperature.

Strong brine and alkalies (lye, soap, paste, etc.) attack aluminum, hence aluminum vessels should not be used for such substances.

(*b*) **Dining-Room Silverware**

All that is usually included under the name "silverware" may be conveniently classed under the two headings "solid" and "plated." Solid or "sterling" ware is an alloy of silver and copper, containing ordinarily about 7 per cent of the latter metal. This is added to give the requisite hardness.

By far the greater part of the silverware in use is of the plated type. The coating of silver is deposited electrolytically upon a suitable base; e. g., steel for knives and forks, German silver for spoons, Britannia metal for hollow ware, etc. The thickness of the silver coating is often expressed by the terms "single," "double," "triple," "quadruple" plate, etc. These terms are loose ones, and their value depends entirely upon the standing and reputation of the manufacturing firm using it. "Triple" plate articles from one source may be equal to only a "double" plated article or even less as prepared by more careful and reliable manufacturers. A much better method of expressing the thickness of the coating is to state the weight of silver used. This plan is coming more and more into use For example, knives may be stamped "15 dwt." (pennyweight), thus indicating that this amount of silver was used in coating a dozen knives. The higher numbers on larger articles are not necessarily indicative of thicker coatings as compared with small pieces of the same shape. A tablespoon has approximately twice the area of a teaspoon, so that if the teaspoon receives 10 pennyweights of silver per dozen the larger spoons should receive 20 pennyweights in order to have a coating of the same thickness. The examples given above are from actual practice. Articles with this weight of silver coating would be classed as high-grade product.

Articles which receive severe wear at certain parts—e. g., the lower side of the bowl of a spoon—should receive an extra coating on such portions to compensate for the added wear here. Silverware so treated can not be detected by visual examination alone, and hence the dealer's word must be relied upon in such cases. The products of all reputable manufacturers are always so treated. However, the wearing quality of the silver is influenced by other factors than mere thickness; e. g., rate of deposition of the silver, amount of buffing, polishing, etc. There is no way of detecting this, and one is thus forced to be guided by the standing and reputation of the manufacturer.

A variety of silver-plated ware which was more common formerly than at present is Sheffield plate. In manufacturing this an ingot of copper or some alloy of copper, as desired, is bound between thick plates of silver and the whole mass is heated sufficiently to weld the plates together, and the built-up metal is then rolled down to the desired thickness after being brought to the proper temperature. The articles may then be stamped, hammered, or spun from the resulting compound sheet.

Silver-plating solutions sometimes advertised for restoring silverware in the home are quite apt to be composed of solutions of mercury salts. When the article to be plated is suspended in the solution, mercury is deposited upon it, producing a very bright silvery appearance when the article is wiped. The same methods are used also by street fakirs.

Care of Silver.—By many it is claimed that the actual use of silverware is the best method of cleaning it and that the periodic cleaning and polishing shortens the life of the article. A method for cleaning tarnished silver electrolytically has recently come into use. The tarnished silverware, which has become blackened by materials containing sulphur, such as foods and gases, is placed in contact with a more active metal, such as zinc, tin, or aluminum, in a pan filled with a hot solution of sodium bicarbonate and sodium chloride; i. e., cooking soda and table salt. The electrolytic action set up causes the impurities which coat the silver to pass into the solution, leaving the metal clean. Sometimes the pan itself is made of zinc or aluminum, but the surface must be kept scoured. Zinc soon becomes corroded on the surface and hence inactive. It should, however, be borne in mind that silver which has been decorated by a method of coloring entirely analogous to the accidental tarnishing which happens in use may lose its distinctive appearance or be seriously marred by such methods of cleaning. For the plain uncolored silver it is a desirable method of cleaning.

(*c*) **Repair of Household Utensils**

Much of the metal repairing done at home may be considered under this heading, by using it in its broadest sense to include both "hard" and "soft" soldering. The general principle is the same throughout; i. e., the uniting of the well-cleaned surfaces of the metal in question by an alloy with a melting point somewhat lower than that of the metal to be joined together. In order that the molton alloy or "solder" may adhere and cover the metal to be repaired, the surfaces must be clean and bright. If the nature of the material will permit, the surface should first of all be cleaned by scraping until the clean metal is exposed. In the soldering operation an appropriate "flux" is used which will prevent the formation of a surface oxide film or dissolve one if already formed. In general, an excess of the solder should be avoided. If the surfaces are well cleaned so that the molten solder adheres to them evenly, a stronger joint will result if the two parts are held firmly in contact so as to squeeze out the excess solder, and are held so until the work cools below the solidification point of the solder than by using a thicker layer of solder as a bond of union. For the greater part of common work the ordinary plumber's or soft solder, consisting approximately of half tin and half lead, may be used. The presence of zinc in the solder is detrimental, while the addition of more tin lowers the melting point, which is essential in case the metal to be repaired will not stand a high temperature. While the use of the soldering copper (improperly called a soldering iron) is very general and gives excellent results after some practice, one may use instead a blowpipe or torch, by means of which a very fine hot flame may be directed immediately upon a spot. Some experience is necessary, however, to insure that the metal to be soldered will not be "burnt" or otherwise spoiled. Solder drawn into the form of "wire" is recommended. A flux much used for the ordinary class of work is a mixture of saturated solutions of zinc and ammonium chlorides. Soldering "rosin" is much used and is very convenient for use when only small areas or spots are to be united. Soldering paste is often the most convenient flux. Solder may be obtained in the form of a tube with the paste inside. No detailed method of procedure can be given, since the manipulations may vary with each article to be repaired and can be learned only by practice.

Alloys of low melting point, such as pewter and Britannia ware, may be soldered if care is exercised. The heating is done best by a blast of hot air, using a very fusible solder containing an excess of bismuth. Tallow may be used as a flux. To produce very strong joints "brazing" or hard soldering is used. The "solder" may be an alloy of zinc and copper, though for the best grade of work silver is generally employed. Borax makes an excellent flux, and for such work a blast lamp or blowpipe is required.

It is of value to know that by the proper method any of the metals in common use may be successfully welded or repaired. By use of electric welding, autogenous fusion by the oxyacetylene torch, or other similar means, nearly any broken casting or metal parts may be repaired. The successful welding and soldering of aluminum is, however, very difficult.

The development of the art of electric welding has rendered the riveting of handles to cooking utensils, the soldering of spouts to teakettles, the joining of two edges of sheet metal by a fold, etc., unnecessary. By a simple application of electric resistance welding, the two parts may be fused together and made one.

(*d*) **Defects of Metals**

A not uncommon defect of certain metals is known as "season cracking." The metal splits spontaneously, often a considerable time after being shaped, and with no apparent cause for the failure. This defect is found to be associated with those metal forms which have been severely cold-worked during the manufacturing, either by drawing, stamping, or spinning. If such articles be annealed for some time after being shaped, "season cracking" is almost entirely prevented. Although such defects are not detectable until the cracking is visible to the eye and the article is ruined, a knowledge of the cause is of interest and the ability to place the blame is of value.

(*e*) Removing Rust

No easy and satisfactory method to clean rusty iron or steel articles has been developed. Mechanical means, such as emery cloth or powder, is probably the most effective when it can be used. Care should be taken on coated surfaces, as the abrasion will remove the coating.

Irregular-shaped articles or those that have stuck together by nesting can frequently be treated by soaking in kerosene, which loosens the rust but can not be expected to produce a clear bright surface. Solution of citrate of ammonia or citrate of soda will also loosen rust. To prevent rusting of tools or other articles, they may be wiped with vaseline or other available grease. This is especially advisable when articles are to be stored for some time.

(*f*) References

Campbell: Manufacturing and Properties of Iron and Steel.
Howe, Henry M.: Metallurgy of Iron and Steel.

4. LIME

(*a*) Definition and Description

Limestone is one of our best-known and most widely distributed rocks. In a pure state it consists essentially of calcium carbonate. There is, however, an important variety known as dolomite, in which nearly half of the calcium is replaced by magnesium. Lime is generally defined as the product obtained by the heating or calcination of limestone until the carbonates are decomposed. The carbon dioxide is driven off as a gas, leaving calcium and magnesium oxides in the form of lime. Of course, all limestones contain more or less impurities, such as sand and clay, which remain in the lime and if sufficient in quantity may impair its quality. Fortunately, this defect is easy to detect, because a lime containing too many impurities will not slake when added to water.

Commercial Forms of Lime and Lime Products.—Lime as defined above is commonly known as quicklime, in contradistinction to the rather loose use of the word lime to include a number of allied materials. When given an opportunity, quicklime absorbs water and carbon dioxide with great avidity. The calcium oxide in the lime enters into chemical combination with water to form calcium hydroxide. This is the reaction which takes place when lime is slaked. If there is an excess of water present, the resultant product will be a lime paste or putty. If, however, there is just enough water to complete the chemical reaction, the calcium hydroxide produced will be in the form of a dry, flourlike powder, which is known commercially as hydrated lime. Air always contains more or less water and carbon dioxide. When quicklime is exposed to the air, it absorbs both of these substances. The resultant product, known as air-slaked lime, is therefore a mixture of calcium hydroxide and calcium carbonate, the proportions of each ingredient depending largely upon the age of the sample. Air-slaked lime may thus be regarded as an intermediate product between hydrated lime (calcium hydroxide) and ground limestone (calcium carbonate).

The four products just enumerated cover the field to be considered in this article. In addition, the following allied materials should be noted:

Dimension stone is stone cut to dimensions for building purposes; it may be limestone, sandstone, granite, etc. Marble differs geologically but not chemically from limestone or dolomite. Cave onyx is the familiar form of calcium carbonate found as stalactites in caves. Chalk, coral, and marl are other forms of calcium carbonate. Rubble or riprap is crushed stone of large size used for filling retaining walls, piers, etc., generally without mortar. Crushed stone of various sizes is used for making roads, as an aggregate for concrete, as a filler for asphalt, as roofing gravel, etc. Finely ground limestone is used as a fertilizer, as chicken feed, as a filler for paper, rubber, leather, and cotton goods, and as an adulterant in foods, paints, etc. Especially pure and finely divided forms are known as "whiting" and "precipitated chalk." Glazier's putty is made by mixing whiting with linseed oil. Precipitated chalk is sometimes used as a mild abrasive, as in dentifrice or silver polish.

Some obsolescent and colloquial terms are apt to cause confusion in the lime industry, and an attempt is hereby made to discourage their use. Among them may be included "stone lime," meaning lime burned from limestone and retaining the original form of the pieces of stone. The material is quicklime; the particular form which it has can make no difference to the purchaser. If it should be desired to have the quicklime in this particular form, the term "lump lime" is more widely used and less apt to be confused with limestone. "Shell lime" is produced from oyster shells either by grinding or by calcining. In the former case, the product is simply calcium carbonate, not lime, while in the latter case it is merely quicklime made from shells. This latter fact is of interest to the purchaser only because lime made from shells is generally more impure than that made from stone. "Marl lime" is marl which has been dried but not calcined. It, therefore, consists essentially of calcium carbonate and has no right to the name lime. "Ground lime" is a prolific source of confusion. In some localities it means ground (i. e., pulverized) quicklime. In other places it means any form of lime which can be applied to the ground as fertilizer. In this sense it includes all forms of oxide, hydroxide, and carbonate of calcium and even the sulphate as gypsum or land plaster.

Quicklime.—Quicklime is generally delivered in lumps just as it comes from the kiln. For special purposes it may be pulverized to any desired degree of fineness. The ordinary package is a wooden barrel containing about 180 pounds net. Of course, these barrels are not air-tight, so that if lime has been stored in them for some time it is apt to be more or less air-slaked. Air slaking is accompanied by disintegration of the lumps, so that a barrel which contains very much fine material is open to suspicion. It should not be condemned hastily, however, for some manufacturers are compelled to break the lumps in order to get the required weight into the barrel. To test the quality, take some of the fine material and mix it with about its own weight of water. If it slakes and generates a considerable amount of heat, it is pulverized quicklime and is not badly air-slaked.

Particular care must be observed in storing quicklime. It must be kept in a receptacle which is perfectly tight to both air and water in order to prevent air slaking. If it does come in contact with water, the heat generated is quite apt to be sufficient to set fire to wood. The only way it can be stored safely and satisfactorily is in a metal bin or can with an air-tight cover.

Hydrated Lime.—Hydrated lime is a fine white powder, which comes packed in paper bags holding 40 or 50 pounds. It is able to absorb carbon dioxide from the air, especially when damp. But it has the ability to protect itself from air slaking, since it is a fine powder and the surface becomes coated with a crust of air-slaked lime, which acts as a preservative coating to protect the inside of the mass. To determine whether or not a sample of hydrated lime is badly air-slaked, mix some of it with enough water to form a cream and add some dilute hydrochloric (muriatic) acid. Hydrated lime will dissolve quietly, but the calcium carbonate contained in air-slaked lime will show an effervescence as the carbon dioxide is driven off. The calcium oxide in hydrated lime has all been satisfied with water, so that when hydrated lime is wet there is no possibility of any further chemical reaction, with its attendant evolution of heat. Consequently, hydrated lime may be stored indefinitely in paper bags without any danger of fire. It is quite permissible to store it in the original package, provided ordinary precautions are taken to keep it dry.

When calcium hydroxide is made into a paste with water and exposed to the action of air, first some of the excess water evaporates and then the calcium hydroxide is attacked by carbon dioxide to form calcium carbonate, with the evolution of more water. This process constitutes the setting or hardening of lime mortar. Obviously, it is immaterial, so far as the chemical reaction is concerned, whether the calcium hydroxide is prepared from calcium oxide (quicklime) by slaking or it is purchased as such (hydrated lime). In other words, quicklime or hydrated lime may be used interchangeably with identical results. When building a house, where large quantities of lime are required, economic conditions may be such as to demand the use of quicklime in preference to hydrate. But for ordinary household purposes (except in some special cases as a fertilizer or disinfectant) hydrated lime is far preferable for the following reasons: It comes in a smaller package, and if the entire quantity is not used the remainder may be stored in the original package without extraordinary precautions against deterioration and with absolutely no danger from fire. It does not require any preparation for use.

AIR-SLAKED LIME.—Air-slaked lime can hardly be considered a commercial article. It can occasionally be obtained in small quantities from dealers who have had quicklime spoil on their hands inadvertently. There is no purpose for which air-slaked lime is used which could not be better accomplished by either hydrated lime or ground limestone. The only advantage of air-slaked lime is its extreme cheapness. Air-slaked lime must, therefore, be regarded as a product which is partially spoiled and which is bought only because it is cheap. Tests for its purity are, therefore, unnecessary. It may, however, contain a considerable amount of calcium oxide, so that storage conditions should be such as to preclude the danger of fire.

(*b*) Mortar

Lime has been used for thousands of years in mortar for masonry. Lime mortar is not so strong as mortar made from Portland cement, but its strength is amply sufficient for all ordinary construction. A lime mortar consists of three essential ingredients—calcium hydroxide, water, and sand. If quicklime is purchased, the calcium hydroxide must be prepared from this by slaking. Contrary to the common opinion, the proper slaking of lime is not a simple operation for inexperienced labor. The best results can be obtained if the slaking is carried out according to the following directions.

Support the mortar box in such a way that one end is a few inches higher than the other. In the lower end put some water, and have a hose handy to add more as needed. Put the lime in the upper end of the box, and work it into the water with a hoe. First add to the water about an equal bulk of lime, and let it alone until the chemical reaction has commenced. This may take from a few seconds to an hour or more, depending upon the magnesia content of the lime and the temperature at which it was burned. When the slaking is well under way, the lumps will have disintegrated and the mass will be quite hot. Stir vigorously with the hoe from now on to prevent local overheating and to insure an even temperature throughout the mass. The water should be kept continuously at or near the boiling point. If the mass gets too hot, add more water, if too cold, add more lime.

Caution: If the temperature drops much below the boiling point, the lime will be "drowned," which will result in a smaller yield of paste and impair its plasticity. If the mass gets so hot that it dries out locally, the lime will be "burned" and will be unsafe to use unless soaked under water for some time. When slaking has been completed with proper care so that the lime is not "burned," the paste should be covered with sand to protect it from the air and allowed to cool. It is better, however, to cover the paste with water and let it age for a week or two. If hydrated lime is purchased instead of quicklime, it is necessary only to mix it with water until a paste of desired consistency is obtained. It is better to add the hydrated lime to the water rather than vice versa, and greater plasticity can be obtained by soaking the resultant paste under water for a day or two, though this is not necessary. To the lime paste thus prepared enough sand and water are added to make a mortar of the desired working qualities.

A word about the sand may be advisable. Lime paste contracts when it sets. This shrinkage is so great that the specimen usually disintegrates; in any event, it cracks badly and has no strength. Sand, acting as an inert filler, tends to prevent this contraction, and the presence of a certain amount of sand is absolutely essential if the mortar is to have any strength. The proportion of sand required for maximum strength varies with the quality of lime, but is generally from one to three times the weight of the quicklime used. More sand of course gives a weaker mortar, but this decrease of strength is slight; so that, for instance, a 1 to 6 mortar is nearly as strong as a 1 to 3. The maximum amount of sand which can be used is governed not by the strength but by the working qualities. It will be found quite difficult to use a mortar as lean as 1 to 6. The sand should be clean and evenly graded as to size, with no extremely fine material.

It must be remembered that the final hardening of a lime mortar depends on the action of the air. For this reason it will not set under water, and its use is, therefore, not recommended for foundation work where the earth is back-filled against the masonry.

(*c*) **Lime in Portland-Cement Mortar**

Lime is being used to some extent as an addition to Portland cement in both concrete and mortar. For this purpose hydrated lime only is of value. The use of quicklime is fraught with so many difficulties as to be almost prohibitive. It is claimed that the addition of about 10 per cent of hydrated lime to the Portland cement used in making concrete improves the material in many respects. The Bureau of Standards is now conducting extensive research work to ascertain the truth of these claims. Mortars made from mixtures of Portland cement and hydrated lime in different proportions show a regular gradation in strength—the more lime, the less strength. However, the working qualities of the mortar are vastly improved by the presence of the lime. This has such an important effect that masonry laid up with mortar containing lime is frequently stronger than when cement alone is used, even though the former mortar is the weaker. When a small amount of cement is mixed with lime mortar, the cement increases the rate of set but does not have any noticeable influence on the strength. Experiments on brick piers recently conducted at Columbia University indicate that the greatest strength can be obtained with a mortar composed of one part of Portland cement, one part of hydrated lime, and six parts of sand, by volume.

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It is sometimes desirable to point the joints in old masonry in order to improve its appearance. To do this, cut out the old joints to a depth about equal to their width. Sprinkle the entire surface with water to decrease its absorptive power. Fill in the joints with a mortar made of lime paste and sand. For this purpose the mortar should contain as much sand as possible, otherwise it is apt to shrink away from the brick as it dries and may fall out. To obtain white joints, one may use either a white sand or marble dust. Pigments may be added to produce colored joints; those generally used are hematite for red, yellow ocher for buff, or lampblack for black. Mortar may be removed from the face of a brick by washing with a dilute solution of hydrochloric acid.

The mortar needed to lay a thousand bricks will require about four-tenths of a barrel of quicklime or 100 pounds of hydrated lime and four-tenths of a cubic yard of sand.

(*d*) **Other Uses of Lime**

The use of lime for plastering and as whitewash are discussed in other sections of this circular. Lime finds many uses about the house and garden other than as a structural material. Among these may be mentioned its use as a fertilizer; as a spray for trees; as a disinfectant, deodorant, and insecticide; as a medicine; and as an agent for water purification.

Fertilizer.—As a fertilizer lime serves many distinct purposes. It is a direct plant food. It is a valuable corrective agent, either to disintrigrate hard clay or to bind together light sandy loam. It creates an alkaline condition in the soil which inhibits the growth of deleterious bacteria and promotes the growth of the beneficial nitrifying bacteria. These latter have the ability to extract from the air that valuable plant food, nitrogen; and the lime tends to fix this nitrogen and hold it until the plants are ready to use it. Lime tends to decompose some of the constituents of a clay soil and liberate the potash they contain. Animal manure and vegetable mulch are valuable fertilizers, but when applied to a sour soil they are quite as apt to do harm as good. They decompose with the liberation of organic acids, which should be neutralized by lime in order to keep the soil in a healthy condition.

Any of the four forms of lime may be used as a fertilizer for general purposes (quicklime, hydrated lime, air-slaked lime, or ground limestone). Three factors govern the selection of one of the four—the price, the content of calcium oxide; and the fineness. Absolutely pure quicklime will contain 100 per cent calcium oxide; hydrated lime, 74 per cent; ground limestone, 56 per cent; air-slaked lime, somewhere between 74 per cent and 56 per cent. Only the extremely fine particles are immediately available as a plant food or as a soil sweetener, so that the fineness of the material is an important factor in determining its value. When quicklime is used, the customary procedure is to buy it in the fall and store it outdoors so that it can air-slake during the winter. By spring it may be considered as being completely air-slaked; i. e., it has all been converted into calcium carbonate and is chemically identical with ground limestone. It is generally cheaper to produce calcium carbonate in this way than to purchase limestone ground to the same degree of fineness. Quicklime itself is a powerful caustic and should never be permitted to come into direct contact with plants or seeds. Hydrated lime and ground limestone are both efficient and safe fertilizers which can be used in the spring in direct contact with seeds. The difference between the two is largely one of time of action. Hydrated lime is immediately and completely available, and it is, therefore, advisable to apply a small amount (not more than 400 pounds per acre) every year. Care must be taken to keep up the supply of vegetable mulch, because the immediate benefit of hydrated lime depends upon its ability to attack this mulch and render it available for plant food. Ground limestone may be applied in larger quantities (about 1 ton per acre) every four or five years. It is not able to attack the mulch, but merely takes care of the products formed by natural decomposition. It is, therefore, slower than hydrated lime in yielding returns. Air-slaked lime should be stored outdoors some little time before using, to insure the absence of calcium oxide. Lime made from dolomite and containing a high proportion of magnesia may be used instead of the high-calcium lime with apparently the same results. Caution: Some plants are injured by the use of lime, viz, cotton, tomato, grape, peach, apple, pear, radish, flax, blackberry, raspberry, and cranberry.

Spraying Trees.—Compounds made from lime are used as insecticides for spraying fruit and shade trees. The most common of these are lime-sulphur spray and Bordeaux mixture. Lime-sulphur spray may be made as follows: In a large iron kettle put 16 pounds of quicklime. Add enough water to slake it to a putty. When it is quite hot, add 15 pounds of flowers of sulphur. Build a fire under the kettle and keep the contents boiling. Add more water gradually, without stopping the boiling, until the whole volume is about 40 gallons. Boil vigorously for one hour. Strain through a fine screen. It is now ready for use and should preferably be applied while still hot.

To make Bordeaux mixture, dissolve 4 pounds of copper sulphate (blue vitriol) in 25 gallons of water. Slake 4 pounds of quicklime to a paste and dilute with water to 25 gallons. Just before use mix the two solutions, being sure to pour the copper sulphate into the lime and not vice versa. Stir vigorously, strain through a fine screen, and apply. Since both of these sprays are applied by pumping them through a hose and nozzle, any coarse particles of impurities in the lime which will not slake will cause difficulty by clogging the apparatus if the spray be not strained. Hydrated lime made for this particular purpose is now on the market; it is all guaranteed to pass a hundred-mesh screen. The use of this material is recommended because it eliminates two operations—the slaking and the straining. In the above formula for lime-sulphur spray use 21 pounds of hydrated lime instead of 16 pounds of quicklime; in the Bordeaux mixture use 5¼ pounds of hydrated lime instead of 4 pounds of quicklime.

Disinfectant.—Lime is of great value about the house and garden as a disinfectant, deodorizer, and insecticide. It is milder than the commonly used chloride of lime, but is free from the offensive odor and possibly harmful effects of this material. In extreme cases the use of quicklime may be necessary, in which case due precautions must be taken to prevent fire. For most purposes hydrated lime will prove much more satisfactory. A frequent application of hydrated lime to chicken coops, stables, and barns will keep conditions sweet and clean without danger of injury to the animals or of fire. The use of air-slaked lime for this purpose is to be condemned, because it may contain calcium oxide, which is dangerous, and it is sure to contain calcium carbonate, which is of little value.

Ground limestone, in pieces from $\frac{1}{16}$ to ⅛ of an inch in diameter may be bought under the name of "chicken grits," which forms a valuable article of diet for chickens.

Medicinal.—The limewater so commonly used for medicinal purposes is merely a saturated solution of calcium hydroxide in water. To prepare it, add about a teaspoonful of hydrated lime to a quart of water (preferably distilled) in a bottle. Shake at intervals during the day and let settle. The lime will not all dissolve but should settle to the bottom, leaving the solution clear. Pour off this solution and keep well stoppered until used. If the solution is exposed to the air, a scum of calcium carbonate will form on it, but this will do no harm other than to diminish the strength of the solution.

WATER PURIFICATION.—Most natural waters contain a number of dissolved salts, such as the sulphates and carbonates of iron, aluminum, calcium, sodium, and potassium. There is generally, also, some free carbon dioxide, and free sulphuric acid is not unknown. Most of these salts in moderate amounts may be regarded as distinctly beneficial to the human system, but some of them, notably the salts of iron and calcium, may be detrimental when the water is used for laundry purposes. Calcium salts are the cause of hardness in water. When soap is added to hard water, the organic acids of the soap combine with the calcium to form insoluble compounds which have no detergent properties, and no lather can be formed until all of the calcium is so precipitated.

Calcium carbonate is soluble only to a very slight extent in pure water. It is much more soluble in water containing carbon dioxide. It follows, therefore, that if the carbon dioxide be removed from the water, most of the calcium carbonate will simultaneously be thrown out of solution. The carbon dioxide can be removed by adding enough lime to combine with it and form the insoluble calcium carbonate. This explains why, when lime is added to a natural water, the water thus treated contains less lime than it did originally—that the "temporary hardness" of water can be removed by the addition of lime. Moreover, the lime will react with the salts of iron and aluminum, throwing these metals out of solution in the form of insoluble hydroxides. These hydroxides, especially that of aluminum, are very bulky and gelatinous and have the power of mechanically collecting and carrying with them minute particles of organic matter and even bacteria. For this reason it is frequently advisable to increase the volume of this precipitate by adding alum to the water, before treating it with lime.

(*e*) Specifications

All quicklime and hydrated lime should be purchased on the standard specifications adopted by the American Society for Testing Materials.

(*f*) References

For more detailed information on this subject, see Bureau of Standards Circular No. 30, Lime: Its Properties and Uses; Bureau of Standards Technologic Paper No. 16, Manufacture of Lime; The Source, Manufacture, and Use of Lime, published by the United States Geological Survey.

5. CEMENT

(*a*) Definition and Varieties

In 1824 Joseph Aspdin, of Leeds, England, obtained a patent on the manufacture of a cement by the calcination of a mixture of clay and limestone. To this material he gave the name "Portland Cement," because of its fancied resemblance, when set, to limestone quarried on Portland Isle, Dorsetshire.

Thus originated the name and substance of one of the most important present-day materials of construction. At the present time Portland cement has largely displaced most other hydraulic cements by reason of its low cost, superior strength, and durability, but a few others are used to a limited extent for special purposes.

In the days when the price of Portland cement was almost prohibitive "Natural cement" was quite extensively produced in this country. Natural cement is manufactured by calcining natural-cement rock (clay-bearing limestone) in somewhat the same manner as lime is obtained from limestone. It differs from Portland cement chiefly in being of more variable composition and of inferior strength, although sometimes setting more rapidly. It is also cheaper than Portland cement and may be used in cases where great strength is not required. In 1900 the production of natural cement in the United States was about equal to that of Portland, but since then the use of the latter has increased enormously while that of the former has greatly decreased.

Puzzolan cement is composed of certain volcanic tufas or ash, pulverized and mixed with slaked lime. The Romans used this type of cement in their construction work, some of which has endured more than 2000 years. In this country puzzolan cement is made from powdered blast-furnace slag and slaked lime. It is inferior to Portland cement in strength and is not widely used.

In recent years magnesium oxy-chloride cement has come to be extensively used in the manufacture of composition flooring. Its base is powdered magnesium oxide, which is mixed with a solution of magnesium chloride before application. The commercial article contains, in addition, a great variety of fillers, such as sand, sawdust, asbestos, etc., and various coloring materials. Composition floors of oxy-chloride cement are more expensive than Portland cement floors, but are less hard and brittle and possess a greater degree of warmth and ease under foot, together with good wearing qualities.

(*b*) Composition and Manufacture of Portland Cement

Portland cement is composed, chemically, of aluminates and silicates of calcium, and the raw materials for its manufacture must therefore contain alumina, silica, and lime.

These are obtained by the use of mixtures of (*a*) cement rock (clay-bearing limestone) and pure limestone; (*b*) limestone and clay or shale; (*c*) marl and clay; or (*d*) blast-furnace slag and limestone. In the majority of cement mills the available raw materials, always under chemical control, are ground together as a dry powder, which is then fed into the upper end of slightly inclined (that is, nearly horizontal) long rotating kilns. These kilns are heated by large blast burners consuming pulverized coal, oil, or gas, blown into the kiln at the lower end. Inside the kilns a maximum temperature of approximately 1300° C (2400° F) is maintained, which is sufficient to produce chemical combination and sintering of the raw materials into a nearly black clinker, but is slightly below the actual melting point of the clinker. After coming from the kiln the clinker is cooled, crushed, mixed with about 3 per cent of gypsum, and ground in tube mills or other grinders to a fine gray powder. This is conveyed to storage bins, from which it is drawn as required and bagged for shipment.

(*c*) Properties and General Uses

Portland cement when mixed with water to a stiff paste becomes a solid mass within 10 hours. It thereafter hardens slowly and gains in strength for an indefinite period, usually attaining its maximum strength after about one year. When mixed with sand and water, it forms a mortar which also becomes very hard and durable, the strength of such a mortar diminishing as the proportion of sand is increased. A cube of cement mortar composed of 1 part by volume of cement to 3 parts of sand one month after molding should bear a load of 1 ton or more per square inch. Thus, a cylindrical column 8 inches in diameter made from such mortar (usually written "1 : 3 cement mortar") will support a weight of 100 ooop ounds without crushing.

In massive work, such as the example last cited, economy is attained without much sacrifice in strength by mixing gravel or broken stone in the mortar. A mixture of this type is called concrete, in which form a very large proportion of all the cement manufactured is used. A very good average grade of concrete for foundations of plain mass work is obtained by the use of 1 part by volume of cement, 2½ parts of sand, and 5 parts of gravel or broken stone, the latter running up to about 2 inches in size for the largest pieces. Concrete made in these proportions is usually expressed as "1 : 2½ : 5 concrete," the succession of numbers indicating the proportions of cement, sand, and stone, respectively. A somewhat richer, denser, and more nearly waterproof concrete is obtained by using the proportions 1 : 2 : 4, this mixture being commonly used in the construction of basement walls and floors, retaining walls, reservoirs, etc. Concrete in the proportions of 1 : 1½ : 3, because of its still greater density and hardness, is generally recommended for the construction of roadways. This type of road if properly laid is one of the best for general traffic.

Theoretically, mortar and concrete depend for their strength upon the adhesive quality or bond of the cement to the particles of sand and stone. As the sand and stone are in themselves stronger than the cement, it follows that the strongest mortar should be that in which just enough cement is used to coat the sand grains and fill the spaces between them, and, similarly, the strongest concrete should be that in which just enough mortar is used to coat the stones and fill the spaces between them. In practical concrete work perfect coating of the sand and stone and complete filling of the spaces with the theoretical amount of cement is impossible, and, therefore, the use of more cement yields stronger concrete. It is, nevertheless, true that the making of good concrete requires very thorough mixing, as well as clean sand and stone. The amount of water used in mixing concrete materials is not generally specified, but no more should be used than will enable the mixture to be handled readily and worked into place without leaving pockets and voids. The use of excess water in mixing the concrete may cause a reduction of 50 per cent or more in strength and make it less durable. Therefore, it is important that too much water should not be used.

Concrete is a material high in compressive strength but low in tensile strength and is, therefore, unsuited in itself for the construction of such members as load-carrying beams and floor slabs, which are, as a rule, supported only at their ends. To overcome this defect, the concrete in such construction is cast around steel rods, to which the cement bonds firmly and which, therefore, become an integral part of the beam or slab. The steel supplies the tensile strength which is lacking in the concrete, and the combination, which is ordinarily called "reinforced concrete," is suited for almost any type of construction in which strength and rigidity are essential.

(*d*) **Household Uses**

It will be found convenient to keep a small quantity of Portland cement for household repairs. This may be preserved indefinitely in a moisture-proof container, such as a covered tin can or glass jar.

Repair.—Defects in the concrete and masonry of a house arise from careless construction, settling, and other causes and are not uncommonly sources of more or less serious trouble. One of the most common cases of this sort is a leaky basement due to cracks in the floor or imperfect joints in the walls. Small leaks of this sort can usually be repaired by the use of cement alone or, preferably, by the use of cement mixed with 1 to 2 parts of sand. For example, suppose that a narrow crack has developed in a concrete basement floor which lets in a considerable amount of water. To repair the defect, chip away the concrete on both sides of the crack to a width of 3/8 or 1/2 inch and to a depth of 1/2 inch or more and clean away carefully all the loose material. Then thoroughly saturate with water the concrete along the crack, allowing it to absorb as much water as it will. Next make a thin cream or "grout" of cement and water, and with a small stiff brush apply it freely to the sides of the channel which has been chiseled out. Finally, mix a sufficient quantity of 1 : 2 mortar, using only as much clean water as will allow it to be handled readily with a trowel and fill the channel with it as completely as possible. After the mortar has set, and especially if the air in the basement is fairly dry, the floor in the vicinity of the crack should preferably be kept wet for a few days by covering with wet sand, burlap, or by frequent sprinkling, to insure proper hardening and a good bond between the fresh mortar and the old. Repairs of joints in brick, tile, stone, and concrete-block walls can be made in a similar manner. Here the old mortar should be raked out of defective spots and the process of wetting, grouting, and filling followed as outlined above. Serious leakage in basements is rather difficult for the householder to overcome by his own unaided efforts and usually requires the installation of proper drainage with a considerable amount of repair work or even reconstruction. In most cases, however, good cement mortar or concrete is the material that must be depended upon to effect the repairs.

A similar mixture may be used for plastering a brick wall, adding, however, hydrated lime (about 10 per cent by weight of the cement) in order to make it more plastic. One of the most essential features is to have the wall thoroughly clean and saturated with water before applying the cement mixture. Two or more thin coats troweled hard are better than one thick coat. This mixture is nearly impermeable to water; hence, nothing is gained by using the so-called "waterproofing" compounds, most of which are worthless.

Rats, mice, and other vermin usually obtain access to houses from the basement through openings into partitions or walls at the first-floor level or else through holes cut for pipes, electric conduits, etc. The fundamental remedy for this type of annoyance is to have the upper part of the house absolutely sealed off from the basement except at the closed door at the head of the basement stairs. The methods of closing all other openings between basement and first-floor level depend upon the type of house, but the householder may bear in mind that cement mortar is absolutely rat and vermin proof and can always be used to seal openings in masonry and concrete. In certain cases large openings between floor joists or studs can be most effectively closed by the use of expanded metal lath or stout wire netting of 3/8 to 1/2 inch mesh and cement mortar. Small openings in woodwork, such as knot holes and large cracks, can also be sealed with mortar, but because the latter is brittle and does not bond well to wood some means must usually be provided to hold it permanently in place. A simple means of doing this, which will answer in most cases, is to drive brads or nails into the wood in such manner that they will be covered by the mortar and support it firmly when set.

Cement is adapted to other repairs about the house, but space is lacking for more than a few general suggestions. It has been used successfully in the sealing of cracks in laundry tubs, furnace casings, and fireplaces; holes where water and gas pipes enter the basement and joints and breaks in drain pipes and vents; in connecting smoke pipes to chimneys; in repairing breaks and cracks in concrete walks and steps; and in patching stucco. In relation to the last three items it is to be borne in mind that cracks occurring in any type of cement-finishing work are generally an eyesore rather than a serious injury which interferes with the purpose they serve, and that any attempt to repair them should not be made unless an improvement in appearance is assured beforehand. The patching of exposed cement work in such a manner that the patch does not show disagreeably is, unfortunately, difficult of accomplishment.

Construction Work.—Especially to the farmers and home owners who live outside the crowded districts of large cities, and who by reason of circumstances or natural inclination are interested in improving their property by the work of their own hands, Portland cement offers many possibilities. Anyone possessing a little mechanical ability and a few tools can, with the aid of Portland cement, build a great variety of household accessories ranging in size from match holders and ash receivers to water tanks and coal bins; on a somewhat larger scale one can put in many permanent improvements, among which may be mentioned walks, floors, steps, driveways, fence posts, benches, watering and feeding troughs, retaining walls, foundations for out buildings, refuse burners, hotbeds, cold frames, culverts, cisterns, tanks, swimming pools, and silos.

The proportions of cement, sand, and gravel to be used in mixing concrete should be varied according to requirements, but for home use on a small scale good results will be obtained by using 1 part by volume of cement, 2 parts of sand, and 4 parts of gravel or broken stone. In estimating the quantities required for any particular job it is first necessary to determine how many cubic feet or yards will be occupied by the finished concrete. Suppose, for example, a cement walk is to be built 40 feet long, 2 feet wide, and 4 inches thick, of 1:2:4 concrete. The walk will contain 40 by 2 by $\frac{1}{3}$ cubic feet, approximately 27 cubic feet, or 1 cubic yard. Now, it is obvious that if 4 cubic feet of cement, 8 cubic feet of sand, and 16 cubic feet of gravel are ordered for the job the amount of mixed concrete will fall short of what is required, for the cement and sand together will largely go into the spaces between the pieces of gravel, and the volume of the mixed concrete will be somewhat greater, but not much greater, than the volume of the gravel alone. Hence, a general rule to be followed on small jobs is to order a volume of gravel or broken stone equivalent to the volume of the finished concrete, one-half as much sand, and one-quarter as much cement; that is, when the above proportions are to be used. For mixtures richer than 1:2:4 generally a lesser volume of materials will be required, the exact volume of concrete to be obtained varying with different materials.

The detailed construction of many of these improvements can not be given here, but certain general information on the use of cement and concrete materials and a few specific directions for typical examples of concrete work about the home will be presented in such manner as to indicate the method of dealing with any particular problem.

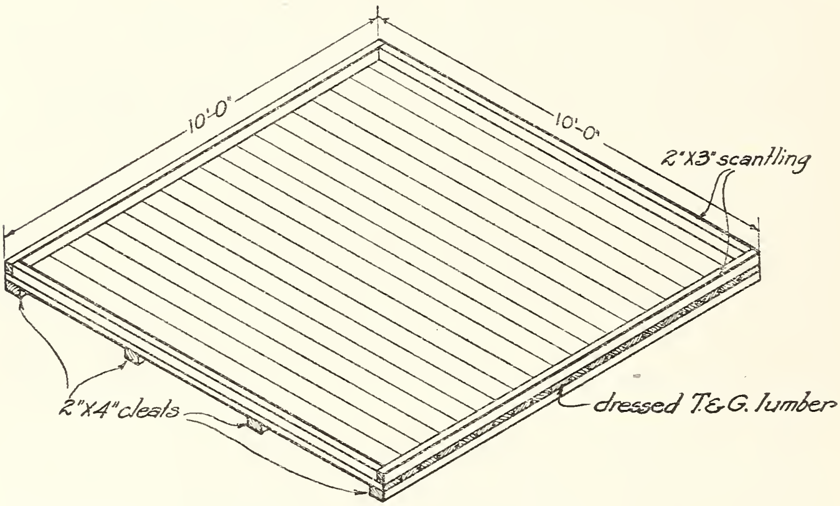

Fig. 5.—*Mixing board for concrete*

(*e*) **Concrete Construction**

Concrete Materials and Tools Required.—The materials required for concrete work are cement, sand, and gravel or broken stone. Cement is sold by the sack containing 94 pounds net or approximately 1 cubic foot. The price varies considerably in different localities, but in small lots can usually be obtained from 50 to 75 cents per sack. Sand and gravel or broken stone are usually sold by the cubic yard (27 cubic feet) or by the ton, the price depending largely on the source of supply and the distance the material has to be hauled, the price ranging between $0.50 and $2 per cubic yard.

The tools required for mixing and placing concrete by hand are a mixing board of 8 to 10 feet square, preferably of tongued-and-grooved dressed lumber. This is large enough for two men to mix at one time ¼ to ⅓ of a cubic yard of concrete. For small "one-man" jobs a mixing box 2 to 3 feet wide and 4 to 6 feet long with sides 6 to 8 inches high will be found convenient. If the ends of the box are sloped inward at the bottom and a single piece of sheet iron just the inside width of the box is laid along the bottom and carried up over the ends, the labor of mixing will be considerably reduced. The other tools required are usually included in the average household kit, viz, a shovel, a rake or hoe, a spade, a wheelbarrow, and three or four water buckets. If the job is large enough to require two or more men on the mixing platform, a shovel for each man will be necessary, or one man may use a rake while the others shovel. If the job is a small

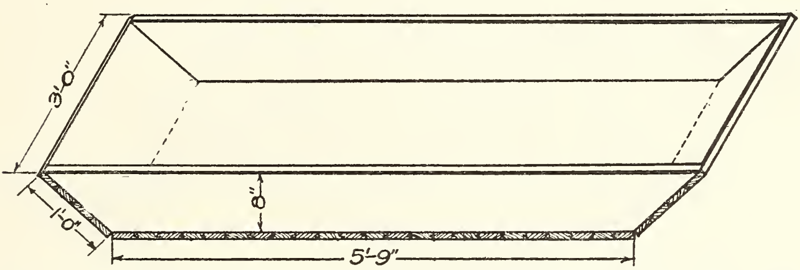

Fig. 6.—*A good type of box for mixing cement in small batches, such as may be readily handled by one man*

one, the hoe and mixing box can be used to better advantage. After mixing the concrete it can be handled either in buckets or wheelbarrows, and the spade is to be used in working the concrete into place in the forms. If for any reason a comparatively dry mixture is to be used, a tamper will be found useful. This can be purchased or easily made from a short piece of timber 4 to 6 inches square provided with a suitable handle.

