DEPARTMENT OF COMMERCE

CIRCULAR
OF THE
BUREAU OF STANDARDS

S. W. STRATTON, Director

No. 106

LIME—DEFINITIONS AND SPECIFICATIONS

[1st Edition]

NOVEMBER 24, 1920

PRICE, 5 CENTS

Sold only by the Superintendent of Documents, Government Printing Office
Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1920

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CONTENTS

1. INTRODUCTION

Up until the present generation the term "lime" has been sufficiently well understood for all practical purposes. Recent progress in the industry has developed many new uses for lime and many new kinds of lime to supply these uses. The result has been a growth of nomenclature which is apt to be confusing to those who have not kept in close touch with the subject. In order that the uninitiated user may be protected from buying a kind of lime which is not suitable for his purpose, and in order that the dealer may gain an intelligent understanding of the kind of lime which the buyer needs, it is thought opportune to explain the meanings of the various trade terms now in use.

2. LIMESTONE

- Sedimentary rocks:
  - Carbonate rocks—
    - Rock minerals.
      - Calcite.
      - Dolomite.
      - Aragonite.
    - Lime-magnesia ratio—
      - High-calcium.
      - Calcium.
      - Magnesian.
      - Dolomitic.

- Sedimentary rocks—Continued.
  - Carbonate rocks—Continued.
    - Purity—
      - Siliceous.
      - Argillaceous.
      - Cement rock.
    - Physical characteristics—
      - Marble.
      - Chalk.
      - Marl.
- Oyster shells.
- Cut stone:
  - Building or dimension stone.
  - Marble.
- Quarried stone:
  - One-man stone.
  - Crushed stone—
    - Sizes.
    - Flux stone.
    - Ballast.
    - Road metal.
    - Chicken grits.
    - Ground limestone.
    - Whiting.
- Precipitated calcium carbonate.

All rocks which form the crust of the earth are divided by geologists into two classes, igneous and sedimentary. The sedimentary were formed by the consolidation of sediment which settled out from a body of water. There are many kinds of sedimentary rocks, but by far the greatest mass of them belong to the group known as carbonate rocks. This group differs from all others in the matter of chemical composition—the carbonate rocks are chemical compounds of some base with carbonic acid. The base may be any one of a number of materials. Thus, carbonate of calcium is the mineral calcite; of magesium, magnesite; of iron, siderite; etc. There are also minerals in which two bases are combined with the carbonic acid, such as brunnerite (carbonate of magnesium and iron), dolomite (carbonate of magnesium and calcium), etc. Another form of calcium carbonate, known as aragonite, differs from calcite in the shape of its crystals but not in its chemical composition. Limestone is a sedimentary carbonate rock, consisting chiefly of calcite or dolomite or of mixtures of the two. Obviously, there are many kinds of limestone, depending upon whether the calcite or dolomite predominates. The former are designated by the term "high-calcium;" the latter, "high-magnesian" or "dolomitic." Intermediate mixtures constitute "calcium" or "magnesian" limestone. There are no sharp lines of demarcation between these different kinds. Many attempts have been made to fix such lines arbitrarily, but these attempts have not been successful, probably because the trade does not seem to be in need of such exact classification.

All limestones contain substances other than calcite or dolomite. Stones are classified according to the quantity and quality of these impurities. If the quantity of them is less than 5 per cent, they are usually not mentioned. If they occur in larger quantities, they give rise to a qualifying adjective, such as "siliceous" (containing silica), "argillaceous" (containing clay), etc. Some limestones contain impurities in such kinds and amounts that when calcined they produce Portland or natural cement. Such stones are known as "cement rock."

Limestones are also classified according to their physical characteristics. When the stone is very hard and compact and of such a nature that it will take a polish, it is termed "marble." "Chalk" is a form which is very soft and can be readily cut. A still softer form, in which the original sediment has not yet been consolidated into rock, is termed "marl."

Oyster shells still form a considerable source of supply of calcium carbonate. They can hardly be classed as limestone.

Owing to the nature of its formation by deposition from water, limestone occurs in beds of greater or less thickness. If the beds are sufficiently thick and the stone is hard and without flaws, it may be cut out with a channeling machine to produce blocks of stone of given dimensions. Such stone is sold as "building" or "dimension" stone. A beautiful color or veining and the ability to take a polish will qualify it for sale as marble. A marble is always a limestone (or dolomite), but a building or dimension stone may be of any composition.

