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Issued February, 1926
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THE BROWN-DUVEL MOISTURE TESTER AND HOW TO OPERATE IT

By

D. A. COLEMAN and E. G. BOERNER, Grain Investigations, Grain Division
Bureau of Agricultural Economics

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THE BROWN-DUVEL[1] MOISTURE TESTER AND HOW TO OPERATE IT

By D. A. Coleman[2] and E. G. Boerner, *Grain Investigations, Grain Division, Bureau of Agricultural Economics*

CONTENTS

The Brown-Duvel moisture tester, as it is commercially known, and its method of testing moisture in grain were developed primarily to meet the demands of the grain trade for a rapid method of determining the moisture content of the various grains, and is specified by the United States Department of Agriculture as the official method for determining the moisture content of the grains for which official standards have been established under the provisions of the United States grain standards act.

Since the method was first developed, it has been further perfected for determining the moisture content of rice, of the more important seeds, of flour and meal, and certain other commodities. Modifications have been made both in the apparatus and in the methods for making tests and more specific instructions have been recently developed for so making the moisture tests as to accomplish greater accuracy and uniformity in the results with the apparatus.

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[1] This apparatus was originally invented by J. W. T. Duvel and Edgar Brown, United States Department of Agriculture, who hold Public Service Patent No. 848616 on the apparatus.

[2] Credit is given John H. Cox and H. C. Fellows, Grain Division, Bureau of Agricultural Economics, and to H. B. Musser, formerly scientific assistant in Grain Standardization, Bureau of Agricultural Economics, for some of the experimental data contained in this bulletin.

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Electrically-heated moisture testers have lately come into general use. Their operation and efficiency have been studied and comparisons drawn between them and the standard gas-heated machines. Wiring specifications have been worked out for electrically-heated machines and piping specifications for gas-heated machines.

Both the construction of the apparatus and the methods of making the tests have been made as simple as practicable, so that reliable tests can be made by any careful worker, even though he has not had the benefit of special chemical-laboratory training.

In making the tests it is of the utmost importance that the operator be a careful and honest worker, who can be depended upon to follow the instructions given for making the tests and who will report results correctly.

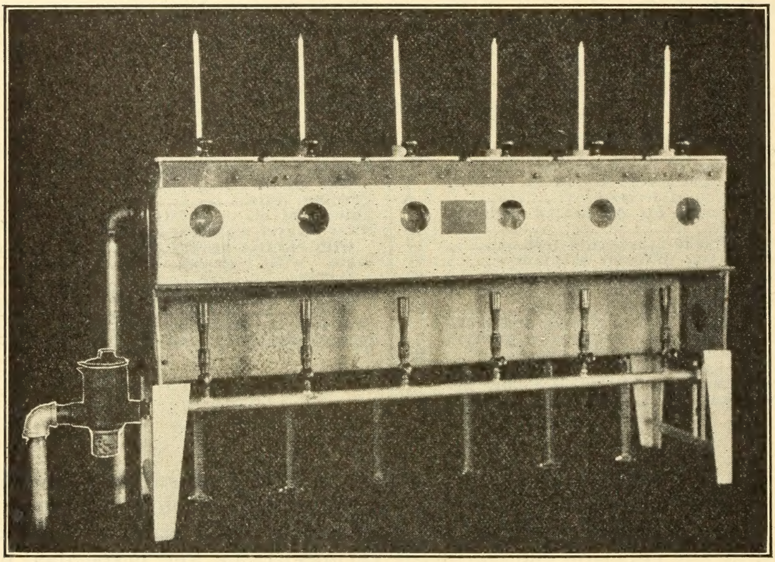

FIG. 1.—Brown-Duvel moisture tester equipped with gas burners and gas-pressure regulator

The instructions for making moisture tests given in this bulletin are applicable only when used in connection with the moisture tester herein described, specified, and illustrated, and do not apply to modified forms of moisture testers.

This apparatus was originally described by J. W. T. Duvel and E. Brown in 1907 in Bureau of Plant Industry Bulletin 99, "A Quick Method for the Determination of Moisture in Grain." Later this publication was reissued as Bureau of Plant Industry Circular 72, under the title, "A Moisture Tester for Grain and Other Substances and How to Use It."

With the use of a Brown-Duvel moisture tester a single moisture determination on grain can be made in 25 or 30 minutes, and with a 6-compartment tester six tests can be made in approximately the same time as for a single test. In commercial work, where a large number of tests are to be made, one man and a helper, with the use of three 6-compartment machines, can readily make 200 or more tests in a day of eight hours, an average of less than two and one-half minutes for each test. The rapidity with which moisture determinations can be made by this method makes it especially valuable for testing many substances other than grain which have a large percentage of water, are difficult to grind, or contain such large quantities of volatile oils that determinations based upon differences in weight during drying are unreliable. In addition, this method obviates the necessity of grinding samples, thus eliminating the loss of water which always accompanies the grinding of material of relatively high moisture content.