Forms.—As concrete is a semiplastic material to be cast in some definite shape or form, molds of some sort are always required to hold it in place until it has hardened sufficiently to support itself and any additional load to which it may be subjected. In most cases the molds are made of lumber and are commonly known as "forms." Good forms are essential for good concrete work, and they add considerably to the total cost of concrete construction. In general, the greater the height of the structure the greater the proportionate cost of form work, for concrete is nearly two and one-half times as heavy as water, and the forms must be sufficiently well braced to withstand the pressure of the freshly mixed material.

The quality of the form work for any particular purpose depends largely on the character of the finished concrete surface desired. If the finished surface is to be smooth and free from pits and pockets, the forms must be of dressed lumber and mortar-tight, in fact, as nearly water-tight as possible. For example, in casting a bench or table the results will be much more pleasing if the exposed sides and corners are run smooth and true in the

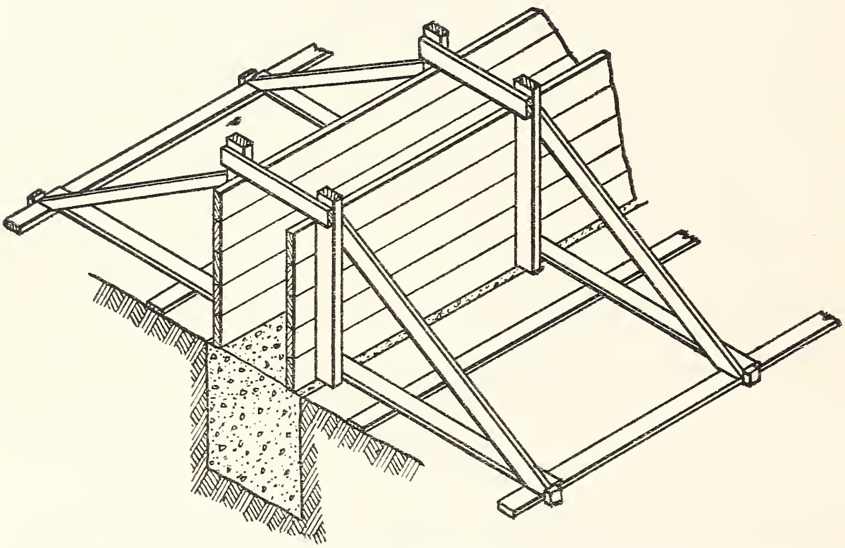

Fig 7.—*The substantial form bracing required for concrete foundation or wall construction above ground*

forms than if the finished work requires "pointing" or retouching to any considerable extent. In such work the forms must be very carefully built and securely braced and the concrete thoroughly worked into place, for the finished job will reflect every imperfection in the forms, even to the knots and grain of the wood. In fact, the results to be obtained in concrete ornamental work of any kind depend almost entirely upon the quality of the forms, and in many cases it is desirable to use sheet metal where a very even surface is required. Either wood or metal forms must be well oiled with mineral oil (kerosene is good) before the concrete is "poured," not only to enable the forms to be taken down easily but in the case of wood to prevent absorption of water from the face of the concrete, which otherwise is likely to result in a weak or dusty surface.

For other than ornamental work such painstaking care is not required in the construction of forms. For walks and roadways, foundation walls, and miscellaneous construction work about the home or farm forms of rough lumber will generally meet the requirements, provided always they be properly braced.

Inspecting and Testing and Storing Concrete Materials.—When cement, sand, and gravel or broken stone are ordered for concrete work, the user should satisfy himself the cement has not hardened in the sacks and that the sand and gravel or stone are reasonably clean; that is, free from dust, clay, mud, and chips of wood. Most Portland cement on the market is of satisfactory quality, and the only test which the home user need to make for his information is that of determining whether it sets hard within a reasonable time. This test may be simply carried out as follows: Thoroughly mix a half cup of cement with sufficient water to form a paste that can be molded into a compact ball in the hands. Place the ball on a piece of glass or metal and set it in the basement or any place where the temperature is between 50 and 80° F and where it will not dry too rapidly. At the end of 24 to 48 hours the ball should be hard enough to resist a fairly heavy blow with a hammer. A similar test may be made by mixing the cement with the sand to determine if the sand is satisfactory. If the mortar is after 48 hours still soft enough to be broken in the hands, it may be worth while to still further examine the sand as follows: Shake vigorously for several minutes a cupful or two of the sand in a 2-quart glass jar nearly filled with water and then allow to settle. After about two hours the clay and silt will settle in a sharply defined layer on top of the sand. If the depth of this layer is more than one-sixth to one-eighth the depth of the sand, the latter requires washing. The clay may be washed out of the sample by repeatedly-shaking up in the jar and pouring off the dirty water until only the clean sand is left. This sand may then be tested by the original mortar-ball test. If this fails to harden properly, the cement should not be used. If it is satisfactory, it will be necessary to wash all sand before using. This can be accomplished by having water overflow from a box into which the sand is shoveled and agitated to float off the lighter material. However, a sand requiring washing should not be used unless no other sand is available at a reasonable price.

Cement should not be stored in a damp place nor exposed to the weather, as it readily absorbs moisture and hardens in the sack. Sacks should not be piled on the ground or on basement floors but on boards or floors which are raised well above the ground. It may be kept indefinitely in fairly dry rooms. Under these conditions it may harden slightly, but this is not usually an injury if the lumps break up easily under the hoe or shovel in mixing.

Methods of Proportioning, Mixing, and Placing.—The measuring and proportioning of concrete materials for small jobs can most readily be done by means of water buckets, the 16-quart size in particular being recommended because it holds approximately ½ cubic foot. If these can not readily be obtained, bottomless boxes holding 1 cubic foot or more can be easily made for measuring the dry materials.

If enough concrete is to be mixed to require the use of a mixing platform, the following method of procedure is recommended: If 1:2:4 concrete is to be made, measure out 8 buckets of stone and spread it on one side of the platform to a depth of 3 or 4 inches; measure out 4 buckets of sand and spread it on top of the stone. Next measure out and spread over the sand 2 buckets of cement, taken as compacted in the bag. The stone, sand, and cement are then to be mixed dry by shoveling into a pile on the other side of the board, not by dumping the shovelfuls in a mass in one place but by shaking off and distributing the shovelfuls so that the materials will mix as they fall. A second mixing should then be given in the same manner by shoveling the pile back to its original position and spreading out as before. Now wet the mass down, using a bucket or hose, being careful not to use too much water. The whole is now to be shoveled back and forth until the stones are well coated with the sand and cement mixture, and enough water is added to enable the concrete to be rammed or spaded into place. The mixing of the stones and mortar is greatly facilitated if one man uses a rake and adds the water as required while the others shovel.

For a smaller quantity of concrete the mixing box may be used. The sand and cement are first mixed dry with a hoe, and the water may then be added and mixed to a mortar. The gravel or broken stone is then worked into the mortar with a final hoeing.

When the mixing has been completed, the concrete is shoveled into buckets or wheelbarrows and dumped into place. The quality of the concrete is greatly improved if during the placing of the mixture it is worked and spaded so that all corners of the forms are well filled and most of the air pockets and voids are eliminated. The mixture should be mushy but not watery. Spading the concrete against the forms brings a layer of smooth mortar to the outside surface, and if the mixture does not seep out at holes or cracks in the forms the resulting surface will be uniform in appearance and show neither sand nor stone. Lightly tapping the outside of the form after the mixture is placed will also assist in obtaining a good surface.

Waterproofing and Surface Treatment.—The home owner will not be especially interested in the question of waterproofing cement mortar and concrete unless he has a leaky basement, inferior stucco on the walls of his house, or is planning to build concrete water tanks for some purpose. In the case first cited he may be assured that if the cement work were properly done in the first place he would not be having trouble and that it will require only good cement mortar and concrete to make the basement tight. The repair of stucco is a more serious matter and will be considered briefly in the chapter on plasters. Water tanks may be made absolutely water-tight by the use of 1:2:4 concrete alone without any waterproofing treatment, provided the material is properly mixed and placed in one continuous operation, the concrete being well spaded against the surface of the forms.

The finishing of large concrete surfaces, such as walks and floors, in a manner to produce satisfactory results is the only difficult part of concrete work for the amateur, yet with a little care and practice he can meet all his back-yard requirements and feel assured that his work will give just as good service as that of the expert who put in the ornamental approach to his front door. The methods to be followed can be most conveniently outlined in the examples of concrete construction hereafter described.

Cement walks and floors not infrequently give trouble from "dusting" and wearing away of the surface to a rough gritty condition. This is usually the result of bringing too much fine cement to the surface in troweling or of allowing the freshly finished surface to dry out too rapidly. This condition, though entirely a fault of construction and not of material, is, nevertheless, a serious defect. Aside from the use of commercial floor hardeners, there are two methods of remedying the dusting of concrete floors,

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both of which are inexpensive and probably as effective as the majority of compounds to be obtained in the market.

The first of these is the application of a water-glass solution (purchased in concentrated form and diluted with 4 to 6 parts of water) in the following manner: First wash the floor thoroughly, removing all dirt and loose particles with broom or scrub brush, and allow it to dry. Then apply the water-glass solution with a brush (a whitewash brush with a long handle is most convenient). This solution will penetrate into the concrete and will soon dry. A day or two later again wash off the floor, using a mop and clean water, and after it has dried again apply the water-glass solution. This treatment is to be repeated until the water-glass solution is not absorbed by the concrete, after which a final washing completes the process. Two or three applications are usually sufficient unless the concrete is very porous. In this case the solution may be made up with less water, say 3 to 4 parts.

The second method is to paint the floor with boiled linseed oil, applying coats on successive days until the oil is no longer absorbed. The oil should be thoroughly brushed into the surface. This treatment fills the pores with a hard elastic gum and appears to be even more effective than the water-glass treatment. On the other hand, it is somewhat more expensive and gives a darker finish than the latter. The use of an oil paint on concrete floors is not generally to be recommended. Most paints will scale or peel from such floors in places, and no subsequent treatment will ever be entirely satisfactory.

Examples of Home Concrete Construction.—The general information given in the preceding pages may well be supplemented by now describing how to build a few useful things about the home for which concrete is particularly adapted.

One of the simplest uses of concrete is in building footings and foundations for garages, chicken houses, and other small buildings. For example, a small house is to be built in which garden tools, cement, lime, fertilizers, and other materials are to be kept. The building is to be 8 feet by 12 feet and to have a wooden floor raised at least 12 inches above the ground. For a foundation build six small piers in the following manner: If the ground is firm, dig six holes about 10 inches square and 12 inches deep, one at each corner and one in the middle of each long side. Then build of rough lumber six boxes 9 inches square inside, 12 inches or more in length as required, and without bottoms. Set one over each hole.

The tops of these forms should be leveled by setting them down a few inches into the holes, the depth of each, of course, depending on the slope of the ground. Be sure that the form which is highest above the ground is set far enough into its hole to hold it firmly in place. After the leveling is completed all loose dirt should be carefully cleaned out of the holes, and the concrete may then be placed. The concrete should be mixed and placed according to the directions given on pages — and —, and the forms should be filled and struck off even with the top. The wooden sills may be anchored to the piers by setting suitable bolts in the top of each pier when the concrete is being placed.

A section of concrete bench in the household workshop is very useful where paints are being handled or where any heat is required, as for soldering, etc. The entire bench may be made of concrete, but as the top of the bench is the important thing it will be easier and cheaper to build the supports of lumber. A bench 6 feet long and 2 feet wide may be built as follows:

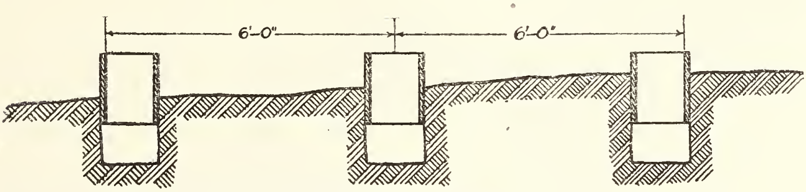

FIG. 8.—*Forms for concrete foundation piers*

Construct the supports of 4 by 4 inch dressed lumber in the form of two trestles in any convenient way, so that the tops of the crosspieces of the trestles which carry the bench top are about 5 feet apart and 32 inches above the floor. Nail temporary wooden cleats along the sides of each crosspiece ⅞ of an inch below the top. Cut ⅞-inch boards 4 feet 4 inches long to rest on these cleats and fit in lengthwise between the crosspieces. The overhanging ends of the bench top require similar forms which can be made of two 6-inch boards each 2 feet long. These rest on the outside cleats and must be supported by temporary props. The sides of the forms should be made of 3-inch boards, which are to be screwed to the edges of the bottom boards, thus providing for a bench top 2 inches thick. As sharp corners of concrete are easily chipped, it is advisable to purchase about 35 feet of small cove molding to line the bottom corners of the form and also the upper edges, the molding in the latter case being carefully nailed to the inside of the forms and flush with the top. Six pieces of ⅜-inch round iron, each 2 inches shorter than the bench top, will also be required for reinforcement.

When the form is completed up to this point, drive a half dozen large nails halfway into each of the crosspieces to anchor the bench top to the trestles, thoroughly oil the inside of the forms, and proceed with the concreting. When about ¾ inch of concrete has been laid in the bottom of the form and well worked into the corners, put in the iron rods at regular intervals, the outside pieces being about 1½ inches from the front and back edges of the slab. Then fill the form with concrete, working it together as compactly as possible and taking special pains to fill the sides

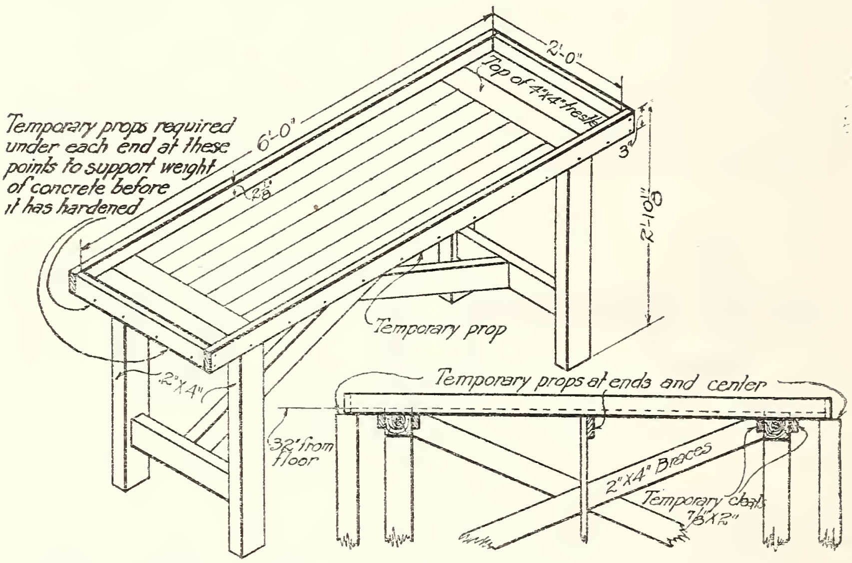

FIG. 9.—*Method of building a workbench of which the top is cast of concrete*

and corners completely. Finally, with a straightedge resting on the front and back edges, strike off the excess concrete with a backward and forward motion. Two or three times over will leave the top flat except for marks of the straightedge, and the gravel and coarse sand should not show. The concrete should now be left for a half hour or more until the water has disappeared from the surface and the concrete is beginning to stiffen. Then, with a plasterer's trowel, bring the surface to a smooth even finish with as little troweling as possible. If water and fine cement work to the surface easily, wait a little longer, bearing in mind that the less the amount of troweling the stronger and harder the finished surface. The forms should not be disturbed until after two or three days and then very carefully removed. If any places require pointing, this should be done immediately with 1:2 mortar while the concrete is still damp. After the concrete is thoroughly dry, the bench may be made more serviceable by applying a good coat of floor wax and then going over it with a hot iron or, preferably, with a blow torch or gas flame. The wax thus strikes in and seals the pores of the concrete, which thereafter will not be affected by any liquids which may be accidentally spilled upon it. It is also fireproof and unaffected by heat which would quickly char or set fire to a wooden bench.

A very pleasing effect may be obtained if the edges and top of the bench be cast with a layer of concrete in which limestone or marble screenings are used in place of the sand and gravel. Upon removal of the forms the surface may be ground with fine sand, emery, or carborundum, thus removing the skin of cement and exposing the stone screenings. A very smooth and true surface may thus be obtained, which may be impregnated with wax after drying, in the manner previously described.

A lawn roller is a very desirable tool to have, yet the thrifty home owner may hesitate to part with $10 or $15 for an implement not frequently required. An excellent lawn roller may be built at home in the following manner, at a cost of $1 to $2 for materials: Obtain from a sheet-metal worker a piece of No. 18 or No. 20 gauge sheet iron 24 by 50 inches and have him roll and rivet it in the form of a cylinder in such manner that the outside shall be smooth and free from projections. A 27-inch piece of ¾ or 1 inch round steel rod will be required for the axle and two pieces of band iron shaped and drilled to form the fork of the handle. The sheet-metal cylinder will not only serve as a form for casting the concrete but will be a part of the finished roller. While the concrete is being placed some bracing will be required to hold the sheet-metal form rigidly in place, which can be arranged as follows: Construct two small platforms of boards and cleats about 2 feet square and 1½ inches in total thickness. In the center of each platform draw a circle which has just the outside diameter of the sheet-metal cylinder. In the center of one of the platforms bore a hole the size of the axle; from the other cut out the entire circle with a compass saw. Eight pieces of board or joist 3 or 4 inches wide and 20 inches long are now to be set on the bottom platform at equal spaces around the circle, edges toward the center and securely nailed. The platform from which the circle has been cut is to be nailed likewise to the other ends of the 20-inch boards. In this manner a firm support is provided for the sheet-metal cylinder and for the lower end of the axle. The form and its support being set on the floor, one end of the axle is driven into the hole in the bottom as far as it will go and the upper end is wired rigidly to the support in such manner that it is exactly in the center of the form. The latter is then filled with 1:2:4 concrete, left to harden for a few days, and when the wooden supports are removed is ready for assembling and immediate use. This concrete roller will weigh about 425

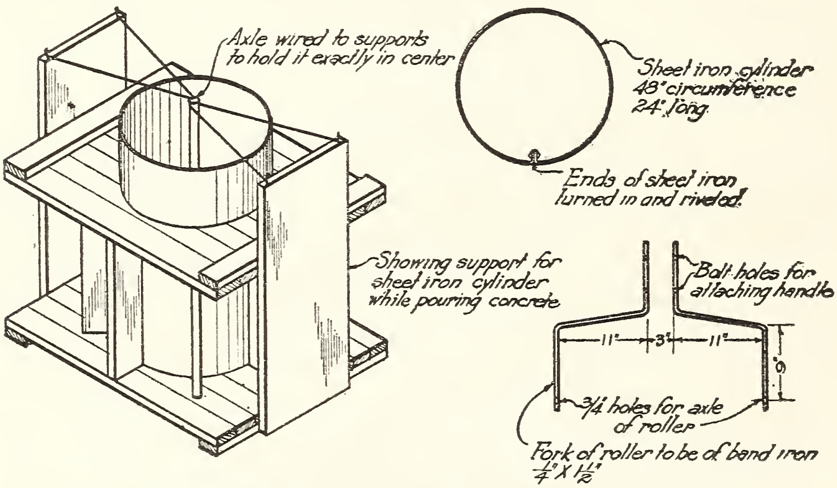

FIG. 10.—*Forms and details for a homemade concrete lawn roller*

pounds. A heavier or lighter roller may be made by increasing or decreasing the diameter as desired.

As a final example of home concrete construction, a method of laying a good serviceable concrete walk will be described. The very great majority of troubles with concrete walks and pavements arises from poorly prepared foundations or sub-bases, and if the home owner will give proper attention to this point he can build a better walk than he can usually buy from a contractor. If the walk is to be laid on fairly level, solid ground, no considerable preparation of the sub-base is necessary. In this case dig a shallow trench, the bottom of which is 4 inches below the surface of and a few inches wider than the finished walk. The side forms are to be constructed of 4-inch boards held in place by pegs on the outside and by 4-inch cross boards on the inside, which mark out the squares or blocks. The tops of all these form boards should be accurately lined to the finished surface and must be held with pegs in such manner that they will not move while the concrete is being placed and finished.

After the forms are in place see that all loose dirt is removed and the sub-base well tamped, wetting it if necessary, to secure a solid bottom. The concrete may then be placed in the following manner: First saturate the sub-base with water, then make a moderately dry mix of 1:2:4 or 1:2½:5 concrete, and begin to fill alternate sections or squares of the walk. The concrete should be thoroughly tamped in place and should be mixed fairly dry; that is, not quite wet enough to "quake" under the tamper. Continue this process with as many sections only as can be com-

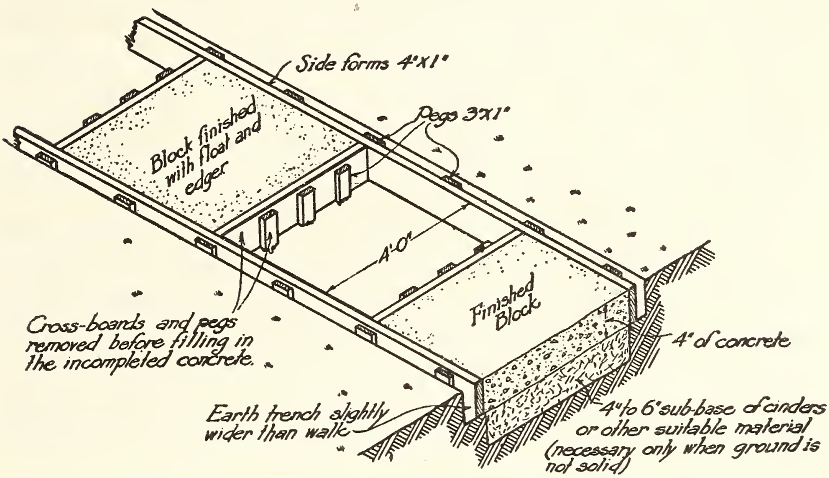

FIG. 11.—*Alternate block method for laying a concrete walk*

pletely finished before the work is interrupted. The top layer of each section, to a depth of 1½ inches, should be filled with a somewhat wetter mix which will require only moderate tamping to bring the mortar to the surface. As the sections are filled go over them with a straightedge in the manner described on page 100, and if a smooth surface is desired follow the method of finishing there given. From the standpoint of service, however, a better surface can be obtained by using a wooden float in finishing instead of a trowel. In this manner an even and more or less sandy surface is produced, which not only tends to hide slight defects of finish but affords a better grip to the shoe.

Unless one is experienced in cement finishing it is better not to attempt any unnecessary decorative work, such as marking the surface into small squares or other patterns, constructing curbs, etc. The only finishing tool required, aside from float and trowel, is an "edger," with which to slightly round the edges of the finished blocks. This is done immediately after the troweling or floating has been completed and eliminates the sharp and slightly ragged edges which would otherwise remain and be unsightly after the forms are removed.

Up to this point alternate squares of the walk are completed, and it is desirable, but not necessary, that they harden for several days before the remainder of the walk is constructed. The cross forms should be taken down as soon as the concrete already placed is fairly hard, and the remaining squares are to be filled in between the completed blocks. The advantage in waiting a few days is that the blocks first laid are less liable to be injured by the subsequent work, but with care the walk can be finished in two or three days. The same method is to be followed as before, except that in finishing at the joints between blocks a little more care is required in running the edger and in cleaning off any fresh mortar from the blocks first laid.

It is important that the newly laid walk be kept from drying out for several days, in order that the concrete may harden properly and develop a good wearing surface. The most efficient method of doing this is to cover the walk the day after it is laid with 3 or 4 inches of earth and wet it down thoroughly twice a day for a week. After this the earth may be removed, and the walk cleaned thoroughly, thus completing the job in a satisfactory manner.

The object in laying a walk in the manner described in the preceding paragraphs is partly to make it an easier task for the amateur, who can handle the separate sections with greater certainty than a long unbroken stretch of walk, but mainly to insure that the walk is laid in separate units, which in case of uneven settlement or upheaval by frost are much less likely to crack than long sections. There will, of course, be considerable bond between the adjacent blocks, but since the weak places are at the joints cracks will be more likely to occur there than elsewhere. If they do occur there they will neither injure the appearance nor the serviceability of the walk.

When a walk is to be laid on filled or soft ground, special attention must be given to the foundation. Unless urgently needed, a concrete walk should not be built on filled ground until the latter has settled for several months or longer, and even then the foundation must be well prepared to insure a satisfactory walk. Preferably, the walk should be made thicker or reinforced as an added precaution. In most cases the following procedure will give good results. Excavate to a depth of 6 inches below the grade of the walk and place the side forms with small stakes on the outside, driven down about 18 inches below grade, spaced not over 2 feet apart. The side forms may be held in place by nailing them lightly from the inside to each stake. Inside the forms excavate about 4 inches more, so that a trench 10 inches deep is formed. Tamp the earth in the bottom solidly and fill in with well-rammed broken stone, brickbats, broken concrete, hard cinders (not fine ashes), or whatever material of this type is available to a depth of about 6 inches. Cross forms of 4-inch boards may now be placed and the laying of the walk carried out as previously described. In spite of these precautions, if the walk is laid near the edge of filled ground, it is liable in time to settle or move sidewise in the direction of the slope of the ground. This movement can generally be prevented if additional fill is put in outside the walk so that the edge of the fill, to which the "slumping" is mainly confined, is 2 or 3 feet away. Many examples of this fault are seen in newly developed residential sections, where hastily laid concrete walks could be saved from early destruction at little extra expense in the manner suggested.

(*f*) References

General textbook: Taylor and Thompson's Concrete, Plain and Reinforced.

Specifications and tests:

- U. S. Government Specification for Portland Cement, Circular 33, Bureau of Standards.
- Strength and Other Properties of Concretes as Affected by Materials and Methods of Construction, Technologic Paper No. 58, Bureau of Standards.

Home and farm uses: [5]

- No. 22, Portland Cement Stucco.
- No. 26, Concrete in the Country.
- No. 115, Concreting in Winter.
- No. 129, Tennis Courts of Concrete.
- No. 133, Concrete Septic Tanks.
- No. 134, Concrete Fence Posts.
- No. 135, Small Concrete Garages.
- No. 137, Concrete Feeding Floors, Barnyard Pavements, and Concrete Walks.
- No. 140, Proportioning Concrete Mixtures and Mixing and Placing Concrete.
- No. 141, Concrete Foundations.
- No. 142, Concrete Troughs, Tanks, Hog Wallows, Manure Pits, and Cisterns.
- No. 110, Manual Training Course in Concrete.

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[5] These booklets on special uses of concrete are published by the Portland Cement Association, 111 West Washington Street, Chicago, Ill. Copies of these bulletins can generally be obtained free of charge with the exception of No. 110, which is furnished free to manual-training teachers; to others the price of this bulletin is 25 cents.

6. PLASTERS AND STUCCO

A. LIME PLASTERS

(a) Properties Desired

Appearance.—The manner in which the inside walls of a house are covered is a matter of no little importance in determining the market value of the structure. By the careful observer wall plasters are judged on two distinct bases—artistic and structural. Of course, if the walls are to be papered, the color of the plaster is of minor importance. If paper is not used, the plaster may be tinted to suit the owner, but care must be exercised to see that the color is uniform throughout the room. Whether papered or not, the plaster should have a plane surface, free from cracks. A wavy surface on a tinted or a papered wall, will reflect the light unevenly and make it appear as though the color is not uniform.

Structural.—For warehouse construction it is necessary that the plaster be able to withstand hard knocks. For the ordinary house, however, no great strength is required of the plaster, provided that the surface does not rub off. When placed on wood or metal lath, plaster has an important structural function in protecting these materials from excessive atmospheric changes. The ability to act as a retarder of fire may be of some advantage. Probably the most important property of a wall plaster is its ability to absorb sound.

In all wall construction the cost of the plaster itself is only a small fraction of the cost of applying it. Other things being equal, that plaster which works most freely under the trowel and can, therefore, be applied with least labor is to be preferred for economic reasons. This is so important that it is frequently advantageous to sacrifice in some degree the properties desired or to pay a much higher price for the plastering materials in order to keep the labor cost within reasonable limits.

The properties attained in a plastered wall depend upon three factors of about equal importance—the construction of the wall, the method of application of the plaster, and the quality of the plastering material.

(b) Backing

Plaster may be applied to almost any kind of a wall. The types of construction chiefly used are wood lath, metal lath, or masonry, such as concrete, terra-cotta tile, brick, plaster board, etc. In all cases the walls (and ceilings) must be so designed as to be practically rigid under the loads they are expected to carry.

Plasters can hardly be called elastic, so that any slight motion, such as might be caused by the settling of a wall or by a sudden jar or too heavy a load on a ceiling, will be apt to crack the plaster. Wood laths should be spaced about ¼ to ½ inch apart, in order that the plaster may be pushed in between them to form a good bond. They should be thoroughly wet and should be permitted to swell before the plaster is applied; otherwise they will absorb water from the plaster and, hence, swell and cause cracks. Metal lath should be fastened to the wall in such a manner as to make it as nearly rigid as possible. Masonry walls should be very rough, in order that the plaster may have something to cling to, and should be wet, to keep them from absorbing water from the plaster.

(*c*) **Application**

For best results plaster should be applied in three coats, which are generally known as scratch, brown, and finish coats, respectively. The scratch coat is applied first. It is designed to form the bond between the wall itself and the body of the plaster. It is pushed into the apertures in the lath or the indentations in the masonry, and the exterior surface is roughened by scratching it with a special tool, in order that the next coat may adhere better. The brown coat forms the main body of the plaster, which is generally ¾ to ⅞ inch thick. The finish coat is applied to give the wall a plane surface of the desired color. For the best results each coat should be allowed to set until quite dry and then should be thoroughly wet before the next coat is applied. The change in volume of wood lath when alternately wet and dry will probably cause cracking of the scratch and brown coats. The cracks can be filled in before the finish coat is applied, but the brown coat must be sufficiently thick and dry to prevent the water used in applying the finish coat from penetrating to the lath.

(*d*) **Materials**

It is evident that the plastering material used in each coat must fulfill different requirements. The most important property of the scratch coat is strength. In the brown coat strength is of secondary importance to plasticity. The finish coat must be extremely plastic, must have sufficient strength to resist ordinary abrasion, and must have the desired color and surface finish. Since the brown coat forms three-fourths of the total volume of the plaster, the cost of material is of greater importance in this coat than in the other two. For these reasons it is customary to use for the three coats plasters of different composition.

Plasters for scratch and brown coats consist essentially of some cementing material, such as Portland cement, Keene's cement, lime, or calcined gypsum; sand; and hair or some similar fiber.

LIME.—Portland cement and lime have been discussed in other sections of this circular. In addition, the danger of "popping" caused by an inferior quality of lime should be considered. When lime is burned at too high a temperature, some of the calcium oxide will combine with the silica and iron in the stone to form compounds which slake very slowly. Compounds of the same nature may be produced if the lime is permitted to "burn" while slaking. These compounds take the form of small granules which, when exposed to the air, will gradually absorb water and swell. If these granules occur in the finish coat or near the surface of the brown coat, they will eventually fall out of the plaster, leaving a little pinhole. Their presence can be prevented by making sure that the lime is perfectly hydrated before using. These compounds are generally removed from hydrated lime during the process of manufacture. It is advisable, however, to soak hydrate under water for two or three days before using, not only to insure the absence of partially hydrated material but also to improve the plasticity. To make a good paste from quicklime, the slaking must be conducted very carefully. Enough water is added to make a cream, which is passed through a screen of about 10 meshes per inch to take out any unburned limestone. The cream should then be allowed to settle for two or three weeks, when the excess water may be drained off, and the paste is ready for use. To test a lime for the presence of materials which will cause popping, spread the paste in a thin layer (1/8 inch) on a glass plate. The particles which are apt to cause trouble are white to reflected light but opaque to transmitted light.

GYPSUM.—Gypsum is a natural mineral, mined in many parts of the United States, consisting essentially of calcium sulphate crystallized with a definite amount of water. When this is heated to about 120° C (248° F), three-fourths of the water is driven off. The material remaining is ground to a fine powder and sold as calcined gypsum or plaster of Paris. This forms the basis of commercial "hard wall plaster." When mixed with water it combines with it and recrystallizes in the form of the original gypsum. This operation constitutes the setting of the plaster. Pure calcined gypsum sets very rapidly. It is, therefore, necessary to add some material to retard the set, in order to allow time for the plaster to be applied. Hydrated lime is frequently used, because it improves the plasticity and also retards the set. A number of organic materials, like glue, dried blood, etc., are also used as retarders. On the other hand, set plaster (gypsum) is a very marked accelerator, so that one should be very careful to cleanse all tools after mixing each batch of plaster. It will be noted that only water is necessary for the setting of calcined gypsum and that this process can take place in the absence of air. But, unfortunately, the set gypsum is slightly soluble, so that it can not be used as a hydraulic cement. Probably the best test for the purity of calcined gypsum is its behavior when mixed with water. A ready-prepared plaster should set quite hard in from 30 minutes to one hour. Plaster of Paris will deteriorate on exposure to the air by taking up water and reverting to the original gypsum. However, the fact that it is a fine powder prevents the access of the air to the interior of the mass, so that not more than a thin layer on the surface of a pile will be spoiled. It is quite permissible to store calcined gypsum in the commercial package (paper bag), taking only ordinary precautions to keep it dry.

KEENE'S CEMENT.—When calcined at over 400° C, gypsum loses all of its water. The material remaining is called anhydrite and has no power to set under ordinary circumstances. There are a number of compounds which may be added to anhydrite and which will cause it to set. The compound usually added is alum, the product so treated being known commercially as Keene's cement. This cement sets more slowly than calcined gypsum, but the ultimate product is the same—gypsum.

(*e*) **Proportions for Coats**

SCRATCH COAT.—The chief requisite for the scratch coat is strength. In exceptional cases it may be desirable to use a Portland-cement mortar, but this should be mixed with lime to improve its plasticity. For ordinary purposes, however, lime or gypsum plaster will be found sufficiently strong. It must be remembered that lime shrinks on setting, and that, therefore, a certain amount of sand is necessary to attain maximum strength. On the other hand, gypsum expands as it sets, so that in this case the sand is strictly an adulterant, causing a decrease of strength. When plastering on masonry, however, it is advisable to add enough sand so that the scratch coat will expand and contract to about the same extent as the masonry when subjected to changes of temperature or humidity. The proportions for scratch coat recommended by the manufacturers are:

	Parts
Hydrated lime	133
Sand	400
Hair	1
Or Calcined gypsum	100
Sand	267
Hair	1
Or Calcined gypsum	100
Sand	200

Brown Coat.—For the brown coat strength is of minor importance, and it is, therefore, permissible to use a higher proportion of sand. This added quantity of sand has two advantages—it decreases the cost, which is very important in the brown coat, and the wall is better able to absorb sound, on account of its increased porosity. On the other hand, too much sand will weaken the plaster to such an extent that it may not be able to withstand even ordinary impact and will also decrease the plasticity so as to make application difficult. The proportions recommended are 100 parts by weight of hydrated lime, 400 parts of sand, and ½ part of hair; or 100 parts of calcined gypsum to 300 parts of sand.

Finish Coat.—For the finish coat it is customary to use a mixture of lime and calcined gypsum. The lime gives the plasticity which is so essential for a plane, smooth surface. The calcined gypsum makes the plaster set more quickly and gives it a harder surface. It may also tend to prevent cracking because of its expansion as it sets. There are two kinds of finish coats, differentiated by their appearance as "smooth" or "sand float." In the first the surface is troweled until it is as nearly smooth and plane as possible. In the second the bonding material on the surface is floated off, leaving the sand grains protruding; the surface is, therefore, plane but not smooth. The proportions of materials to be used in the finish coat depend upon the condition of the weather, the time of year, and the inclination of the plasterer. The following proportions are recommended as a guide but are not to be adhered to rigidly: For smooth finish, 1 part by volume of calcined gypsum to 3 parts of lime paste. For sand-float finish, 1 part by volume of calcined gypsum to 2¼ parts of lime paste and 3 parts of sand.

(*f*) **Quantities**

To cover 100 square yards of surface with three-coat plaster will require about 1600 pounds of calcined gypsum or 1200 pounds of hydrated lime, 1¾ cubic yards of sand, and 2 bushels of hair.

(*g*) **Usual Defects**

It is generally difficult to determine the cause of any failure which may occur in wall plaster. Some of the more prevalent defects may be enumerated as follows: 1. "Popping" is the term applied when small particles of the plaster pop out of the wall, leaving pinholes. This is due to insufficient preparation of the lime before application. 2. If the surface of the plaster can be rubbed off easily, it is probable that the brown coat was not wet sufficiently before the finish coat was applied. This is also the usual cause of lack of bond between the coats, which may cause the finish coat to scale off in patches. 3. Lack of strength may be due to two causes—oversanding of the brown coat, which is indicated by a tendency of the sand to "run" when the finish coat is punctured; or undersanding, which is indicated by craze cracks in the finish coat. 4. A plaster which is frequently wet is apt to fall off eventually, especially if the scratch coat is calcined gypsum on metal lath. By far the greater number of defects, however, are due to the construction of the building and not to the plaster. The settling of foundations and the jarring of ceilings beyond their rigidity are the causes of almost all large cracks.

B. PORTLAND CEMENT PLASTER—STUCCO

Portland-cement plaster, as distinguished from lime or gypsum plasters, is one in which the binding material is largely or wholly Portland cement. Cement plaster, because of its resistance to the action of water, is particularly adapted for use wherever excessive dampness occurs and for all exterior work which is exposed to extreme weather conditions.

(*a*) **Uses**

The most extensive use of cement plaster, aside from underground construction, is in the form of "stucco," which is the general term for any kind of plaster applied to the exterior of houses or other buildings. The stucco house is rapidly coming to be a very common type of residence construction, especially in the suburban districts of large cities; hence, a brief enumeration of the advantages and disadvantages of stucco construction will be of interest to prospective home builders.

There are several different types of construction on which stucco exteriors are used, the most common being the frame house in which the outside walls are sheathed with boards laid diagonally, then covered with tarred felt or sheathing paper. Over this wood or metal lath is applied, which supports the outside coating of stucco. Reliable figures show that this type of house costs on the average from 2 to 5 per cent more than the same type covered with clapboards or weatherboards and has the very decided advantage of being better protected from neighboring fires and of costing less for maintenance.

A modification of the foregoing type is one in which the outside sheathing is omitted, metal lath is fastened directly over the studs, and the stucco is applied to both sides of the metal lath before the interior is lathed and plastered. This type costs about the same as that in which the sheathing is used and has the advantage of a heavier cement coating, which insures the protection of the metal from rust. The frame of such a house requires special bracing, and it is advisable, also, to have insulating felt put into the outside walls, but these features add comparatively little to the cost, and a house so constructed is one of the best that can be built at a cost of $3000 to $5000.

In frame houses with stucco exteriors both wood and metal lath are widely used. Wood lath is cheaper, but it has the disadvantage of expanding and shrinking with changing moisture conditions, and many cases are known where this defect has resulted in the fall of large sections of the exterior coating. The main disadvantage of metal lath is its liability to corrosion, with consequent destruction of the plaster coating. This defect can be overcome by the use of galvanized lath well embedded in cement plaster. Especially in the back-plastered type of house, described in the preceding paragraph, the possibility of the lath rusting seriously is remote.

Stucco is also applied to houses built of brick, concrete block, and hollow terra-cotta tile. In such construction the stucco is mainly for decoration rather than protection, interior conditions being largely independent of the condition of the stucco. Houses of this type are better than frame houses, being generally warmer in cold weather, more nearly fireproof, and costing less for maintenance and insurance. The first cost is of course somewhat higher than for frame construction.

(*b*) Tendency to Crack

All stuccos are liable to crack from various causes, and probably all do crack to a greater or less extent. The durability of plaster and stucco construction is the subject of an extensive investigation undertaken by the Bureau of Standards in 1915, the first step being the construction of a test building containing 56 large exterior panels representing practically all the common types of stucco construction.[6] Of these 56 panels only 2 have been found to be entirely free from cracks, although many are practically uninjured by the cracks which have thus far developed.

In the case of frame stucco houses extensive cracking may result in damaging the interior, as well as detracting greatly from the external appearance; in the case of brick, tile, or concrete houses the cracking of the stucco is generally an injury only in so far as it affects the appearance. As cracks of any sort are much less prominent on a rough surface, the rougher finishes are to be recommended for stucco houses; for example, the "pebble dash" or "rough cast" surfaces, in preference to the smoother finishes as ordinarily given with trowel or float.

(*c*) Proportions in Mixtures

There is much difference of opinion as to the best mixtures to use for exterior stucco. Perhaps that most commonly recommended is a mixture of 1 part cement, 2½ or 3 parts of sand, to which is added about 1/10 part of hydrated lime, by weight of the cement. Mixtures containing even more sand are recommended by some; others advocate the use of straight cement-and-sand stucco; still others favor high-lime stuccos, that is, mixtures containing more lime than cement. Up to the present time it has been impossible to get reliable comparative data on the durability of different stuccos. Many variables enter into the problem, such as weather conditions and workmanship, which are rarely recorded, yet which undoubtedly contribute largely to the durability of this type of construction. Moreover, stucco specifications are rarely followed exactly unless the work is under constant supervision, because plasterers are inclined to use their own judgment in developing easy-working mixtures, which are not necessarily those designed to give best results.

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[6] Bureau of Standards Technologic Paper No. 70, Durability of Stucco and Plaster Construction, First Progress Report, 1916. This paper may be obtained on application to the Superintendent of Documents, Government Printing Office, Washington, D. C., for 15 cents.

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(*d*) Repair of Stucco

As stucco construction becomes more common the repair of stuccos becomes an important consideration. Aside from replacing entire walls, the methods of repairing stucco are few, the possibilities being practically limited to pointing, patching, and painting. Large cracks may be "pointed up," defective spots may be chipped out and patched, and small cracks and discolorations may be covered with paint, but the results are not, as a rule, satisfactory. About the only method which can be recommended at the present time is to do what pointing and patching is necessary with the same mixture as was used originally, first wetting the adjacent stucco thoroughly, and letting the repaired areas dry out slowly. Should the renovated portions show badly after drying out, the entire wall, or if necessary the entire house, after thoroughly saturating the surface may be gone over with a thin cement wash, which will tend to eliminate the differences in color and texture.