When the beds are not sufficiently thick or regular to permit of channeling, the stone is drilled and blasted. This produces pieces of irregular shape and size. The largest size which it is practicable to handle is a piece which can be picked up by a steam shovel—say about 1 cubic yard. Such large pieces are not marketed, but there are stone crushers large enough to take them and break them down to commercial sizes.

The largest commercial size is known as "one-man" stone. This is a piece as large as one man can handle—say about 1 cubic foot.

Such stone finds some use as "rubble" in the erection of rough stone masonry and is also used for the manufacture of lime.

Smaller sizes, obtained by crushing and screening the product of the quarry, are sold under the general name of "crushed stone" and can be had in any desired size. In specifying such stone the maximum size is always stated, and the minimum size is also stated, if there is one. Thus, 4-inch stone is material, the largest pieces of which will pass through a ring 4 inches in diameter; 4 to 2½-inch stone is the same material, except that all pieces which will pass a 2½-inch ring have been screened out.

Crushed stone is used for a great many purposes and frequently derives its trade name from its use. "Flux stone" is a particularly pure limestone which is used as a flux in the manufacture of pig iron. Crushed limestone of the proper size is used as "ballast" for railroads, or as "road-metal" for macadam roads. Still smaller sizes are used as the coarse aggregate in concrete and asphalt. Pieces about one-eighth to one-sixteenth inch are sold as "chicken grits." Finely ground limestone is used in the manufacture of Portland cement, glass, pottery, and numerous other materials. If not too fine, it may be used as "sand" in the manufacture of mortar or plaster. An extremely fine grade, containing no grit, is sold as "whiting" for the manufacture of paper, textiles, paint, putty, etc. Precipitated calcium carbonate is an extremely pure and finely divided material which is used as an ingredient in silver polish, dentifrices, table salt, etc.

A large quantity of ground limestone is sold as agricultural lime. For this purpose there is no definite limit as to size or purity. There is, however, an economic limit, for the finer it is ground and the more nearly pure it is the greater its value to the farmer.

3. LIME

Quicklime *v.* slaked lime.
Lump lime *v.* ground lime.
Stone lime *v.* shell lime.
Kind of kiln: Rotary, pot, etc.
Kind of fuel: Wood-burnt lime.
Burning temperature: Core, or overburnt lime.
Selected *v.* run-of-kiln lime.
Use:
- Agricultural lime.
- Chemical lime.
- Structural lime.

Lime is the product resulting from the calcination of limestone. The stone is a carbonate of calcium, or of calcium and magnesium.

When it is calcined (burnt), the carbonic acid escapes as a gas into the air. The material remaining is the oxide of calcium or of calcium and magnesium. This, then, is lime, properly so called. The adjectives used to describe the composition of the stone are equally applicable to the lime. Thus a lime may be high-calcium or dolomitic, siliceous or argillaceous, etc. The material as it comes from the kiln is frequently called "quicklime" to distinguish it from "slaked lime," which has been treated with water. Quicklime is commonly sold in large pieces, as "lump" lime. It may be put through a crusher to make "ground" lime. "Stone lime" is made from limestone, while "shell lime" is made from oyster shells. The quality of the lime depends to some extent upon the kind of kiln in which it was burnt; rotary-kiln lime is noted for its ability to slake very quickly; pot-kiln lime usually contains some coal-ashes mixed with it. The fuel used is also important, wood-burnt lime usually being accepted as the best. It is of course impracticable for the quality of the product of any kiln to be entirely uniform. It will contain more or less overburnt lime and underburnt lime or core. If these materials are sorted out and discarded, the resultant product is termed "selected" lime; otherwise it is called "run-of-kiln" lime.

Lime is divided into three classes, according to its use: Agricultural, chemical, and structural. Agricultural lime is applied to the soil to neutralize acidity; it is used in sprays for fruit trees, etc. Chemical lime is used as a chemical reagent in the manufacture of other materials. Structural lime is a building material, used for making mortar, plaster, stucco, concrete, etc.

In both the agricultural and chemical fields the word lime is given a much broader meaning than is indicated above. It means apparently any material which will produce the same effect as lime. Thus the farmer speaks of liming his field, even though the material he uses is ground limestone or air-slaked lime. A glass chemist figures out the amount of lime required for a batch of glass and then puts in an equivalent amount of limestone. In all such cases if the oxide form is meant, it is better to use the word quicklime. Agricultural experts are now endeavoring to introduce the term "burnt" lime, to include quicklime, hydrated lime, and air-slaked lime, in contradistinction to ground limestone, which has not been burnt. In the structural field, lime includes quicklime, hydrated lime, or slaked lime, but not ground limestone or air-slaked lime.

4. SLAKED LIME

Lime putty.
"Running-off."
Burning and drowning.

When quicklime is mixed with water it slakes. Slaking is denoted by the complete disintegration of the lumps of lime, considerable expansion in volume, and the evolution of heat. The resultant product is a plastic mass, termed "lime putty" or "slaked" lime. Pieces of core, coal ashes, and similar impurities will not disintegrate, but remain as lumps. They are removed by washing the putty through a coarse screen (one-eighth inch), letting it settle, and draining off the excess water. This process is known as "running off" the lime. After standing for at least 12 hours the putty may be mixed with sand or gypsum and used as plaster or mortar. Lime can be spoiled by careless slaking. If too little water is used, the lime may "burn," and the resultant product is apt to be unsound unless it is soaked for some time before use. Too much water will "drown" the lime. This results in the production of a smaller quantity of putty than the lime should yield. Many building codes require that lime putty shall be aged for not less than one week before use. The lime must not be permitted to dry out during this aging.

Chemically speaking, quicklime is composed of the oxide of calcium mixed with more or less of the oxide of magnesium. On slaking, the calcium oxide combines with water, but the magnesium oxide does not—at least not to any great extent in a reasonable period of time. Slaked lime is therefore a mixture of calcium hydroxide, magnesium oxide, and a decided excess of water.

5. HYDRATED LIME

Masons' hydrate.
Finishing hydrate.

Quicklime may be slaked with just enough water to combine with the calcium oxide, in which event the product will be a dry powder instead of a putty. This powder is sold as "hydrated" lime. Chemically, therefore, hydrated lime is identical with slaked lime. It differs from the latter in that it contains no excess water. To make mortar or plaster of hydrated lime simply mix it with water and let it age for 12 hours. No "running off" is required. Use in the same way as putty made from quicklime. For addition to Portland cement mortar or concrete hydrated lime may be handled in the same way as the cement, being added directly to the mixer.

The adjectives used to describe limestone and quicklime are used with the same meaning to describe hydrated lime wherever they are applicable. In addition, there are two classes of structural hydrate—"masons'" and "finishing." Masons' hydrate is used for all structural purposes except the final coat of plaster. This "finish" coat requires such a high degree of plasticity that lime for this purpose must be either finishing hydrate or else putty made from quicklime.

6. AIR-SLAKED LIME

When either quicklime or hydrated lime is stored without reasonable protection from the weather it will absorb water and carbonic acid from the air. The mass heats slightly, and any lumps of quicklime will disintegrate. The product, termed "air-slaked" lime, is a carbonate of calcium and magnesium chemically identical with limestone. It can be used as ground limestone for agricultural or chemical purposes, but is worthless as a structural material.

Air-slaked lime should not be confused with hydrated lime. The two materials are similar in appearance, but radically different in composition. Since hydrated lime is a hydroxide, a putty made from it will absorb carbonic acid when exposed to the air, and will "set." A putty made from air-slaked lime, which is already a carbonate, can not absorb carbonic acid, and can not set.

7. SHIPMENTS AND PACKAGES

Limestone.
Ground limestone.
Agricultural lime.
Quicklime:
  Federal lime-barrel law.
Hydrated lime.
Air-slaked lime.

Limestone, whether as cut stone or crushed stone, is usually shipped in bulk. Ground limestone comes in burlap bags of various sizes. Possibly the most common size weighs 167 pounds net, or 12 bags to the ton. Paper bags, 24 to the ton, are also used.

Many States prescribe by law that a bag of fertilizer must be marked to show its net weight, the minimum guaranteed analysis of the contents, and the name of the manufacturer. These laws apply to "agricultural lime," whether it is ground limestone, ground quicklime, or hydrated lime.