Stucco coatings may also be obtained in the market which improve temporarily the appearance of stucco exteriors and may give good service if the defects are confined to discolorations. Cracks so covered will generally reappear in the course of time and are, hence, very difficult to hide effectively.

7. PAINTS, PAINT OILS, AND VARNISHES

Paints and varnishes are used to protect and decorate surfaces of wood, metal, and other materials. They are applied in thin coatings, which harden after application.

(*a*) Definitions

A paint is essentially a mixture of solid and liquid which gives an opaque coating; a varnish is essentially a liquid which gives a transparent coating. The solid matter in paint is the pigment or coloring matter. The liquid (linseed oil, for example) is called the vehicle. While varnish is used in very much the same manner as paint, it could not properly be classified as paint, because it does not contain any solid particles of pigment. On the other hand, white wash, which is not ordinarily called a paint (largely because of its cheapness) complies with the definition.

(*b*) Drying of Paint and Varnish

Water paints, such as whitewash and spirit varnishes, such as shellac in alcohol, dry by simple evaporation of a volatile liquid, this being water in the case of white wash and alcohol in case of shellac.

The drying of oil paints and varnishes, however, is quite different, and in order to understand this attention must be drawn to certain peculiarities of the so-called drying oils. Suppose four plates of glass are coated, one with a thin film of water, another with gasoline, another with a heavy mineral oil, and another with linseed oil, and all four plates are exposed to the air for several days. The water and gasoline will evaporate and leave the plates dry and in practically the condition in which they were before applying the liquid. The plate covered with heavy mineral oil will be found to be greasy, while the plate covered with the linseed oil will also have a coating on it, but this coat will first become tacky and finally set to a hard varnish-like film. If this experiment is tried with other vegetable oils, it will be found that some of them—olive oil, for example—behave very much like heavy mineral oils; that is, there is only a very slight tendency toward the formation of a varnish-like coating. Other oils, such as corn and soya bean, will behave in a manner similar to linseed oil; that is, there will be the formation of a more or less tacky mass, with perhaps the final formation of a varnish-like surface. Oils which behave like linseed oil are called drying oils. It will be seen from this illustration, however, that the term "drying" as applied to such an oil is not similar to the drying which takes place on the exposure to dry air of a material wet with water. The drying of a substance wet with water is really the removal of the water by evaporation. The drying of a drying oil is a change taking place in the liquid. This change is accomplished by an absorption of oxygen and is hastened by dry weather and by sunlight. It is also accelerated by the presence of certain substances which will be discussed later. (See "Drier.")

(*c*) **Ingredients**

The materials used in making paints are too numerous to mention in a publication of this character, and brief mention only can be made of some of the more important materials so used.

Linseed oil, which is the oil obtained from the seed of the flax plant, is the most important of the drying oils. This oil enters into commerce as raw linseed oil and boiled linseed oil. The raw oil varies in color from pale straw to dark amber and has a mild characteristic odor. It frequently contains considerable sediment or cloudy or mucilagenous matter, which is generally objectionable, as perfectly clear oil is preferred by all painters. Good raw linseed oil when spread in thin films and exposed to the air and light will generally dry to a fairly hard film free from tackiness in from two to six days. Refined linseed oil is oil that has been treated by a variety of methods to remove the mucilagenous matter and at the same time some of the color. In properties it differs little if any from good raw oil.

The term "boiled" as applied to linseed oil is strictly a misnomer, since linseed oil does not boil as water does but when heated to a sufficiently high temperature undergoes decomposition. It was, however, long ago observed that if linseed oil is heated to a temperature somewhat below its decomposition point with oxides of lead and manganese some of the metals go into solution and the oil dries more rapidly than raw oil. This method of heating all of the oil with metallic oxides is practically obsolete. In modern practice the manufacturer of boiled oil first makes a very concentrated boiled oil; that is, one containing a comparatively large percentage of dissolved lead and manganese, 15 to 20 times as much as is required in boiled oil. This material, known as "crusher's drier," is mixed with raw linseed oil in the proportion of about 1 to 16 and the mixture heated to incorporate completely the "crusher's drier" with the oil. In some cases the "crusher's drier" is made from rosin and oxides of lead and manganese instead of linseed oil and the oxides. Boiled oil made in this way is called "resinate boiled oil," while that in which no rosin is used is called "linoleate boiled oil." If properly made and no excessive amount of rosin is used, a "resinate boiled oil" may be as good as a "linoleate boiled oil," but the fact that much boiled oil contains an excessive amount of rosin and is, consequently, of inferior quality has caused "resinate boiled oil" to be looked upon with suspicion.

There is another type of boiled oil, derisively called "bunghole oil," which is simply raw oil to which a drier, usually a turpentine or light mineral-oil solution of lead and manganese resinate or linoleate, has been added without heating.

The advantage of boiled oil over raw oil is that it dries more rapidly. It must be remembered, however, that in most paints where raw oil is used a certain amount of "drier" is added which hastens the drying. There is little if any material difference between results obtained with boiled oil and with raw oil with the proper addition of drier.

Driers.—Certain metals, especially lead and manganese, when in solution in drying oils cause the drying to take place more rapidly. While certain pigments, such as red lead, act as driers and some driers are in paste form, most so-called driers are in liquid form. These are known as "driers," "oil driers," "Japan driers," or simply "Japans." They consist either of solutions of lead or manganese salts, of acids of linseed oil or of resins, or of mixtures of such salts dissolved in volatile solvents, such as turpentine or light petroleum oil. The amount of lead and manganese present is relatively small. The ash of liquid drier, which usually consists of the oxides of lead and manganese with sometimes some lime, varies from about 0.5 per cent to 15 per cent, usually from 5 to 8 per cent. Strictly speaking, an "oil drier" should contain no varnish resin, and a "Japan drier" should contain such resin, but this distinction is not adhered to in the trade, and many manufacturers use the terms so loosely that the name can not be taken as any indication as to whether the material contains resin or not.

VOLATILE THINNERS.—Turpentine, which is the volatile liquid made by distilling the resin of pine trees, is the most important volatile thinner used. This has excellent solvent, evaporating, and flatting properties and is preferred for general paint and varnish operations. It is, however, expensive, and in many cases the cheaper volatile liquids, such as light mineral oil, variously known as "benzine," "naphtha," "petroleum spirit," "turpentine substitute," etc., may be successfully used. "Coal-tar naphtha" or crude benzol is also so used in certain cases. Alcohol, carbon bisulphide, and numerous other volatile liquids also enter into some paint preparations.

In addition to drying oils and volatile thinners, varnishes are important liquid constituents of certain paints.

PIGMENTS.—The number of substances used as paint pigments is so great that no attempt can be made in a publication of this character even to mention more than those in common use. In general, a paint pigment should consist of very finely divided particles; it should possess hiding power, that is, in the vehicle used; it should form as nearly as possible an opaque coating; and it should have no injurious action on the vehicle or the surface on which the paint is to be applied. It should not have an excessive tendency to settle out from suspension in the vehicle. There are a great many colored substances which have good hiding power; but most white substances which might otherwise be suitable for paint pigments give, with oil mixtures, a coat which is quite transparent. There are, practically, only four substances which can be used as white pigments of good hiding power. These are white lead or basic carbonate white lead, sublimed lead or basic sulphate white lead, zinc white or zinc oxide and lithopone (a material composed of zinc sulphide and barium sulphate). (The rather indefinite mixtures of lead sulphate and zinc oxide obtained from zinc lead ore and known as "leaded zinc," or "zinc lead," etc., may be considered as mixtures of sublimed lead and zinc white.) White "extending" pigments, such as barytes, whiting, silica, asbestine, etc., when used alone with oil do not make opaque films, but are sometimes used in connection with the true-white pigments mentioned above and are also used with numerous colored pigments which have good hiding properties.

Among red pigments may be mentioned red lead and various iron-oxide pigments. Yellows include chrome yellow (lead chromate) and ocher, which is an earthy pigment containing hydrated oxide of iron. The principal blues are Prussian blue and ultramarine. Greens are made by mixing yellow and blue. Blacks are various carbon pigments, such as lampblack, which is soot; graphite, a mineral substance; and bone charcoal, known as ivory black, drop black, or bone black. Various artificial coloring matters in the form of "lakes"—that is, the artificial (coal-tar) colors thrown down on a base such as white or red lead, barium sulphate, etc.—are used. The most brilliant reds, for example, belong to this class.

(*d*) **Varnishes**

Varnishes may be classed as spirit varnishes and oil varnishes. Spirit varnishes are simply solutions or partial solutions of resinous substances in volatile solvents. Shellac varnish is a solution of gum shellac in alcohol. Damar varnish is a solution of damar resin in turpentine. In this class may be included the collodion or zapon varnishes, which are solutions of nitrated cellulose in solvents such as amylacetate and alcohol-ether mixtures. Oil varnishes are not made by simple solution of varnish resins in solvents. The important varnish resins, of which there are quite a number, as kauri, Manila copal, Zanzibar copal, etc., are not soluble in their original condition. The varnish maker can, however, by heating and addition of drying oils and drying metals, produce a substance which can be thinned with some volatile thinner to produce the well-known oil varnishes. Oil varnishes differ widely in properties, and there is no easy way of determining their quality. In general, common rosin as a constituent in considerable quantity causes the varnish to be of inferior quality, giving a film which turns white on exposure to water and which does not last well. Some excellent varnishes, however, are made with rosin and China wood oil. Oil varnishes generally contain from 40 to 60 per cent of volatile thinner (turpentine or light mineral oil). "Long-oil varnishes"—that is, those which contain a large amount of drying oil (say, 40 to 60 per cent drying oil and from 5 to 20 per cent resins)—yield coats which while not so hard are more resistant to weather than those produced by "short-oil varnishes"; that is, those which contain a relatively large amount of varnish resins (say, 20 to 35 per cent resin and 25 to 40 per cent drying oil). A spar varnish may be taken as an example of a long-oil varnish, a rubbing varnish as an example of a short-oil varnish.

(*e*) **Paints**

If an attempt is made to prepare an oil paint by mixing the dry pigment and vehicle in a bucket by hand, it will generally be found very difficult to obtain a sufficiently uniform mixture. The pigments, may, however, be ground in a mill to a uniform paste with a small amount of oil, and this paste can be easily mixed with more oil, etc., to form a satisfactory paint. On this account the painter who mixes his own paint generally purchases his pigments in paste rather than in dry form. Some pigments require more oil than others to make a satisfactory paste. White-lead paste, for example, contains about 8 to 10 per cent of linseed oil. White-zinc paste contains about 17 per cent of linseed oil. The other white pigments are not commonly sold in the form of paste, but the various tinting pigments, such as chrome yellow, lampblack, drop black, ocher, etc., are commonly sold as pastes, the proportions of pigment and oil varying greatly with the different pigments. Putty is of the same general nature as paste paints. Ordinarily, putty is whiting ground to a paste with linseed oil. It is important that the oil should be linseed oil, and the not infrequent addition of mineral oil can only result in the production of a very inferior article. The vehicle for best-quality outside paint (last coat) would generally consist of 90 to 95 per cent of raw linseed oil and from 10 to 5 per cent of Japan drier. The following may be taken as representative compositions of such white paints:

White-Lead Paint.—To make about 1 gallon of white-lead paint (weighing about 21 pounds to the gallon), mix together 14 pounds of dry white lead, 7 pounds of raw linseed oil, and ¼ pound of Japan drier; or 15 pounds of white-lead paste, 6 pounds of raw linseed oil, and ¼ pound of Japan drier.

Finished Paints and Painting.—Since the composition of a paint must be varied in order to secure the best results, depending upon the character of the surface to which it is to be applied and the nature of the exposure, it seems best to consider the paint and method of application together. From what has been said in speaking of pigments it is apparent that for white or for very light-colored or tinted oil paint one or more of the expensive lead or zinc pigments must be used in order to get a paint which will have satisfactory hiding properties. Of the white pigments which furnish sufficiently opaque films with oil, lithopone has the disadvantage of producing a paint which does not wear well for outside exposure, although it is much used for interiors. We can, therefore, consider that we must use one or more of the pigments white lead, sublimed lead, or zinc white for white or light-colored outside oil paints. White lead is commonly handled by dealers in painters' supplies in the form of paste. Zinc white is frequently so handled, but it is not common to find the other white pigments handled in paste form. Paints mixed by the painter, therefore, are usually white-lead paints or white-lead and white-zinc paints. (White zinc is very seldom used alone to make an oil paint.) "White lead and linseed oil" has been most extensively used in the past, and many experts still prefer it for general outside use. White lead, however, has a tendency to chalk; zinc white, on the other hand, has a tendency to crack. A mixture of the two pigments produces a coat which appears on the whole more satisfactory than that from either alone, the zinc decreasing the tendency to chalk and the lead decreasing the tendency to crack. The addition of small amounts of the so-called "inert" white pigments, such as silica, barium sulphate, etc., seems to produce a still more satisfactory paint.

In all painting attention must be given to the character of the surface on which the paint is to be applied. In all cases the surface should be clean and dry. New wood often is very difficult to paint. The resins in such wood as yellow pine and cypress tend to destroy any paint that is laid over them. When possible, it is best to allow a new house to stand unpainted for at least six months or even a year after the woodwork has been completed. By this exposure to the weather the resins are brought to the surface and are either washed away or hardened, and the resulting wood surface is in much better condition for painting than a new sturcture. This delay is objectionable, however, and painters adopt several methods of treating new wood. Coating all knots and other places where rosin appears with shellac varnish is a common precaution. A plan which is not so universally used but which appears to be quite satisfactory is to add a small amount of benzol (coal-tar naphtha) to the paint used as priming or first coat. Benzol is an excellent solvent for the wood resins, and its addition tends to cause the paint to penetrate the pores of the wood. The proportions of ingredients in a paint may be varied to a considerable extent. The following are only illustrations but are believed to represent good practice:

White Lead Mixed on the Job, for Outside Exposure.—It is most convenient to make a base paint which is somewhat too thick for spreading and from this prepare the paint for the successive coats. Such a base can be made by mixing 15.5 pounds of white-lead paste, 3 pints of raw linseed oil, and 5 ounces of turpentine Japan drier. To the base add, according to the coat and character of wood, as follows:

Additions ot above base		First coat		Second coat, all woods	Third (last) coat, all woods
		Basswood	Yellow pine or cypress		
Raw linseed oil	pints	¼	¼	....	1½
Turpentine	do	1⅔	1⅔	1	....
Japan drier	ounce	....	1	....	....
Benzol	pint	....	⅔	....	....

The paints for the above coats will contain from 66 to 72 per cent pigment and will weigh from 17½ to 20 pounds per gallon.

Ready-Mixed Paint.—A typical example of a ready-mixed paint has the following composition:

	Per cent
White lead	27
White zinc	33
Linseed oil	35
Turpentine Japan drier	5

This paint weighs about 15¾ pounds to the gallon.

An example of a ready-mixed outside white paint containing some extending (inert) pigment has the following composition:

	Per cent
White lead	24
White zinc	31
Silica and silicates	7
Linseed oil	35
Turpentine Japan drier	3

This paint weighs about 15½ pounds to the gallon.

In the practical application of the above ready-mixed paints by a competent painter the following additions were made:

Additions to 1 gallon	First coat		Second coat, all woods[a]
	Basswood	Yellow pine or cypress	
	Pint	Pint	Pint
Raw linseed oil	1/6	1/6	
Turpentine	1/2	1/2	1/3
Benzol		2/3	

[a] Third coat applied without additions

It is evident from what has been said above that there is considerable variation in composition of white paints of good quality; but in general it may be stated that for repainting a frame house the last coat should contain from 60 to 75 per cent of pigment and from 25 to 40 per cent of vehicle. The pigment should contain not more than 15 per cent of extending (inert) material, such as barium sulphate, silica, asbestine, etc., and not less than 85 per cent of approximately equal parts of white lead and white zinc. The vehicle should consist of raw linseed oil with a small amount (not over 10 per cent) of Japan drier. If more than one coat is required, the under coats should be of the same nature as the last coat, except that the 25 to 40 per cent of vehicle should consist of about 75 to 80 per cent of raw linseed oil, about 10 to 15 per cent of turpentine, and not over 10 per cent of Japan drier. The addition of turpentine is to assure bonding with the old paint and to produce a better surface upon which to apply the final coat.

For light tints small amounts, seldom as much as 10 per cent and frequently less than 1 per cent, of coloring matter are added to white paints.

For dark paints the vehicle portion should be of the same general nature as in whites. For dark shades of red or brown there is probably nothing more satisfactory or cheaper than the oxide-of-iron pigments. These vary much in color, giving both brown and dull reds. They also vary in fineness and specific gravity, but, in general, paints of this nature will contain from 40 to 60 per cent of pigment. A dark green will usually contain from 60 to 70 per cent of pigment, which generally consists of 20 per cent of chrome green (lead chromate and Prussian blue) and 80 per cent of barium sulphate.

Painting should be done in clear, moderately warm weather. Great care should be taken that each coat is thoroughly dry before applying the next coat. It is a good plan to observe when the paint appears to be thoroughly dry and then wait at least 48 hours longer before applying another coat. All nail holes, cracks, etc., should be carefully filled with putty after the priming coat. If putty is applied to unpainted wood it will not stick. The surface on which another coat of paint is to be applied should not be glossy. The proper "flat" surface is generally secured by having some volatile thinner in the under coats; but should such a coat have any gloss it should be lightly sandpapered or rubbed with steel wool to remove all gloss. For inside work it is often preferred to have the final coat "flat." Inside paints, therefore, generally contain somewhat more volatile thinner than outside paints. Also, since drying is not so rapid indoors, more drier is frequently added.

Wall Paints.—Within the last few years the use for interior walls of paint which can be washed has become very general, and quite cheap paints which answer very well for such use, both on plastered walls and interior wood, are now commonly sold. These usually contain about 65 per cent of pigment, generally lithopone, about 20 per cent of turpentine substitute (light mineral oil), and about 15 per cent of nonvolatile vehicle. The important constituent seems to be the nonvolatile vehicle. It is important to have the paint contain enough thinner to allow some addition of oil for first coats and still be of proper brush consistency without any danger of drying with a gloss. The property of China wood oil of "bodying" (or thickening) to a great extent makes it a valuable constituent, hence the nonvolatile vehicle in such paints is usually a rosin China wood oil varnish.

Enamel Paints.—Enamel paints are made with a varnish vehicle. In other respects they differ little from oil paints. An example of such a paint is zinc white in damar varnish.

Red-Lead Paint.—Red lead is only used for protecting iron and steel. Experience and tests indicate that from a practical standpoint this material is certainly one of the best if not actually the best for this purpose. Contrary to usual practice with other paints, red-lead paint is usually mixed on the job from dry red lead, linseed oil, and sometimes a little turpentine and Japan drier. Red lead consists of oxides of lead, and ordinarily when mixed with linseed oil will in the course of a few days cake to a hard mass in the can. On this account it has been found necessary not to mix the pigment and vehicle until the time of application of the paint. (Within the last few years red lead remarkably free from the lower oxides of lead has been produced, and it has been found that this material can be successfully kept in paste form. This is not, however, representative of most red lead.)

A very satisfactory formula for red-lead paint is:

Dry red lead (pounds)	20
Raw linseed oil (pints)	5
Japan drier (pint)	½
Turpentine (pint)	½

This will make about 1 gallon of paint, which will weigh about 25 pounds.

(*f*) Stains

Shingle Stains.—Shingle stains are similar to paints but are made much thinner and usually contain coal-tar cresote as part of the vehicle, thus assisting in preserving the wood. The pigment should be of the best quality, have the maximum color strength, and should be exceedingly finely ground in oil. The amount of pigment seldom exceeds from 1½ to 2 pounds to the gallon of stain. The vehicle is generally about 40 per cent creosote oil, 40 per cent heavy benzene, and 20 per cent benzene Japan drier. It is best to dip the shingles in the stain before putting on the roof, but shingle stains are frequently applied with a brush. A shingle stain is intended primarily to preserve the wood, but on account of appearance the shingles should be uniformly colored, hence the pigments used should possess great color strength and be very opaque.

Wood Stains.—While similar to shingle stains in that they are exceedingly thin paints, wood stains differ from shingle stains in several important respects. They are not intended for protection and are generally used in connection with other methods of treating wood, hence creosote oil does not enter into the vehicle. Also, they are not generally intended to hide completely the original color of the wood but to modify such color and bring out contrasts of grain, etc. Hence the pigments used should not be too opaque. Finely ground siennas, umbers, and ochers are examples of suitable pigments. From 1 to 2½ pounds of suitable pigment is used to the gallon in a vehicle composed of about 70 per cent linseed oil, 20 per cent turpentine, and 10 per cent drier in the case of the so-called oil stains, while the varnish stains have a vehicle of thin varnish. Sometimes aniline dyes are used instead of the insoluble pigments mentioned. Very brilliant stains can be produced in this way, but such stains are very likely to fade. Water stains are solutions of dyes in water. These not only tend to fade but have the disadvantage of "raising the grain" of the wood.

(*g*) Bronze Paints

Bronze paints, which are frequently used for coating metal, such as radiators, consist of finely divided metal in a vehicle of celluloid varnish (so-called "banana oil"), being a solution of nitrocellulose in amyl acetate. This has a very disagreeable odor, and as a good bronze paint can be made with a pale China wood oil-resin varnish with a petroleum-oil thinner, this type is generally to be preferred. The pigment (finely divided aluminum) in aluminum-bronze paint usually amounts to from 15 to 19 per cent.

(*h*) Water Paints

WHITEWASH.—The cheapest of all paints is whitewash, and for certain purposes it is the best. Lime, which is the basis of whitewash, makes a very sanitary coating and is, hence, to be preferred for cellars and the interior of stables and other outbuildings. Ordinary whitewash, made by slaking quicklime and adding water to produce a mixture of proper and uniform spreading consistency, affords the most sanitary coating, but does not adhere so well as does whitewash to which certain additions are made. Five pounds of quicklime will suffice to make about 1 gallon of ordinary whitewash.

The additions made to ordinary whitewash which tend to make a material which will produce a better or more lasting coat are quite various, such as salt, flour paste, milk, glue, cement, alum, zinc sulphate, sodium silicate, soap, etc.

The following recipe is a very old one, having been successfully used on wood, brick, and stone by the Bureau of Lighthouses for many years:

> Slake half a bushel of unslaked lime with boiling water, keeping it covered during the process. Strain it and add a peck of salt dissolved in warm water; 3 pounds of ground rice put in boiling water and boiled to a thin paste; half a pound of powdered Spanish whiting and a pound of clear glue, dissolved in warm water; mix these well together and let the mixture stand for several days. Keep the wash thus prepared in a kettle or portable furnace, and when used put it on as hot as possible, with painters' or whitewash brushes.

For making small quantities of whitewash it will usually be found convenient to use powdered hydrated lime instead of quicklime. This product is already slaked.

Whitewash may be tinted by the addition of colors, but care should be taken not to use colors which are affected by lime. Yellow ocher, siennas, umbers, iron-oxide red, ultramarine blue, boneblack, etc., may be used. If dry lampblack is used it must be first stirred in hot water containing some soap or in cold water containing borax, otherwise it will be found difficult to wet the lampblack.

Calcimines or Cold-Water Paints.—Calcimines have as their bases whiting, clay, silicates, etc., instead of caustic lime, as in whitewash. These materials do not adhere, and it is necessary to use a binder of some kind, generally glue or casein.

The following recip s, taken from "White Paints and Painting Materials," by Scott, are representative of this class of material:

Ordinary white stock (calcimine).—(*a*) 16 pounds of whiting mixed until free of lumps with 1 gallon of boiling water; (*b*) ½ pound of white sizing glue; soak 4 hours in ⅛ gallon of cold water. Dissolve on a water bath and pour into 16 pounds of whiting mixed until free of lumps with 1 gallon of boiling water. This will make about 2 gallons, weighing 12¾ pounds per gallon. It is of proper brush consistency and may be used at once but is better after standing a half hour. This material will cover per gallon about 270 square feet on plaster, 180 square feet on brick, or 225 square feet on wood.

Cold-water casein paint.—8 pounds pure casein, 10 pounds air-slaked lime, 1 pound pulverized borax, 60 pounds whiting. Mix the dry ingredients thoroughly and keep in a sealed package until wanted for use, then stir in cold water (or, better, warm water) to produce a mixture of proper brush consistency.

Calcimine may be tinted in the same manner as whitewash, using only colors which are not affected by lime.

(*i*) Floor Wax

While floors are very frequently varnished and look very well when newly treated, varnished floors are hard to keep in good condition. A waxed floor, on the other hand, may be kept in good condition indefinitely with a moderate amount of care. In fact, a properly cared for waxed floor improves with age, which is more than can be said for any other floor finish.

The following formula furnishes a very good floor wax:

	Parts by weight
Carnauba wax	2
Ceresin	2
Turpentine	3
Gasoline (sp. gr. 0.725)	12

The waxes are melted by heating in a vessel of hot water, and the turpentine and gasoline are then added and the mixture cooled as rapidly as possible, while vigorously stirring to produce a smooth creamy wax.

Another formula which has been found very good is:

Turpentine	pint	1
Beeswax	ounces	4
Aqua ammonia	do	3
Water (about)	pint	1

Mix the beeswax and turpentine and heat them by placing the vessel in hot water until the beeswax dissolves. Remove from the source of heat, add the ammonia and water, and stir vigorously until the mass gets creamy.

In making either of the above waxes be very careful to heat only by setting in hot water and have no flames in the room, since both gasoline and turpentine are very inflammable.

Floor wax should be applied in very thin coats and thoroughly rubbed with a heavy waxing brush or a heavy block wrapped in burlap or carpet.

(*j*) **Removing Paint and Varnish**

The most efficient method of removing old paint and varnish is by burning with a painter's torch. The heat causes the film to soften and it can be scraped off. This method, however, can only be used on flat surfaces and where slight scorching of the wood is not objectionable. A hot solution of caustic soda (concentrated lye) 1 pound to the gallon is also quite efficient. This should be applied with a fiber (not bristle) brush until the paint softens. This is very hard on the hands and also raises the grain of the wood, and surfaces treated with it should be thoroughly washed with water and allowed to dry before repainting. It will also be necessary to sandpaper such surfaces.

There are a number of paint and varnish removers on the market, most of which consist of mixtures of benzol, acetone, and methyl alcohol, with frequently the addition of some waxlike body which retards evaporation of the volatile solvents, which are the real active constituents.

(*k*) **Care of Brushes**

Brushes for applying oil paints must be well cleaned after using, though for keeping overnight it is generally sufficient to wrap them in several thicknesses of paper. Some painters keep their brushes overnight by putting them in water. If, however, the brush is not to be used for several days, the paint should be washed out of it. Turpentine is one of the most satisfactory materials for washing a brush, but it is expensive, and a brush can generally be washed as well with kerosene, which is much cheaper. After washing off the paint with kerosene the brush should be rinsed with gasoline or benzine, then thoroughly shaken and well washed with soap and warm water. As soon as this washing is complete the brush should be shaken thoroughly, so as to throw as much water out of it as possible, and hung up with the bristles down to dry. When dried the brush should be thoroughly protected from dust. If much painting is being done, it is less trouble to keep the brushes in turpentine or kerosene. For this purpose hooks should be fastened on the inside of a pail with a close-fitting cover, the brushes being suspended either by holes in the handles or by loops of string, so that they hang in the kerosene or turpentine in the bottom of the pail. The bristles should be submerged in the liquid but should not touch the bottom of the pail. If kerosene is used for cleansing, it should be removed by shaking the brush and rinsing it in turpentine before using again with paint. Brushes used with whitewash or calcimine should simply be washed and not put in the same liquids in which the brushes for oil paints are kept. If a brush has been used for shellac varnish, it should be kept in alcohol or in the varnish itself. In general a varnish brush may be kept in the varnish in which it is used.

(*l*) Precautions to be Observed in Painting

Do not use any paints containing compounds of lead about stables or outbuildings where the fumes from decaying organic matter occur, since these gases are likely to darken the lead paints. Do not use with lead compounds any pigments which may liberate compounds of sulphur. For example, ultramarine blue, which contains sulphur in a form in which it may be set free, is a beautiful and very permanent blue and may be used with zinc white but should not be used with white lead or any other lead pigments. Prussian blue, on the contrary, does not contain sulphur and may be used with lead pigments.

Remember that turpentine and benzine are very inflammable; hence, special precautions should be taken not to bring paint containing these substances near any light or open fire.

Many pigments are poisonous, and the workman should be particularly careful to remove all paint stains from the skin and not under any circumstances allow any paint to get into his mouth. A man should not eat in the same clothes in which he has been painting, and before eating should not only change his clothes but wash all paint stains from his skin. It is not advisable to use turpentine or benzine in removing paint stains from the hands, but by oiling thoroughly with linseed oil or, in fact, with any fatty oil and then thoroughly washing with soap the paint may be removed, provided it has not been allowed to dry too thoroughly on the hands.

(*m*) References

Sabin, A. H.: House Painting; and Technology of Paint and Varnish.
Bureau of Standards Circular No. 69, Paint and Varnish.

8. BITUMINOUS ROOFING

(*a*) General Considerations

The term "bituminous roofing" is applied to any roofing in which bituminous material forms an essential constituent. The bituminous materials used for the purpose are the tar pitches, obtained as residues from the distillation of coal or oil tar, and the asphalts, obtained either by softening certain refined natural asphalts with especially prepared petroleum oils, or as residues from the careful distillation of asphaltic-base oils. From the standpoint of application, this class of roofing may be divided into the "built-up" type, in which the various materials are assembled on the building, and the "prepared" or "ready" roofing, which simply requires to be nailed or otherwise secured to the roof deck. The ordinary gravel-surfaced tar or asphalt roof is a typical example of the first class, while the "prepared" type is represented by the heavy-weight saturated and coated felts or by the "asphalt shingles." Certain kinds of roofing are, however, intermediate between these two types.

The chief considerations in the selection of any roofing material are the fire risk, serviceability, appearance, and cost.

From the standpoint of fire risk, bituminous roofings, particularly of the "built-up" type, deserve more consideration than is usually given them. This fact is best illustrated by the ratings given such roofing by the Underwriters' Laboratories. When properly laid, the better roofings of this kind have been given ratings in Class A, the best rating given by the Underwriters' Laboratories. This Class A "includes roof coverings which are not flammable and do not carry or communicate fire; which afford a very high degree of heat insulation to the roof deck; which possess no flying-brand hazard; which do not slip from position when exposed to high temperature, and which are durable and do not require frequent repairs."

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On the other hand, the "prepared" or "ready" roofings are usually rated as more hazardous and require higher insurance premiums. Some asbestos-felt roofings are rated almost as safe as the built-up type of roofing and some "asphalt shingles" as less hazardous than other types of "ready" and prepared roofing.

From the standpoint of serviceability, bituminous roofs vary greatly. Some of the "prepared" types show a life of but three or four years, while a "built-up" roof composed of the best materials and laid with careful workmanship should last from 15 to 30 years, and not a few cases are on record where such a roof has stood for over 40 years without necessitating any extensive repairs. Failures are not uncommon but are usually chargeable to poor workmanship. The "prepared" types, with the exception of the "asphalt shingle," are, for the most part, used on temporary or, at most, semipermanent structures, while the "built-up" roofing is used on most large permanent buildings.

The question of appearance is so largely determined by personal taste that no definite distinctions can be made. The "built-up" types are usually constructed from the standpoint of service, with appearance as a secondary consideration, though such a roof is frequently covered with vitrified-clay tile when appearance becomes an important factor. Certain two-ply asbestos felts are now being made by saturating and coating one sheet of the felt and rolling into this coating a second sheet which is unsaturated. This leaves one white side, and the felt is laid with this side exposed, thus presenting a pleasing appearance. Pleasing architectural effects are often obtained with the "prepared" type by the use of molded wooden battens over the joints of the roofing or more especially by the use of the "asphalt shingle."

These bituminous roof coverings, even of the "built-up" type are by no means the most expensive materials which can be used, and many of the "prepared" or "ready" roofings are less expensive than shingles in most parts of the country. If a "built-up" type of roof is properly laid, the cost of maintenance is, perhaps, as low as on any roof that can be laid. The "ready" or "prepared" roofings, though they do not, for the most part, show a serviceability of many years, are yet frequently an economical roofing, and even the cheapest of them may at times be used to advantage on temporary structures.

(*b*) **Built-up Roofing—Materials and Construction**

Tar Pitch—*Preparation.*—Coal tar is obtained as a by-product of the destructive distillation of soft coal, either in the manufacture of illuminating gas or of coke. Tars from the various types of gas retorts and by-product coke ovens differ somewhat in composition, owing to the variation of temperatures employed, the highest temperatures prevailing in the gas retorts. As a result, the tars from gas retorts contain a higher proportion (10 to 40 per cent) of "free carbon" than do coke-oven tars (4 to 15 per cent). This "free carbon" is not a pure carbon, but is a material in the tar which is insoluble in carbon bisulphide and benzol and which, when separated from the tar, closely resembles lampblack. The coal tar from either source is separated from the ammoniacal liquor and is then subjected to a second distillation, by which the more volatile constituents are expelled, leaving a residue of coal-tar pitch, which is the material used for roofing, waterproofing, and other types of work.

In the manufacture of water gas, either coal gas or an oil of petroleum origin is used to increase the luminosity of the flame. The oil is introduced by spraying on a very hot grid, thus resulting in a decomposition or "cracking" of the oil and the formation of a small amount of tar. This tar, however, contains but a small amount of "free carbon" (usually less than 2 per cent). The pitch produced by further distillation of this tar is being offered on the market, but has not proven satisfactory for roofing purposes and will not be further referred to.

Properties.—Even though pitch manifests many of the characteristics of a solid, it is really a very viscous liquid and, consequently has no sharply defined melting point. The so-called "melting point" is simply the temperature at which it flows readily, as determined by some arbitrary method; e. g., the gradual heating of a cube of the pitch in a water bath till it drops from the wire on which it is suspended.[7] As defined by this test—the cube method in a water bath—the so-called "melting point" should be between the limits 57° and 68° C (135° to 155° F). The pitch used on a single job should not vary in melting point more than 2.5° C (5° F) in either direction from the specified desired melting point, but the wider limits are given to obtain materials suitable for different climatic con-

[7] For details of this method see article by S. R. Church, Journal of Industrial and Engineering Chemistry, vol. 3, p. 227.

ditions, a material of low melting point being desirable for cold climates and vice versa.

The "free-carbon" content—i. e., the matter insoluble in carbon bisulphide or a benzol—toluol mixture[8]—should be between 15 and 35 per cent. A certain amount of "free carbon" in a pitch is desirable, because it prevents an undue susceptibility to temperature changes, and, on the other hand, a too high percentage of "free carbon" indicates a greater decomposition or "cracking" of the tar than is desirable. If this "cracking" is excessive, a partially coked condition will result, which will be indicated by a granular appearance when the pitch is pulled out slowly. Such pitch should not be used. The minute particles of "free carbon" should not be mistaken for coked pitch.

Sometimes a pitch which is too hard for use is fluxed or softened by the addition of an oil or tar of lighter consistency, forming a so-called "cut-back" pitch. Such pitches may frequently be recognized by the oily feeling of the pitch.

On the other hand, a tar of too light consistency is sometimes thickened by the addition of a finely ground mineral filler, such as Portland cement, limestone, soapstone, silica, etc. While these products will prevent, to a great extent, the flowing of the pitch, the results obtained with them are at best uncertain, and it is probable that the serviceability of the tar is frequently materially reduced by such additions.

Asphalt Products—*Source and Preparation.*—Some of the asphalts most extensively used for roofing purposes are as follows:

Trinidad Asphalt: This is obtained in its native state from an asphalt lake on Trinidad Island, off the coast of Venezuela. The crude asphalt is far too hard for use as a roofing material and must be softened by heating with some fluxing oil. Trinidad asphalt always contains some fine mineral matter, as much as 43 per cent, on a dry basis, in the crude material.

Bermudez Asphalt: This comes from Bermudez Lake in Venezuela. It is much softer than Trinidad asphalt and contains from 2 to 5 per cent of mineral matter.

Artificial asphalts are prepared as residuals from the careful distillation of such asphaltic-base crude petroleums as those of California, Texas, and Mexico.

Certain very hard asphalts, such as gilsonite, grahamite, and elaterite, are sometimes used in small amounts as agents for

[8] For details of method see Bulletin 314 of the Department of Agriculture, Methods for the Examination of Road Materials.

tempering or modifying the properties of the asphalts mentioned above.

The blown oils are prepared from asphaltic or semiasphaltic-base oils by blowing air through them while the asphalt is maintained at a relatively high temperature.

Properties.—Asphalts, like tars, are in reality viscous liquids, and the so-called "melting point" must be determined by arbitrary methods. As determined by the cube method in air bath,[9] the melting point for roofing purposes should be not less than 60° C (140° F), and for best work, except under exceptional conditions, it is believed inadvisable to use a material melting over 100° C (212° F).

No asphalt for roofing purposes should be unduly hard and brittle but should lend itself to slow bending without breaking. It should show some ductility; e. g., the property of being pulled out without breaking off sharply.

With the exception of the mineral matter naturally in some asphalts, such as those from Trinidad and Bermudez Lakes or mixtures containing these, all these asphaltic materials should be almost entirely soluble in carbon bisulphide.

Comparison of Tar and Asphalt for Roofing.—"Built-up" roofs of both asphalt and coal tar have been used with considerable success throughout all parts of the country. Asphalt is somewhat less affected by temperature changes and may be used on somewhat steeper slopes, but except for this it has few advantages over the coal-tar pitch, which, as a rule, is much less expensive. It is essential that asphalts be not heated too hot, either in the process of preparation or application, as such overheating will ruin the best material and is likely to result in the scorching of the felt to which it is applied. Likewise, coal-tar pitch should not be overheated or kept at a higher temperature than necessary for too long a time, because such heating, in addition to the possibility of scorching the felt, acts as a distillation process and unduly hardens the pitch. Blown oils, or "blown asphalts," as they are called, are not the best for holding the stone surfacing, because of their lack of adhesiveness.

Saturated Felts—*Preparation.*—The raw felts used for this purpose are made on a paper-making machine and, for the most part, are composed of torn-up cotton-rag stock, to which is added more or less jute, old paper stock, etc. The felts thus made are

[9] For details see Bulletin 314, Department of Agriculture, Methods for the Examination of Road Materials, p. 14.

passed through a vat of hot tar pitch or asphalt, by which they become saturated. The term "wool felt" as applied to these felts is a misnomer, for rarely does more than 10 per cent of the fiber consist of wool, and more often the only wool present is incidental in the none too carefully selected cotton-rag stock that is used. Felts of asbestos fiber are also made and impregnated with asphalt in a like manner. Woven fabrics of jute and cotton are manufactured for special purposes where strength is all-important, but many of them are of doubtful value except under peculiar conditions.

Tar-saturated felts come in rolls 32 to 36 inches wide and, as a rule, weigh about 14 to 15 pounds per square (108 square feet),[10] though other weights are to be had. Asphalt-saturated felts also come in rolls of the same width and are to be had of almost any desired weight. For a "built-up" roof of five-ply or over a minimum weight of 14 pounds per square seems about what should be required, while if the roof is to be less than five-ply a heavier saturated felt should be required which will weigh not less than 25 pounds per square. Sometimes felts coated, as well as saturated, with asphalt are used. This coating is accomplished by passing the saturated felts over a set of rolls and playing on one or both sides a stream of hot asphalt. It is customary in such saturated and coated felts to dust on the coated surface some powdered soapstone, fine sand, cork dust, or like material to prevent sticking together in the roll.

Properties.—Few criteria can be given for selecting a good felt for roofing. Most manufacturers place on the market, for competitive purposes, one or more brands which are made of very little rag stock and are largely composed of the cheaper jute, ground wood, old newspaper stock, etc., so one can not hope to get a high-grade article if he is seeking for the cheapest material of the kind on the market. Other things being equal, the best felt is the heavier and the more uniform product. It must be strong enough to stand handling and must be sufficiently pliable to bend double without cracking. A portion of the felt torn apart and examined with a good hand magnifying glass should show a thorough saturation of the fibers, and none of them should present a clean or yellow appearance. This appearance of the fiber does not apply to asbestos felts, since asbestos does not absorb bituminous materials.

[10] In general roofing, 100 square feet constitute a square, but the felt manufacturers allow 8 square feet for lap and sell 108 square feet of felt as one square.

Asbestos felts are sometimes used with asphalt for roofing, but so far do not seem satisfactory for use with coal-tar products. Asbestos fiber does not absorb the bitumen, and the felts can not be said to be saturated with asphalt. This type of felt has not been in use for as long a time as have the rag felts, and while the asbestos does not decay the wearing properties of the sheet asbestos are questionable, especially since it is not customary to protect them by a gravel or crushed-slag coat. The blanketing influence of such a felt on fires within the building is a point which has probably been overestimated. Such a roof is lighter than the ordinary "built-up" type, but this lightness lowers its heat-insulating qualities and on wood sheathing seems to more nearly approach for first-class work the conditions met in ready or prepared roofing.

Construction.—This type of roof is of value only on roof decks of little slope and is not advisable where the incline exceeds 3 inches to the foot horizontally. Such a roofing may be laid on either a concrete or wooden roof deck, but it is essential that the roof deck should be reasonably smooth and, if it be made of wood, that it be free from wide cracks and that all knot holes be covered, preferably with pieces of sheet metal. It is adaptable either to coal-tar pitch or asphalt used with a felt saturated with a like material. If coal-tar pitch be used on a wooden roof deck, it is advisable that the roof deck should first be covered with a good grade of sheathing paper, to prevent any coal-tar pitch from "cooking" through the felt and ultimately finding its way into the interior of the structure and also to protect the coal-tar pitch against drying out from below. If asphalt is used, this detail is not so important as with coal-tar pitch. Sheathing paper is not necessary in case of a concrete roof deck. In laying this type of roofing it is essential that each layer of felt be smoothly and evenly laid and that all joints should be so lapped that in all places there will be the specified number of layers of felt on the roof. The felt should, in all cases, be so uniformly and thoroughly mopped with hot coal-tar pitch or asphalt that in no place shall felt touch felt. If there is any possibility of wind disturbing the roof from underneath, the felt may be secured in place by the use of a few well-galvanized, large-headed nails, but care should be exercised that all nails be covered with at least two plies of felt. The felt should be turned up against all adjacent vertical surfaces and properly cemented to the same.

Proper flashing must be provided if one would expect to get a satisfactory and lasting leak-proof roof. The flashing is a lap joint of metal or other material to keep the roof water-tight where it joins a chimney, wall, or other vertical surface.

When the last layer of felt is laid and the flashings are in place, the entire roof surface should be covered with a thick layer of hot pitch or asphalt, as the case may be, and while this is still warm at least 400 pounds of clean, dry, washed gravel or 300 pounds of crushed slag per hundred square feet of surface should be embedded in this pitch or asphalt. This gravel or slag should consist of pieces from ¼ to ⅝ inch in size and be free from sand or dust. The gravel or slag layer is not so essential in the case of a roof built up with asbestos felts, but when the ordinary felt is employed the use of slag, gravel, or tile is almost imperative.

(*c*) "Ready" or "Prepared" Roofing

Felts (Roll Type)—*Preparation*.—The "ready" or "prepared" bituminous roofings are of the same general type and made of the same materials as the saturated felts described as felts for the "built-up" roofings (see p. 133), except that most of these "ready" or "prepared" felts are coated with bitumen and, in addition to being saturated, are usually surfaced with some ground mineral substances or other material to prevent sticking in the roll. With the exception of the shingle type and a few others, these materials come in rolls of one or two squares and are usually accompanied by the nails and cement necessary to lay them. They vary from the lightest felt, made in the most inexpensive manner and of the cheapest materials, to a several-ply sheet so heavy that it can not be rolled. They are made either with coal-tar pitch or asphalt, but, since in the case of coal-tar felt, if it is to be put up in rolls, it is not possible to coat the felt and avoid the layers sticking together, the coal-tar products do not enter greatly into the field of "ready" or "prepared" roofing, except in so far as ordinary saturated tar felt is used for very temporary structures. The cement which accompanies many of these "ready" roofings consists usually of an asphalt or mixture of asphalts dissolved or thinned with a petroleum distillate, though sometimes a cement is furnished which has not been dissolved in any solvent but which is calculated to be used hot.

These "ready" or "prepared" roofings which come in rolls have certain inherent weaknesses which would prevent their use on many permanent buildings. One of these weaknesses is the fact that, despite all care to lay them properly, they will frequently stretch or wrinkle after being exposed on the roof for some time, thus resulting in a bagging of the felt. As time goes on and the saturant hardens, these wrinkles become weak spots, especially if they are walked on or abused in any way. Another source of weakness is the fact that, except for the narrow lap, the roof deck is covered with but one layer of the material, which is not desirable, because, in addition to other objections, such a roof has neither great heat-insulating properties nor great fire-resisting qualities. Again, if the roof deck be rather flat, it is possible for water to be backed up under this lap and pass through the sheathing into the interior of the building. If the roof deck be of wood and knot holes and cracks are not covered with sheet metal or otherwise cared for, these become a source of imperfection, and above them the felt may be readily broken through. If a tear starts at any point and the wind is allowed to get under the felt, its light weight makes it possible to be torn from the roof with little resistance.

Asbestos-impregnated felts are also made for this purpose, sometimes of several plies of felt and, in some cases, reinforced with a woven fabric in the interior of the felt. Some of the heavier brands are quite expensive and often approach the cost of a five-ply "built-up" roofing. While the asbestos will not burn, the average thickness of these felts is such that the heat-insulating value is not great. From the standpoint of fire protection they are generally overvalued.

Properties.—In general, the heavier the felt, the more satisfactory is the material. The manufacturers frequently designate the thickness of the felt by the number of ply, but lack of uniformity of practice makes this designation inconsistent. With some manufacturers a two-ply felt means two separate felts cemented together with a bituminous material, while with others it means simply that a two-ply material is heavier than that sold as one-ply. The weight of a felt is most often designated by number, meaning that the felt weighs that number of pounds per 480 square feet;[11] e. g., a No. 55 felt weighs 55 pounds per 480 square feet. The saturant should be of such consistency that it is workable at a temperature low enough to preclude possibility of damage to the felt by scorching, and, at the same time, the felt after saturation should remain pliable and not liable to fracture

[11] Paper scales were originally built for a 480-sheet ream, and on weighing a 1-square-foot sheet the weight per 480 square feet would be read directly on the beam.

on quick bending; but this detail must be left to the manufacturer, who should know the properties of his material. The coating should be stable and not easily affected by the wind or sun and must retain its life and elasticity or the roofing is a failure. Frequently—that is to say, once every year or two—it is advisable to coat an asphalt-felt roofing of this kind with a good grade of asphalt paint to revive this coating and keep it in good condition. The mineral surfacing, while giving an added weight which should not be considered in judging the weight of the material, has advantages which make it desirable in many cases.

Since there are so many low-grade materials on the market and so few criteria for judging the quality, except by service test, and since guaranties are uncertain, the consumer must, to a great extent, rely on the honesty and reputation of the manufacturer to secure a high-grade article.

Application of the Material.—These felts may be laid in a variety of ways. The most common method is to lay the sheet parallel with the eaves, starting at the bottom of the roof. The sheet must be stretched to avoid wrinkling or bagging. Cleats or heavily galvanized nails with large heads are recommended, and care must be exercised that the nails are never driven into cracks. Tin caps are not believed desirable, because of the tendency of these tin caps, when not kept consistently coated, to disintegrate through the corrosion of the iron or steel base of which they are made, thus allowing the nails to stand high and clear of the roofing, so that the felt is easily torn by high winds. The next layer of felt is allowed to lap 2 or 3 inches over the first layer, and prior to nailing the lap should be coated with the cement into which the new layer is embedded. Care must be taken to provide proper flashing, well secured, about all vertical surfaces.

The felt may also be laid with the pitch of the roof, and this is of advantage in that it permits felt to be better stretched before being secured to the roof deck. For architectural effect, when the felt is laid with the pitch of the roof, wooden battens may be used over the laps, resulting also in a better protection of the felt against the possibility of being torn by high wind.

Asphalt Shingles.—Some of these "prepared" roofings heavily surfaced with coarse sand or crushed slate are cut up into shingles of various sizes. One size in common use is 8 by 12¾ inches. This shape of shingle is laid American style as ordinary wood shingles. Another common "asphalt shingle" is approximately square, with two of the corners cut off at an angle, and is laid according to the French or diagonal method. For the most part, these shingles are used on the smaller buildings, particularly dwelling houses, and from an architectural standpoint they present a very pleasing appearance when freshly laid. They are not satisfactory for slopes less than 3 inches to the foot horizontally. Such shingles have not been in general use a sufficient time to judge what may properly be expected of them. Some such roofs which have been laid for less than five years present an unsightly appearance, due principally to the tendency of the shingle to curl but in part to the tendency of the mineral surfacing to become detached from or enveloped by the bituminous coating when the latter is softened by the heat of the sun.

(*d*) Reference

Volume 14, Proceedings American Railway Engineering Association, report of committee 6 on buildings.

II. FLEXIBLE MATERIALS

1. RUBBER

(*a*) What is Rubber?

The term "rubber," as commonly used, includes not only the crude material as it is obtained from the rubber trees but also any manufactured article composed wholly or in part of rubber. Generally speaking, this does not cause confusion, since the public seldom has to deal with the pure raw material. However, for the purposes of this chapter, we shall confine the term "rubber" to the pure material and use the term "rubber compounds" to designate mixtures of rubber with other materials.

Before the discovery of America the natives of tropical America were acquainted with some of the useful properties of rubber and utilized them in the preparation of water bottles, shoes, and shields. The early explorers soon noticed this peculiar material, and many specimens were collected and sent to Europe, but for a long time the only practical use made of rubber was in waterproofing coats.

The true beginning of the rubber industry occurred in 1839, when an American, Charles Goodyear, discovered that by heating together sulphur and rubber there resulted a material which possessed new and remarkable properties totally unlike the crude rubber from which it was made. This treatment was called "vulcanization." A few years later it was found that a change in rubber similar to that produced by vulcanization could be produced by treating rubber with sulphur chloride. These two processes laid the foundation for the modern rubber industry, and it is interesting to note that almost no change has been made in these since the time they were first put into practical use and that no other methods of vulcanization have been discovered.

(*b*) Compounding Materials

In order to appreciate fully the reasons for good and bad quality in rubber goods, it will be necessary to consider the various materials which are used in preparing rubber compounds.

RUBBER.—Rubber occurs in the latex (or sap) of certain trees, shrubs, and vines which grow abundantly in the Tropics. Incisions are made in the trees and receptacles placed below these to catch the latex as it flows from the cuts. The rubber is coagulated by exposure to the air, smoking, or treatment with weak acids. The valley of the Amazon River yields the largest quantity and best quality of wild rubber.

Some years ago it was foreseen that the increasing demand for rubber would exhaust the available supply of wild rubber and attempts were made to cultivate rubber trees on plantations. These efforts have proven so successful that the quantity of rubber raised on plantations has increased from practically nothing in 1905 to more than 100,000 tons in 1915, or almost twice the yield of wild rubber in 1905. The result of this increased supply has been the gradual reduction in the price of crude rubber in the face of an enormous increase in consumption caused by the development of the automobile industry.

Reclaimed Rubber.—It has been found practicable to take waste and scrap rubber and by means of certain processes, too technical to be described here, to recover a large part of the used rubber. This reclaimed rubber is never as good as the crude rubber used originally but possesses to some degree the useful properties of new rubber. Indeed, it is no exaggeration to say that the best grades of reclaimed rubber are superior to some of the poorer grades of new wild rubber. This material finds extensive use and has been largely responsible for keeping the prices of rubber goods within reasonable limits.

Rubber Substitutes.—The enormous demand for rubber has led many to seek a material which would be able to replace at least part of the rubber used in manufacturing. Two principal classes of substitutes exist—first, the natural and artificial bitumens or asphalts and, second, the oxidized and sulphonated oils. The former find extensive use in the manufacture of the cheaper qualities of insulated wire and give very satisfactory service. The value of the second class is questionable.

Vulcanizing Accelerators.—In vulcanizing rubber with the aid of heat certain materials are added which cause the vulcanization to take place at a lower temperature and in a shorter time than would otherwise be necessary. Lime, magnesia, litharge, aniline oil, and aniline derivatives are examples of vulcanizing accelerators.

Other Compounding Materials.—There are but few articles which are made from rubber and sulphur only. Generally, mineral fillers are added to the compound to give it toughness and wear-resisting properties. Such fillers must not be looked upon as adulterants, but are essential to the life of the finished article.

(c) Household Uses of Rubber.

Wire.—Electric lighting, cooking, heating, etc., depend upon the use of rubber-insulated wire to conduct the current to the place where it is wanted. The current used in the house is usually of comparatively low voltage (about 110 volts), and a low grade of rubber compound is perfectly satisfactory for the insulation. Reclaimed rubber is used almost exclusively.

Washers and Gaskets.—Washers and gaskets are usually cut from a sheet of the required thickness. Their principal use is in making water-tight joints in the plumbing.

Matting.—Rubber matting is used extensively for stair treads hallways, bath rooms, and porches. It should be free from objectionable odor and should have sufficient resiliency not to crack on bending.

Garden Hose.—Most of the rubber used in garden hose is of the cheapest variety possible. Few rubber articles are abused as much as the average householder abuses his garden hose. It is dragged over gravel, cinders, tin cans, bent around sharp corners, left out in the hot sun for hours at a time, and, consequently, its life is short, usually one season. Good grades of garden hose can be bought, and with reasonable care should easily last three or four seasons.

Surgical Goods.—Under the heading of "surgical goods" we have ice bags, hot-water bags, syringes, tubing, etc. These articles should be of the best quality obtainable. They are usually required in cases of emergency, and when such occasion arises it is imperative that these articles be ready for service. Cheap goods mean poor quality, and poor quality is a poor investment.

Children's Articles.—Rubber nipples for milk bottles and rubber toys are used extensively. It is particularly important that they shall be free from any poisonous minerals which would be dissolved by the saliva. This is recognized as necessary with nursing nipples, but it is of equal importance in the case of toys.

Office Sundries.—The principal rubber articles in the office are rubber bands and erasers. The former are usually of very good quality, containing from 60 to 90 per cent of new rubber. Cheaper bands contain reclaimed rubber and substitutes.

Tires.—Since the automobile may be considered part of the household equipment, we find rubber playing a most important part. Without rubber there would be no pneumatic tire. The tire casing consists of a number of layers of fabric with rubber as the adhesive which binds them together, covered with side walls and tread of rubber compounds. The latter contain 40 to 50 per cent of new rubber, while the side walls usually contain a smaller amount. The service required of these tires is so severe that few manufacturers care to use anything but the best of new rubber. Inner tubes contain from 60 to 90 per cent of rubber, and in these also we seldom find anything but new rubber and mineral fillers. Reclaimed rubber and substitutes find little use in the best tire casings and inner tubes. Carriage tires, of course, do not receive as hard service as automobile tires and therefore do not need to be of as good quality.

Wearing Apparel.—Rubber enters into our wearing apparel in the form of waterproof coats and hats, overshoes, gum boots, canvas shoes with rubber soles, rubber heels, etc. Waterproof clothing is usually vulcanized by the cold process in order not to injure the fabric. Overshoes and gum boots contain the cheapest quality of reclaimed rubber on the market. The most important point with these articles is that they must be waterproof. The better grades of canvas shoes have soles made from a much better rubber compound.

There is a growing demand for a substitute for leather for soles of shoes. There are a number of these substitutes being made from a mixture of rubber with various kinds of fiber, ground leather, etc. Their value is as yet problematical, but undoubtedly there is a big field for rubber as a substitute for leather.

Garters and suspenders depend upon rubber for their usefulness. They contain a long thread of pure rubber having the maximum amount of stretch. Very similar to these are the various kinds of rubber bandages, etc.

Hard Rubber.—Among the articles made from hard rubber we find combs, brushes, rulers, insulators used in the electric lighting system, etc. The difference between hard and soft rubber is that the latter contains about 1 part of sulphur to 10 or 12 of the rubber, while hard rubber contains much more sulphur, usually 1 part to 3 of rubber. Naturally the latter must be heated for a much longer time and at a somewhat higher temperature than is needed for soft rubber.

(*d*) Useful Properties

This rather brief summary of the more important uses in the household shows to what extent rubber enters into the materials used in our everyday life. It has come to be a necessity largely on account of desirable qualities peculiar to this material. Of these, by far the most important is its elasticity. Crude rubber when stretched returns slowly to a state of equilibrium. When partially vulcanized it returns more quickly, but still much more slowly than when properly vulcanized. In every case the piece of rubber which has been stretched will not return exactly to its original length. This increase in length is called "set," and the manufacturers aim to have this quality at the lowest point consistent with good manufacturing practice. Pure new rubber, properly vulcanized, will stretch from 9 to 10 times its original length. Compounds containing 50 per cent of rubber will stretch only five or six times their lengths, while compounds with still smaller percentages of rubber will stretch even less. These figures are not exact; they depend not only upon the quality of the rubber and the degree of vulcanization but also upon a number of other points too technical to be discussed here.

The elasticity of rubber is the one property which distinguishes it from every other substance known, but it has other properties which are of value. Pure rubber is very soft, but by the addition of the proper mineral fillers it may be made tough and strong, having very desirable wear-resisting properties. Rubber, both in the hard and soft condition, is a good electrical insulator. In the hard form it is used extensively in electrical apparatus, although it may be replaced by other materials, but in the soft form it is used on insulated wire and cable and has no real substitute.

(*e*) Inspecting and Testing

If rubber articles were bought in quantity for household uses, typical specifications, methods of inspection, testing, etc., could be given, but unfortunately this is not the case. Small pieces can not be removed from the articles for the purpose of making a careful examination without in many cases destroying the value of the article. Even where such sampling is possible the cost of the testing is prohibitive. Hence, the small purchaser has three means of insuring quality: (1) Reliability of the seller; (2) the guaranty of the maker; (3) experience with articles of a definite brand.

The first is of questionable value, for with the best of intentions the retail stores frequently are without the technical information which is necessary to adequately protect their customers. The second is much better, provided, of course, the guaranty is clearly stated and backed by a reputable manufacturer. Automobile tires are largely sold on this basis, and the method has given a considerable amount of satisfaction. The guaranty is usually on the basis of mileage under normal conditions of service, and the better class of manufacturers are usually prompt to make good any failures. Skill and care in manufacture, together with the use of the best materials, make these failures a very small percentage of their total output.

(*f*) Proper Care of Rubber Goods

There are two agencies which hasten materially the deterioration of rubber goods—heat and sunlight. At 70°C (160°F) articles which would otherwise last 5 or 10 years are destroyed in three weeks or less. At higher temperatures the action is even more rapid. These facts will explain the deterioration of waterproof coats, hot-water bags, etc., which are thrown over steam radiators to dry. In direct sunlight rubber bands which ordinarily would last four to six years have become worthless in three months. The ideal storage for rubber goods when not in use is in a cool, dark place.

Oil has also a serious effect on rubber. This is particularly noticeable in the case of automobile tires and inner tubes. The oil is absorbed by the rubber and in a short time produces a soft spot. It is, therefore, of the utmost importance to remove any oil from rubber goods as soon as possible, and it pays to take precautions that the two do not come in contact with each other at all.

(*g*) References

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2. LEATHER

(*a*) Definition

Leather is made from the skins of animals, the process being called tanning. The purpose of this process is to produce a serviceable article that will not decay from the raw hides or skins. The principal skins used for this purpose are those of cattle, sheep,

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goats, horses, and pigs. To a much less extent, for special purposes, skins of other animals are used, such as alligator, seal, etc. Furs may be considered under this heading, the essential difference being that in this case the skin is tanned without removing or in any way injuring the hair.

(*b*) **Tanning**

The process of tanning, as followed since early times, consisted of treating the skins, after removal of the hair, with a solution of tannic acid. The tannic acid combined with some of the constituents of the skin to form a tough substance which was insoluble in water. The progress of the art in modern times has shown that for the lighter skins, such as calf, goat, sheep, colt, etc., a better and cheaper article can be obtained by the so-called "mineral" tanning. Other methods are used to a much less extent than either of these two in preparing leather for special purposes.

It is impossible here to do more than mention briefly the various processes used in the production of leather. Up to a certain point practically all skins are treated in the same way. The skins are soaked to soften and remove salt, dirt, etc., and then treated with some reagent, usually lime, arsenic sulphide, or sodium sulphide, which will loosen the hair. The hair is removed and the skin is treated to remove the lime and open the pores and swell the hide, so that the tanning process may be the more readily carried out.

Organic Tanning.—This is usually done in the case of the heavier hides, such as would be used for soles, harness, belting, etc. The hides, after they have been freed from lime, are suspended in vats containing bark and wood and wood extract, the latter consisting largely of tannic acid. The principal tanning materials used in this country are the hemlock, chestnut, oak, and chestnut wood extract. This part of the process continues usually for several weeks, until the hides have taken up as much as possible of the tannic acid. After tanning the hides are treated with oil (stuffing) and dried. After a few minor treatments they are ready for marketing. In the case of sole leather, it is rolled in a sammied condition, so as to make the fibers more compact and make the leather more solid and serviceable.

Chrome Tanning.—This is usually applied to the lighter skins, such as calf, colt, goat, and sheep. The process is essentially the same as for the heavier hides up to the point of removing the lime after unhairing. The skins are then treated with a solution of sodium bichromate and hydrochloric acid, and after the chromic acid is absorbed it is reduced with sodium thiosulphate ("hypo"). Various processes have been devised whereby this may be carried out in one operation.

The finishing of the skins is carried out very much like the heavier hides. In addition to the oiling, they are usually dyed (black, tan, etc.) and glazed.

OTHER METHODS OF TANNING.—Alum tanning is frequently used for light-colored leather (white kid, etc.). In this treatment either alum or sulphate of aluminium replaces the ordinary tanning reagents.

Considerable leather is still made by the oil tanning, probably the oldest known method. After the unhairing process the excess of water is removed. Cod-liver oil or other oils and fats are worked into the skins. The oxidation of the oils yields materials which combine with the fiber of the skins, so that the fiber is covered with a waterproof coating. Chamois leather, now made entirely from sheepskin, is usually made by this process.

(*c*) **Uses of Leather**

SHOES.—By far the most important application of leather, so far as the individual is concerned, is in the manufacture of footwear, which amounts to more than a half billion dollars per year in the United States.

The purchaser in selecting shoes should consider first the type of footwear that is best adapted to his requirements; after which the quality and style should be chosen according to taste and means. It may be said in a general way that the quality of a shoe, as measured by its durability, increases with the cost up to the point beyond which increased cost can be justified only on the ground of special handwork by skilled labor. It is only by accident that shoes of good quality and finish are purchased at a low price, and it is advisable, when practicable, to buy only of reputable dealers or to select from brands or trade-marks of known quality.

In the case of shoes to be used for ordinary street and house wear, single soles of moderate thickness and soft thin uppers are usually most satisfactory.

It should not be expected that patent-leather shoes or shoes having thin soles and uppers of delicate texture will give satisfactory service if subjected to rough usage or if repeatedly worn in the rain. Under such conditions a more substantial shoe, even though of a cheaper grade, is to be preferred.

Harness, Straps, Etc.—These are usually made from vegetable-tanned hides that have been stuffed with grease, usually tallow and cod oil. It is important that they be well tanned from strong stock and then properly stuffed, as a break may result in a serious accident.

Upholstering.—Considerable leather is used by the upholstering trade in leather-covered cushions and furniture. Calf and goat skins are preferred for this purpose, on account of their wearing qualities and the appearance of the finished skins. Cheap furniture is sometimes covered with sheep or split hides, but such material does not wear well.

Bookbinding.—While not used to the extent that it was formerly, there are still many books bound in whole or in part with leather. The tendency is to use thinner leather than that formerly employed for the same purpose. The use of strong "tannages" and of mineral acids in the process of dyeing contribute to the short life of such leather, which, when new, has the appearance of good quality. The most durable leather for bookbinding is said to be that tanned with oak bark or sumac.

Wearing Apparel.—Under the heading of "wearing apparel" we have gloves, belts, etc. Gloves are usually made from sheep skins, even the so-called "kid" glove being made largely from sheepskins which come from Arabia. Chamois leather is much used for washable gloves, since it is a particular property of oil-tanned skins that they readily take up water.

Trunks, Bags, etc.—There are few trunks made to-day which do not use some leather, although we have gone very far away from the old rawhide trunks which gave such excellent service when properly cared for. Travelling bags and suit cases are made from sole leather, calf, goat, pig, alligator, and other skins. The most durable are probably those made from solid sole leather, but the tendency is to use cardboard covered with a thin split of hide to give the appearance of solid leather.

Fancy Articles.—Under the heading of fancy articles we include pocketbooks, cigar, card, and toilet cases, and similar articles. Nearly every kind of leather is used in the manufacture of these articles.

(*d*) Selection of Leather Articles

The quality of leather is difficult to determine by casual inspection except by those who from experience have become familiar with the different grades and tannages. In some cases it is possible to judge with a reasonable degree of accuracy from the general texture of a piece of leather whether or not it is suited for a particular use, as, for example, in the case of shoe leather or harness leather. On account of the many different kinds of leather now in general use, and owing to the fact that this material, as a rule, is seen by the purchaser only in the form of finished manufactured articles in which the outer surface alone is available for inspection, it is impossible to prescribe any tests for the determination of quality. This is particularly true of embossed leather, in which the surface has been so altered as to prevent recognition. A few suggestions may be made, however, that are generally applicable in the selection of such manufactured articles of leather as are commonly found in domestic use.

In selecting a leather article of any kind with which the purchaser is not familiar, no better rule can be given than to rely upon the advice of a reputable dealer rather than risk one's own judgment in accepting a cheaper material from a questionable source.

Artificial products closely resembling real leather may sometimes be detected by the use of a magnifying glass. The judgement is materially assisted in such cases if a piece of real leather of similar texture is used in comparison.

Leather made from the skin of some animals, such as the alligator and pig, have distinguishing features by which such leathers may be readily identified, but even these leathers are imitated, and by means of carefully embossed surfaces the deception is sometimes concealed.

What is known as "split leather" is produced by cutting the tanned hide into two or more sheets or thicknesses. The outside split is extensively used for suit cases and other articles in which it is desirable to show the grain surface of the leather. The other splits are largely used in the production of inner soles and other parts of shoes. The uppers of cheap shoes such as are used by laborers are often made of thin split cowhide.

(*e*) Care of Shoes

The life of shoes may be considerably prolonged by the exercise of a little care. It is a curious fact that if a wet shoe is placed too close to the fire the interior of the sole is sometimes utterly ruined before the surface of the leather shows appreciable signs of injury. The temperature of a steam radiator is sufficient to injure a wet shoe sole. Wet shoes should be dried slowly, and, if possible, shoe trees should be inserted to prevent their losing shape and becoming uncomfortable. It is apparent, therefore, that it is a matter of economy to keep two or more pairs of shoes, wearing them in rotation. Some leather manufacturers claim that two pairs of shoes worn alternately will outlast three pairs of shoes worn consecutively.

Shoes when not in use should be stored where there is circulation of air and, of course, should be cleaned before putting away. Perspiration is bad for leather, and shoes wet in this manner should be dried as soon as possible.

(*f*) General Preservation of Leather

All leather articles will dry out and become brittle unless treated with some form of dressing. Shoes are usually so treated. Liberal use of neat's-foot oil, castor oil, or tallow will keep the leather soft and pliable but with an oily surface which will catch dust and dirt and be unsightly. Hence, this treatment is not to be recommended except for shoes intended for rough outdoor use. (See p. 151.)

To keep the leather in good condition and permit polishing, most of the tan and russet dressings contain a mixture of waxes (Carnauba, beeswax, etc.) with a small quantity of neat's-foot or castor oil, thinned to a soft paste with turpentine, gasoline, or benzine. A satisfactory formula is as follows:

	Parts
Carnauba wax	2
Beeswax	2
Neat's-foot oil	1

Heat in water bath till melted and then add turpentine until a soft paste is obtained when mixture is cold.

This should be applied to the clean, dry leather with a rag or a piece of waste, rubbing hard until no more polish is absorbed and finally polishing with a clean cloth. A higher polish will be obtained by reduction of the quantity of oil, but the leather will not be so well preserved.

There are many preservatives and waterproofing preparations on the market, which vary from a very thin limpid liquid containing small quantities of the true preservative thinned with large quantities of volatile liquids (benzine, turpentine, etc.) to a thick heavy grease containing no volatile matter.

In general, the thick greases are more effective, but leather so treated can not be polished, and dirt and dust will stick to the surface. It will, therefore, be necessary to consider the results desired and vary the treatment accordingly.

(*g*) Waterproofing

The ordinary oak-tanned sole leather offers much less resistance to the penetration of water than chrome leather, a fact which makes chrome soles the more desirable for shoes to be used in wet weather. Rubber-composition soles, which have recently come into very general use, are practically waterproof. Water often finds its way into a shoe through the stitches around the sole or through the upper, if the leather is of an absorbent structure as in the case of "vici kid." A liberal application of ordinary shoe polish in the form of salve will be found to increase somewhat the water-resisting quality of such leathers. The benefit, however, is only temporary. For strictly waterproof shoes a close-grained oiled leather should be selected. In the case of shoes intended for rough wear, as in the country, the old-fashioned method of greasing the uppers with tallow is very good, and a very efficient way of rendering the soles waterproof is to apply several coats of linseed oil. Linseed oil should not be applied to the uppers, however, because it will make the leather stiff and liable to crack. It should be remembered that leather so treated as to resist the penetration of water will also prevent to a great extent the penetration of air. Waterproof shoes are uncomfortable to most people on account of a lack of ventilation.

(*i*) References

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3. TEXTILES

(*a*) Definition and Varieties

Materials which have been spun or woven or which bear resemblance to spun or woven materials, together with the raw fibers and intermediate products of the manufacture of any of those materials, have been grouped together, by usage, under the generic name "textiles." According to this interpretation of the term, the class includes a very large variety of articles, the importance of which, in household economy, is surpassed only by the foodstuffs. In the scope of this circular it is possible to refer, in a brief and general way only, to the more important aspects of the subject.

The textile fibers are usually divided according to origin into animal, vegetable, mineral, and artificial fibers. The animal fibers include silk, wool, and various kinds of hair. The most important vegetable fibers are cotton, linen, jute, hemp, and the rope fibers, especially manila and sisal. The only mineral fiber of practical importance is asbestos. This is usually spun in combination with cotton. Various kinds of artificial silks constitute the important artificial fibers.

Silk is a continuous fiber secreted by the silkworm for the formation of its cocoon. It is a very lustrous, almost transparent fiber with great strength and elasticity. Threads are formed by reeling together the fibers from several cocoons, although spinning is resorted to for the utilization of tangled and broken fibers in the manufacture of spun silk. Silk is used for garments and for decorative purposes when a handsome and lustrous though expensive material is desired.

Wool and hair are very closely allied, and it is often impossible to distinguish between them. Wool is understood to be the hair of the common or domestic sheep, but the hair of the Angora, Thibet, and llama goats, technically called "mohair," "Cashmere," and "alpaca," respectively, are practically identical with certain kinds of sheep's wool and may be used interchangeably with them. The crimpy or curly shape of the wool fiber makes it especially valuable for use in articles through which it is desired that the rate of heat transmission shall be small or, in other words, where warmth is desired. The ability of the fibers to felt or interlock, under the combined influence of heat, moisture, and pressure, has been attributed by some authorities to their scaly surface. This property is the basis of the manufacture of felts and is of great importance in the finishing of certain classes of goods requiring a smooth, apparently structureless surface.

A great deal of wool fiber is recovered from materials which have previously been through some of the manufacturing processes. This reclaimed fiber is sometimes called "shoddy," "mungo," or "extract" and is used with or without the admixture of new wool. Its value depends on the value of the original fiber, the previous treatment, the treatment necessary for recovery, and the kind of material for which it is to be used. It is a mistake to assume that reclaimed fiber is always inferior to new fiber, although such is usually the case.

Materials made from wool fiber are classed as "woolen" or "worsted" according to the process used in manufacturing. For worsted materials the spinning process is designed to give a smooth thread, with all fibers lying parallel as far as possible and with relatively few projecting fiber ends. For woolen materials, on the other hand, an effort is made to cause the fibers to lie in all possible directions with respect to the length of the yarn, giving a rough yarn with a relatively large number of fiber ends projecting. Worsted yarns are particularly suited for use in serges and other fabrics in which the thread structure should be clearly seen. Woolen yarns will felt together more readily and are, therefore, used for overcoatings, broadcloths, and other materials in which there is little or no thread structure visible.

Besides the use of mohair, Cashmere, and alpaca for outer garments and linings, a very important application is made of the hair of the rabbit and of some other animals in the manufacture of felt hats.

COTTON.—Cotton fiber grows attached to the seed of the cotton plant like a hair. It is very cheap and abundant and is used for nearly all kinds of textile articles. In structure it is flat and spirally twisted when fully ripe, conditions which make it especially adaptable to spinning.

When cotton material is treated with a cold concentrated solution of caustic alkali (lye) and afterwards washed with water, the fiber becomes much straighter and rounder and the material becomes stronger and more lustrous. This process is called mercerization and is used to give an appearance similar to silk.

LINEN.—Linen is obtained from the bast or inner bark of the flax plant. The separation of the fiber from the accompanying woody matter is effected after "retting"; i. e., exposing to conditions of moisture suitable for developing fermentation. The method and care used in retting determine, in a large measure, the final properties of the fiber. Linen fiber is cylindrical, and, under the microscope, there may be observed irregularities and cross markings similar to bamboo. If properly retted, it will possess considerable tensile strength and, after bleaching, will have an almost silky luster. It is used chiefly for thread, twine, table linen, towelings, handkerchiefs, and dress goods. It is almost never used for collars, cuffs, and shirt bosoms, though such articles are frequently spoken of as "linen."

JUTE.—Another important bast fiber is jute, which is used for twine, burlap, cheap upholstery, and binding thread in the manufacture of carpets and rugs. It is very cheap and is used in larger quantity than any other fiber except cotton. The characteristic properties are its relatively low tensile strength and durability, its high luster in the better grades, and its natural yellow or brown color, which it has been found possible to remove only with serious damage to the strength of the fiber.

Hemp.—Hemp is a name which is loosely applied to a large number of fibers used in the manufacture of twines and ropes. True hemp is a bast fiber very similar to flax, being in general somewhat coarser and stronger. If carefully prepared, it may be used as a substitute for flax for everything but the finest grades of linen; but its chief applications are found in twines, ropes, carpets, and other articles for which its great strength especially adapts it. Like jute, it has a dark color, which can not be successfully removed by present methods without injury to the fiber.

Manila Fiber.—Manila, or "abaca," and sisal hemp are the most important of the fibers used for making ropes and heavy cordage. Both are obtained from the leaves of tropical plants, from which they are separated without a previous retting process. Manila is the more valuable of the two, as it has greater strength, pliability, and resistance to rotting when used where it is exposed to frequent wetting. It is very difficult to distinguish between these two fibers, which are frequently mixed in various proportions.

Artificial Silk.—The high price of silk has led to many attempts to produce a similar fiber by artificial means. The result has been the invention of several varieties of artificial silk, all of which have a luster similar to that of silk but are deficient as compared with the latter in finess of fiber, elasticity, and strength, especially when wet. The process of manufacturing artificial silk consists essentially in forcing through fine tubes certain viscous solutions, usually made from cotton or wood pulp, of such nature that the resulting fine filament may be quickly solidified. Several of these filaments are combined to form a thread. Artificial silk is used as a cheaper substitute for silk, particularly for braids, ribbons, and other decorative purposes, and for hosiery.

Its lasting qualities are not quite as good when used in wash fabrics as compared with draperies, curtains, upholstery fabrics, and the like; however, its consumption in the manufacture of dress goods, shirtings, etc. (which fabrics are usually constructed of a fine cotton warp and artificial silk filling), and in the manufacture of hosiery, proves that it is occupying an important place in the textile business, both from the standpoint of alleviating the immense demand for pure silk and of making possible the production of beautiful fabrics, which, while not possessing all of the desired characteristics of pure silk, are of sufficient worth to fill the demands of ready market.

(*b*) **Preparation and Properties of Finished Products**

In manufacturing textile materials it is first necessary to remove the impurities which accompany the fiber in nature. In the case of wool these impurities consist of various kinds of fat, vegetable matter, mineral matter, and potash salts, the total weight of which is often more than the weight of the clean fiber. They are removed by washing in soap and water. The cotton seeds are removed from the fiber mechanically by "ginning." The woody materials surrounding the bast fibers are softened by retting and are subsequently removed by mechanical treatment. The silk fiber is covered with a gum called "sericin." This is easily washed out by working in a soap solution near the boiling temperature. Too severe treatment during these operations may make the fiber harsh or weak, and if the treatment is mechanical the fiber may be broken up considerably.

CONSTRUCTION OF THREADS, YARNS AND FABRICS.—For converting the cleaned fibers into yarn or thread they are subjected to a series of processes the object of which is to produce a continuous strand in which the fibers are arranged according to a certain plan, to give to this strand a uniform diameter, and to introduce a twist which will hold the fibers together and give a reasonable amount of strength. These processes are variously designated as "carding," "preparing," "drawing," and "spinning." Two or more yarns are often twisted together to make a "ply" yarn.

A great many different methods are used in combining threads to form fabrics. The most usual method, weaving, consists of arranging one series of threads parallel to each other and another series at right angles to the first, in such a way that each thread of one series passes alternately over and under one or more threads of the other series. The threads (yarns) running lengthwise of the cloth are called "warp," while those running crosswise are called "filling" or "weft." The woven edges of a fabric are known as "selvages." A great deal of variety of pattern may be obtained by changing the order of raising and lowering the various warp threads. The machine employed for making this cloth is called a "loom."

Knitting is a name given to the process of forming fabrics by drawing a series of loops through the last series previously formed. It is fundamentally a single-thread process, although several threads may be used for convenience in manufacture. Patterns are produced by omitting some of the loops, these being picked up again later.

Laces and nets are fabrics in which the threads of one series are tied or twisted around those of another series at their crossing points.

The final process in the manufacture of a textile fabric is called "finishing." It differs from the previous processes in that it is not a part of the construction of the cloth, though directly dependent on it, but is designed to modify it in such a way that it will acquire the desired qualities of appearance and "feel" in a more or less permanent way. A very large variety of treatments is given according to the particular finish desired; hence, it is impossible to give a general description of the process. It usually includes, however, the correction of some of the defects incident to previous processes, such as replacing missing threads and removing knots; washing out the grease and dirt acquired during manufacture; brushing and shearing or cutting off the projecting fiber ends to give the cloth a smooth, even surface; and, finally, pressing to remove all creases and give a finished appearance which will assist in marketing the goods. Among other processes used according to the character of product desired are "napping," "singeing," and "fulling."

Napping consists of brushing up some of the fiber ends lying near the surface of the cloth by means of wire or other sharp points. This is invariably followed by shearing to make the nap raised of uniform length. Napped goods have a fuzzy face, which may or may not be apparent upon casual inspection.

For the production of fabrics having an exceptionally clear face with each thread showing distinctly the cloth is passed rapidly over a gas flame or a very hot metallic plate, the result being that all loose fiber ends are singed off. This process is called "singeing." If properly done, it will add greatly to the luster and beauty of the cloth without materially weakening it.

In general, the most important process in the finishing of woolen cloth is fulling. It consists in applying a soap solution to the cloth and passing it between rollers in a continuous loop. The pressure of the upper roller, the heat generated by friction, and the moisture and alkalinity of the soap give ideal conditions for the production of felt. Consequently, the threads become firmly felted together and the thread structure becomes very indistinct. The greater compactness of the cloth, owing to shrinkage during the process, may cause it to be stronger than previously, even if the fiber itself is weakened.

Cotton and linen fabrics are frequently pressed between heavy rollers to produce a lustrous face. The results of this process, called "calendering," are, for the most part, of a temporary character, the luster acquired being removed by washing.

Starch is applied to cotton and linen fabrics for a variety of purposes—to add strength to the warp yarns during weaving; to increase the weight of the finished cloth; to enable further increase in weight to be secured by means of loading materials, such as China clay; to fill up the interstices, thus making the material more compact in appearance; and to permit the production of a better luster during pressing. Other substances are frequently added to the starching or sizing mixture to give greater softness or to prevent the formation of mildew.

Pile fabrics, such as velvets, velours, and corduroy, are made be weaving some of the threads in such a way that they may be subsequently cut and left standing perpendicularly out from the fabric. A great variety of beautiful effects can be obtained in this way. Attention is called to the difference between pile and nap, the former being whole threads and the latter fiber ends projecting from threads which have not been cut.

Bleaching and coloring of textile materials may be performed at almost any point during their manufacture. Bleaching consists in removing the natural color or changing it into a different chemical compound having a less objectionable color. This process always weakens the fiber, and it should not be expected that bleached materials will have the same durability as unbleached materials of the same character.

Coloring matter is applied to textile materials in various ways according to the fiber, the nature of the coloring matter, the shade and fastness of the color required, and the stage of manufacture which the material has reached. Coloring matters are relatively seldom applied alone, salts, acids, gums, and other substances being added for developing or modifying the color, causing it to be evenly distributed, increasing its fastness, or facilitating its application.

It is commonly supposed that vegetable coloring matters are more permanent than those derived from coal tar, usually designated as aniline colors. This is not always the case, some of the fastest as well as some of the most fugitive colors being made artificially. The chief advantage of the aniline colors is their tremendous variety. Practically any conceivable shade may be obtained in a variety of ways by proper use of these dyes.

(*c*) **Information as to Purchasing**

In buying textiles one should first decide what properties are of especial consequence with reference to the particular use that it is intended shall be made of the article. He should then endeavor to ascertain to what extent these properties are present in the sample under consideration. The properties which usually are of interest are fineness of texture, strength, variety of fiber, length of fiber, uniformity and freedom from defects, shade and fastness of color, character of finish, and adulterants or materials present other than the fiber from which the article is supposed to be made. The examination of materials should be comparative as far as possible.

The texture of a fabric is considered to be fine if the yarns from which it is made are relatively small in diameter and if there is a relatively large number of yarns in an inch or other unit length or width of fabric. This is a very important consideration in nearly all fabrics, as it is very closely connected with the cost of manufacture. Other things being equal, the finer the texture the more the fabric should cost. Ordinarily a careful inspection will be sufficient to determine the essential facts, but it is sometimes necessary to pull out a few threads in each direction, leaving a fringe of thread ends, the character and frequency of which can than be easily determined. For careful comparison it is advisable actually to count the number of threads in an inch of cloth in each direction. In the same way, the number of loops in a unit length of knitted fabric together with the sizes of the yarns will be of great value in determining the quality of the material. In case ply yarns or yarns made up of more than a single strand are used, the significant aspect is the size of the single strand, not the size of the whole yarn.

The strength of a material is closely related to the wearing qualities. The quickest and most convenient way of testing the strength of a fabric is to grasp it firmly between the thumb and forefinger of each hand with the ends of the thumbs touching.

The thumbs are then turned in such a way as to bring the backs together. This will cause the tips of the thumbs to be forced through the cloth, and the pressure necessary to produce rupture in this manner will show the strength of the fabric. This test should be applied in each direction. If the cloth is too strong to be tested according to this procedure, a few threads of each kind may be taken out and their individual strength tried by breaking. The results of the latter test, considered with reference to the frequency of the threads, will give an indication of the strength of the cloth.

(*d*) **Identification of Fiber**

The importance of correct judgment as to the variety of fiber from which a textile article is made has been very much overestimated. If it were possible to analyze completely all the physical and chemical properties of a material, the fiber used would be quite immaterial to the purchaser. Since a complete analysis is not possible, it is necessary to supplement the knowledge obtained from other sources with that acquired by experience in using materials made from the various fibers. It should, however, be constantly borne in mind that the qualities of any fiber differ very much according to conditions of growth, treatment during manufacture, and the influences to which it is subsequently exposed.