When quicklime goes direct from manufacturer to consumer, or when the retailer has facilities for storage, the lime is shipped in bulk in box cars. The usual retail package is the wooden barrel. Federal law prescribes that a barrel of lime shall weigh either 180 or 280 pounds net, and shall be marked to show its weight, the name of the manufacturer, and the place where it was made. The larger barrel is used in New York City; practically all other markets use the 180-pound barrel. The cost of wood is now so high that steel barrels are coming into use in many localities. A steel drum which can be sealed air-tight has found extensive use as a container for chemical lime, where the lime must not be air-slaked in transit. A new package which is in use in one locality is a waterproofed pasteboard carton, holding 90 pounds.

The standard package for hydrated lime is a paper bag holding 50 pounds. A smaller package, about 10 pounds, has recently come on the market to be retailed by grocers for use on kitchen gardens and lawns.

Air-slaked lime is not packed or shipped. It can be obtained by the load from local manufacturers or dealers.

8. STORAGE

Quicklime.
Hydrated lime.

Quicklime, when exposed to the air, will absorb water and carbonic acid and air-slake. The final product is of no value as a building material. The storage of quicklime therefore requires especially constructed bins or buildings, designed to be as nearly air-tight as possible, and, above all, to keep the lime dry. The amount of heat generated by air-slaking is frequently sufficient to set fire to wood. The storage of quicklime in a wooden bin or building constitutes a serious fire hazard.

The air-slaking of hydrated lime is indicated by the formation of a crust of hard material at the exposed surface of the package. This crust and the fineness of the powder make it difficult for the air to penetrate very far into the package, so that usually only a negligible proportion of it is spoiled. The air-slaking of hydrated lime is not accompanied by the evolution of enough heat to be dangerous. Hydrated lime should therefore be stored in the same way as Portland cement: It should be reasonably protected from the weather, and should be kept dry.

9. PROPORTIONS FOR USE

- Agricultural lime:
  - For lawns and gardens.
  - For farms.
- Structural lime:
  - Whitewash.
  - Mortar—
    - Lime mortar.
    - Cement-lime mortar.
  - Plaster—
    - Scratch coat.
    - Brown coat.
    - Finish coat.

The following figures, quoted largely from various publications of the National Lime Association, give an idea of the quantities of lime required for various agricultural and structural purposes:

For lawns or gardens, apply 17 pounds of ground quicklime or 22 pounds of hydrated lime, or 30 pounds of ground limestone, per square rod.

For farms, the quantity cf lime to be used depends upon too many factors to permit making any general statement. The present condition of the soil and the kind of crop to be raised must be considered. For general purposes, it may be stated that 1120 pounds of quicklime, 1480 pounds of hydrated lime, or 1 ton of ground limestone, per acre, will usually be satisfactory.

Whitewash may be made according to the following formula: Add enough water to 12 pounds of hydrated lime to make a thick cream. Dissolve 1 pound of washing soda in 1 gallon of boiling water, and add this to the lime. Dissolve one-fourth pound glue and 1 pound rice flour in three quarts of water. Add this to the above mixture and apply. The above quantities will make enough whitewash to cover about 600 square feet.

Enough lime mortar to lay 1000 bricks can be made from 1⅛ barrels of quicklime, or 5 bags of hydrated lime, and one-half cubic yard of sand. If a stronger mortar is desired, use 1½ bags of hydrated lime, one-half barrel of Portland cement, and one-half cubic yard of sand.

The first, or scratch, coat of plaster should consist of 100 pounds of hydrated lime, 350 pounds of sand, and three-fourths pound of hair. For the second, or brown, coat, use 100 pounds of hydrated lime, 400 pounds of sand, and three-eighths pound of hair. The third, or finish, coat is made of one volume of calcined gypsum to two volumes of lime putty, using either quicklime or finishing hydrate.

10. WORK OF THE BUREAU OF STANDARDS

Cooperation with other organizations.
Laboratory research.
Collection and distribution of information.
Routine tests.

The work which the Bureau is conducting on the general subject of lime may be divided into four classes: (1) Cooperation with other organizations in the development of standard specifications; (2) laboratory research work to obtain information about the properties of lime; (3) the collection and distribution of information about new developments in the manufacture and use of lime; (4) routine tests of lime intended for purchase by different branches of the Government service.