Animal and Vegetable.—In general, it is very easy to distinguish between fibers of animal origin and those of vegetable origin. The test most easily applied is that of burning a small portion of the material. It is better to apply this test separately to each kind of thread present. If a charred bead remains at the burned end and if there is given off an odor similar to that of burning hair, there is animal fiber present; otherwise, there is not. This test will not reveal the presence of small quantities of vegetable fiber. The animal fibers are, however, very much more soluble in alkaline solutions than are the vegetable fibers. Consequently, a boiling solution, made from 5 parts of caustic soda (lye) in 100 parts of water, will completely dissolve all wool and silk present in a few minutes, leaving behind the cotton or other vegetable fiber, the amount of which may then be easily observed.

Wool and Silk.—Wool and silk are so dissimilar in appearance that it is seldom necessary to make tests to distinguish between them. An examination of single fibers is sufficient, in practically all cases, to confirm the results of a superficial examination of the fabric.

Cotton and Linen.—The distinction between cotton and linen can be accomplished with certainty only by means of the microscope. The greater natural length of the linen fiber, however, will often be of great assistance. If there are found fibers of a length greater than 1½ inches in a thread presumed to contain linen, it is very likely to be entirely linen, for cotton and linen are very seldom mixed in spinning. Most fabrics containing cotton and linen have cotton warp threads and linen filling threads.

Artificial Silk.—Artificial silks are ordinarily of vegetable origin and may be distinguished from natural silk either by the burning test or by the caustic-soda test as described above. They usually become very weak when wet, so that the threads break very easily after holding in the mouth for about a minute.

The principal way of recognizing jute is by its pale yellowish-brown color and its lack of strength. It is much weaker than the other fibers commonly used for the same purposes. When used or upholstery and other pile fabrics, the harsh feeling of the goods fwill disclose its presence.

(*e*) Simple Methods for Testing

The freedom of a fabric from structural defects may be determined by a close inspection. The most common forms of defects are the absence of threads from their proper places, the presence of extra threads, the presence of too few or too many threads per inch of filling in portions of the fabric, thick or thin places in the threads in either direction, and misplacement of threads, which will tend to destroy the symmetry of the pattern.

"Fastness" is the name applied to the property of colored goods of retaining the original shade under conditions of use. Tests for fastness must be so designed that they will indicate the ability of the color to withstand the influences to which they will be exposed. The usual destructive agencies are light, water, soap, perspiration, friction, and, in some parts of the country, alkaline dust.

Fastness to soap and water is necessary for all goods that are to be washed. This property may be tested by thoroughly washing a small piece, drying, and comparing the shade with that of the unwashed material. Very often colors which do not lose seriously in shade during washing will, nevertheless, run or "bleed" into other material washed with them. In case the color forms only a part of the fabric, this is a serious fault, for the shade or whiteness of the other portion may be disastrously affected.

Fastness to friction, the absence of which is sometimes called "crocking," may be tested by rubbing a piece of the material on a white surface, such as a piece of white cloth.

Some colors are very fugitive when exposed to the action of acids. Such colors are not suitable for use in articles which are liable to become wet with perspiration. Resistance to acids may be tested by working a sample of the material in dilute acetic acid or vinegar.

Fastness to alkalies can be tested by treating the material with a solution of washing soda.

It is, unfortunately, impossible to determine quickly the fastness of colors to light. If a sample is exposed to direct sunlight for several days, without any intervening glass, and if, at the end of that time, it shows relatively little change as compared with the shade of the original material, it may be considered to be reasonably fast for most purposes.

An important test that may be made to supplement the test for strength is the test for length of fiber. A few fibers are removed from each kind of yarn found in the sample. If they are found to be very short, the quality of the material is quite likely to be inferior.

Textile materials are usually purchased with especial reference to their finish. The finish determines, in a very large measure, the ultimate appearance of any fabric, and, as the esthetic value is often of primary importance, the character of the finish is carefully noted. In general, the finish of a material is desirable or undesirable according as it pleases or fails to please the purchaser, when examined superficially; and, as this is largely a matter of individual taste, no fixed rules can be given. However, the finish may or may not be of such character that it will be permanent when put in use. It is, therefore, advantageous at times to make simple tests, such as washing or rubbing (imitative of the conditions of use), observing whether the finish has been disastrously affected.

Except for the use of starch in cotton and linen fabrics previously mentioned, the most important instance of the use of nonfibrous materials for increasing the weight of textiles is the loading of silk. Silk has an exceptional affinity for certain metallic salts, and its weight may be increased several times by introducing it in solutions of these salts. This will make a firm fabric out of

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one which would otherwise be very flimsy. There is no objection to this proceeding, provided that the material is not expected to have much durability. Cheap silks usually contain a considerable amount of loading and should not be expected to last long. If a very heavy ash remains after burning a piece of silk fabric, there is indication of the presence of metallic loading matter.

With a careful study of the nature of any material and the conditions to which it will be subjected in use, the householder will often be able to devise simple tests, other than those mentioned above, to assist in the determination of the value of the material for the particular use in view.

(*f*) Removal of Spots

To remove spots from textile materials, various solvents may be used, depending on the nature of the spot and the ability of the color and finish of the material to withstand the action of the solvent. In case of doubt it is advisable to try the procedure proposed for removing a spot on an inconspicuous place to determine whether it would be safe for use. The following list gives some of the applications that may be made of common reagents:

Nature of spot	Reagent
Gelatin, mucous liquid, blood, white of egg	Lukewarm water.
Grease, lard, tallow	Benzine or strong alcohol, then soap solution.
Kerosene, machine oil	Benzine, then soap solution.
Varnish, resin, wax, paint	Turpentine or benzine, then soap solution.
Fruit, red ink, wine	Expose white cotton or linen goods to the vapor of burning sulphur or immerse them in a chlorid-of-lime solution. If the goods contain wool, silk, or dye, treat with a lukewarm soap solution containing ammonia.
Black ink, iron rust	Lemon juice (or citric acid) and salt. These spots may be very difficult or impossible to remove from silk material.
Lime, lye	Vinegar or lemon juice.
Acids, vinegar	Baking soda or weak ammonia.

"Mildew" is a name given to several varieties of fungous growth which will attack and injure cotton, linen, and some other fibers in storage. The conditions most favorable to the growth of mildew are the presence of moisture and of starch or animal matter, a relatively high temperature, and poor circulation of air. If goods are attacked by mildew, they should be immediately washed and exposed to the sun and air. If the action has not gone too far, the mildew spots may be completely removed. In any event, this procedure will definitely stop the growth.

After cleansing with the various agents mentioned, the goods should be thoroughly rinsed with pure water. In some instances double treatment is necessary. For instance, the rusty spot left by dirty machine oil should be treated with lemon juice and salt after the oil has been removed.

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4. PAPER

(*a*) **Origin**

What we term "paper" did not exist, except in China, before the eighth century and was not manufactured in Europe before the twelfth. In very early times records were kept upon stone or clay tablets or, indeed, upon nearly any material which could be cut or scratched. The first material to be used which had any resemblance to paper was papyrus, made from a water plant extensively cultivated in ancient times in the delta of Egypt. From the twelfth century until the fourteenth parchment was the ordinary writing material in Europe. Parchment is skin, usually from the sheep or goat, so prepared that both sides may be written upon. Fine parchment or vellum is prepared from the skins of calves, kids, or dead-born lambs. Parchment, being greasy, does not take ink readily, and at the present day is not regarded as a desirable writing material. It must not be confused with parchment paper, the manufacture of which is described later in this chapter.

The invention of paper is attributed to the Chinese statesman T'sai Lun, who is said to have made paper from bark, hemp, rags, and old fish nets in 105 A. D. In 704 A. D. the Arabs captured the Chinese city of Samarkand and there learned the art of paper making. Among the earliest Arabian documents written on paper still in existence is one dated 866 A. D. The Greeks learned the art through trade with Asia, but paper was not extensively used in Greece until the middle of the thirteenth century. Paper was made by the Moors in Spain in 1154; in Genoa, Italy, in 1235, and in Germany about the end of the thirteenth century. It was not made in England until the first part of the sixteenth century. The first mill in the United States was started by William Bradford at Germantown, Pa., in 1690. This mill was known as the Rittenhouse Mill. At first all paper was made by hand. The first paper-making machine was invented in 1799 by Louis Robert in France. Henry and Sealy Fourdrinier, of London, bought the English patents and so perfected the machine that it has been given the name of "Fourdrinier." Handmade paper at the present time is almost a curiosity.

(*b*) Description

Paper is a sheet of felted fibers composed essentially of a material known to the chemist as cellulose. Cellulose is the material composing the cell walls of plants and trees. Cotton is very nearly pure cellulose. Wood contains cellulose in a combined form known as ligno-cellulose. This compound may be broken up and the cellulose obtained in a more or less pure form by various chemical processes to be described later. Since cellulose exists in almost all forms of plant life, it is theoretically possible to make paper from any vegetable material. To do so, however, would be neither practical nor profitable. In the first place, the cellulose must be separated from the useless noncellulose material by a chemical process, and the yield of cellulose is in the case of many materials very small and of poor quality. Thus, the cost of obtaining the cellulose is likely to be so great that it will cost much more than the product obtained from wood. Moreover, many of the proposed paper-making materials are available only at certain seasons of the year and are too bulky to permit storing or transporting for any distance. Therefore, a mill built to handle these products would either have to stand the expense of abnormal transportation charges or else lie idle a portion of the year. The question resolves itself into an economic one. If the material can be produced at the same cost and of quality equal to that derived from wood, then it will be profitable to make it. Of course, if there are by-products to share the expense of manufacture, then the process may prove profitable. It is possible that ultimately the utilization of by-products will make it possible to use many materials that can not be economically used under present methods.

(*c*) Sources

While cotton and linen rags continue to be used, either wholly or in part, in the manufacture of the highest grades of paper, yet by far the greater portion of the paper which comes into the house is made from wood. In 1911 over 4 000 000 cords of wood were used in the United States for this purpose. This seemingly large amount of wood represents a little less than 1 per cent of the total annual cut of wood. The wood is prepared for use in paper making in four ways, the products being known, respectively, as "sulfite pulp," "soda pulp," "sulfate pulp," and "mechanical" or "ground-wood pulp."

Sulfite Process.—Spruce is the principal wood used in the manufacture of sulfite pulp, although hemlock, fir, and pine are used to some extent. These woods all belong to the group known as the conifers. The process is essentially as follows: The bark is completely removed and the logs are cut into chips by special machinery. The chips should be of uniform size and free from dirt and knots. In another part of the mill a liquid is prepared in which the chips are cooked. This is made by causing sulfur dioxide to react with limewater. The resulting liquid contains a mixture of calcium and magnesium bisulfites and a small amount of sulphurous acid. A strong acid could not be used, as it would destroy the cellulose. After cooking from 8 to 50 hours, depending upon grade of material desired, the pulp is carefully washed and screened to remove uncooked particles. It is also bleached to a satisfactory color if the pulp is to be used in making white papers. The pulp has been mixed with a great deal of water and is of a milky consistency from the washing and screening process. This large amount of water renders the pulp capable of flowing or being pumped from place to place. It is now ready for the paper maker. If, however, it is desired to keep the pulp as such, the excess of water is removed and the pulp is stored in the form of very thick sheets known as "laps," or it may be dried on special machinery and kept in rolls.

Soda Process.—In the soda process poplar wood and other woods of the broad-leaf variety are used and the cooking liquid is a solution of caustic soda (sodium hydroxide). The general method of work is very similar to that in the case of sulfite pulp.

Sulfate Process.—Sulfate pulp is made in a manner very similar to the process of making soda pulp, the difference being in the nature of the cooking liquor, which contains sodium sulfate. This pulp is very seldom bleached and is for that reason rarely found in anything but wrapping paper, for which it is well suited on account of its strength.

Ground Wood or Mechanical Pulp.—Ground-wood pulp is the cheapest variety. The wood, usually spruce, is freed from bark and cut into short lengths, which are pressed against revolving grindstones. The wood is ground or torn off into tiny fibers by the rubbing action of the stone. Sawdust would not serve the purpose, because fibers derived therefrom are too short to mat or felt together. The stone is kept cool by a stream of water, and the temperature, the speed of the stone, and the amount of pressure used to hold the wood against the stone are all factors affecting the character of the pulp. Ground-wood pulp is not as good as the pulp produced by the above described chemical processes, the so-called "chemical pulp." It has its special application, however, in the manufacture of cheap papers, like news-print paper, etc. A paper could not be made entirely of ground-wood pulp, as it would not have sufficient strength, but when mixed with 15 to 25 per cent of sulfite pulp it may be used for the cheaper grades of printing paper, such as news-print paper. Ground-wood pulp is not completely bleached; hence, it has a yellow color, which is partially neutralized by the addition of a blue colorant. This, however, leaves the pulp with a greenish tint, which is neutralized by a very little red color. The principle is the same as that in the use of bluing in washing clothes.

Esparto pulp fills the place in England which is occupied by soda pulp in this country. It is made from esparto grass, a material imported from Africa.

Manila and jute fibers are used in the manufacture of strong wrapping papers, and for this reason old rope and bagging are paper-making materials.

Straw is made into a coarse pulp, which is used for cardboard such as is used in the partitions in egg crates and for the corrugated cardboard used in packing. It is, however, possible to make a pulp from straw by chemical treatment which will yield an excellent paper.

Old paper is also used in the manufacture of paper. Waste paper of high grade is valuable in the manufacture of cheaper grades. The pulp made from old papers may be mixed with other varieties of pulp. Old newspapers are converted into cheap cardboard such as is used for pasteboard boxes.

The very highest grade of paper is made from rags, either cotton or linen. It could be made from raw cotton fiber, but that would be much more expensive. Also, in the case of clean white rags the paper maker obtains a product which has already undergone a considerable amount of washing and boiling, all of which has helped to remove the noncellulose materials, and for certain uses may actually be better for his purpose than raw cotton would be. But all rags are not clean and many of them are colored. Hence the rags must first be sorted, the wool separated from the cotton and linen, and the white rags from the colored. There are more than a dozen different grades into which the rags are sorted. The woolen rags are used for roofing felts.

The rags are run through machines which beat out the dust and cut them into small pieces. They are then boiled with a solution of soda ash, caustic soda, or lime, depending on the quality of rags used, in order to clean them by the removal of the color, dirt, grease, etc. After the boiling operation the mass of rags is very carefully washed and shredded to reduce it to a pulpy mass, which is then bleached. After the bleaching the mass is washed again, since it is essential that every trace of bleach be removed. By this time the rags have been reduced to a pulp.

Thus, it is seen that whatever the material from which the paper is made it is first reduced to a pulp and that in all but the cheapest papers this pulp consists of approximately pure cellulose. Groundwood pulp is not pure cellulose, but, as we have already seen, it is used only in cheap papers and then only in connection with other varieties of pulp.

(*d*) How Paper is Made

All through the paper and pulp mill there is in use a vast amount of machinery, of which only passing mention can be made. There are, however, a few machines so intimately connected with the manufacture of paper that it is almost impossible to gain a clear idea of how paper is made without some understanding of the function of the machines. The first of these is the "beater."

This is a rectangular tub or vat having rounded ends, the tub being divided into two channels by a central partition parallel to the long side of the tub but not extending for its full length. In one of these channels there is a revolving roll having steel knives or bars embedded parallel to the axis of the roll. Directly under this revolving roll there are additional steel knives or bars formed into a bedplate, which remains stationary. The cutting action of the revolving roll is dependent upon the space between the knives of the roll and those of the bedplate, and the pulp circulating in the tub is acted upon as it passes between the roll and the bedplate. The result is to separate the fibers and then by a suitable "cutting" or "brushing out" action, as may be desired, the fibers are reduced to a pulpy mass.

Contact with water under these conditions has a pronounced effect upon the cellulose, and if the beating be prolonged there takes place a change known as "hydration." Pulp for news-print papers is seldom subjected to any beating action; in fact, some mills merely stir it in large tanks. With the better grades of writing paper the beating may take 8 or 10 hours, and it is not too much to say that the ultimate quality of good writing paper is more dependent upon the proper control of the beating operations than upon any other part of the process.

During the beating process sizing and loading materials may be added to the pulp. Everyone who has tried to write with ink upon blotting paper or upon news-print paper has noticed that the ink penetrates the paper and spreads to such an extent that good pen writing is impossible. In the manufacture of writing paper some material must be added which will cause the paper to resist this penetration of ink. This material, which is called "size," is a preperation made by boiling rosin with soda. The size is added to the mass in the beater, and after it is completely stirred in a solution of aluminum sulfate is added. This material is known as "rosin" sizing. In the case of printing papers sizing is not so essential; in fact, news-print paper is only very slightly sized. With most cheap papers, where the time of beating is relatively short, it is necessary to add what is known as "loading." China clay, talc, and calcium sulfate are common loading materials. The advantages of loading are that it fills in the spaces between the fibers, thus giving a smoother sheet and one which takes a better surface in the subsequent printing operations, and also makes the sheet more opaque. A reasonable amount of loading in printing paper will improve its quality and is not an adulteration, but when added in excess it weakens the paper. The best grades of writing paper contain no loading material.

After the pulp is beaten it is ready to be made into a sheet of paper. A paper machine consists of several parts. The first part, known as the "wet" end, consists of an endless belt of wire cloth containing 60 or 70 meshes to the inch. This belt runs rapidly over rolls at each end and is supported by smaller rolls at frequent intervals. The beaten pulp, which has been mixed with 135 to 200 times its weight of water and has the appearance of diluted milk, flows out onto the moving screen or wire-cloth belt through an opening which assists in controlling the amount and the rate of flow. The framework upon which the wire screen rests is so arranged that the wire is given a rapid shaking motion in a direction at right angles to that in which it is moving. The purpose of this is to cause the fibers to "felt"; that is, to lie more closely together and interweave for the purpose of giving added strength to the paper. As the wire moves forward the bulk of the water drains through the wire-cloth belt. The side of the sheet of paper in contact with the wire receives a seivelike impression.

In order that both sides of the sheet may be alike, there is placed above the sheet and resting upon it a hollow roll covered with wire cloth which makes a similar impression to that given by the wire cloth in contact with the wet mat of pulp. This is called a "dandy roll." If a true watermark is desired, a raised design is placed upon this dandy roll so that it will be pressed into the sheet. Where this impression is made the paper is thinner, and, as a result, the design is visible when the paper is held to the light. A paper having no impressions or marks from the dandy roll is a "wove paper." Sometimes special wire coverings are placed around the dandy roll, with the result that the paper shows, when held to the light, parallel lines spaced from ½ to 1½ inches apart at regular intervals in one direction and fine parallel lines closely spaced at right angles to the widely spaced lines. Such a paper is called a "laid" paper, and the dandy roll is then called a "laid" dandy roll. "Laid" papers are an imitation of old handmade paper and are only suitable for an edition de luxe, where it is desired to secure the effect of handmade paper. After the fibers in the pulp are formed into a sheet, the latter leaves the wire cloth and passes through the press part of the machine, all the while being completely supported upon a wide, woolen, endless belt called a "felt." Here much of the water is squeezed out between weighted rollers. Then it goes to the driers—large hollow drums heated by steam—where most of the remaining water is dried out by evaporation. Some papers are dried entirely at this time. The best papers, such as high-grade bond and ledger, however, complete their drying by hanging for some time in lofts and are, therefore, called "loft-dried."

Some papers are "tub" sized as well as "engine" sized; that is, after the paper has passed over a few of the drying rolls it is passed through a bath of glue or gelatin and then continues over the remainder of the drying rolls. After passing through the bath of glue or gelatine the web of paper may be cut into sheets and hung to dry over poles in a drying loft. The method of sizing with glue or gelatin is also called "animal" sizing, since the glue and gelatin are of animal origin.

Most paper is "calendered." When the paper comes off the last drying roll, it passes between a number of highly polished, hardened cast-iron rolls, which impart a polish to the sheet. Some paper is "supercalendered" by passing through an additional set of calenders consisting of alternate hardened cast-iron rolls and rolls made of pressed paper.

There is frequently seen paper which has the appearance of linen. This so-called "linen-finish" paper need not and usually does not contain linen. It is quite likely to be made entirely from wood pulp. The finish is secured by a process known as "plating." Sheets of paper and sheets of fabric having the desired surface are placed alternately until a suitable-sized pack is obtained. This is then placed between zinc plates and the whole subjected to heavy pressure between rollers. The design on the fabric is forced into the paper.

An embossed paper is made by passing the sheet between two rollers, one of which is of steel and has a raised design, while the second is of a softer material and has the same design sunk below the surface of the roll.

A "coated" paper is made by applying a coating in a manner somewhat similar to that used for tub sizing. The very smooth, glossy pages upon which the illustrations in books and magazines are sometimes printed are coated paper. Halftone printing is a common method for reproducing photographs and illustrations in printed matter. Halftone illustrations require a very smooth paper, such as either a coated paper or a supercalendered paper. The blurred indistinct pictures in a newspaper show the effect of printing halftone pictures on a paper which is not smooth. The new "offset printing" process, however, will work even on a blotting paper or upon any rough-surfaced paper.

"Deckle-edged" paper is used in many books, especially with "laid" papers in editions de luxe to imitate handmade paper. The name is derived thus: When the pulp flows out upon the machine wire, it is kept from flowing over the edges by two rubber strips known as "deckles." If a little of the pulp works under the edge of this strip, a rough, feathery edge is produced. Normally all paper, as made, has more or less of a deckle edge, which is trimmed off when the paper is cut.

Parchment paper is made by exposing the paper to the action of sulphuric acid for a few seconds. A paper resembling parchment paper in appearance is made by prolonged beating.

(*e*) **Uses of Paper**

The principal uses of paper are for writing, printing, and wrapping. Printing papers cover a great range of quality and cost. Enormous quantities are used for newspapers. For this use a paper is made largely from ground-wood pulp, to which a small amount of loading and size is added. It is the cheapest of printing papers. Book papers may range from a good grade of news-print paper to a very high-grade product made entirely from high-grade rags. They differ from writing papers in that they are softer and are sized less. This softness is secured by the materials used and their treatment in the beating. In many cases soda pulp is depended upon to give the necessary softness to a book paper. English book papers are likely to contain esparto pulp in place of soda pulp.

Wrapping papers are usually made from sulfite pulp. Very strong papers often contain a considerable portion of manila and jute fibers.

Wall paper is a fairly cheap news-print paper with just enough sizing to keep the paste from soaking through.

Parchment paper, which is waterproof paper, is finding extensive use in the home for such purposes as paper dishrags, shelf covers, and even to replace rubber sheeting in the sick room.

Papers of very light weight, called "tissue" papers, are used for patterns, for wrapping fragile material and jewelry, and for ornamental purposes. Toilet paper should have smooth surface, soft texture, and tear about equally well lengthwise and transversely.

Paraffin paper is a light weight tissue coated with paraffin and is useful for wrapping foodstuffs and greasy, sticky, or moist materials.

Paper towels are well known. Here it is desired to have what is practically a blotting paper; that is, an unsized paper which is very absorbent. Some paper towels are strong and of a texture suitable for vigorous rubbing.

Writing paper varies from a very cheap paper up to the very high grade used for valuable documents. Once the term "bond" paper was applied only to the very best papers, such as were used for printing bonds. Now, however, the term has little meaning, except that a "ledger" paper is thicker than a bond. Since the grades of writing papers are so numerous, it is impossible to give any simple general test to determine quality for all uses. For all ordinary purposes an all-wood paper with an attractive finish is good enough. Such a paper should be clean and show an even texture or formation when held to the light. It should be fairly stiff, and it should rattle when shaken. It should, of course, take ink well. If a paper serves the purpose to which it is put, then little more can be asked of it. For permanent documents, such as wills and deeds, the best paper is none too good, but for the ordinary temporary needs if a paper is strong enough, looks well, has a satisfactory feel, and takes writing well it is acceptable. The finish is purely a matter of taste, and if a person uses much paper he can scarcely do better than to go to some large concern handling all grades of paper, and there, with a wide variety of grades and finishes before him, even the novice will seldom err in picking out a satisfactory paper at a reasonable price. Some very fine paper is sold in attractive boxes at rather high prices, and some very inferior paper is also sold in attractive boxes at comparatively high prices. It is likely to be worth while for the purchaser to consider the relative cost of buying paper by the pound or by the ream.

Building papers are made from waste paper and waste pulps, are heavy, and used for heat insulation between walls and floors.

(*f*) Purchasing Paper

The methods of testing paper involve the use of apparatus usually found only in testing laboratories. If a purchase of paper is to be made for the household, however, it may best be done by securing samples of several makes of the same general kind and comparing each sample with all the others. In this way they may be graded in the order of their quality as found by noting their general appearance, weight, color, strength to resist tearing, ability to withstand folding or creasing, etc. Having decided on the relative grade of each paper, mark each sample with its price per pound, pounds per ream, and size of the ream in inches. A ream of paper is either 480 or 500 sheets, and the size may vary from 8 by 10½ inches or less to 44 by 64 inches or more, depending on its use.

Wherever possible, paper should be purchased by the pound instead of by the box or quire. This is especially true of writing paper in boxes. The most expensive way to purchase is to buy the ordinary box of writing paper containing 24 envelopes and 24 sheets of folded note paper. Purchase in this way is often more than twice as expensive as purchase on a straight, quantity-pound basis.

(*g*) **Preventing Deterioration**

Some papers deteriorate much more rapidly than others. Papers made from ground-wood pulp are particularly liable to deteriorate; hence such papers should not be stored for any length of time as they become brown and brittle. The bleached, chemical, wood papers are not troubled in this way and with fair treatment in storage should last many years. Papers made from new cotton and linen rags are the best and most durable.

Conditions of storage also play an important part in the life of a paper. Papers should be stored in a room free from direct sunlight, free from fumes of illuminating gas or the products of combustion therefrom, and also free from acid fumes and dust. The room should have a good circulation of air, which is kept moistened to prevent brittleness of the paper, due to excessive dryness in the air. A good circulation of damp air is preferable to no circulation and a dry atmosphere.

(*h*) **References**

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Stevens, Henry Potter: The Paper-Mill Chemist. London; 1908. Scott, Greenwood & Son.

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[13] These books may be secured through the Paper Trade Journal, 10 East Thirty-ninth Street, New York, N. Y.

III. STATIONERY

Writing papers, which are classed as stationery, have been discussed with the general subject of paper. Inks and adhesives are the chief items of stationery remaining.

1. INKS

(*a*) Kinds of Ink

Inks may be conveniently divided into a number of classes based upon the uses to which they are to be put; for instance, writing inks, stamping inks, marking inks, drawing inks, and printing inks.

(*b*) Composition of Writing Inks

BLUE-BLACK INKS.—When ink first came into general use in connection with a quill pen, as distinguished from the former method of brush and paint, it was found that a suitable material could be made by mixing iron sulphate, or copperas, as it is often called, and the extract obtained by treating nutgalls and barks of trees with water. When solutions of these materials were mixed, a rather dirty-looking liquid resulted, which, when used for writing, gave at first a light blue-black or greenish-black color. This ink was found to have certain disadvantages, among which might be mentioned a decided tendency to deposit, on standing, a black substance and leave a liquid which was not as good as the original ink and to form molds and growths on the surface of the ink. To prevent the formation of a black deposit or precipitate, small amounts of sugar sirup and vinegar were added. To prevent the formation of molds, creosote was sometimes added. These remedies were to a large extent effective, but their careless use often produced an ink which, when judged in the light of the modern article, would be pronounced thick and gummy and utterly unfit for use.

Later on it was found that ink could be made of seemingly good quality by the combination of the extract of logwood with such chemicals as alum or chromate of potash. Inks so made were cheaper, and as they seemed to do the same work they were very generally adopted. Then the aniline dyes were discovered, and one of the first uses to which the blue and black dyes were put was in the manufacture of inks. The preparation of inks by the use of these dyes was very simple, involving merely the addition of water to the dyestuff. The ink industry seemingly took a great forward leap. Not only were prices lowered, but a great number of different colors could be obtained which were much better in appearance than the dull brownish-black of former times. However, some of the more observant users of ink noticed that records made with these newer inks were fading rapidly, so rapidly, in fact, that they were not suited for permanent records. Numbers of the manuscripts which had been considered permanent were in such condition that in order to save them they had to be copied. In copying these what ink should be used? Should they try for more permanent dyes, resort to chrome-logwood inks, or go back to the old iron-tannin inks? In the investigation which followed it was found that in spite of the number of dyes which had been developed those suited for writing purposes lacked permanence. It was found that the chrome-logwood inks also lacked permanence and had a tendency to mold in the inkwell. This was almost impossible to overcome. This narrowed the selection down to an ink of the iron-tannin group. The defects of the first inks of this class were recognized and intelligent effort was put forth to remedy these defects, so that now a good grade of ink can be obtained from many of the ink manufacturers by stating that it is desired for permanent records. The formula for United States Government standard writing fluid is as follows:

(1) The writing fluid must be gallo-tannate of iron ink, not inferior in any essential quality to one properly prepared after the following formula, in which all the ingredients are of the strength and quality prescribed by the United States Pharmacopœia and the percentage of true acid present in the sample of tannic acid used has been determined by the Loewenthal and Schroeder method:

Take of pure dry tannic acid, 23.4 grams; of gallic acid, in crystals, 7.7 grams; of ferrous sulphate, 30 grams; of dilute hydrochloric acid (U. S. P.), 25 grams; of carbolic acid, 1 gram; of dye, Bavarian blue D. S. F. (Schultz and Julius, No. 478), 2.2 grams; make to a volume of 1000 cubic centimeters at 60° F with water.

(2) Deliveries will be subjected to the following tests, as compared with the standard ink described above:

(*a*) A fluid ounce allowed to stand at rest in a white glass vessel, freely exposed in diffused daylight for two weeks to the light and air, at ordinary room temperatures, protected against the entrance of dust, must remain as free from deposit upon the surface of the ink or on the bottom and sides of the vessel.

(*b*) It must contain no less iron and must have a specific gravity of 1.030 to 1.035 at 60° F.

(*c*) It must develop its color as quickly.

(*d*) After a week's exposure to diffused daylight the color must be as intense a black when used upon paper, and it must equally resist changes from exposure to light, water, air, alcohol, and bleaching agents.

(*e*) It must be as fluid, flow as well, strike no more through the paper, nor remain more sticky immediately after drying.

In making the ink dissolve the tannic and gallic acids together in about 150 cubic centimeters of warm water, dissolve the ferrous sulphate in about 150 cubic centimeters of cold water, and dissolve the Bavarian blue in about 700 cubic centimeters of warm water. Add the hydrochloric acid to the ferrous sulphate solution, then immediately mix it with the cooled solution of the tannic and gallic acids, dilute to a volume of 1000 cubic centimeters and mix thoroughly, add the carbolic acid, and allow the mixture to stand for several days.

The ferrous sulphate (or iron sulphate) and the tannic and gallic acids unite to form the real active principle of the ink. The hydrochloric acid is added to prevent the formation of sediment, the Bavarian blue is a water soluble blue dye which is added to give the ink a pleasing first color so as to render it legible until the intense color of the ink itself has had time to develop, and the carbolic acid is added as an antiseptic to prevent the formation of mold.

The Government standard writing fluid may seem to the person who uses it for the first time to be rather thick and slow flowing. These objections usually are brought forward by those who have been in the habit of using commercial writing fluids. If the Government standard ink were to be diluted with an equal volume of pure water, it would approach very closely the composition of most of the writing fluids and fountain-pen inks on the market. For important records, however, it should never be diluted. After it has been used for a while one becomes accustomed to it and realizes that the advantages which it possesses far outweigh the seeming disadvantages which were first noticed.

(*c*) **Hints on the Use of Ink**

In order to get the best results from any material, it should be used correctly, and the following may be given as precautions to be observed in the use of ink:

1. Use ink in a self-closing inkwell whenever possible. There will be a saving in the amount of ink used, and the ink will be kept in much better condition.

2. In case an open inkwell has to be used, choose one holding very little ink in preference to one of larger capacity and keep the inkwell covered when not in use. More trouble is caused by the

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failure to observe this precaution than from all other causes combined.

3. Clean the inkwell frequently. Do not allow sediment to accumulate. Use fresh ink each time the well is cleaned.

4. Before filling a fountain pen with ink, first of all clean the barrel and the point of the pen thoroughly with warm water. By doing this it is entirely possible to use one of the heavier inks such as Government standard writing fluid in a fountain pen.

5. Never mix two different kinds of ink, for, unless they are of almost identical composition, both are likely to be spoiled.

Ink forms such a small item in the general economy of the household that none but the best should be used, since the one bottle of ink is likely to be used on all classes of correspondence and even on legal documents, such as wills, deeds, etc., which are of importance as permanent records.

(*d*) **Red and Marking Inks**

Inks of this class are made by dissolving dyes in water. For the preparation of a red ink the following formula has been used:

Dissolve 5.5 grams of croceine scarlet, 3–B (Schultz and Julius, No. 160), in 1000 cubic centimeters of pure water. (For explanation of terms, see p. 179, "Stamping inks.") This ink, like others made from aniline dyes, is altered by exposure to light and should not be used on records of a permanent nature.

Marking Inks.—Inks of this class are a real necessity in places where the laundering for a number of people has to be done in one place at one time. Of a number of samples of marking inks examined, a majority have had as a basis silver in some one of its forms. Inks made from silver are expensive, but the markings are very permanent and a small amount of the ink goes a long way, so that the cost per garment marked is very small. Marking inks are coming into more general use as people are gradually beginning to recognize the saving in time, money, and anxiety effected by the proper marking of all articles of clothing with the name of the owner. If only for the assistance in identifying those injured in accidents, the work is worthy of encouragement. It is probably best to purchase from a reliable manufacturer the small amount needed by the ordinary householder. In case one has the inclination, 2 ounces of marking ink can be made as follows:

Place in a teacup a small piece of silver about the size of a dime and cover it with a small amount of warm water, not over an ounce, then add nitric acid a few drops at a time until the coin is dissolved. Be careful with the nitric acid, as it is very dangerous and should not be allowed to come in contact with anything except glass or porcelain. Do not add too much acid, as it is better to add a little and allow it to act on the silver until no more fumes come off, and then add more acid than to add a large amount at one time. It will be found that very little acid is required to dissolve the coin. Cool the solution, then add ammonia water a little at a time until the liquid smells rather strongly of ammonia, add a drop or two of ordinary writing ink to give a faint color, and pour into a small bottle holding about 2 ounces. This bottle should be of brown glass. If a clear-glass bottle is used, it should be wrapped with several thicknesses of heavy paper to completely exclude the light, because if light gets to the ink it will cause the silver to be deposited in the form of a black sediment and spoil the ink. This ink should be plainly marked "Poison" and should be placed in a safe place.

NOTE.—If nitric acid should accidently be spilled upon the skin or clothes, treat the spots at once with ammonia water and wash immediately with water. The brown fumes that come off while the silver is dissolving are poisonous and should not be inhaled.

GENERAL DIRECTIONS FOR USING MARKING INK.—Use a marking pen or if one is not at hand use a ball-pointed writing pen. The marking pen and the ball-pointed pen work freely over the fabric and do not catch in the threads if care is taken to have the general direction of the writing sloping from left to right or vice versa. In marking rough fabrics hold the cloth firmly, making use of a small embroidery frame for holding the work, or pull the cloth tightly over a smooth surface such as the arm of a chair.

(*e*) Miscellaneous Inks

INDELIBLE INKS.—This indefinite term is sometimes applied to record-writing inks, sometimes to marking inks, and sometimes to violet copying inks or inks made by dissolving the central part of a so-called indelible pencil in water. The use of this term should be avoided, as it would be better to use the specific name for a given ink based on its use.

STAMPING INKS FOR USE WITH RUBBER STAMPS.—Probably the most useful inks of this class are made up by dissolving various aniline dyes in glycerin. Satisfactory stamp inks can be made by dissolving in each case 5 grams of the dye specified in 100 cubic centimeters of a mixture of equal parts of water and pure glycerin, specific gravity 1.143 at 15.6° C.

Black.—Nigrosine, soluble (Schultz and Julius, No. 602).
Blue.—Bavarian blue, D. S. F. (Schultz and Julius, No. 478).
Green.—Light green (Schultz and Julius, No. 435).
Red.—Magenta (Schultz and Julius, No. 448).
Violet.—Formyl violet, S-4-B (Schultz and Julius, No. 468).

In making inks according to the above formulas the desired strength of glycerin can be made by mixing equal volumes of pure glycerin and water. The dyes stated above are mentioned by trade name and are also given by reference to the standard reference table for dyes written by Schultz and Julius. In this book, called "A Systematic Survey of the Organic Coloring Matters," the dyes are described and referred to by numbers, so that, e. g., in the above formula for red stamping ink the red dye used is commonly called "magenta," and its reference number in the book written by Schultz and Julius is 448.

Safety Inks.—Inks which are put on the market as antifraud ink, check-writing ink, safety ink, etc., are in most cases made from some form of soluble iron blue; for example, soluble Prussian blue. Records made with these inks are usually not attacked by acid or by ordinary ink eradicators. These acid-proof inks are, however, readily acted on by alkalies, such as ammonia and even soap, so that they are strictly no more erasure-proof than ordinary inks. While the Government standard writing fluid is not entirely fraud proof, it will meet the requirements of a safety ink as well as most of the so-called fraud-proof inks on the market. Safety inks which have as a basis carbon in a finely divided form should really be considered in a separate class, which would also include black drawing inks. These inks make good appearing records, which are altered only with great difficulty.

Printing Ink.—This ink is made by grinding certain solid substances called pigments (for example, lampblack and Prussian blue and various dyes) in a vehicle composed of oils and varnishes. The essential difference between the use of printing ink and writing ink is that in the case of printing ink a definite amount of the ink is first transferred to the printing surface and this ink in turn is transferred to the paper on which the printing is to be done. The amount of ink taken by the impression is limited by the amount of ink supplied to the printing surface, and the character of the surface on which the printing is to be done has a relatively small influence on the impression. For this reason it is possible to print on such materials as blotting paper and news-print paper, while it would be impossible to use writing inks on these papers without forming a blot. Printing ink finds so very little use in the household that it need not be considered further in this circular.

(*f*) Removal of Ink Stains

It must be clearly recognized at the start that differences in the materials have a great deal to do with the fastness of stains.

For example, a spot of a certain ink on a cotton cloth might be removed by the use of water or a little soap and water, while a spot of this same ink on a light-colored wool could be removed only by the use of acids, with great risk of permanent damage to the cloth itself. It must also be recognized that the different kinds of ink would necessarily take different methods for the removal of their stains; thus an iron-tannin writing ink would be treated differently from a red ink, and both would be treated differently from an ink made from soluble Prussian blue, such as is used in most safety and antifraud inks. All that can be done here is to give a few general directions.

1. As soon as the stain is made remove the stained fabric from the action of strong light. Sunlight, contrary to popular belief, will not fade ordinary black writing inks but will set the stain so as to make its removal very difficult. Stains made by red, green, and violet inks may be almost entirely removed by rinsing with water and exposing to the action of direct sunlight.

2. If the stained fabric is large and can not be treated as a whole because of its size or because of changing the color of the surrounding parts, separate the stained part from the rest of the fabric by some such device as clamping in an embroidery frame or fastening over the top of a Mason jar or a crock, preferably by means of rubber bands or by several thicknesses of coarse thread or string.

3. First remove as much of the stain as possible by treating with tepid water. Then pour warm or fairly hot water through the cloth. Next try the action of warm soap solution, working the fabric gently with the tips of the fingers.

In a number of cases fresh stains can be removed by these three procedures. In case the stain does not come out, there are a number of things which might be tried, those which are less likely to injure the fabric being named first.

4. For white goods soak the stain in warm milk. Sour milk or milk soured by the addition of a small amount of vinegar will usually work better on most ink stains.

5. Treat the stain with lemon juice, preferably warm, by pouring the juice through the cloth held in place over a jar or otherwise secured as in paragraph 2.

6. Make a paste of lemon juice and table salt and apply it to both sides of the stained fabric, allowing it to stand for some time. Remove the layer of salt and rinse the fabric. Sometimes

after the treatment with lemon juice and salt a faint stain may still be seen, which can be further removed by the use of bleaching-powder solution.

7. Soak the spot in a cup of milk to which has been added several tablespoonfuls of kerosene. For articles which can be put through a regular washing process this will be found to be one of the most effective methods. Goods which can not be washed or which would hold the kerosene and show a grease stain should, preferably, be treated by one of the other methods, or in case the kerosene and milk mixture has been used they should be given a washing in clean gasoline. Gasoline must be used with extreme caution because of its great inflammability.

8. Professional cleaners make use of various strong acids and other chemicals; for example, oxalic acid, hydrochloric acid, etc. When these chemicals are used by persons who are experienced in their use, they do the work very well, but they are poisonous and should be handled with great care. Moreover, they are very injurious to the fabric unless they are fully removed after they have done their work. The goods which have been treated with these acids should be rinsed in several changes of water and should finally be rinsed in water to which has been added a small amount of soda or ammonia.

Removing Ink Stains from Floors and Woodwork.—Very often ink stains on varnished woodwork can be removed with very little damage to the woodwork by first moistening the spot with water and then rubbing carefully with a small piece of cloth containing some soap and one of the fine-grained commercial polishing powders which are capable of polishing silverware and glass without scratching. The rubbing should be done with care, and the soapy layer containing the ink should be fully removed before it has time to dry. A second application may be necessary, but two will usually be found to be enough.

(*g*) Typewriter Ribbons and Carbon Paper

Typewriter ribbons are of two kinds—copying ribbons and record ribbons.

Copying ribbons are those which contain water-soluble dyes, making it possible to obtain an exact reproduction of the written matter by placing a thin sheet of paper, called press-copying paper, over the writing and then covering it with a damp cloth and subjecting the whole to pressure. The press copy is produced by the dye of the ribbon impression dissolved in the water furnished by the wet cloth. The writing so made is the same as would be made by the solution of the aniline dye in water and is open to the same objection as mentioned under inks made from aniline dyes alone, namely, that the impression is easily affected by exposure to light and, therefore, is not suitable for permanent records. The copying ribbons which are commonly used are called black copy blue, blue copy, purple copy, and red copy. Of these, the only one worthy of any consideration on the grounds of suitability for permanent records is the black copy blue, and it would be better even to omit this one and use in its stead a black record ribbon and produce a copy of the writing by the use of carbon paper.

Record ribbons are made from materials which are insoluble in water and so do not yield a press copy. Ribbons of this class form by far the large majority of those used and are put on the market under the names of black record, blue record, purple record, and red record. The purple and red record ribbons are not at all suited for use on permanent records, as they are not proof against the action of light. Blue record ribbons may or may not be fast to light, but in case that they are fast to light they are not nearly as suited for record purposes as is the black ribbon, because they are nearly always capable of alteration by means of simple household chemicals. The black record ribbon is by far the best for general use. It is made by forcing into or transferring to a piece of specially tough, strong, finely woven cloth a mixture of carbon usually in the form of lampblack, and various oils and greases and dyes to produce the desired tone. The blow with which the type hits the ribbon forces some of the ink into the pores of the paper, actually transferring carbon from the ribbon to the paper and thereby making a very durable record, which is practically unaffected by the action of light and chemicals. Where a copy of the writing is desired, a black record typewriter ribbon used in connection with black carbon paper is to be recommended.

CARBON PAPER.—Carbon paper is paper (usually a fine grade of tissue paper) which has been covered with a coating of waxy material containing carbon or other suitable pigment. Carbon papers are commercially obtainable in black and other colors, such as blue, purple, and red. As in the case of inks and typewriter ribbons the bright colors should not be used because of lack of permanence. The so-called colored carbon papers are not carbon papers, since they contain no carbon in their make-up and, hence, lack the permanence which the carbon imparts to the record in the case of black carbon paper.

The waxy coating in the case of black carbon paper is made by incorporating finely divided carbon, in the form of lampblack, and dye, to give a satisfactory tone, into a mixture of melted waxes, such as beeswax, carnauba wax, etc., and softening oils such as oleic acid and mineral grease. This mixture is applied in a smooth and even layer while still in the melted condition to the surface of the paper, and, after cooling, the surface is polished by means of fine brushes.

(*h*) **Simple Home Tests of Inks and Writing Materials**

The question whether or not the record which is obtained possesses permanency can be answered by making a few simple tests. All that is necessary is a fairly good grade of writing paper upon which to make with writing inks a series of lines; with stamping inks a number of impressions, using the end of a rubber stopper or an ordinary cork; and with typewriter ribbons and carbon papers regular impressions, using a typewriter and the ribbon or carbon paper to be tested. To determine the action of water on them, strips of the records should be immersed in water and allowed to stand for about 24 hours and the effect noted. Other portions should be half covered with cardboard or heavy paper and exposed to the action of sunlight and the atmosphere, out of doors, for at least a week. After removing the covering material the exposed portions should be compared with those which have been protected. A permanent record should show no signs of alteration under this treatment.

(*i*) **Dyes**

The use of dyes in the household is generally limited to the small packages which are sold ready for use according to the directions accompanying the package. Such dyes are generally made artificially but are sometimes extracted from roots or barks. Coloring matters are very widely distributed in the vegetable kingdom, and all countries where the textile arts have attained any great development, notably in the East, had, until recent times, their own series of indigenous products which were used as dyestuffs. In Donegal, Sutherland, and other localities the homespun tweeds are still largely dyed by means of the various lichens, roots, barks, and nuts found in the neighborhood. The rapid advances of modern chemistry have made possible the manufacture of some dyes formerly obtained from plants. Indigo and alizarin are examples of such products. As the result of an interesting investigation, it has been shown that the Tyrian purple of the ancients, described by Pliny as obtained from mollusks, is identical with one of the indigo derivatives. Under the law of the ancient Romans the use of Tyrian purple was confined to royalty. Its productoin became a lost art for many centuries. Modern science has placed it within the reach of all. The artificial dyes are commonly called aniline dyes or coal-tar dyes, the former name because they were first prepared from aniline and the latter because the majority of them are made from the products of distillation of coal tar. The coal tar is distilled at successively increasing temperatures, five or six distillates being collected at various temperatures. The distillates are subjected to further treatment, in order to separate the various products which they contain. After purification the benzene, toluene, phenol, naphthalene, anthracene, etc., are ready to be converted into dyes by special processes, which involve care in the many chemical operations which are employed.

Certain dyes may be applied to fabrics directly. They may not be applied to all classes of fabrics, as certain are suitable for dyeing cotton, others for silk, and still others are useful for wool. Certain dyes are not applicable to fibers without the help of assistants called mordants. The function of a mordant is to combine chemically with the dyestuff and fix the latter upon the fiber. Several metallic salts are useful for this purpose. By varying the mordant it is often possible to obtain marked differences in the colors produced with a given dye.

The removal of dyes from fabrics is very difficult and sometimes impossible.

(*j*) **References**

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2. ADHESIVES

(*a*) **Varieties of Adhesives**

Glue, mucilage, paste, and adhesive cements of various kinds are classed together, not only because they are largely made from the same materials but on account of the similarity of the uses to which they are put and because there is no sharp dividing line between them.

Glue.—Glue, which is a more or less impure gelatin, belongs to the class of proteids, those highly complex, nitrogenous substances which are so abundant in animal bodies, less so in plants, and without which life as we know it could not exist. White of egg, the casein or curd of milk, lean meat, the gluten of wheat and other grains, and the skins of animals consist of one or more proteids, together with variable amounts of water, fat, salts, etc.

Gelatin and glue are obtained by boiling or steaming the hides, bones, etc., of animals. The solution is allowed to cool, whereupon it sets to a jelly. This is cut into sheets of varying thickness and dried in the air before it is placed on the market. Isinglass, or fish glue, is a form of gelatin obtained from the swimming bladders and other parts of fish. Originally it was prepared only from the swimming bladders of sturgeons.

Mucilage.—Mucilage is commonly made from gums which exude from wounds in the bark or other parts of various species of plants. Some familiar examples are the gum often seen on cherry, peach, and plum trees, gum arabic, and gum tragacanth. They swell up or dissolve in water and are very different from the resinous exudations from spruce, pine, and similar trees.

Pastes.—Pastes are usually made from flour, starch, or dextrin. Flour is essentially a mixture of starch and gluten, both of which have adhesive properties. Starch belongs to the carbohydrates. Dextrin is made by heating starch either alone or with acids.

Cements.—Cement, as the term is used in this connection, refers solely to adhesive cements, which are made from a great variety of materials. Portland and other hydraulic cements are discussed elsewhere.

(*b*) How to Apply Adhesives

In general, the surfaces to which adhesives are to be applied should be dry and free from grease or other impurities. If the material is very porous, it may be necessary to first fill the pores by applying one or more preliminary coats, each of which is allowed to sink in. The final coat of adhesive is to be put on very thinly and then the two surfaces pressed into the closest possible contact. This applies especially to wood, china, etc., where joints made in this way will be stronger as well as less unsightly than if a thick layer of the adhesive is applied.

While many adhesives, if they do not decay or become moldy, can be kept for a long time without impairment of their strength, others should be used as soon as possible after they have been prepared. Some which must be warmed before applying often dry out or become too stiff and must have some water or other appropriate liquid mixed in to give the proper consistency.

(*c*) **Testing Adhesives**

There are no tests that can be satisfactorily employed to determine definitely the quality of glue, paste, and mucilage when purchasing them, but something can be told from their appearance, odor, etc.

Dry glue should have no odor of decay. Transparency and a light color do not always indicate good quality, since the strongest glues are often dark in color and not especially transparent.

Mucilage should be of light color, not too thin, and without moldiness or sour odor. It should not show any dirty sediment or any tendency to settle out in a thick, gummy layer. If it does not contain sufficient preservative, the first sign of moldiness or bacterial growth is often a darkening at the surface. The dealer should not be allowed to shake or invert the bottle before allowing the customer to inspect it.

The paste in a new jar is often too dry, in spite of the usual layer of paraffin over the top. It will show cracks if the finger is pressed downward and sidewise upon the surface. This fault is easily remedied by punching a few holes reaching to the bottom of the jar and filling them with water. Properly prepared paste will not become moldy.

(*d*) **Formulas for Adhesives**

Many dozens of formulas for adhesives could be given, but it seems preferable to select a few of the best and those which require only the most easily obtainable materials.

If a particularly light-colored adhesive is needed, gelatin may be substituted in the formulas below whenever glue is called for.

HOT GLUE.—Dry glue is somewhat more than covered with cold water and allowed to soak thoroughly (usually over night). The excess of water is poured off and the glue melted in a gluepot (a form of double boiler). It must be applied hot. For small quantities or for occasional use a gluepot can be improvised by setting a cup, tin can, or wide-mouthed bottle in a saucepan or large can of water, which is then heated. To prevent excessive heating of the glue, the inner vessel should rest upon a couple of small sticks or a bent piece of wire. By frequent melting or long-continued heating glue gradually loses its strength, so that it is best not to make up at one time more than will be needed for the work in hand.

Liquid Glue.—Certain acids and salts added to melted glue prevent it from forming a jelly when cold, though when the water evaporates the glue is almost as strong as it would have been otherwise. This is taken advantage of in making liquid glues, typical formulas for which are as follows:

Soak 30 grams (1 ounce) of dry glue in 90 cubic centimeters (3 fluid ounces) of acetic acid of 10 per cent strength. Warm gently to dissolve the glue. In place of acetic acid, the strongest vinegar may be used, but it is not as satisfactory.

Soak 100 parts by weight of glue in 110 parts of water, heat, and add 40 parts of nitric acid of specific gravity 1.32 (35° B). This is one of the most frequently recommended formulas, but inexperienced persons should not attempt to handle such a dangerous substance as strong nitric acid.

Waterproof Glue.—A solution of potassium bichromate is mixed with ordinary hot glue. The amount of bichromate should be about one-fiftieth of the weight of the dry glue. This glue quickly becomes insoluble when exposed to sunlight and more slowly in diffused light or in the dark. Small lots should be prepared as needed from time to time.

Liquid glue is made according to the above formula, reserving a small part of the acid in which to dissolve 0.6 gram (9 grains) of potassium bichromate. The melted glue and the bichromate solution are mixed. It is inadvisable to make more than one or two days' supply at a time.

Tannin makes glue insoluble. This can be taken advantage of in glueing leather together or in glueing leather and cloth to metal. One part of crushed nutgalls is soaked for some hours in 8 parts of water and strained. The leather is then painted with the hot liquid and a thin coat of hot glue is applied, after which the surfaces are pressed together. By the same treatment leather and cloth can be glued to metal. If possible, the surface of the latter should be roughened.

Miscellaneous.—Isinglass soaked in water, dissolved by gentle heating and mixed with zinc white, is good for use on ivory or bone. Precipitated chalk may be used instead of zinc white but is not quite as good. White lead should not be used. The use of acids must be avoided, so that liquid glue can not be used.

A glue or cement for glass, metals, etc., is made by mixing a warm solution of gelatin or isinglass with an equal volume of a thick solution of gum mastic in alcohol. It must be kept well corked. Before use it is melted by setting the bottle in hot water. The surfaces to be joined must be warm and perfectly clean. This is the so-called Armenian or jeweler's cement.

For some purposes, such as bookbinding, attaching labels to glass or metals, etc., ordinary glue may be too brittle when thoroughly dry. The addition of a small proportion of some substance that attracts moisture from the air or of a liquid which does not readily evaporate is often an improvement. Glycerin, molasses, and honey are the substances generally employed. The quantity added should not be more than one-twentieth of the weight of the dry glue.

MUCILAGES.—Dry glue is soaked in a mixture of 1 part by volume of water and 1 part of strong vinegar and warmed to dissolve the glue, after which about ¼ part of alcohol is added. The addition of a few drops of a strong solution of alum gives more "body." The amount of glue taken will depend on how thick a mucilage is desired.

Dextrin is added, a little at a time, to hot water until the solution is of the desired consistency. When cold, a few drops of oil of cloves is mixed in thoroughly, to serve as a preservative. The addition of a little glycerin or sugar prevents the mucilage from becoming too dry and brittle.

Gum arabic is dissolved in about twice its weight of warm water and strained through cheesecloth, if necessary. A few drops of oil of cloves are to be added as an antiseptic. The addition of a little glycerin keeps it more elastic when dry.

Limewater, diluted with three or four times its volume of rain or distilled water, gives a clearer mucilage than does ordinary water. For labels to be affixed to glass or metal a little alum or aluminium sulphate is sometimes added.

Dissolve two parts of gum arabic in an equal weight of warm water and add ¼ part of previously soaked gelatin. The addition of a little glycerin will cause labels coated with the mucilage to adhere more satisfactorily to metals and glass.

Stir powdered borax, a little at a time, into cold water until no more dissolves. In this dissolve casein until the liquid is of the proper consistency. This makes a very strong adhesive that keeps for a long time. If made thick enough, this will serve as a cement for porcelain or glass.

Casein is prepared by allowing well-skimmed milk to stand in a warm place until it curdles. It is then strained through a cloth. The curd is tied up in cloth, boiled in water to remove grease, thoroughly squeezed out, and spread on paper to become bone dry. In this condition it will keep for a long time in a tightly corked bottle.

PASTES.—Dissolve dextrin in moderately hot water until the solution has about the consistency of honey, cool somewhat, and stir in a few drops of oil of cloves to prevent molding.

Flour, 115 grams (¼ pound), and alum, 15 grams (½ ounce), are mixed to a paste with 230 cubic centimeters (½ pint) of cold water, then poured into 470 cubic centimeters (1 pint) of boiling water and heated until thick. When nearly cold, add 30 drops of oil of cloves. When properly thinned, and especially if made from rye flour, this paste is suitable for paperhanging. If it is not to be kept more than a few days, the oil of cloves may be omitted.

Soak 1 part of dry glue in 10 times its weight of water. Melt it in a double boiler and add gradually, with constant stirring, 4 parts of laundry starch mixed with 8 or 10 parts of cold water. Heat until it thickens, cool, and stir in 1 part of glycerin and enough oil of cloves to impart a strong odor.

This is excellent for pasting labels on wood, paper, or cardboard. If half of the water is replaced by strong vinegar, the paste will adhere to metals. If made from gelatin and arrowroot, the paste will be much whiter and may be used for photographs. In this case the glycerin is unnecessary.

CEMENTS.—Freshly prepared curd from soured skim milk is mixed intimately with ¼ its bulk of lime, which has been slaked by adding just enough water to cause it to fall to a powder. This cement, which is good for wood, marble, metals, and glass, should be used immediately as it soon sets to a hard mass. When used on marble or wood, it is advisable to first paint the surface with a solution of casein (curd) in borax solution or ammonia to fill the pores.

Powdered and sifted quicklime mixed to a paste with white of egg quickly sets to a hard cement that can be used on ivory, marble, glass, porcelain, etc.

A waterproof cement for cisterns, casks, etc., is made from glue, mixed with ¼ its weight each of boiled linseed oil and red ocher. The glue is soaked and melted in as little water as possible and the other ingredients are then thoroughly mixed in. The cement should set in two or three days.

Powdered whiting or air-slaked lime mixed with hot glue will adhere to wood and metals. Liquid glue containing acid should not be used.

Litharge and glycerin mixed to a paste form a cement that adheres strongly to metals, glass, etc. It is not softened by heat and resists the action of water.

Beeswax and rosin melted together in the proper proportion for the desired consistency form a cement that will adhere strongly if applied to warm metal or glass surfaces. It may be mixed with whiting, etc., to give it more body.

Shoemakers' wax and shellac melted together at not too high a temperature give a more tenacious cement than the preceding. The metal or glass to be cemented must be hot enough to just melt the cement. By changing the amount of shellac from ½ to 2½ or 3 times the weight of the wax the resulting cement will vary from moderately ductile to quite hard and brittle.

An excellent aquarium cement is made by mixing 10 parts each by volume of litharge, fine sand, and plaster of Paris and 1 part of powdered rosin with enough boiled linseed oil to make the mixture somewhat stiffer than ordinary putty. The aquarium can be filled with water in three or four days, even though the cement may not have set hard.

Rubber cement is made by dissolving crude rubber in gasoline or benzene (benzol). Other ingredients, such as dry mineral fillers, gums, or resins, are sometimes added to adapt the cement for particular purposes.

In cementing two rubber surfaces together they should first be thoroughly cleaned with gasoline. This is absolutely essential to securing satisfactory adhesion. If the surfaces of the rubber are very smooth, they should be roughened slightly with sandpaper and again cleaned. A small quantity of cement is now spread over each surface, and after allowing a few minutes for the major part of the solvent to evaporate the two surfaces are stuck together and kept under pressure for several hours to give the solvent time to evaporate completely.

(*e*) **References**

Brannt and Wahl: Techno-Chemical Receipt Book.
Fernbach: Glues and Gelatin.
Henley: Twentieth Century Book of Recipes, Formulas, and Processes.
Scientific American Cyclopedia of Formulas.
Scientific American Cyclopedia of Receipts, Notes, and Queries.
Standage: Agglutinants of all Kinds for all Purposes.
——— Sealing Waxes, Wafers, and other Adhesives.

IV. CLEANSING AGENTS AND PRESERVATIVES

1. WATER

(*a*) Impurities

All natural waters contain some impurities, which, for convenience, may be divided into two classes—suspended and dissolved impurities. In general, the substances in the first class, which may consist of organisms such as bacteria or of inorganic material (clay, etc.), can largely be removed by proper filtration or by sedimentation, while the removal of dissolved material requires special treatment. While, under proper supervision, large municipal filters prove effective in removing most of the bacteria in water, small household filters are likely to prove a source of contamination unless carefully and intelligently used. The only sure method of purifying, for drinking purposes, water of doubtful purity is by boiling actively for several minutes.

(*b*) Hard and Soft Water

In the use of water as a cleansing agent the dissolved impurities are important, since they usually consist of mineral salts (e. g., compounds of calcium and magnesium), which by forming insoluble compounds with soap prevent the latter from exercising its cleansing action. There is no sharp distinction between hard and soft water, the former being defined as water containing a considerable amount of dissolved calcium and magnesium salts. Owing to the wide variation in the mineral content of waters in different localities, water of the same composition may in one place be designated as hard water and in another as soft water. In general, it may be well to call attention to the fact that the proportion of total dissolved material in even hard waters used for domestic purposes is usually very small, being rarely over 1 000 parts per 1 000 000. For convenience, hard water may be arbitrarily defined as that which contains over 100 parts per 1 000 000 of dissolved calcium and magnesium salts.

A simple test for the relative hardness of water may be made by adding to the water a soap solution prepared by dissolving 1 part of pure white soap in 100 parts of 95 per cent grain alcohol and adding 150 parts of distilled water or pure rain water. The turbidity produced indicates the relative hardness, curdy flakes being formed with very hard water. No permanent lather will be produced until sufficient soap solution has been added to precipitate all the calcium and magnesium salts.

In addition to this effect on the consumption of soap, hard water is objectionable in that it frequently causes corrosion of hot-water boilers, which action is due to dissolved carbonic acid and also to chlorides when present in considerable amount. Such corrosion is indicated by the presence of rust in the water from the hot-water boiler. Unfortunately, there is no simple remedy for this difficulty in the household, excepting the use of copper boilers, such as are used in some localities.

(*c*) Temporary and Permanent Hardness

Hard water which can be made soft by the simple process of boiling has what is termed temporary hardness. Such water, which contains dissolved calcium carbonate (usually derived from limestone), may be readily recognized by the fact that upon boiling, the water, originally clear, acquires a milky or opalescent appearance. Such water may be rendered soft also by the addition of limewater or slaked-lime, but the boiling method is preferable in the household.

Permanent hardness can be removed by the addition of certain substances the purpose of which is to precipitate the calcium and magnesium salts and thereby reduce the subsequent consumption of soap. Among the most effective of these precipitating agents are sodium carbonate (washing soda), sodium silicate (water glass), borax, and ammonia. When, as is frequently the case, one or more of these substances is present in soap, the preliminary addition of such substances may be unnecessary in order to obtain the full benefit of the soap as a cleansing agent. It should be noted that any of the substances named above, when used in considerable amount, is likely to have an injurious effect upon the skin.

Perfectly pure water can be obtained only by distillation. Rain water, when carefully collected, is the purest water ordinarily obtainable for the household and is especially useful when very soft water is desired.

2. SOAP

(*a*) Classification

Soap may be defined as a metallic salt of fatty acids. The common water-soluble soaps are prepared by the action of alkalies (usually caustic soda) upon fats or oils or upon the fatty acids

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derived from them. From the standpoint of use, soaps may be divided into three groups—toilet, laundry, and scouring soaps. When placed on the market, all soaps except scouring soap contain considerable amounts of water, sometimes over 30 per cent. The frequent household practice of allowing the soap to dry for some weeks before using has the advantage of rendering the soaps harder and thereby reducing the waste. If, however, the soap is allowed to become too dry, it becomes so difficult to dissolve as to materially reduce its efficiency.

(*b*) **Toilet Soaps**

These soaps should be free from all substances, such as free alkali, which are injurious to the skin and also should be free from unpleasant odor due either to perfume or to the soap stock. As a rule, the white floating soaps (which are made by incorporating air into the soap before it solidifies) are the most nearly pure. Transparent soaps are not necessarily pure; in fact, many such soaps contain large amounts of rosin and sugar.

Liquid soaps are usually water solutions of soap. As they seldom contain more than 20 per cent of true soap, they are not economical. They usually contain 3 per cent or more of glycerine, which has an emolient value and also prevents excessive foaming in the container.

Shaving soap is a high-grade toilet soap made in such a way as to produce a rich and permanent lather. After use it should never leave the skin dry or produce any irritation. Shaving powder, the use of which is increasing, has the advantage of greater cleanliness and is also economical. Shaving cream, while not so economical, possesses the same advantage of cleanliness and in addition usually contains an appreciable amount of glycerine, which is desirable in such soaps.

(*c*) **Laundry Soaps**

These soaps usually contain rosin (replacing in part the fatty acids), which should not be considered an impurity, since the rosin soap possesses some detergent value and also serves the purpose of retaining moisture and thus keeping the soap more readily soluble. It is sometimes desirable that these soaps should contain appreciable amounts of sodium carbonate, sodium silicate, or borax, since, as previously stated, these substances, though frequently added as fillers, may be very beneficial when hard water is used. It would be desirable if the housekeeper could obtain two grades of laundry soap suitable, respectively, for hard and soft water.

Naphtha soaps contain small amounts of volatile petroleum distillates added for the purpose of assisting the cleansing action. When used, they should not be subjected to boiling water nor be stored for long periods, as in either case the naphtha will be lost, since it is volatile. If kept in air-tight containers there may be enough naphtha liberated to be explosive if near a flame, upon opening the containers. Chipped laundry soap is usually pure and low in moisture. It is suitable for fine fabrics and should be used with soft water. Soap powders never consist solely of powdered soap but always contain a large amount of sodium carbonate.

(*d*) **Scouring Soaps**

In general, these contain some abrasive material, such as sand, powdered pumice, infusorial earth, volcanic ash, etc., together with soap and sodium carbonate. They are in either cake or powder form, and their value to a great extent depends on the character and finess of the abrasive. When used on polished surfaces, there should be no visible scratches produced.

3. MISCELLANEOUS CLEANSING AGENTS

(*a*) **Sodium Carbonate (Washing Soda)**

This is an effective cleansing agent, not only through its property of softening water but also because of its action on grease. It should be entirely soluble in water and free from caustic alkali. Most of the washing sodas contain sodium bicarbonate in addition to sodium carbonate. This insures freedom from caustic alkali, which can not exist as such in the presence of sodium bicarbonate. So-called soda crystals contain over 60 per cent of water, and when the water is expelled by heating or otherwise the clear crystals disappear and the material becomes an opaque powder with a corresponding increase in strength.

(*b*) **Lye**

Lye is, strictly speaking, caustic potash, but the common lye as purchased is invariably caustic soda. Owing to its very corrosive action upon the skin, it should be used only with the greatest care. It use in cleaning drain pipes depends upon its action on grease accumulated in them. It is very effective sometimes in clearing out drain pipes, but at times it seems only to increase the trouble. It is probable that the soap formed from the action of the lye on the grease accumulates more rapidly than it can be dissolved by water and hence increases the stop-page. There is also the added objection that lye corrodes lead pipes and attacks the surface of enameled sinks, etc., and, therefore, should not be used frequently, if at all.

Lye may be used for the domestic preparation of soap from waste fat, adequate directions for which are usually given on lye containers.

(*c*) **Borax**

Borax or sodium borate is used to soften water and as a cleansing agent. It should be entirely soluble in water.

(*d*) **Ammonia Water**

Ammonia water is of great value in softening water and for cleansing, especially glass. Recently cloudy or turbid solutions of ammonia have been put upon the market. These have been found to contain small amounts of soap and sodium carbonate, the presence of which probably adds little if any to the cleansing value of the ammonia. So-called ammonia powder, which is usually a mixture of ammonium carbonate and sodium carbonate, is a very effective cleansing agent for glass, etc.

(*e*) **Organic Solvents**

Organic solvents are frequently used for removing grease from fabrics, the most commonly used being benzol (benzene), alcohol, turpentine, benzine, gasoline, chloroform, and carbon tetrachloride. All of these, except the last two, are inflammable and should be used with the greatest caution, preferably out of doors. On the other hand, chloroform and carbon tetrachloride possess anesthetic properties and, therefore, should not be inhaled to any extent. Of these solvents, carbon tetrachloride is probably the safest and most satisfactory for household use. It is frequently sold under various trade names as a noninflammable cleaning fluid. By the addition of carbon tetrachloride to gasoline noninflammable mixtures are formed, which are better cleansers than are the separate liquids. Mixtures containing less than 60 per cent of gasoline will not burn, although if they contain over 25 per cent of gasoline they will "flash" if brought near a light. Since, however, there is a possibility of the gasoline and carbon tetrachloride evaporating at different rates, and thus producing inflammable residues, all such mixtures should be used with caution.

(*f*) **Bleaching Agents**

The most commonly used bleaching agent is chloride of lime or "bleaching powder," which should have the characteristic odor of chlorine. Various bleaching solutions upon the market are usually solutions of "bleaching powder" or of sodium hypochlorite. They are weaker and less economical to the purchaser than is the dry bleaching powder. All of these bleaching agents are likely to exert a deleterious effect upon fabrics especially if the latter are delicate. Whenever possible, therefore, the bleaching should be accomplished by exposure to sunlight and moisture.

(*g*) **References**

Braunt, Wm. T.: The Practical Dry Cleaner, Scourer, and Garment Dyer. H. C. Baird & Co.

Owen, Frank Allen: The Dyeing and Cleaning of Textile Fabrics. J. Wiley & Sons, 1909, 253 pages.

Pawlie, Edward: The Practical Handbook of Garment Dyeing and Cleaning. M. M. Frank, 1909, 357 pages.

4. BLUING AND STARCH

(*a*) **Bluing**

The most common substances used in laundry bluing are indigo, Prussian blue, ultramarine, and aniline blues, the last two being used principally in the solid bluing. As a rule, the most satisfactory materials for bluing are indigo and aniline blue, which are not readily affected by weak alkalies or acids. Prussian blue is decomposed by even weak alkalies, such as ammonia, and may thereby produce rust spots upon the clothes.

(*b*) **Laundry Starch**

While starch from various sources has practically the same composition, the size and character of the grains varies greatly and, therefore, the suitability for various purposes—e. g., stiffening of clothes—also varies. Although rice starch is said to be the best laundry starch, in this country most laundry starch is prepared from corn or wheat, while in Europe potato starch is generally employed. In the process of ironing part of the starch is changed to dextrin, adding to the gloss and stiffness. Gum arabic and wax—e. g., paraffin—often are added to starch to increase the gloss.

5. MATERIALS FOR FIREPROOFING COTTON FABRICS

For the purpose of reducing the inflammability of cotton fabrics, especially of those having a napped surface, such as outing flannel, treatment with various substances in solution has been proposed. Among these substances may be mentioned alum, ammonium sulphate, ammonium phosphate, etc. It has been shown that impregnation with such substances is very effective, but, owing to the fact that they are removed by washing and therefore require frequent application, they have not found extended use. Thus far no simple household methods of permanently fireproofing cotton goods have been developed.

6. POLISHES

(a) Metal Polish

These usually consist of some abrasive material in suspension in a liquid or semiliquid vehicle. The principal difference in composition between the paste and liquid polishes is in the vehicle employed. The abrasive materials should possess such hardness, fineness, and shape of particles as will best accomplish the desired polishing without producing scratching.

Obviously, a finer grade of material, such as rouge (oxide of iron) or whiting (calcium carbonate), is required for highly polished surfaces than for relatively dull surfaces—i. e., kitchen utensils—in which latter case various siliceous materials are generally employed. The vehicle in the pastes is usually some fairly heavy mineral or fatty oil or both, to which soap is sometimes added. The liquid polishes usually contain gasoline or kerosene and sometimes ammonia, soap, etc. As a rule, the liquid polishes are more efficient where much tarnish is to be removed, but they should be used with care if they contain inflammable constituents.

(b) Glass Polish

Polishes for glass usually contain fine siliceous material or, preferably, softer material, such as whiting (calcium carbonate). In addition, they frequently contain soap, sodium carbonate, or compounds of ammonia, for the purpose of removing grease, etc.

(c) Furniture Polish

Furniture polish should remove dirt and grease readily from varnished surfaces, restore their luster, and be capable of nearly complete removal, so as not to leave the surface in such condition as to hold dust nor to leave any objectionable odor. Though there are a great many different furniture polishes on the market, there is not a great difference in efficiency. A satisfactory furniture polish can be prepared by mixing 1 part of raw linseed oil and 2 parts of turpentine and adding a small amount of beeswax. The presence of vinegar (acetic acid), wood alcohol, etc., in such polishes is usually superfluous and may be detrimental.

(*d*) **Floor Polish**

Floor polishes may be roughly classified as pastes (the so-called floor waxes) and liquids. The former usually consist of beeswax or similar wax together with turpentine, mineral oil, etc., to produce the desired consistency. The liquid polishes, which are easier of application, usually contain the same materials as the pastes but have a larger proportion of oil. In addition, they may contain water, limewater, potassium carbonate, etc. (See pp. 126 and 127 for recipes.)

(*e*) **Stove Polish**

Stove polish usually consists of such materials as graphite, bone black, etc., mixed with either water, turpentine, or oil. Stove polishes should not contain any readily inflammable liquids. However, such polishes are on the market and they can not be too strongly condemned.

(*f*) **Shoe Polish**

The ordinary black shoe polishes generally contain wax (beeswax or carnauba wax), nigrosine (a black dye), soda solution, soap, turpentine, etc. After the wax has been emulsified by boiling in the soda solution (a solution of borax may also be used), it is mixed with a hot solution of ordinary laundry soap and sufficient nigrosine to give the desired depth of color. This cools to a soft paste. If the liquid form is desired, the best grade of Castile soap is used.

Another method is to dissolve carnauba or candelilla wax or a mixture of the two with beeswax and ceresin or paraffin in hot turpentine and mix with very finely pulverized bone charcoal.

Brown shoe polishes consist of such substances as soft soap, wax, glycerine, linseed oil, turpentine, shellac, etc., to which is added some dye; i. e., annato, aniline yellow, etc.

7. DISINFECTANTS

Since materials used for disinfecting frequently enter into the operation of a household, brief reference to their properties and uses will be made in this circular. Details regarding their germicidal properties and methods for their application may be found in publications of the United States Department of Agriculture and the Bureau of the Public Health Service.

Among the most important disinfectants may be mentioned the following:

(*a*) **Formaldehyde**

This substance, which in its pure state is a gas, is usually obtained in the form of a water solution known as formalin, which is supposed to contain 40 per cent of formaldehyde but which rarely contains over 38 per cent. It may also be secured in a solid (condensed) form known as paraformaldehyde, or "paraform."

Formaldehyde gas, which is the real disinfecting agent, may be liberated from the solution by (1) the application of heat; (2) slow evaporation, such as takes place from sheets soaked in the solution; and (3) pouring the solution upon permanganate crystals. In the latter case twice as much formalin must be used for a given space, since about half of the formaldehyde is destroyed in the reaction. The gas may be liberated from paraform by the application of heat or of permanganate solution.

In general, about 10 ounces of formalin is required for 1000 cubic feet of air space. Disinfection is effective only when the temperature of the room is above 15° C (60° F) and when the humidity is high. Disinfection requires from 6 to 24 hours, depending upon the conditions employed. Formaldehyde is not poisonous and under the proper conditions is a very powerful disinfectant.

(*b*) **Carbolic acid**

This substance, the scientific name of which is phenol, when in the pure state is a white solid. The true "liquefied carbolic acid," contains 10 per cent of water and 90 per cent of phenol and should not be confused with "crude carbolic acid," which consists of coal-tar oils with some cresols but little or no phenol, or with "liquid carbolic acid," which consists of cresol. In general, a 5-per-cent solution of phenol is employed for disinfecting. Owing to its expense and its extremely poisonous qualities, it is not suitable for extensive use.

(*c*) **Cresol**

This substance, also known as "tricresol" or "liquid carbolic acid," is a mixture of three very similar compounds, all of which are superior to carbolic acid as disinfectants. The pure United States Pharmacopœia cresol is a colorless liquid, having an odor resembling carbolic acid; other grades, having a yellow or straw color, contain from 90 to 98 per cent of cresol. For general disinfection a 2-per-cent solution of cresol, made by completely dissolving the cresol in warm water, is recommended, being more efficient than a 5-per-cent solution of carbolic acid.

Owing to the difficulty in completely dissolving cresol in water, a mixture known as "compound solution of cresol," consisting of equal parts of cresol and linseed-oil-potash soap, is often used. This mixture is readily soluble in water and is applied in a 4-per-cent solution.

(*d*) **Pine Oil**

A very efficient general disinfectant, known as the "Hygienic Laboratory pine-oil disinfectant," and recommended by the United States Bureau of the Public Health Service, consists of pine oil, rosin, and sodium hydroxide (caustic soda or lye). It is prepared as follows: Ten parts by weight of pine oil (obtained by the steam or solvent process in the manufacture of wood turpentine) and 4 parts by weight of rosin are heated together in an enamel pail until the rosin is dissolved. The mixture is cooled to 80° C (176° F), and 2 parts by weight of a 25-per-cent sodium hydroxide solution is added, being stirred thoroughly; e. g., with an egg beater. After cooling the mixture is kept in metal or glass containers until used. The solution is diluted with 400 or 500 parts of water before application as a disinfectant, which is very efficient. When mixed with cold water, it makes a milk-like emulsion.

(*e*) **Chloride of Lime (Bleaching Powder)**

This compound, which is calcium hypochlorite, is made by the action of chlorine gas upon lime. Its disinfectant action depends upon the liberation of chlorine gas when exposed to the atmosphere. Owing to its rapid deterioration after its container is opened, its efficiency is often uncertain. It is generally employed in a mixture containing 6 ounces of the chloride of lime to 1 gallon of water.

(*f*) **Mercuric Chloride (Bichloride of Mercury or Corrosive Sublimate)**

This is a very powerful disinfectant, but owing to its very poisonous properties and the fact that its action is prevented by the presence of albumenoids—e. g., in blood, excreta, etc.—its usefulness is limited. It is usually sold in the form of tablets, which contain ammonium chloride to facilitate solution in water. It is generally used in solutions containing 1 part of bichloride to 1000 parts of water, though in some cases, especially for spores of bacteria, a 1 to 500 solution is employed

(*g*) **References**

U. S. Department of Agriculture Farmers' Bulletin 345, Some Common Disinfectants, and Farmers' Bulletin 480, Practical Methods of Disinfecting Stables.

Bureau of thePublic Health Service, Reprint 287, The Practical Use of Disinfectants, and Reprint 304, An Efficient Liquid Disinfectant.

8. PRESERVATIVES

Under this heading we will refer only to such substances as are effective in the preservation of food through their property of excluding air and, therefore, bacteria from the food; e. g., paraffin, sealing wax, water glass, etc. For information regarding numerous substances which in some cases are added to foods as preservatives and for evidence regarding their effects upon the human system reference should be made to the numerous publications of the United States Department of Agriculture.

(*a*) **Paraffin**

This is by far the most satisfactory substance for excluding air and bacteria from foods, since it is not dissolved or attacked by fruit or vegetable juices and can, therefore, be placed in direct contact with jellies, etc., without imparting any taste or odor. It also has the advantage of adhering readily to glass and metal and can, therefore, be used to coat jar caps, etc., and thus insure tight joints. It is entirely insoluble in the body fluids and, hence, harmless, even if small particles should be swallowed with the food. When paraffin is melted for use, it should be heated to a fairly high temperature (above 100° C or 212° F) for some time, especially if it has previously been used. Such heating insures expulsion of water, which, if present, is likely to cause bubbles and, hence, defective protection and also destroys any mold spores in the paraffin or upon the surface of the jelly, etc., upon which the paraffin should be poured while it is still above 100° C.

(*b*) **Sealing Wax**

Sealing wax, which was formerly used in sealing cans, etc., is now seldom used, except for sealing bottles. In no case should sealing wax be placed in direct contact with food, and care should be taken to prevent small particles from entering the food. Many samples of sealing wax, especially those intended for stationery, contain poisonous constituents; e. g., compounds of lead, mercury, and arsenic.

(*c*) **Water Glass**

This is a solution of sodium silicate, which substance is made by heating together soda and silica (sand). Being soluble in water, it is not suitable to use in contact with foods, even though in small amounts it is probably not harmful. Its sole use as a preservative is in the treatment of eggs, for which it is well adapted, since it penetrates and thereby seals the pores in the egg shells and prevents access of air. Water glass as purchased is usually a sirupy liquid, having a yellowish color and a specific gravity of about 1.4 and containing from 35 to 40 per cent of sodium silicate. It may also be obtained as a white or yellowish solid. It should not contain a large excess of free alkali. Details of its application in the preservation of eggs may be found in publications of the Department of Agriculture. In general the eggs are immersed in a solution of water glass, made by diluting 1 part by volume of the sirupy liquid with 10 parts by volume of water.

(*d*) **Reference**

Farmers' Bulletin 128, Eggs and Their Uses as Food.

V. FUELS, ILLUMINANTS, AND LUBRICANTS

The combustion of fuels furnishes the principal source of heat and light and an important source of power for household purposes. The financial importance of the sources of heat, light, and power to the average householder is considerable, for in many cases 5 per cent or more of the income may be expended for them either directly or indirectly as a part of the rent for heated apartments. While the amounts expended for lubricants are usually insignificant, the durability of many household appliances depends largely upon the quality of the oils with which they are lubricated. It is evident, therefore, that a material saving may result from a careful and intelligent purchase and use of these commodities.

The fuels which are commonly used in household operations are of three groups: (1) Solid fuels, such as hard or soft coal, coke, wood, charcoal, and rarely, also, lignite and peat; (2) liquid fuels, such as kerosene or "coal oil," gasoline, crude oil, fuel oil, other products of petroleum oil, and alcohol; and (3) gaseous fuels, such as gasoline or "air" gas, natural gas, manufactured or "city" gas, and acetylene. The important characteristics of each fuel are described in a later section.

1. WHAT IS COMBUSTION?

All of these common fuels owe their fuel value to two elements, carbon and hydrogen, which occur usually in combination with each other and sometimes with other elements which do not add materially to the heat produced. The combination of these two elements with the oxygen of the air, which takes place with the liberation of heat and light, is the usual form of combustion. The hydrogen, in whatever form it is to begin with, combines with the oxygen of the air to form water vapor, which in some appliances condenses to a liquid form. This occurs when the products of combustion are cooled sufficiently. The carbon is burned to carbon dioxide if the combustion is complete. If for any reason the burning is incomplete, some of the carbon may leave the flame with only half as much oxygen as it can utilize; that is, in the form of carbon monoxide. Or it may even escape without combining with any oxygen; that is, in the form of soot or "smoke." Carbon dioxide is familiar to all as the gas which is used to charge the so-called "soda-water." It is a harmless diluent of the atmosphere and has no odor or taste. Carbon monoxide is the most dangerous constituent of city gas, of the so-called "furnace gas" which results from the incomplete combustion of solid fuels, and of the products of incomplete combustion resulting from gasoline engines or improperly used gas appliances. Carbon monoxide, when chemically pure, has no odor or taste, but it is always found associated with other gases which have distinctive odors, so that, with reasonable care, most persons may guard themselves against accidental asphyxiation. The odor of leaking city gas is well known; the odors of "furnace gas" and of incompletely burned city gas, while not so pungent, are still very noticeable and easily recognized as signs of danger after one has become acquainted with them. Carbon monoxide is also usually present in the exhaust from a gasoline engine, sometimes in dangerous quantities. Many cases of fatal asphyxiation occur because of failure to appreciate the danger from air contaminated by the exhaust from automobile engines.

When the carbon is alone it burns as a solid, but hydrogen and practically all of its combinations with carbon burn with a flame. The simple glowing of charcoal without production of any considerable flame illustrates the first of these forms of combustion. In this process the hot solid substance is combining directly with oxygen from the air with the production of both heat and light. However, the combination of carbon and oxygen immediately forms a gas (carbon monoxide) which is able to burn still further, for it can combine with as much more oxygen as it already contains to form carbon dioxide. This second stage of the burning is usually accomplished in an almost invisible flame near the hot surface of the burning solid fuel, but is sometimes noticeable in the form of a blue flame, which is seen just above the glowing charcoal or over the bed of hot fuel in a fireplace or furnace using hard coal or coke. This sort of combustion takes place in the case of hard coal, coke, and charcoal.

Soft coal, peat, lignite, or wood are largely made up of compounds of carbon and hydrogen. When these substances are heated they first give off gases which in general nature resemble the ordinary city gas. These gases are burned in yellow or luminous flames, which are much the same as the flame of an open-flame gas burner. In the yellow flame there is set free by the heat of the flame itself a large number of minute particles of carbon, much resembling in form the finest soot. These carbon particles burn by first glowing, as does the solid charcoal in a grate fire, with the formation of carbon monoxide, which is then burned completely in the outer part of the flame. However, some of the gases which are formed by the wood or coal do not form such particles of carbon during combustion. The burning of these gases contributes to the heat set free by the whole process, but unless the flame which they form is in contact with some other substance which is heated up to glowing there is no light given out. After the coal or wood has burned for a time it can not give off more of the combustible gases; the remainder is then nearly pure carbon in the form of coke or charcoal, and it, therefore, burns by glowing and with the formation of a pale-blue flame.

When oil or alcohol is burned, the same thing occurs as when wood is burned, for the fuel is first converted by the heat into combustible vapors, which are consumed in flames more or less luminous according to the nature of the fuel used and according to the kind of appliance in which it is burned. When acetylene or city gas is burned in open-flame lights, the same process is followed, except that the fuel is already in the form of a gas when it reaches the burner. In the case of natural gas used in a simple open-flame burner the changes are different simply because this fuel contains only a small percentage of those gases which first give up carbon to glow during burning. The natural gas, therefore, burns with an almost nonluminous flame.