Under the first class would come cooperation with the American Society for Testing Materials in the preparation of specifications for various kinds of lime; also, with an interdepartmental conference of the Government in the preparation of standard specifications for lime for use in the chemical industries. In cooperation with representatives of a number of national associations of manufacturers and users, the Bureau is preparing a national code dealing with wall plaster as a structural material.

The research work in class 2 includes such matters as the development of standard methods of testing lime for strength, time of set, soundness, plasticity, etc.; determination of the effect of the burning temperature and of the impurities on the properties of lime; the effect of the addition of lime to Portland cement mortars and concretes; investigation of the causes of plasticity and of unsoundness; measurement of the color, the acoustical properties, and the fire resistance of lime plasters; and many similar matters.

Under class 3 may be included the measurement of the fuel efficiency of different types of limekilns and different kinds of fuel. A comparison of the designs of kilns, hydrators, and stone crushers used by the industry is now being made.

11. PUBLICATIONS

Many of the subjects listed above have been covered in reports published in the Proceedings of the National Lime Association, Proceedings of the American Society for Testing Materials, Journal of the American Ceramic Society, or Rock Products and Building Materials. In addition, the Bureau has issued three publications on lime: Circular No. 30, "Lime: Its Properties and

Uses," gives a somewhat detailed statement as to the quality of lime best adapted to different uses. Technologic Paper No. 16, "The Manufacture of Lime," contains descriptions of 19 representative lime plants, and a criticism of their equipment and methods. Circular No. 96, "Recommended Specifications for Lime for Use in Cooking Rags in the Manufacture of Paper," is fully explained by its title.

12. SPECIFICATIONS

Circular No. 96 is the only specification for lime which has been issued by the Bureau as a Bureau specification. It is the first of a series of similar specifications which are being developed by the Interdepartmental Conference on Chemical Lime. In addition, the Bureau has taken an active part in the work of the American Society for Testing Materials, and thereby shares the responsibility for the three specifications which this committee has issued: No. C 5–15, for quicklime; No. C 6–15, for hydrated lime; and No. C 6–19 T, for masons' hydrated lime.

TENTATIVE SPECIFICATIONS FOR MASONS' HYDRATED LIME[1]

1. Definition.—Masons' hydrated lime is a dry, flocculent powder resulting from the hydration of quicklime.

2. Uses.—Masons' hydrated lime may be used for making lime mortar, for scratch or brown coat of plaster, or for addition to Portland cement mortar or concrete.

I. CHEMICAL PROPERTIES AND TESTS

3. Sampling.—The sample shall be a fair average of the shipment. Three per cent of the packages shall be sampled. The sample shall be taken from the surface to the center of the package. A 2-pound sample to be sent to the laboratory shall immediately be transferred to an air-tight container, in which the unused portion shall be stored until the shipment has been finally accepted or rejected by the purchaser.

4. Chemical Properties.—(*a*) The chemical composition of the hydrated lime shall be determined by standard methods of chemical analysis.

(*b*) *Impurities.*—The sum of the silica (SiO_2), ferric oxide (Fe_2O_3), and alumina (Al_2O_3) expressed on the sample as received shall not exceed 5 per cent.

(*c*) *Carbon Dioxide.*—Carbon dioxide in the sample as received shall not exceed 3 per cent.

(*d*) *Calcium and Magnesium Oxides.*—Calcium and magnesium oxides shall constitute not less than 90 per cent of the nonvolatile portion.

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[1] Serial Designation; C 6–19 T, issued by the American Society for Testing Materials as No. C 6–19 T, is recommended by the Bureau pending the issue of a revised specification which is now being developed. These specifications are issued under the fixed designation C 6; the final number indicates the year of original issue, or, in the case of revision, the year of last revision. Issued, 1917. Revised, 1919.

II. PHYSICAL PROPERTIES AND TESTS

5. FINENESS.—(*a*) A 100-g sample shall leave not more than 0.5 per cent of its weight on a standard 30-mesh sieve, and not more than 15 per cent of its weight on a standard 200-mesh sieve.

(*b*) The fineness test shall be made as specified in section 12.

6. CONSTANCY OF VOLUME.—(*a*) A pat of mortar, covered with a skim coat of neat paste, shall be subjected to the action of steam. If the steam has no visible effect on the pat, the sample shall be reported as being "sound." If the pat disintegrates, the sample shall be reported "unsound" and the shipment rejected. If the sample cracks, pops, or shows other minor defects, it shall not be reported as either sound or unsound, but its behavior shall be noted.