When a mixture of gas and air is formed inside a burner such as that of the gas range, the gas is first partially combined with the oxygen of that air previously mixed with it inside the burner. This takes place in the greenish-blue inner cone of the flames which form just above each burner opening; and then the products of partial burning pass on out through the outer cone of the flame, gradually meeting enough oxygen from the surrounding air to complete their combustion. In this second stage of burning the same changes occur as in the final burning of the flames from coal, wood, or any other fuel. The only reason that this final blue-flame burning is so much more evident here is that the pale flame is not obscured by having within it so many brightly luminous particles of glowing carbon.

2. THREE MEANS OF HEAT TRANSFER

Everyone is familiar with the three ways in which heat is conveyed from one place to another or from one object to another. There are in our everyday experiences innumerable examples of the conduction of heat through substances so that the cooler part becomes hotter by travel of heat through the substance itself. A common example of convection of heat is the flow of heated air from the furnace carrying heat to rooms above, there to be given up to other objects which are cooler. The third method of heat transfer is by radiation or travel through the air without movement or heating of the air itself. That this latter method is a very real and important method of heat transfer is clear when one recalls the common experience of sitting before an open fireplace, when the parts of the body which are exposed to the heat radiated from the coals or flames may be uncomfortably heated while other parts shielded from this radiation are cold because the surrounding air is cool. This heat transfer may take place from fire to body even in a direction opposite to that of the flow of the air. Both the useful distribution and the useless losses of heat depend upon this means of transfer. Thus, with every heating system or appliance satisfaction and efficient operation require consideration of conduction, convection, and radiation.

3. THE AMOUNT OF HEAT AVAILABLE FROM FUELS

From any particular substance which may be used as a fuel a definite amount of heat can be released by combustion. This quantity is known as the heating value of the fuel. The unit of measure of this property is commonly called the British thermal unit, which is the amount of heat required to warm 1 pound of water 1 degree Fahrenheit. For example, if a pound of coal has a heating value sufficient to heat 13 000 pounds of water from one temperature to another 1 degree Fahrenheit higher, it is said to have a heating value of 13 000 British thermal units, or more commonly 13 000 Btu (spoken of as B-t-u).

The amount of heat produced is not by any means the same for different fuels. For instance, a pound of wood produces only about two-thirds as much heat as a pound of good coal. The amounts of heat produced per pound of the average grades of different fuels are given in the table following.

When comparing the figures in the right-hand column of the table, showing the number of gallons of water which could be heated for 1 cent, it should be borne in mind that these are theoretical figures, based on the assumption that, in each case, all the heat developed by the combustion of the fuel is applied to the heating of the water. In practice there is a wide diversity among the different fuels in the amount of the heat that is lost or wasted.

Comparison of Fuels

Material	Heating value	Assumed price	Gallons of water which could be heated from 32° to 212° F for 1 cent
	Btu per lb.		
Soft wood	8000	\$5 per cord (1½ short tons)	32.0
Hard wood	8000	\$5 per cord (2½ short tons)	53.3
Soft coal	13 000	\$4 per short ton	43.0
Hard coal	13 000	\$7 per short ton	25.0
Coke	12 000	\$5 per short ton	32.0
Charcoal	16 000	\$25 per short ton	8.5
Fuel oil	18 000	\$1.25 per barrel (42 gallons)	30.0
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
Ice (to absorb heat)	160	\$0.35 per 100 pounds	[a] .32
	Btu per cu. ft.		
Natural gas	1000	\$0.40 per 1000 cubic feet	17.0
Manufactured gas	600	\$1 per 1000 cubic feet	4.2
	Btu per kw. hr.		
Electricity	3400	\$0.10 per kilowatt-hour	.23

[a] Water from 212° F to 32° F, gallons for 1 cent.

NOTE.—Ice in melting absorbs 143 Btu per pound, 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° F 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.

It is evident that in practically all cases of fuel utilization only part of the heat is usefully employed; the percentage of the total heat which a fuel can yield that is usefully applied in any case is a measure of the efficiency with which the fuel is used.

(*a*) References

Further information as to the character, sources, and composition of various fuels can be secured in the following Government publications:

Saving Fuel in Heating a House; by L. P. Breckenridge and S. B. Flagg. Bureau of Mines Technical Paper 97. Available from Superintendent of Documents, Government Printing Office, Washington, D. C., for 5 cents.

Government Coal Purchases. Bureau of Mines Bulletin 41. Available from Superintendent of Documents, Government Printing Office, Washington, D. C., for 15 cents.

Graphic Studies of Ultimate Analyses of Coals; by O. C. Ralston. Bureau of Mines Technical Paper 93. Available from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 10 cents.

Economic Methods of Utilizing Western Lignites; by E. J. Babcock. Bureau of Mines Bulletin 89. Available from Superintendent of Documents, Government Printing Office, Washington, D. C., for 15 cents.

4. CHARACTERISTICS OF FUELS

(*a*) Coal

Coal, which is by far the most important domestic fuel, is commonly classed as either anthracite (hard coal) or bituminous (soft coal). All coals are composed mainly of fixed carbon, more or less volatile compounds of carbon, hydrogen, etc., mineral matter or ash, and water. Of these, the ash and water are of no value to the consumer. In anthracite coals there are only a few per cent of volatile compounds and some 3 per cent of water, while very soft bituminous coal may contain up to 30 per cent or 40 per cent of volatile matter and a correspondingly small amount of fixed carbon. Between these two extremes are coals of all degrees of hardness. It is mainly the volatile matter in coal which produces flame and smoke. Hence, for household purposes the harder coals, containing more fixed carbon and less volatile matter, are generally preferred, particularly since the harder coals are cleaner to handle.

The amount of water contained in soft coals when normally dried in the open air does not often exceed 5 per cent and is generally about 3 per cent. The amount of ash in both hard and soft coals differs very greatly with different mines and even with different samples from the same mine. For some of the best coals the amount of ash may run as low as 3 per cent, while for some of the poor grades, especially of anthracite, it reaches 30 per cent. Even more ash than this is found in some coals, but these are hardly salable, being too difficult to burn.

In general, soft coals are likely to contain less ash that hard coals, and the amount of heat per pound or ton is, therefore, likely to be greater from soft coals than from anthracite. This apparent advantage of soft coals is often more than offset by the accumulation of soot in flues of stoves and furnaces, which reduces the efficiency of the heating appliance so that a smaller percentage of the heat produced is utilized.

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Aside from these more commonly used coals, there are still softer coals, known as subbituminous and lignite, which contain very much larger percentages of water, up to 40 per cent in some cases. These coals are not very widely used except locally, and they vary greatly in quality.

On account of the variation in the quality of coals, especially because of the variable quantity of ash, larger users are buying coal on the basis of the number of heat units per ton; in other words, are paying for heat and not weight.

The laboratory tests required for this method of purchase are not practicable for the householder, largely because of the difficulty of securing proper samples of the coal in question. Since one lump of coal may be nearly pure coal while another may be half ash, a very large number of lumps must be picked at random and ground up together in order to get a fair sample of the whole pile. This process is expensive and can be followed advantageously only for large shipments of coal. It has been suggested that some plan might be devised whereby a city or county officer could test and certify samples of coal from every large shipment; say, every train load of coal received in his territory. However, no such plan seems to have been tried and difficulties might be encountered in its operation. Many cities buy coal for municipal purposes on a basis of tests for the heating value, and where this is done the results of tests might perhaps be made public for the benefit of private users.

(*b*) Coke

The coke available for domestic use is usually made by heating bituminous coal in retorts for the production of coal gas, and it is, therefore, a by-product of the gas works. However, some coke which is made by other processes of treating coal is also available in certain districts, though this kind is generally sold for foundry or metallurgical furnace work, for which work it is the only kind suitable. Gas-house coke is softer and more readily breaks up with handling. It also contains larger amounts of volatile matter, which makes it more readily kindled and burned in household appliances than the hard, bright-grey colored metallurgical cokes.

(*c*) Wood

With the common fuels other than coal or coke the purchaser has little choice of quality except, perhaps, as to wood. Here the amount of heat per pound of dry wood is nearly the same no matter what kind of wood is considered, but as wood is usually sold by the cord measure and not by weight it is important to know something about the relative weight per cord. If the user will occasionally have a load of dry wood weighed, he can easily calculate approximately what is the most economical sort of wood for him to buy. This will be the wood of which he can get the greatest number of pounds per dollar, provided always that the wood is thoroughly dry when weighed.

(*d*) **Charcoal**

The characteristics of the grades of charcoal sold for fuel vary according to the kinds of wood and the care used in their preparation. Since charcoal usually serves only as a kindling material or for fireplaces where it gives an attractive fire, size and convenience of handling are important characteristics.

Charcoal fires, when used without a flue, are very liable to produce "furnace gas" containing the dangerous carbon monoxide, and fatal results have occurred from their use. An effective flue should always be provided.

(*e*) **Petroleum Products**

Petroleum and natural gas are obtained from the earth by drilling deep wells. The gas comes to the surface, often under great pressure, and requires but little preparation to be ready for use. The petroleum may also be forced up by the subterranean pressure, but in the course of time the pressure decreases and resort must be had to pumping. Only a small part of the crude petroleum can be used without preparation. The greater part of it goes to refineries, where a variety of petroleum products are made by distillation. In the process of distillation the lightest and most volatile products are first driven off, and then, as the temperature is increased, the heavier products are obtained. The principal products of interest to the householder are thus obtained in the following sequence: Gasoline, kerosene or "coal oil," fuel oils, lubricating oils, paraffin or asphalt, and pitch. Different crude oils differ in composition. Thus, paraffin is obtained from petroleum from Pennsylvania and eastern fields, whereas the petroleum from the western and southwestern States yields principally asphalt instead of paraffin.

Gasoline is best known as a fuel for automobile and other motors, and its use is rapidly increasing. Since only a small part of the crude oil is recovered as gasoline, every effort is being made to increase the yield of this product by other methods of distillation which form gasoline by breaking up part of the other constituents of the oil. Gasoline is extracted also from natural gas, in which it was previously considered as an "undesirable wetness" of the gas and was allowed to go to waste.

The amount of kerosene obtained from a crude oil is always large, and this may be increased, if desired, to as much as 70 to 75 per cent of the crude petroleum.

The part of the oil remaining after the lighter portions, containing gasoline and kerosene, are removed is the source of lubricating and fuel oils. The former require careful treatment to render them suitable for lubricants, but practically any of this material can be used as a fuel oil without special preparation. In fact, the crude oil itself may be used as a fuel, but this practice is less common than formerly because of the rapidly increasing value of the lighter constituents.

(*f*) Natural Gas

In different districts natural gas is of different composition, but its principal constituent is always methane, or "marsh gas," which is a compound of carbon and hydrogen that has a very low lighting value for the open flame but a high heating value, about 1100 Btu per cubic foot. The natural gas also contains other hydrocarbons, compounds of hydrogen and carbon, which contribute to the heating value of the mixture, and in some fields considerable percentages of nitrogen are found. This latter gas is not combustible, and so serves only to reduce the value of the mixture in which it occurs. The heating value of the natural gas supplies now utilized in cities is generally above 1000 Btu per foot; but it is as low as 750 Btu. in some places, depending upon the proportions of the various grades of gas locally available.[14]

(*g*) Manufactured Gas

The manufactured gas supplied in this country is usually made by the coal-gas, the carburetted-water-gas or the oil-gas process. These have been described by the Bureau in its Circular No. 32, "Standards for Gas Service," [15] and in that publication can also be found a discussion of the various constituents of these city gas supplies and also a description of common American gas-distribution methods.

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[14] See "Composition of the Natural Gas Used in Twenty-five Cities," by G. A. Burrell and G. G. Oberfell Bureau of Mines Technical Paper 109. Available from Superintendent of Documents, Government Printing Office, Washington, D. C., for 5 cents.

[15] This circular is available from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 35 cents. (See pp. 173 to 187 for the material referred to.)

(*h*) **Gasoline Gas**

Gasoline gas, or air gas, as it is often called, is a mixture of air and gasoline vapor which is produced by passing air over or bubbling it through such gasoline as is readily vaporized by this process. This product is not commonly employed except in some laboratories, shops, and country installations, where city gas is not available. The heating power of such gas is dependent upon the character of the gasoline utilized and the temperature at which the gasoline is kept during vaporization.

(*i*) **Acetylene**

Acetylene is a hydrocarbon gas (composed of carbon and hydrogen) which is formed by the action of water on calcium carbide. It is a gas of peculiar properties and requires care in its generation and use in order to insure safety. Only standard forms of generators should be utilized in preparing the gas, and these should be carefully operated and the calcium carbide should be carefully stored. It is urged that the rules which have been adopted by the fire underwriters be carefully followed by anyone utilizing this product. Copies of these rules can be secured through fire-insurance companies, insurance commissioners, or city fire-prevention departments.

5. WHAT THE USER OF FUELS DESIRES

The first question which arises in the selection of a material or an appliance for producing heat is that of cost. Other things being equal, the combination of fuel and apparatus which necessitates the least expenditure per year is the best, but to determine which is really cheapest one must know the initial cost of the installations, the prices of the available fuels, the cost for repair, maintenance, and operation of the appliance, and the quantity of the various fuels which will be required, or, in other words, the quality and efficiency of use of the materials. In no case, however, is the factor of cost the only one of importance. Reliability, safety, and convenience are of equal or greater interest to the householder, for obviously he does not wish to have interruptions of the heating service nor is he willing to use unnecessary care or give an undue amount of time to the operation of his heating apparatus, whether for warming the house, heating water, or other purposes.

For the production of light or power the problem is practically the same. Low cost, safety, reliability, and convenience are the four great factors of interest to the user.

6. HOUSE HEATING

The object of house heating is to secure conditions of temperature which are comfortable and healthful for the occupants. Comfort and health, however, depend upon ventilation and humidity as well as temperature; hence, these two factors should always be carefully considered in connection with modes of heating.

Heat is usually produced by burning some sort of fuel in one of several types of heating appliances. 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, 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.

(*a*) 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 4 pounds of coal per day burned in a good furnace 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.

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 by 10 to 15 per cent if the average winter temperature is 10° F lower.

(*b*) Kinds of Appliances and Fuels for Them

The appliances commonly used for house heating are of four classes:

1. Furnaces, which are utilized for heating a number of rooms or commonly an entire building.

2. Stoves, which are placed within the room to be heated. (This group includes also those appliances in which gas and oil are burned and which are connected to a chimney by a flue pipe.)

3. Fireplaces and wall heaters, which are fixed in location and generally connected to a chimney or flue.

4. Portable heating appliances, which are not connected with flue or chimney and which often are in place only when in operation.

Any fuel may be utilized in furnaces, stoves, or fireplaces, but, of course, the type of appliance should be suitable for the fuel to be employed. Portable heating devices, however, usually employ only gas or liquid fuels or electricity. It is impossible to advise in any detail regarding what fuels or heating appliances should be employed for any particular case or to give any details of operation, but the following section gives certain principles which are applicable to all heating appliances. The technical paper (No. 97) of the Bureau of Mines already referred to also gives a considerable amount of detailed information on this subject.

The ratio of the amount of heat which reaches the rooms to be heated to that available from the fuel burned may be termed the efficiency of a heating appliance.

A furnace has an efficiency from 40 to 75 per cent, depending largely upon the care and skill of the operator but depending also upon the size, construction, and suitability of the heating appliance and the rate at which the fuel is burned. For furnaces coal is most commonly employed, and except in a few instances is the cheapest material for heating. However, in some localities natural gas or wood are so cheap as to render them more economical. Gas and oil can be employed with considerably higher efficiency than coal or other solid fuels, because there is no necessary loss in imperfect combustion and because of the greater ease and precision with which the fire can be controlled.

Stoves, like furnaces, may be used with almost any fuel. Since they are located in the room to be heated, the heat escaping to the immediate surroundings is usefully applied, and on this account stoves are sometimes more efficient than furnaces. However, this advantage is in practice largely offset by the disadvantage of the smaller size and less economical control of the fire. Hence, in general, a stove can be expected to have about the same efficiency as a furnace.

Fireplaces commonly serve as auxiliary heating devices and, except in very mild climates, are suitable only for such service, since their efficiency is very much less than the efficiency of a stove or of a furnace. In many cases the efficiency may be only 10 to 20 per cent, since a large percentage of the heat escapes up the chimney unused. Practically only the radiant heat is utilized, and, hence, the new type of radiant heaters give much better results.

Wall heaters which are not connected to chimneys or flues are, of course, much more efficient, but their use should be strongly condemned because of the danger which may result from their improper operation. Such heaters which do not have flues are often inadequately insulated, and there is danger that they will set fire to the house. They also discharge into the room all of the products of combustion of the fuel and on this account are subject to the same criticism as are the portable heaters described in the next paragraph. Of course, electric heaters, whether inserted in a wall or of portable type, must be safeguarded from contact with combustible material, but they give off no products of combustion and, hence, never require a flue.

With portable heaters practically all of the heat is utilized in the room to be heated. But such appliances should serve only as auxiliary heating devices, since their continuous use, even though the combustion of the fuel is perfect, is undesirable because of the excessive increase in the humidity of the air and in its carbon-dioxide content. Moreover, if the combustion of the fuel is not perfect, they introduce a danger because of the poisonous products of the incomplete combustion. Because of lesser likelihood of producing such products yellow-flame gas heaters are often preferable to those with a blue flame; and any incomplete combustion with a yellow-flame burner results in producing a soot or smoke that gives warning of the danger.

In the use of portable heaters care should be taken that they are not placed too near to combustible material and that they do not set fire to the floor or rugs on which they stand. For portable gas appliances only the best quality of flexible tubing should be used, since defective or cheap tubing introduces danger of leakage of gas or disconnection of the tubing during use. In any case the gas should be shut off at the pipe rather than at the appliance, so that gas will not escape if the tubing is broken or disconnected when the appliance is not in use. Permanent piping should be used wherever possible. When using flexible metal tubing, the users should protect it from excessive heat, since the rubber or other material used to make the tubing gas tight is easily damaged by excessive temperatures.

(*c*) **Gas for Heating Purposes**

For heating purposes either blue-flame or yellow "luminous"-flame devices may be employed. With the yellow flame it is essential that the burner be kept clean and so regulated that no smoke or soot is given off during burning of gas. In general, yellow-flame appliances are suitable only for fireplaces or portable heaters; but for the latter class of devices the yellow flame is preferable for the reasons given above.

Blue-flame gas-heating appliances are preferably used connected with a flue or set in a fireplace that has an effective flue. If used without a flue, care should be exercised to see that the construction is such that the blue flames from the burner openings are permitted to burn freely without coming in contact with any metal part of the heater. Such contact cools the flames so as to produce products of incomplete combustion. Contact of the flames with the baked-clay or refractory material which is used in some modern gas heaters, and which becomes red-hot as soon as the heater is lighted, is not open to this objection.

The burners of blue-flame heating appliances are usually provided with an air shutter by which the quantity of air mixing with the gas within the burner can be regulated. Nothing should be allowed to interfere with the free flow of air through the shutter, and the shutter should be opened sufficiently so that the flame above each burner opening will have a sharply defined inner blue or bluish green cone. This indicates an adequate amount of air mixing with the gas in the burner. The burners should be kept clean and carefully adjusted so that the flame will at all times be entirely blue and not capped with yellow. However, the air shutter should not be so wide open as to permit the gas to "fire back" and burn within the burner itself. If the gas burns inside the burner, combustion is incomplete and dangerous products of partial burning are given off.

This improper burning of the gas within the burner, known as "lighting back," is accompanied by a roaring noise. If a blue-flame gas heater makes an unusual noise, it should be turned out at once, and lighted again after waiting a moment.

Since the gas flame gets only a part of the required air through the burner, it should be provided with sufficient air reaching it around the burner so that no long, lazy, "licking" flames form above the burner.

In the flue pipe leading from the gas appliances to the chimney a damper is sometimes inserted, but this is not desirable in most cases. If the draft is excessive or if the flue from the gas appliance interfered with the draft from a coal stove which is using the same chimney, a damper may be used, but in every case there should be an opening through or around the damper sufficient to prevent entire closing of the flue pipe in case the damper is shut while the appliance is burning. A back-draft diverter which serves to check the draft is always preferable to a damper for control of excessive drafts. If the escape of products of combustion from appliances is by any means unduly interrupted, these products settle down over the burner and smother the flame and may even extinguish it. It is evident, therefore, that under no circumstances should this obstruction be permitted. A device known as a "draft hood," designed to prevent this smothering by obstruction or back-draft in the flue, should be used on every flue-connected gas appliance.

The odor of "furnace gas" is familiar to all and is recognized as a sign of danger. It is of equal importance to recognize as a warning the odor which generally accompanies incomplete combustion of gas. One may familiarize himself with the nature of this odor by lighting a gas-stove burner through the air shutter so that the gas will burn within the burner for a moment. Every member of a household should be taught to regard the odor thus produced, and also the accompanying sound, as a sign that the appliance is not properly operated.

In general, when the odor of unburned gas or this odor of incomplete combustion is noted, the source of the trouble should at once be located, and a remedy provided. If the method of correcting the conditions is not apparent, the gas company or a reputable gas fitter should be called upon for immediate assistance. If the odor is caused by leaking gas, no fire should be used in trying to locate the leak. If the odor is strong, the windows should be opened and rooms vacated until the gas company's man arrives.

7. COOKING

Cooking appliances may be divided into three classes as regards their fuels or sources of heat: (1) Coal and wood stoves or ranges, in which the fuel is burned in a fire box within the stove; (2) gas, oil, gasoline, and alcohol stoves, etc., as well as some electric stoves, in which nothing but the burner itself and the cooking utensil has to be heated; (3) fireless cookers and some electric ovens or gas or electrically heated fireless cookers, in which the heat is supplied inside a well-insulated space so that it is lost only slowly to the outside.

In nearly all cooking operations the amount of heat actually utilized is only a very small percentage of the whole. With a coal or wood stove or range probably not more than a few per cent of all the heat produced ever reaches the receptacles in which foods are being cooked, but with gas, gasoline, and oil stoves sometimes as much as 50 or 60 per cent of the heat may reach the receptacles, kettles, etc. In any case only a small percentage of the heat thus utilized would be needed if it were not for the losses from the exposed sides of the heated receptacles and the evaporation of water. In fireless cookers and in some gas and electric cookers provision is made for conserving this heat by surrounding the hot container with thick insulating walls.

No very definite conclusion can be drawn as to the relative economy of different cooking appliances, since this economy depends upon the sort of cooking operations considered—whether baking, boiling, or frying, etc.—and upon the skill and care of the person in charge of work. However, it may be said that in spite of the fact that city gas costs from 5 to 10 times as much per heat unit as coal and electricity from 5 to 20 times as much as city gas, there is by no means as great a difference as this in the cost of cooking by these different methods when in the hands of equally careful persons. This is due to the increased efficiencies of the appliances using the more expensive fuels and the practicability of intermittent use of them.

In many household problems it may be of interest 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 five 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 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, as is now being done in some of the newer types of gas ovens. 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.

8. POWER PRODUCTION

Household power-producing appliances, exclusive of electric motors, include gas, gasoline, and oil engines and so called hot-air pumping engines.

The gas, gasoline, or kerosene engine requires for its operation an intimate mixture of air with gas or with vaporized fuel. The same engine can usually be made to run with either of these fuels, provided the proper mixture of air and vaporized fuel can be secured. This vaporization is usually effected in a carburetor and the type and adjustment of the latter depend upon the kind and quality of fuel to be used. Gasoline is much more easily vaporized than kerosene and some grades of gasoline are more easily vaporized than others; hence, different vaporizing devices or carburetors are required or at least different adjustments of the same device when different fuels are used. Very nearly the same amount of work can be done with a gallon of kerosene or gasoline; hence, as long as there is a very decided difference in price between gasoline and kerosene it is good economy to use kerosene wherever possible. Satisfactory devices for using kerosene in stationary engines can be purchased.

The automobile at present involves by far the most extensive and important use of fuel for power production by the general public. Hence, the general interest in the quality and price of gasoline or other motor fuels.

The fuel for automobiles commonly sold under the name of gasoline is not a simple substance, but a mixture of an indefinite number of compounds derived from the distillation of crude petroleum. These compounds differ chiefly in their volatility; that is, the ease with which they can be vaporized. When properly vaporized, there is no very great difference in their behavior in an automobile engine. However, for satisfactory service at least two properties are very important: (1) A sufficient amount of the more volatile compounds to permit starting an engine when cold; (2) no considerable amount of those compounds which can not be completely vaporized in the particular engine in which the fuel is used.

The properties of a motor fuel are determined by laboratory tests, the most important of which is called the distillation test, in which a certain definite amount of gasoline is boiled away in a standard flask. As the fuel boils off, the temperature rises. The temperature at which a certain amount, say 20 per cent, has evaporated indicates the relative starting quality of the fuel. The temperature at which the last tenth, say, disappears indicates relatively the ease with which substantially all of the fuel can be vaporized.

Unfortunately, no simple test has been devised by which the purchaser can determine these characteristics easily for himself, and until it is possible to secure from the dealer some reliable information as to the properties of the fuel which he is selling the purchaser of "gasoline" can hardly do otherwise than accept what is offered for sale.

However, a fuel which is satisfactory for one engine may be unsuited to another. A fuel which starts almost any engine may be unsuited for continuous use, or a fuel which would not start at all in a cold engine might be entirely satisfactory after the engine was heated up. The design and construction of automobile engines has been changing rapidly, and a fuel which is suitable for use in engines built recently may not give satisfaction when used in engines built some years earlier. It is very important, therefore, that some means be found for giving the purchaser of fuel some information as to its characteristics, in order that he may use the cheapest and most plentiful grade which will give satisfaction in his particular engine.

The charge has often been made that gasoline is mixed with kerosene as an adulterant. Probably this practice is much less common than is supposed and is confined to local dealers. However, since there is no sharp demarcation between gasoline and kerosene, the inclusion in the gasoline of considerable percentages of the high-boiling compounds in the process of manufacture has about the same effect as adding kerosene. In fact, it is sometimes almost impossible to detect the difference even by experimental methods.

While many devices for vaporizing kerosene in automobile service are being tried, apparently as yet none is entirely satisfactory. However, the production of a satisfactory kerosene vaporizer is mainly a matter of sufficiently improving on methods already well understood, and such devices will very probably be developed in the near future.

The amount of fuel, particularly liquid fuel, used to produce power in a gas or gasoline engine depends to such an extent upon the care and skill of the operator that no definite figures can be given. However, under the best of practical conditions 1 gallon of kerosene or gasoline, 180 cubic feet of city gas, or 110 cubic feet of natural gas should produce 10 horsepower-hours of work. Better fuel economy than this is hardly to be expected in small engines as they are designed at present.

Electric motors are commonly rated as to their power in kilowatts rather than in horsepower. One horsepower is equivalent to ¾ kilowatt or 1 kilowatt to 1.34 horsepower. However, a motor rated at 1 horsepower or ¾ kilowatt will require considerably more than ¾ kilowatt of electrical power to be supplied to it, because some power is always lost in friction and heat in the motor itself.

9. HOW LIGHT IS PRODUCED

The production of light is almost always accomplished by heating up to a high temperature some substance which gives out the desired light. The heating is done in the filament of an incandescent electric lamp by the passage of the current; the gas mantle is heated by the flame which burns within it; and the yellow flame of a gas burner is due to the high temperature produced in the small particles of carbon (soot) which are glowing, both because of the heat of the flame and because of their own combustion.

The intensity of any light increases very rapidly with the increase of the temperature of the substance which is giving out the light rays. This is due to the fact that a much larger amount of energy is given off in the form of light at the higher temperatures and less of the energy radiated is in the form of heat. It is, therefore, evident that it is desirable to produce as high a temperature as practicable when light is desired. The modern lamps, such as gas mantles and metal-filament electric lamps, are more efficient than the older lamps chiefly because they can be run at higher temperatures. For the same reason they give light which has relatively more blue and less red in it and is, therefore, nearer to daylight in color.

10. LIGHTING

The important materials used for household lighting are candles, kerosene oil, electricity, and gas of various kinds, including natural gas, ordinary manufactured or "city" gas, acetylene, gasoline or "air" gas, and some compressed gases, such as Blau gas and Pintsch gas. The choice of material to be used is generally determined more by considerations of availability, convenience, and expense of installation than by difference in cost of operation. It is, in fact, somewhat difficult to make any exact comparisons of cost except for particular cases, and the statements of costs given below will apply only approximately to any particular case. The cost will naturally depend on the candle power 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-candlepower lamp 100 hours or a 50-candle power 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 economical for household use. For example, it would be absurd to burn an exceedingly large lamp just because its cost per candle-hour might be small.

The question of cost is still further complicated by the fact that the expense of installing piping or wiring, which may often be a very important consideration, varies widely, so that no general figures would be of any value. This applies also to isolated systems for lighting a single house, such as acetylene generators or private electric plants. The figures given below cover running costs only and are based on ordinary prices for the materials used.

(*a*) **Candles**

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 cost about $2.

(*b*) **Kerosene Oil**

Kerosene oil, the most widely used illuminant, is far more economical than candles, 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. In fact, the only household illuminants which can produce light more cheaply than the ordinary kerosene lamp are the modern gas-mantle lamps and tungsten electric lamps. The different sizes of kerosene lamps do not differ greatly in efficiency. The large round-wick lamps give more light than the smaller flat-wick types but burn correspondingly more oil.

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. A few types appear to be really valuable developments, but the majority of those on the market are unreliable. Before investing any considerable amount of money in any oil-burning mantle lamp, one should insist on a thorough trial of the lamp in actual use.

(*c*) **Acetylene**

Acetylene has great advantages for small installations, such as country homes or hotels or small towns, particularly because of the comparative ease with which calcium carbide can be handled and stored and the gas can be generated. There are on the market many reliable generators which require very little attention for their operation. Open-flame burners are used because no mantle burner has been devised which will give reliable operation with this rich gas. The cost per 1000 candle-hours is about 25 cents, that is, about the same as for "city" gas with the old open-flame burners, for while the acetylene gives about 10 times as much light per cubic foot it also costs about 10 times as much.

(*d*) **Natural Gas**

Natural gas, as has already been stated, gives very little light in an open flame and for lighting purposes is, therefore, always burned in mantle lamps. In such lamps it gives a large output of light for a given volume of gas because its heating value is high (see p. 208). With natural gas at 30 cents per 1000 cubic feet, burned in a well-adjusted mantle lamp the cost per 1000 candle-hours should not exceed 2 cents, a considerable part of this being for mantles.

(*e*) **Manufactured Gas**

Manufactured gas of the kinds commonly supplied in this country can be used in open-flame burners, but this is decidedly wasteful except in locations where a small amount of light is sufficient and mantles are likely to be broken. In the interest of economy and good service gas companies in the future are likely to furnish gas more on the basis of its heating value, and less attention will be given to open-flame candlepower; hence, it will become more and more advantageous to use mantles.

With the gas commonly furnished at present the cost per 1000 candle-hours with open flames is about 25 cents. If mantle lamps are used, the efficiency depends on the care which is taken to keep them in good condition, but a good lamp in fair condition should give four or five times as much light as the open flame, making the cost for gas only 5 cents for 1000 candle-hours.

To balance against this large saving in gas, there is the cost of the lamp and of mantles. Usually a mantle lamp substituted for an open flame gives more light and uses less gas, and if a year's use of the lamp is considered it will generally be found that the

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saving in running expense is more than sufficient to pay for the lamp, while one will have had a great deal more light.

If the burner happens to be located where the light of the open flame is sufficient, still a great 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.

In order to get the best results from mantles, it is necessary that the householder shall know something about the adjustment of the lamps. Good operation of the burner depends on securing the proper mixture of air with the gas. The air is drawn into a mixing tube through ports located near the base of the lamp, and in most lamps these ports are provided with sliding covers which can be turned so as to close the air ports more or less completely. In the great majority of cases, with the gas now furnished, the air ports should be open as wide as possible. The first step in adjusting a lamp should, therefore, be to find these ports and see that they are open. (A few types of more modern lamps are made without any covers for the air ports, so that they are necessarily open.)

The lamp also has a regulating screw or valve which controls the amount of gas admitted. (This refers to a valve in the lamp itself, not to the cock by means of which gas is regularly turned on and off.) This regulating valve should first be turned so as to reduce the amount of gas until one can see definitely that the mantle is not as bright as it can be. Starting from this the valve should be opened until the mantle is made as bright as possible, and then it should again be closed just enough to make a perceptible but very slight decrease in the brightness. This procedure will usually give an adjustment at which the lamp operates efficiently.

If the lamp fires back—that is, the gas ignites in the mixing tube—the gas must first be turned off entirely. Then the air ports should be partly closed and the above process of adjustment tried again.

In many cities the gas companies employ men for the special work of remedying faults in gas appliances, and assistance will be freely furnished in case the householder has difficulty in getting proper adjustment of lamps or other appliances.

(*f*) **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." The tungsten lamps are so much superior that the other kinds are rapidly going out of use. About 80 per cent of the incandescent electric lamps made in this country at present are tungsten.

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 kilowatt-hour, the cost of current for any lamp is easily calculated. The kilowatt-hour is 1000 watt-hours, and the number of watt-hours used by an electrical device is simply the watts multiplied by the number of hours burned. For example, a 50-watt lamp in 20 hours uses 1000 watt-hours or 1 kilowatt-hour. At 10 cents per kilowatt-hour current for such a lamp costs ½ 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 filament are, however, decidedly different. In round numbers the tungsten lamp gives three times as much light as the other lamps for a given power consumption.

It is a rather common practice to substitute for the old carbon lamps new tungsten lamps taking practically the same number of watts. This of course gives much more light but makes no saving in the lighting bills. In some cases in making the change it would be advantageous to use lamps of lower wattage, thus reducing the cost and at the same time increasing the amount of light. The cost of the lamps is small compared with the cost of the power used, and one can well afford to throw away the old lamps and buy the new.

As an example of the economy to be obtained by using the more modern lamps, consider a particular case where a 40-watt tungsten lamp (giving 40 candles) is substituted for a 50-watt Gem (giving 20 candles), a size which has been most widely used for household lighting. The average tungsten lamp of standard makes, if not subjected to excessive jarring, is expected to burn for 1000 hours, which is about one year's use. The 50-watt lamp burning for 1000 hours would consume 50 000 watt-hours or 50 kilowatt-hours. If electric power costs 10 cents per kilowatt-hour, the total bill for this lamp would be $5. (No charge is included for lamps because power companies have generally furnished free renewals of such lamps.) The 40-watt lamp in 1000 hours uses 40 kilowatt-hours, costing only $4. To balance against the saving of $1 in power there is the cost of the lamp, which is about 25 cents. (The present standard list price is 27 cents, but in many places lamps are furnished by the power companies at less than list prices.)

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 10 watts means a saving of one-tenth cent per hour. If the 25-cent lamp gives 250 hours of service, one has at least lost nothing by buying it and has had the benefit of a candlepower double the previous value. When ordinary carbon lamps are in use instead of Gem lamps, the advantage to be gained by changing to tungsten lamps is still greater.

In conclusion, with regard to all kinds of lamps, it should be said that really satisfactory lighting can never be obtained without the use of shades, reflectors, or other fixtures which protect the eyes from the direct light of the source, whether it be flame, mantle, or filament. A discussion of the general principles of lighting is given in Bureau of Standards Circular No. 55 (pages 75 to 81), which can be obtained on request from this Bureau.

11. STORAGE OF FUELS

Aside from the waste of fuels in storage, by weathering of coal, decay of wood, and leakage and evaporation of oils, etc., which are generally well understood, the storage of fuels always involves some risk of fire. For most solid fuels, such as coal, coke, wood, etc., this risk is unimportant, but for gasoline and to some extent for kerosene there is serious risk not only of fire but also of dangerous explosions under certain conditions which are not always well understood.

Nearly all fuels except hard coal, coke, and charcoal are vaporized before they burn. For example, the bright flame from soft coal, wood, or oil is caused by the burning of vapor which has been produced by the heat. Any of these fuels if heated will produce combustible vapors, which when mixed with air will burn and if mixed with air in certain proportions will explode violently.

The temperature which a fuel must reach in order to produce dangerous vapors depends largely upon the fuel. For most solid fuels this temperature is well above the boiling point of water. For kerosene it may be considerably below this, perhaps as low as 150° F., while gasoline and alcohol will produce dangerous amounts of vapor at any ordinary temperatures. For example, the vapor from a few drops of gasoline or alcohol on a clean plate or tin dish can be readily lighted with a match before the match flame touches the surface. With kerosene this can not be done unless the plate is heated. This illustrates one of the very serious dangers in the handling of gasoline. Gasoline vapor, being much heavier than air, remains near the floor. Hence, if there is a leaky or open gasoline can in a closed room, it is quite possible for the floor to be covered with an invisible layer of combustible vapor, which will ignite from a match, cigar, or cigarette stub or even a spark struck from the heel of a shoe. Once ignited the flame may spread all over the floor of the room and set fire to the gasoline from which the vapor came.

After a time a layer of vapor mixes with the air of the room, and when this mixture reaches a certain stage, instead of burning quietly if ignited, the whole will explode with great violence. Such an explosion may easily wreck a whole building.

Under some conditions certain materials, worst of which are perhaps oily rags or waste, may take fire of their own accord. Other materials, including some grades of soft coal, some kinds of celluloid, and various sorts of refuse, are also liable to spontaneous combustion. All oily rags, waste, as well as miscellaneous rubbish, should be disposed of or at any rate put where they can not set fire to other objects. Spontaneous combustion of coal in domestic use in this country seems to be extremely rare, although fires in the coal bunkers of steamships are of rather common occurrence.

12. LUBRICANTS

Lubricants may be either oils, greases, or solids. The difference between an oil and a grease is not very clearly defined. Greases are usually semisolid at room temperature, but both "liquid greases" and "nonliquid oil greases" are on the market. Graphite and talcum powder might be mentioned as familiar examples of solid lubricants.

All lubricants act by keeping rubbing surfaces apart and thus reducing the friction and wear, and for this function it is necessary that the material used be such as will stay in place and retain its suitable properties at the temperature and pressure of the bearing. The greater the pressure tending to force a lubricant out from between the surfaces the greater must be its viscosity, or what might be called its resistance to flow. Viscosity is the property of a liquid which makes "cold molasses" pour with its proverbial slowness. Molasses is very viscous, but water has but little viscosity; or, expressing the same idea differently, water is very fluid but the molasses is "thick."

If one stirs molasses briskly, it takes more force than to stir water, because the friction in the fluid is greater. In the bearing the lubricant must, in effect, be stirred as the bearing moves. It is evident, therefore, that a lubricant should not be used which is more viscous than necessary. On the other hand, a lubricant should be used which is viscous enough to keep it from being forced out of the bearing, thus permitting metal-to-metal contact and increased friction. Every oil becomes less viscous with an increase of temperature. Therefore, an oil must be selected which will not become too fluid at the highest temperature to which it will be exposed. Allowance must be made both for the atmospheric heat and for the heat which is always generated in a bearing from the friction.

It is evident, from what has been said, that it is very important to be able to measure the viscosity of an oil. In chemical laboratories viscosity is measured by instruments called viscosimeters, in the most common forms of which a certain amount of oil is allowed to flow out through a tube of small diameter, called a capillary. The instrument most generally used by oil refiners in the United States is the Saybolt Universal viscosimeter, in which the length of the capillary is about eight times its diameter. The number of seconds which is required for 60 cubic centimeters (about half a gill) of oil to run out is called the "viscosity," though it is not the true viscosity to which we have been referring all along nor even proportional to it. However, viscosity in seconds will serve to identify an oil. If it is found that an oil which will flow out of a viscosimeter in a certain time will give satisfactory service, then an oil of another brand having the same time of discharge might be expected also to give satisfaction, if both oils were of the same quality in other respects than viscosity. There is a slight error in this assumption, because the time of flow depends on density as well as on viscosity, but the difference in densities between different lubricating oils is so small that it can be neglected in rough comparisons.

When it is not a case of comparison between one laboratory and another, but someone merely wishes to compare the viscosities of two oils, it is not necessary to use a viscosimeter of standard dimensions. Almost any oil container with a small opening or orifice in the bottom will answer the purpose. We may, for example, take a tin can, such as is used for canned corn or peas, and put a hole in the bottom of about 5 millimeters (3/16 inch) diameter. Then two oils will have approximately the same viscosity if it takes the sme length of time for the can to empty.

The following table gives roughly the times in seconds indicating suitable viscosities for different kinds of oil, measured both with the Saybolt Universal viscosimeter and with the "No. 2" tin can holding 625 cubic centimeters (21 ounces) of liquid, when the liquids are at 37.8 degrees centigrade (100 degrees Fahrenheit).

Liquid	Time, Saybolt	Time, tin can
	Seconds	Seconds
Water	28	60
Olive oil	200	67
Oil for lawn mowers and light machinery	125	64
Automobile oil, light	165	65
Automobile oil, medium	210	67
Automobile oil, heavy	335	73

It will be noted that the Saybolt instrument shows a much greater variation in the time of discharge than does the tin can. This is because a capillary is much more sensitive to changes in viscosity than is an orifice or hole in this metal. For very accurate work capillaries with diameters only about 1/200 of their length are used.

The advantage of greases over oils is that they are not consumed except when the bearing is operating. Axle grease is a familiar example. When the bearing is cold, the grease is too viscous to run, but when the bearing is warmed up by friction the grease melts and lubricates the bearing, until a temperature is reached at which just enough lubricant is used to keep the bearing at an even temperature. Greases decrease in viscosity with an increase of temperature more rapidly than do oils. This is the result of adding lime or lime soap to the oil for preparation of the grease. Sometimes what are known as "fillers" are also added. These consist of materials such as powdered gypsum, talc, mica, and so forth, some of which are lubricants while others are not. They are put in to make the grease stiffer, but in general the best grease is one which has the desired consistence with the least amount of filler.

Animal and vegetable oils are excellent lubricants, but they are now so expensive as compared with petroleum products that they are but little used. They are superior to petroleum oils in that they lose viscosity less rapidly with an increase in temperature. They are, however, more apt to become rancid and form fatty acids, which are injurious to a bearing.