(*b*) The constancy of volume test shall be made as specified in section 13.

III. PACKING AND MARKING

7. PACKING.—(*a*) *Kind of Package.*—The hydrated lime shall be packed in either cloth or paper bags.

(*b*) *Size of Package.*—The cloth package shall contain 100 pounds, net weight, of hydrated lime. The paper package shall contain 50 pounds, net weight, of hydrated lime.

8. MARKING.—Each package shall be clearly marked to show the net weight of hydrated lime contained in the package, the name of the manufacturer, and the name of the brand, if any.

IV. INSPECTION AND REJECTION

9. INSPECTION.—(*a*) All hydrated lime shall be subject to inspection.

(*b*) Hydrated lime may be inspected either at the place of manufacture or the point of delivery, as arranged at the time of purchase.

(*c*) The manufacturer shall furnish the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere with the operation of the works.

(*d*) The purchaser may make the tests to govern the acceptance or rejection of the hydrated lime in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

10. REJECTION.—Unless otherwise specified, any rejection based on failure to pass tests prescribed in these specifications shall be reported within 5 working days from the taking of samples.

11. REHEARING.—Samples which represent rejected hydrated lime shall be preserved in air-tight containers for 5 days from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

V. METHODS OF TEST

12. METHOD FOR DETERMINING FINENESS.—Fineness of hydrated lime shall be determined as follows:

Place 100 g of the sample as received on a standard 30-mesh sieve having openings averaging 0.0198 inch. This sieve shall be nested above a standard 200-mesh sieve having openings averaging 0.0029 inch. Wash the material by means of a stream of water from a faucet. A small piece of rubber tubing attached to a water faucet will be found convenient. The velocity of the stream of water can be increased by pinching the tubing, but it should not be sufficient to cause any danger of splashing the sample over the sides of the sieve. Continue the washing until the water coming through the sieve is clear. Then dry the residue upon the 30-mesh sieve to constant weight in a drying oven whose temperature is maintained between 100 and 120° C in an atmosphere free from carbon dioxide. Calculate the weight of this residue as percentage of the original sample. Then wash the material which has passed the 30-mesh sieve and remained on the 200-mesh sieve through the latter as described above. Treat the residue on this sieve in the same manner as described above for the 30-mesh sieve and add the percentage retained to the percentage residue on the 30-mesh sieve. The sum of these two shall be reported as the residue on the 200-mesh sieve.

13. Method for Determining Constancy of Volume.—Constancy of volume shall be determined as follows:

To 20 g of the sample add 100 g of clean, washed, graded sand which shall all pass the No. 20 sieve and which shall all be retained on the No. 100 sieve. Mix thoroughly and add enough water to make a good plastic mortar of a rather dry consistency. Spread out on a clean glass plate, to form a layer about one-eighth inch thick by about 4 inches square. The pat shall be of even thickness throughout, and not tapering at the edges. If the mortar is too dry to work well, add more water. Place this pat in a closet to set for 24 hours. The temperature in the closet should be between 65 and 75° F, and there should be free circulation of air in the closet, without allowing any direct draft to hit the pat. At the end of 24 hours remove the pat from the closet and soak it in water, until a film of water stands unabsorbed on the surface of the pat. Examine the pat carefully for cracks. If any are found, too much water was used in making the pat, and it should be discarded and a new one made.

Mix 20 g of the sample with enough water to form a thick cream. Spread this out in a thin layer on the surface of the pat. Let it stand for 15 minutes to permit possible air bubbles to form. Trowel to a smooth even surface, making this skim coat as thin as possible without allowing the sand to show through. Put the pat back in the closet for another 24 hours, so that the skim coat can set. Examine carefully to insure the absence of any cracks or pops. Provide a vessel partially filled with cold water and having a perforated cover. Suspend the pat in this vessel in such a way that the water can boil without touching it. Gradually bring the water to a boil, and keep it boiling gently for 5 hours, the pat being surrounded by steam during this time. Turn out the fire and permit the water to cool for at least 12 hours before the cover is removed from the vessel. The pat is then removed and examined for cracking, popping, or disintegration.