In the process of refining petroleum oils they are often treated with acid to remove impurities, treated with alkali to remove the acid, and, finally, washed to remove the alkali. If these processes are not carried out with great care, the resulting oil may be left with an excess of acid or of alkali, either of which is injurious. The best lubricating oils are not acid treated but are purified entirely by filtration. It is advisable to test bicycle or sewing-machine oils to see whether there is an excess of acid which may attack the bearings. This may be done by placing one drop on a piece of polished copper and letting it stand for 24 hours. If the oil is of good quality, the metal should not be discolored at the end of that time.

If there is an excess of alkali in an oil, this will unite with the organic acids to form a soap, which, though needed in greases, is a distinct disadvantage in oils. Soap makes an oil lose viscosity too rapidly as the temperature increases, so that there is danger of the oil not being viscous enough to prevent metallic contact on hot days when the oil is at its highest temperature. It is not unusual, on automobiles, for example, to use a different oil for summer than for winter, so as to have a lubricant of more nearly uniform viscosity all the year round.

Just as there is danger of an oil becoming too fluid in summer, there is danger that it will be too viscous in winter. This may be due to the fact that the paraffin has not been entirely removed. For out-of-door use in winter, as, for example, on motor-driven pumps, it is important that the oil should not get too viscous at low temperatures. If the oil is too thick to flow and reach the rubbing surfaces, it can not lubricate, even though its "lubricating value" is entirely unaffected by the cold. It is a simple matter to expose a sample of oil to outdoor temperature in winter. If it will not pour out of the bottle after exposure, it would not flow freely enough to act as a lubricant at the temperature to which it was exposed.

This test is particularly important in the case of pumps driven by electric motors so that it is not difficult to start under load. With a circular saw, for example, the saw can be gotten up to speed before commencing to saw; but a pump must begin to do work as soon as it starts, and the extra resistance of a chilled oil may prevent the motor from starting.

With automobile oils it is very important that there should not be too much carbonization, as this fouls the spark plugs and makes the engine miss fire. The simplest test for carbonization is to try the oil in service, though laboratory methods exist by which this can be avoided.

As has been pointed out, a good oil should be free from acid or soap, should not solidify at too high a temperature, and should be of the desired viscosity at the temperature at which it is to be used. The required viscosity increases with the pressure to which the oil is subjected in the bearing and decreases with the velocity of rubbing. In this connection, by "pressure" is meant the value obtained by dividing the load on a bearing by the projected area. In the case of a circular bearing or journal the pressure would thus be equal to the load divided by the product of the length and the diameter of the journal. The velocity of rubbing is equal to the continued product of 3.14 by the diameter of the journal by the number of revolutions per minute.

VI. QUANTITY IN THE PURCHASE AND USE OF MATERIALS

1. IMPORTANCE OF KNOWLEDGE OF QUANTITY

In purchasing materials for household use it is, of course, as important to see that the correct quantity of goods is furnished as to insist on specified quality. Because the articles can generally be weighed or measured more easily than they can be tested for quality and because the legal machinery for enforcing delivery of the correct quantity is more generally provided, one usually has less difficulty in obtaining the correct amount of goods due him. One should, however, be familiar with the legal requirements or the current local practice in weighing and measuring to be sure that he is getting full value in quantity purchased. The subject of weighing and measuring in the purchase of household supplies is quite fully covered in Bureau of Standards Circular No. 55 on "Measurements in the Household." Attention is here invited to some of the more important points of the subject.

2. CONFUSION OF UNITS

Because of the number of different units in our United States system of weights and measures which have the same name but different values, it is necessary to carefully distinguish between them at times in making purchases. The distinction between some of these is given below.

(*a*) Long and Short Tons and Hundredweight

Although the short ton of 2000 pounds and especially the short hundredweight of 100 pounds (avoirdupois) are coming to be used very generally, still the long ton of 2240 pounds is the legal requirement in the sale of some commodities in some States as, for example, coal in Maryland and the District of Columbia and anthracite coal in Pennsylvania. In deliveries of coal the driver's delivery slip ought always to show the net weight of the load.

(*b*) Avoirdupois, Troy, and Apothecaries' Pounds and Ounces

While the avoirdupois pound is larger than the troy or apothecaries' pound, the former consisting of 7000 grains and the latter of 5760, the troy or apothecaries' ounce on the other hand is larger than the avoirdupois ounce, the former consisting of 480 grains while the latter consists of 437.5 grains. The troy and apothecaries' systems are alike in the weight of their pounds and ounces, the difference between the two systems being in their further subdivisions, the troy subdivisions of the ounce being pennyweight and grains, while the apothecaries' subdivision is into drams, scruples, and grains. (See p. 246 for tables of these systems.)

The confusion of the avoirdupois and the apothecaries' system is most likely to occur in the purchase of drugs and chemicals. Usually, these articles when sold in bulk are and should be sold by the avoirdupois system, but as prescriptions are put up by the apothecaries' system there are some druggists who will also sell their bulk goods by the same weights, especially if there are no city or State regulations on the subject. As the troy weight is practically only used for weighing gold and silver and other precious metals and this custom is well known, there is less likelihood of confusion of its units with the avoirdupois system.

(*c*) **Fluid Ounces and Ounces of Weight**

The fluid ounce should never be assumed to represent the same quantity of material, even of water, as the avoirdupois or apothecaries' ounce of the same material, although in Great Britain the fluid ounce of water does weigh an ounce avoirdupois.[16]

(*d*) **Dry and Liquid Quarts and Pints**

Confusion of the dry and liquid quarts and pints is common unless there is an adequate enforcement of weights and measures ordinances. Since the dry quart is 16 per cent larger than the liquid quart a considerable loss results to a purchaser when he is sold a dry commodity by liquid quart measure. In purchasing a quart measure at the hardware store for home use one can determine whether it is a dry or liquid quart by filling it with water and weighing it. The water contained in a dry quart measure should weigh 2 pounds 6¾ ounces while a liquid quart measure would hold only 2 pounds 1⅓ ounces of water.

3. UNCERTAINTIES IN UNITS

Buying by other units than the customary ones of length, weight, and capacity often leads to disputes because of the uncertainty of the value of the unit specified. In some cases these

[16] The United States fluid ounce of water at 4° C. weighs 1.04315 avoirdupois ounces in vacuo. Even at 15-5/9° C. (60° F.) when weighed in air it weighs 1.04103 avoirdupois ounces, while in apothecaries' ounces these weights are 0.95078 and 0.94886, respectively. Only for a liquid having a density of about 0.9586 would a fluid ounce of the material weigh an ounce avoirdupois. The common statement of "a pint's a pound" would apply strictly only to a liquid of density 0.9586 and a pint of water would weigh, in air, 1 pound 0.67 ounce. The weight per pint of liquids heavier than water can be found by multiplying this value by the specific gravity of the liquid in question.

other units are defined by laws; in other cases they are only defined by current practice and that often varies greatly in different localities. It is well to familiarize one's self with the local practice in regard to such units before purchasing materials in order to avoid misunderstandings. A few of these uncertain units are noted below.

(*a*) Barrels

Many commodities are handled and sold in units of "a barrel" and yet this unit varies with nearly every commodity and differs in one State from that of another. In the case of some commodities the practice is very general to put a certain weight of the commodity in the barrel as, for example, 196 pounds to a barrel of flour, 300 pounds to a barrel of sugar, and 376 pounds to a barrel of cement. In the case of other commodities, while the barrel may be filled by weight, the number of pounds varies in different parts of the country or in different factories or mills. For example, lime has heretofore been sold in barrels of various weights of contents from 165 to 300 pounds. A law recently passed by Congress, however, has established two definite sizes of lime barrel and fixes them at 180 and 280 pounds of lime net weight. The weight of potatoes per barrel has in some States been fixed by law, the weights varying from 160 to 174 pounds, while in other States the volume of the barrel has been defined and a barrel of potatoes would consist of this volume of the article.

It is hoped that a law passed by Congress March 3, 1915, and effective July 1, 1916, will do much to secure uniformity in measurements of fruits, vegetables, and other dry commodities. This law establishes a standard barrel for such commodities having a head diameter of 17⅛ inches, an outside bulge circumference of 64 inches and a distance between heads of 26 inches, or a barrel having a capacity of 7056 cubic inches (or 105 dry quarts). This law applies to all dry commodities except such as have heretofore been sold exclusively by weight or numerical count (such as flour, sugar, and cement). Exception is also made of cranberries for which a special sized barrel is prescribed, one having a head diameter of 16¼ inches, an outside bulge circumference of 58½ inches, and a distance between heads of 25¼ inches. Provision is also made for three-quarter barrels, half barrels, and third barrels. The enforcement of this law will do much to remedy existing evils in the variety of sizes of barrels in use.

In the use of barrels for liquids considerable irregularity of practice also exists but the capacity is more likely to be marked on the barrel and the custom for any one commodity is more definite so that there is less opportunity for any misunderstanding in the purchase and sale of liquids.

(*b*) **Sacks and Bags**

In the purchase of commodities by the sack or bag there is still more chance for confusion than is the case with barrels, except in the case of certain commodities where the practice of packing a certain number of pounds to a sack is well fixed, as of cement 94 pounds to the sack, and sugar 100 pounds to the sack. In the case of flour the usual weights are in submultiples of a barrel as ½ barrel, ¼ barrel, ⅛ barrel, etc., expressed in pounds, but the custom is growing to drop the ½ pound, ¼ pound, and ⅛ pound from the weight of the ⅛, $\frac{1}{16}$, and $\frac{1}{32}$ barrel size and make their weights 24, 12, and 6 pounds.

In the case of potatoes a common practice is to put 2½ bushels by weight in a sack, the weight being according to the weight per bushel of potatoes in the State in which they are sacked.

(*c*) **Heaped and Stricken Bushel**

It is well known that most bulky commodities, such as potatoes, apples, turnips, and other fruits and vegetables, are sold by the heaped bushel while grains and seeds are sold by the stricken bushel. Inasmuch as the same measure is used for defining these two quantities the amount by which the bushel should be heaped for the bulkier commodities is an uncertain quantity. In the early use of the original Winchester bushel the measure was defined as having an outside diameter of 19½ inches and a depth of 8 inches; hence, the inside diameter of the measure, having a capacity level full of 2150.42 cubic inches, was 18½ inches, and, in the early use of the heaped bushel, the heap was defined as a cone having this outer diameter of 19½ inches as the diameter of its base and a height of 6 inches; hence, the heap on the bushel measure was more than 25 per cent of the stricken measure.

In the State laws the manner of heaping the measure has been variously defined; in some cases they state that the commodities shall be "duly heaped up in the form of a cone as high as the article to be measured will admit"; in other cases that the commodities shall be "heaped as high as may be without especial effort or design." In States which have been lax in the enforcement of their weights and measures laws there has gradually grown up the custom of using bushel measures having smaller diameters and greater depth than that given above, so that, in giving a heaped measure, it was not necessary to give so large a quantity because the cone of the heap would be smaller. Purchasers of such commodities should therefore familiarize themselves with the laws and regulations in their State, which specify the dimensions of the bushel measure and the method of heaping, and should see that when purchasing by dry measure they receive the full quantity required by law.

The commodities sold by stricken measure include dried beans and peas, berries and small fruits, and peanuts. In the purchase of small quantities of such articles, such as a quart or pint, care should be taken that the sale is made by dry measure and not by liquid measure, as the liquid measure is approximately 15 per cent smaller than the corresponding dry measure.

(*d*) Bushel by Weight

The sale of dry commodities by weight is increasing rapidly in this country and is almost universal in the Western States. In other States the amount of a commodity to be given for a bushel is specified as being a certain weight of the commodity, these weights, of course, varying with the different commodities. Each State has a large number of weights per bushel defined in their State laws. These weights differ very materially in some States from those in adjoining States, and, in many cases, the specified weight does not correspond closely to either a stricken or a heaped bushel of the commodity as it might be measured with a bushel measure. Furthermore, the actual weight of a stricken or heaped bushel of a commodity varies with the season or with different years, depending upon the amount of moisture contained in the article. It is therefore important to specify in purchases whether a bushel of the commodity determined by the legal weight per bushel or one determined by measurement is to be delivered. A table of weights per bushel of some of the more important commodities is given on pages 250–252.

(*e*) Boxes for Fruit and Berries

In the sale of small fruits and berries by the box it is usually understood that the box should hold either a dry pint or a quart, or a multiple of these units. Until recently, however, many States have been very lax in the enforcement of this requirement. A national law [17] has recently been passed specifying that the

[17] Act No. 248, 64th Cong., approved Aug. 31, 1916.

standard basket or other container for small fruits, berries, and vegetables shall be of the following capacities: Dry half pint, dry pint, dry quart, or multiples of the dry quart. The passage of this law will bring about uniformity throughout the United States in this matter. The law will be in effect after November 1, 1917.

(*f*) **Baskets**

In the sale of fruits and vegetables in larger baskets than the quart there has, in the past, been much diversity of practice, many different sizes of baskets being used for this purpose. However, with the passage of the act mentioned above, and the enforcement of the net-weight clause of the pure-food law, which requires the marking of such containers with their net contents, there should follow a great reduction in the number of sizes of such containers in use.

The act establishing the standard basket for berries, etc., includes also the standardization of the Climax basket commonly used for grapes, specifying that only three sizes of this type of basket shall be used, a 2-quart, a 4-quart, and a 12-quart basket.

(*g*) **Board Feet**

The board foot, or 1 square foot in area by 1 inch thick, is usually used in the measurement of lumber, except in the case of small material like molding, which is sold by the running foot; shingles, which are sold by the thousand; or posts, poles, and similar materials sold by the piece. When the lumber is less than an inch thick the usual custom is to treat it in measurement as if it were an inch thick. In some cases, however, account is taken of the thickness when it runs below ⅞ inch. Usually, however, allowance is made in the price of such thin material rather than in the measurement. For material 1¼ or 1½ inches thick in the rough, the number of square feet of superficial surface is increased by ¼ and ½, respectively, to take account of the increased thickness. Similarly, for material 2½ inches thick the superficial surface is multiplied by 2½ to give the correct number of board feet.

The number of board feet in dressed lumber is usually based on the thickness of the board before planing; hence, boards ⅞ of an inch dressed are treated as 1-inch material, and similarly boards 1⅛ inches thick are treated as 1¼ inches, the usual amount taken off in dressing being about ⅛ of an inch. In the measurement of flooring the width of the board is taken in a similar manner;

i. e., from the width of the original piece before trimming. It thus includes the full width of the board, including the tongue in tongued and grooved material. Where there is any possibility of misunderstanding as to the unit of measurement of lumber, the method to be used should be definitely agreed upon between purchaser and salesman.

(*h*) Cords

In the sale of firewood the most common unit that is established by law in most of the States is the cord of 128 cubic feet, usually measured in piles 4 feet high, 8 feet long, where the wood is cut in 4-foot lengths. Local practice, however, varies fromt his occasionally and a cord is sometimes considered to be a pile 4 feet high, 8 feet long, of whatever the customary length for cutting the wood is in that locality. This is sometimes 1½ feet, 2 feet, or 3 feet, and occasionally 5 feet. Practice also differs in different parts of the country as to the method of measurement of a cord of sawed and split wood, the most common method probably being to treat it as the cord of wood before sawing and splitting necessary to give this cord of sawed and split wood. Sellers of sawed and split firewood often have a wagon box of such dimensions as is supposed to hold an amount of the sawed and split wood which was in the original cord of wood before sawing and splitting. In some States in the sale of small quantities of sawed and split wood the sales are made by the basket. Sometimes this basket is equivalent to a heaped bushel; in other cases it is a basket of special dimensions specified in the State law. Purchasers of wood in this form should familiarize themselves with the law or practice in their community.

4. NET CONTENTS OF CONTAINERS

In accordance with an amendment to the national food and drugs act approved March 3, 1913, it is required that all food packages shall now be marked with the net contents, either in weight, measure, or numerical count, with the exception of the certain small-sized packages. However, this act applies only to food, and only to food put up in package form. It does not, therefore, include drugs or other commodities used in the household. A number of States have net-weight laws requiring the marking of packages of other commodities, but the practice is not general as yet.

(*a*) **Required Markings on Food Packages Under the National Law**

The regulations issued by the Department of Agriculture, in connection with the enforcement of the amendment to the food and drugs act mentioned above, specify that the statement of quantity of the contents shall be plainly and conspicuously marked on the package, and that the quantities so marked shall be the amount of food in the package. The act provides for the establishment of tolerances to allow for the necessary variations in packing and the changes in weight of contents, due to variations in climatic conditions, etc. Statements of weight shall be in avoirdupois pounds and ounces. Statements of liquid measure shall be in terms of the United States gallon of 231 cubic inches or its customary divisions—i. e., gallons, quarts, pints or fluid ounces—and statements of dry measure shall be in terms of the United States standard bushel and its customary subdivisions. In case of articles in barrels, the marking shall be in terms of the United States standard barrel and its lawful subdivisions. (See above, p. 236.) Packages containing 2 avoirdupois ounces of food or less are exempt from marking in terms of weight. Those containing 1 fluid ounce of food or less are exempt from marking in terms of measure, and when the marking is given in numerical count, packages containing 6 units or less are exempt from the requirement.

(*b*) **Importance of Checking Up the Marked Contents of Packages**

In order that the requirement for the marking of packages with their net contents may be of the greatest value, it is very desirable that purchasers occasionally check the accuracy of the marked contents and report to the proper authorities any discrepancies which they may find. It is often the case, also, that through ignorance packers of food products doing a small business, or serving only a local territory, neglect to mark the contents on their packages and such violations of the law may escape the notice of the regular inspectors. The reporting of such cases will assist in putting the sale of foodstuffs on a uniform basis throughout the country, working greater justice to all, both producers and consumers.

(*c*) **Desirability of Checking Other Packages**

It is readily seen that the marking of the net contents on food packages makes it possible to compare more accurately the relative value of two brands, since the prices per unit can be readily

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determined and the only question then remaining is the relative quality of the two brands. For the same reason it is desirable that packages of other commodities be similarly marked and, until such laws are enacted, it is doubly important that the consumer frequently determine the contents of such packages as he may purchase. This applies to many household materials which are sold in package form, especially where packages apparently of very nearly the same size are sold at the same price; for example, washing powders and cleaners, soap, ink, library paste, glue, paint and varnishes, tacks, screws, brads and other hardware, stationery and other paper articles, threads, yarns, twine, etc.

(*d*) **Methods of Checking Contents**

In order to properly check the contents of such packages each household should be provided with a suitable scale for making weight determinations and with at least one or two measuring cups which are known to be accurate. The methods of checking by weight will readily occur to the reader.[18] The checking of the capacity of packages will often have to be delayed until the contents of the package are consumed unless one wishes to empty the package at once and determine its volume.

The contents of a cylindrical can or paint pail can be determined with considerable accuracy by measuring the circumference with a tape and by measuring the height of the can. The diameter of the can can be determined by taking 7/22 of the circumference, then subtracting from this a slight amount for the thickness of the can, multiply the result by itself and the product by 11/14. This result should be multiplied by the height of the can less proper allowance for the inset and thickness of the ends. The result, if the measurements have been made in inches, will be the contents in cubic inches, and this can be reduced to gallons or fractions of a gallon by dividing by 231.

Methods for checking deliveries of coal, wood, and ice are given in Bureau of Standards Circular No. 55, pages 33 to 35. The reading of gas, electric, and water meters is also fully described in that circular.

5. FORM OF CONTAINERS TO PREVENT LOSS

In the handling of materials, and especially in the case of materials kept for some time while being used, or before use, large losses frequently occur because of the faulty form of container

[18] Detailed suggestions are given in Bureau of Standards Circular No. 55 on "Measurements for the Household," pp. 20–28.

used. As these losses are gradual, the accumulative effect is often not realized. Attention is called to various forms of such losses with the idea that they may be prevented. The use of collapsible tubes for holding pastes and liquids is an advantage, as they prevent evaporation, chemical deterioration from contact with air, and contamination from foreign substances and dirt. They are more sanitary than many forms of container heretofore used. Many materials can now be purchased in this form such as cold cream, vaseline, library paste, collodion or liquid court-plaster, tooth paste, soft soaps, etc. The cap should always be replaced after using.

(*a*) **Losses by Leakage**

Leakage from cans, especially of oils or gasoline, in which the material as it leaks out quickly evaporates, are often overlooked since there is little or no evidence on the outside of such leakage. One method of detecting such leakage is to fill the can to a definite point which can be seen from the top and, leaving the can closed for several days, note whether the level of the liquid has fallen in that time.

(*b*) **Losses by Evaporation**

Losses due to evaporation of water or alcohol or other solvent material may often amount to a large proportion of the material, especially in dry climates. In addition to the loss of the material, the deterioration of the remaining material is sometimes more serious. Such losses are usually due, of course, to the material not being properly covered or sealed when not in use. Special methods have to be used in some cases to check this loss.

(*c*) **Losses by Deterioration of Contents**

In addition to the deterioration of materials due to losses by evaporation, they may also deteriorate greatly from lack of proper care, sometimes owing to the absorption of water, or sometimes from the growth of mold on the surface, or from contamination with other substances. Similar precautions in keeping the container sealed will usually check such losses.

(*d*) **Losses in Use**

Ink.—The losses in ink may be very large, both in quantity, due to evaporation, and in deterioration of quality, in consequence of evaporation. Such losses, however, can be checked by the proper covering of inkwells and especially by the use of some of the patented inkwells which automatically close the opening after the pen has been dipped into the ink. For example, an open inkwell in the course of six days, during which the relative humidity was 70 per cent or above, lost 23 per cent by weight. During two of these six days, with the cover on, the loss was less than 1 per cent; hence, practically the loss averaged over 5 per cent a day when the inkwell was left uncovered. Another inkwell partially designed to prevent loss, having a hard-rubber float, which was depressed by the dipping of the pen into the ink, lost 13½ per cent in the same time. A patented inkwell which automatically closed the inkwell after the dipping of the pen lost only 1 per cent. Besides the loss of the ink itself, the increased care necessary and the gumming of the ink after part has evaporated are added reasons for taking precautions to check such losses.

Glue and Paste.—The rapid drying of glue if the cover of the container is not kept tightly in place is well known. In the case of glue, however, there is not so much loss of material as loss of time necessary in heating up the glue again after it has dried. Library paste and similar pastes when purchased in the special glass containers made for the purpose usually have a coating of paraffin over the surface to prevent the deterioration of the paste before use. If this paraffin is wholly removed upon opening the bottle, deterioration is apt to begin over the whole surface. This can be checked by keeping the cover tightly in place when not in use and by keeping water in the special well for the brush, which will prevent the paste from drying out rapidly. If only a little paste is to be used at a time, losses can be checked further by cutting only a small hole through the paraffin and using the brush through this hole. This exposes less of the surface to the atmosphere and so reduces the drying process or the growth of mold.

Paint and Oil.—Paints when not in use should be kept tightly covered, otherwise a hardened film will form on the surface. There will also be losses from evaporation of the solvents and deterioration of the contents from the accumulation of dirt and dust on the surface if the cover is not kept closed. Paint brushes should not be left in the paint but should be cleaned and kept in turpentine or kerosene to prevent drying out.

Tinctures.—The loss due to evaporation of tinctures containing alcohol may become quite serious if the bottle is left uncorked, since a reduction in the amount of alcohol in which the material is dissolved will add greatly to the strength of the tincture, with bad results in its use, causing in the case of iodine, for instance, severe burns in its use when it is too strong.

Lime and Cement.—The losses in lime and cement are chiefly due to the absorption of moisture. They should, therefore, be kept in a dry place. If they are to be kept any great length of time, they should be purchased in tight barrels rather than in bags, since more moisture is absorbed through the latter.

Fruits and Vegetables.—All housekeepers are familiar with losses in fruits and vegetables due to evaporation or to the growth of mold or development of rot, so that it is unnecessary to give detailed methods of preventing this loss. Each housekeeper must learn by experience which of the places available is the best for keeping the particular kind of fruit or vegetable in question. Both moisture and temperature conditions play very important part in the keeping quality of fruits and vegetables.

Ice.—In preventing the loss of ice one should keep clearly in mind what it is which we wish to conserve in the use of ice. Ice is purchased to cool materials, usually by first cooling the air surrounding the materials in question. As the object of the ice is then to cool the air, it is not desirable to cover the ice, since that would prevent the object sought, but rather the air when cooled should be kept covered by insulating it from warmer objects. This means that it is important that the ice box or refrigerator should be well insulated and that the ice in the refrigerator should not be insulated by the use of a blanket or paper.

An exception to this rule of the uselessness of an ice blanket occurs when conditions are such that a refrigerator can be iced only at intervals of several days. Under such circumstances somewhat more uniform conditions can be obtained by partially covering the ice with a blanket or paper during the first day when the supply is extra large and removing the blanket when the ice is partly melted.

Since many refrigerators on the market are not sufficiently insulated, it would be well for housekeepers to place a thermometer in the refrigerator and read it several times during the melting of one filling of ice to ascertain at what point the temperature rises too high for the adequate keeping of food. The growth of bacteria in foods increases enormously as the temperature approaches 60° F, and a sufficient supply of ice should be kept in the ice box at all times to prevent the temperature reaching this point. Further details on the subject of refrigeration will be found in Bureau of Standards Circular No. 55 on "Measurements for the Household," pages 50 to 55.

Gas and Water.—The leakage of gas and water from pipes, even though the leak is a small one, may amount in the course of 24 hours to a considerable quantity. In some cities regular inspection of fixtures is made to check such losses. The householder in his own interest, however, should note such leakages and have them corrected at once.

6. MEASUREMENT OF MATERIALS IN BULK

Methods of measurement of materials in bulk have been given in Bureau of Standards Circular No. 55 on "Measurements for the Household,"[19] pages 30 to 37, and hence need not be given in detail here. Tables giving the weights per bushel of various commodities, the number of cubic feet of coal per ton, and weights of water per gallon and per cubic foot, etc., are given on the following pages.

7. TABLES

(*a*) 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

[19] This publication may be procured from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 15 cents.

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 p. 249.)

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

[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 2½ acres.

(*b*) Table of the Equivalents of the Common Capacity Units Used in the Kitchen

Units	Fluid drams	Tea-spoon-fuls	Table-spoon-fuls	Fluid ounces	1/4 cup-fuls	Gills (1/2 cup-fuls)	Cup-fuls	Liquid pints	Liquid quarts	Cubic centi-meters	Liters
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
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
1 tablespoonful equals..	4	3	1	1/2	1/4	1/8	1/16	1/32	1/64	15	0.015
1 fluid ounce equals....	8	6	2	1	1/2	1/4	1/8	1/16	1/32	30	0.030
1/4 cupful equals	16	12	4	2	1	1/2	1/4	1/8	1/16	59	0.059
1 gill (1/2 cupful) equals.	32	24	8	4	2	1	1/2	1/4	1/8	118	0.118
1 cupful equals.........	64	48	16	8	4	2	1	1/2	1/4	237	0.237
1 liquid pint equals.....	128	96	32	16	8	4	2	1	1/2	473	0.473
1 liquid quart equals...	256	192	64	32	16	8	4	2	1	946	0.946
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
1 liter equals...........	270	203	67.6	33.8	16.9	8.45	4.23	2.11	1.06	1000	1

(*c*) Table of the 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 1916. 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.

States	Apples		Barley	Beans[a]	Beets	Blue-grass seed	Buckwheat	Carrots	Clover seed	Shelled corn	Corn meal[a]	Cottonseed[a]
	Apples[a]	Dried apples										
United States	50		48	60			42			56		
Alabama		24	47	60						56	[b] 46	32
Arizona												
Arkansas	[c] 50	24	48	[d] 60		14	52		60	56	48	33⅓
California			50				40			52		
Colorado			48	60		14	52		60	56	50	
Connecticut	48	25	48	60	[e] 60		48	50	60	56	50	[f] 44
Delaware										56	[b] 44	
District of Columbia												
Florida	[c] 48	24	48	[g] 60						56	48	[h] 32
Georgia		24	47	[d] 60		14	52		60	56	[b] 48	30
Hawaii			48							56		
Idaho	[c] 48	24	48	60	56	14	50	50	60	56	48	
Illinois	[c] 50	24	48	[d] 60	60	14	52	50	[i] 60	56	[j] 48	32
Indiana		25	48	60		14	50		60	56	50	
Iowa	48	24	48	[k] 60	56	14	48	50	60	[l] 56	48	
Kansas	[c] 48	24	48	60	56	14	50	50	60	56		
Kentucky		24	47	[d] 60		14	56		60	56	50	
Louisiana			48							56		
Maine	44	25	48	[m] 60	60		48	50	60	56	50	[f] 44
Maryland	[c] 50	28	48	[k] 60		14	48	50	60	56	48	
Massachusetts	48	25	48	[m] 60	60		48	50	60	56	50	[f] 44
Michigan	48	22	48	60		14	48		60	56	50	
Minnesota	[c] 50	28	48	[m] 60	50	14	50	45	60	56		
Mississippi		26	48	[d] 60		14	48		60	56	48	32
Missouri	48	24	48	60		14	52	50	60	56	50	33
Montana	45		48	60	50	14	52	50	60	56	50	
Nebraska	[c] 48	24	48	60	56	14	50	50	60	56		
Nevada	[c] 48	24	48	60	56	14	50	50	60	56	48	
New Hampshire	48	25	48	[d] 60	60		48	50	60	56	50	
New Jersey	50	25	48	60	60		48	50	60	56		
New Mexico	45	24	48	60	56	14	52	50	60	56	50	32
New York	48	25	48	60			48	50	60	56	50	[f] 44
North Carolina	[c] 48	24	48	[n] 60	50	14	50	50	[o] 60	56		[p] 30
North Dakota	50		48	60	60		42		60	56		
Ohio	48	24	48	60	56		50	50	60	56	48	
Oklahoma	48	24	48	60		14	52	50	60	56	50	32
Oregon	45	28	46				42		60	56		
Pennsylvania	45	25	47	[k] 60	56	14	48	50	60	56	50	
Rhode Island	48	25	48	60	50		48	50	60	56	50	[f] 44
South Carolina	[c] 50	24	48	[k] 60	50	14	50	50	[o] 60	56	[b] 50	30
South Dakota	48	24	48	60	56	14	52	50	60	56	50	
Tennessee	[c] 50	24	48	[k] 60	50	14	50	50	[o] 60	56	[b] 50	28
Texas	45	28	48	[d] 60			42		60	56		32
Utah												
Vermont	48		48	60	60		48	50	60	56	50	
Virginia		28	48	[q] 60		14	48	50	60	56	48	30
Washington	[c] 45	28	48				42		60	56		
West Virginia	[c] 50	24	48	[r] 60		14	52	50	60	56	48	
Wisconsin	44	25	48	60	50	14	50	50	60	56	50	[f] 44
Wyoming												

[a] Not defined.
[b] Bolted; unbolted, 48 pounds.
[c] Green apples.
[d] White beans.
[e] Sugar beets.
[f] Sea island; upland, 30 pounds.
[g] Shelled.
[h] Sea island, 46 pounds.
[i] Sweet-clover seed; unshelled, 33 pounds.
[j] Unbolted.
[k] Dried.
[l] Field corn.
[m] White runner pole beans, 50 pounds.
[n] Dry.
[o] Red and white.
[p] Sea island, 44 pounds.
[q] Navy and soja.
[r] Dry and shelled.

	Cranberries	Cucumbers	Flaxseed (linseed)	Hempseed	Hungarian grass seed	Millet	Oats	Onions		Orchard grass seed	Parsnips	Peaches [a]
								Onions [a]	Onion sets			
United States			56				32					50
Alabama							32					
Arizona												
Arkansas			56			50	32	57		14		
California							32					
Colorado				44			32	57				
Connecticut			55				32	52			45	
Delaware												
District of Columbia												
Florida						50	32	56				[b] 54
Georgia			56	44			32	57				
Hawaii							32					
Idaho			56	44	50	50	32	57			50	48
Illinois	33	48	56	44	50	50	32	57	[e] 30	14	50	48
Indiana	33			44		50	32	48		14	55	
Iowa		48	56	44	50	50	32	52	[e] 28	14	45	48
Kansas			56	44	50	50	32	57			50	48
Kentucky			56	44	50	50	[d] 32	57	[e] 36	14		
Louisiana							32					
Maine	32		56	44	48	50	32			14	45	48
Maryland			56	44	50	50	32	54		14		[f] 40
Massachusetts	32		55				32	52			45	48
Michigan	40		56	44	50	50	32	54		14		
Minnesota	36	48	56	50	48	48	32	52	[e] 28	14	42	48
Mississippi			56	44	50	50	32	57				
Missouri		48	56	44	48	50	32	57	[g] 28	14	44	48
Montana			56	44	50		32	57			50	
Nebraska			56	44	50	50	32	57	[g] 25		50	48
Nevada			56	48	50	50	32	57			50	48
New Hampshire	32		56				32	52			45	48
New Jersey			55				32	57				[h] 50
New Mexico		48	56	44	50	50	32	57	[e] 30	14	42	48
New York			55				32	57				
North Carolina		48	56	44	48	50	32	57	[e] 28	14	50	[h] 50
North Dakota			56			50	32	52				
Ohio			56	44	50	50	32	56	28		50	48
Oklahoma		48	56	44	48	50	32	57	[g] 28	14	44	48
Oregon							32					
Pennsylvania	40	50	56	44	50	50	32	50	28	14	50	48
Rhode Island			56	44	50	50	32	50			50	48
South Carolina		48	56	44	48	[i] 50	32	[h] 56	[e] 28	14	50	[h] 50
South Dakota		48	56	44	50	50	32	57	[e] 30	14	42	48
Tennessee		48	56	44	48	[i] 50	32	56	[e] 28	14	50	[h] 50
Texas			56	44	48	50	32	57				50
Utah												
Vermont	32	48	55		50	50	32	52			45	48
Virginia			56	44	48	50	32	57		14	50	
Washington			56				32					
West Virginia	36	[b] 50	56	44	50	50	32	55		14	42	48
Wisconsin	35	[b] 50	56	44	48	50	32	50	32		44	48
Wyoming												

[a] Not defined.
[b] Green.
[c] Top sets; bottom sets, 32 pounds.
[d] Shelled.
[e] Bottom sets.
[f] Peeled; unpeeled, 32 pounds.
[g] Top sets.
[h] Matured.
[i] Geman, Missouri and Tennessee.

	Peanuts (or "ground peas")	Pears [a]	Peas		Potatoes		Red top	Rye	Timothy seed	Tomatoes	Turnips [a]	Wheat
			Green peas unshelled	Peas [a]	Potatoes	Sweet potatoes						
United States	......	50	......	60	......	......	......	56	......	......	......	60
Alabama	......	......	......	60	60	55	......	56	......	......	55	60
Arizona	......	......	......	......	......	......	......	......	......	......	......	......
Arkansas	......	......	......	60	60	50	14	56	60	......	57	60
California	......	......	......	......	......	......	......	54	......	......	......	60
Colorado	......	......	......	......	60	......	......	56	45	......	......	60
Connecticut	......	......	......	60	60	54	......	56	45	......	[b] 50	......
Delaware	......	......	......	......	......	......	......	......	......	......	......	60
District of Columbia	......	......	......	......	60	......	......	......	......	......	......	60
Florida	22	60	......	......	60	60	......	56	......	......	54	60
Georgia	25	......	......	60	60	55	......	56	45	......	55	60
Hawaii	......	......	......	......	......	......	......	56	......	......	......	60
Idaho	......	......	......	[d] 60	60	50	......	56	45	56	55	60
Illinois	[e] 20	58	32	[f] 60	60	50	14	56	45	56	55	60
Indiana	......	......	......	......	60	55	......	56	45	......	55	60
Iowa	22	45	50	[f] 60	60	50	14	56	45	50	55	60
Kansas	......	......	......	[d] 60	60	50	......	56	45	56	55	60
Kentucky	[e] 24	......	......	60	60	55	......	56	45	......	60	60
Louisiana	......	......	......	......	......	......	......	56	......	......	......	60
Maine	[e] 20	58	28	60	60	54	14	56	45	56	[b] 50	60
Maryland	22	......	......	[f] 60	60	60	[g] 14	56	45	60	60	60
Massachusetts	[e] 20	58	28	[h] 60	60	54	......	56	45	56	55	60
Michigan	......	......	......	60	60	56	[i] 14	56	45	......	58	60
Minnesota	22	45	......	[h] 60	60	55	[i] 14	56	45	50	55	60
Mississippi	[c] 24	......	......	60	60	54	......	56	45	......	55	60
Missouri	......	48	56	60	60	56	[i] 14	56	45	45	[j] 42	60
Montana	......	45	......	60	60	......	......	56	45	......	50	60
Nebraska	......	......	......	[d] 60	60	50	......	56	45	56	55	60
Nevada	......	......	......	[d] 60	60	50	......	56	45	56	56	60
New Hampshire	[e] 20	58	......	60	60	54	......	56	45	56	55	60
New Jersey	......	......	......	60	60	54	......	56	45	......	......	60
New Mexico	22	48	......	60	60	50	......	56	45	50	56	60
New York	......	......	......	60	60	54	......	56	45	......	......	60
North Carolina	22	[k] 56	30	[l] 60	56	56	14	[m] 56	45	56	50	60
North Dakota	......	......	......	60	60	46	......	56	45	......	60	60
Ohio	......	......	......	60	60	50	......	56	45	56	60	[n] 60
Oklahoma	22	48	56	60	60	55	[i] 14	56	45	45	[j] 42	60
Oregon	......	45	......	......	60	......	......	56	......	......	......	60
Pennsylvania	22	50	56	[f] 60	60	54	14	56	45	60	60	60
Rhode Island	......	......	......	60	60	54	......	56	45	56	50	60
South Carolina	23	[k] 36	[o] 30	[l] 60	60	50	14	56	45	56	50	60
South Dakota	20	......	50	60	60	46	14	56	45	50	55	60
Tennessee	23	[k] 56	30	[l] 60	60	50	[i] 14	56	45	56	50	60
Texas	......	......	......	......	60	55	......	56	45	55	55	60
Utah	......	......	......	......	......	......	......	......	......	......	......	......
Vermont	[e] 20	58	28	60	60	54	14	56	45	56	60	60
Virginia	[p] 22	......	......	......	60	56	40	56	45	60	55	60
Washington	......	[q] 45	......	......	60	......	......	56	......	......	......	60
West Virginia	......	......	......	[l] 60	60	50	14	56	45	56	......	60
Wisconsin	......	48	......	60	60	54	14	56	45	56	42	60
Wyoming	......	......	......	......	......	......	......	......	......	......	......	......

[a] Not defined.
[b] Common English.
[c] Ground peas.
[d] Shelled dried peas.
[e] Roasted; green, 22 pounds.
[f] Dried.
[g] Redtop grass seed (chaff); fancy, 32 pounds.
[h] Smooth peas.
[i] Redtop seed.
[j] Common.
[k] Matured.
[l] Dry.
[m] Seed.
[n] Domestic.
[o] Not stated whether shelled or unshelled.
[p] Virginia peanuts.
[q] Green.

(*d*) **Approximate Volume in Cubic Feet of 1 Ton of Coal**

Size	Tons of 2240 pounds		Tons of 2000 pounds	
	White ash	Red ash	White ash	Red ash
Egg	39.3	42.3	35.1	37.7
Stove	39.6	42.7	35.4	38.1
Nut	40.4	43.1	36.0	38.5
Pea	41.9	43.9	37.4	39.2
Buckwheat	42.3	44.4	37.7	39.6

(*e*) **Weight of 1 Gallon and of 1 Cubic Foot of Water**

This table gives the weights of 1 gallon (231 cubic inches) and of 1 cubic foot of pure (distilled) water for each degree of temperature of the centigrade scale from 0° to 40°. The weights are for weighings made in air at 760 mm pressure (the normal atmospheric pressure at sea level) and against brass weights. More extensive tables of the weight of water under various conditions may be found in Bureau of Standards Circular No. 19. This table can be used in the testing of large capacity measures by weighing the water which they contain, reading the temperature of the water at the time of weighing, and computing the volume from these weights. Undistilled but filtered fresh river water weighs from 1 to 3 parts in 10 000 more than the figures given below. Spring and well water may vary from 3 to 60 parts in 10 000 more than the weights given below, depending upon the amount of foreign matter, mineral and vegetable, which the water contains. This table may also be used to determine the weight per gallon or per cubic foot of any liquid or solid of which the specific gravity ir terms of water at some temperature is known. This is done by multiplying the weight of water at the temperature for which the specific gravity is known by the specific gravity. Thus, if a certain gasoline has a specific gravity of 0.65, compared with water at 60° F ($16\frac{2}{3}$° C), 1 gallon of the gasoline will weigh 0.65 times 8.327, or 5.413 pounds. The weights corresponding to $15\frac{5}{9}$° C (60 F) and $16\frac{2}{3}$° C (62° F) have been included in the table because of the frequent use of these temperatures in engineering and industrial work, especially in stating specific gravities.

Temperature, °C	Weight in air		Temperature, °C	Weight in air		Temperature, °C	Weight in air	
	1 gallon	1 cubic foot		1 gallon	1 cubic foot		1 gallon	1 cubic foot
	Pounds	Pounds		Pounds	Pounds		Pounds	Pounds
0	8.335	62.347	15	.329	.305	30	.301	.093
1	.336	.351	$(15\frac{5}{9})$ 60° F	(8.328)	(62.299)	31	.298	.074
2	.336	.354	16	.328	.295	32	.295	.054
3	.336	.356	$(16\frac{2}{3})$ 62° F	(8.327)	(62.288)	33	.293	.034
4	.336	.357	17	.326	.285	34	.290	.014
			18	.325	.274			
5	.336	.356	19	.323	.262	35	.287	61.993
6	.336	.355				36	.284	.971
7	.335	.353	20	.322	.250	37	.281	.949
8	.335	.350	21	.320	.237	38	.278	.927
9	.334	.346	22	.318	.224	39	.275	.904
			23	.316	.209	40	.272	.881
10	.334	.341	24	.314	.194			
11	.333	.335						
12	.332	.329	25	.312	.179			
13	.331	.322	26	.310	.163			
14	.330	.313	27	.308	.146			
			28	.305	.129			
			29	.303	.111			

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(For analytical outline see "Contents," p. 3.)

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