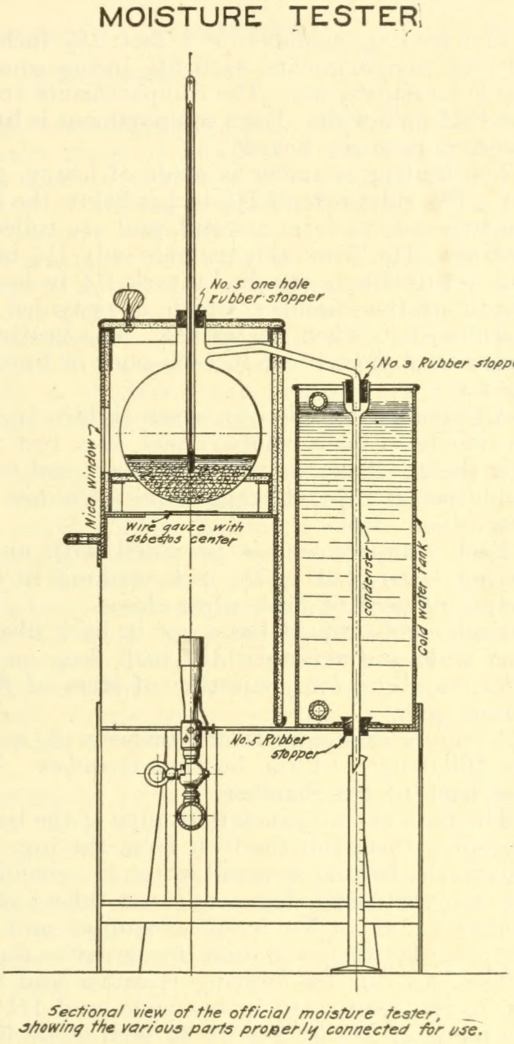

FIG. 2.—Cross section of Brown-Duvel moisture tester, showing the various parts properly connected for use

DESCRIPTION OF THE APPARATUS

The apparatus consists of a heating chamber divided into compartments so that a number of samples can be tested at the same time, a tank for cold water through which the condenser tubes pass, and a suitable stand for supporting the heating chamber and cold-water tank, together with numerous accessories, including thermometers, distillation flasks, and graduated measuring cylinders.

Figure 1 shows an external view of a standard 6-compartment moisture tester set up ready for use. Figure 2 is a cross section through one of the compartments of the tester, showing the position of the flask and the flask support within the compartment, the adjustment of the thermometer, and the proper connections of the various parts.

Figures 1 and 2 show testers equipped with burners for using gas as fuel. The form of construction, however, is such that alcohol or gasoline burners, or electric heaters can be used, provided the directions herein given are carefully followed.

CONSTRUCTION SPECIFICATIONS

The heating chamber is 3 feet 2½ inches long, and is divided into six compartments, each 5½ inches square and 6½ inches deep, inside measurements. The compartments are separated by air spaces one-half inch wide. Each compartment is lined with $\frac{3}{16}$-inch asbestos sheeting (transite board).

The heating chamber is made of heavy, galvanized iron throughout. The sides extend 7½ inches below the chamber on the back and the two ends to form a stand, and are rolled at the bottom for firm footing. The front side extends only 1½ inches below the chamber, and to this side is attached a rack 1¼ inches wide extending the full length of the chamber which is provided with holes for holding thermometers when not in use. The heating chamber has a hole 3 inches in diameter cut in each end, in line with the burners. (See fig. 1.)

A galvanized angle iron seven-eighths inch wide is riveted around the inside of each compartment as a rest for the wire gauze used over the gas flame, on which the flask seat is placed. Each compartment has a 2¼-inch round mica window for observation during test.

Each compartment is provided with an asbestos-lined (transite board) cover with a 1¼-inch opening in center to allow for projection of neck of flask when closed.

Each compartment has a cut in back five-eighths to three-fourths inch wide and seven-eighths inch deep on center line of compartment, to allow for projection of stem of flask which leads to condenser tank.

A copper condenser tank 4 inches wide and 12 inches deep extends the full length of the heating chamber. This is mounted on the base back of the chamber.

The tank has a ½-inch inlet pipe at the bottom and a ¾-inch overflow pipe three-fourths inch from the top. The tank has six openings in the bottom so arranged as to coincide with the center line of the compartments for condenser tubes; these openings are large enough to take a No. 5 rubber stopper and are reinforced by a copper plate 1½ inches in diameter sweat to the bottom.

The base for the heating chamber and condenser tank is 3 feet 3¾ inches long, 11¼ inches wide, and 11½ inches high. The legs are made of 2½ by 2½ by ⅛ inch angle iron and tied across back and ends by 1 by 1 by ⅛ inch angle iron. Tie angles are mitered at corners and set inside of legs to form seat for chamber and tank.

The end legs are tied 2½ inches from bottom by a ¾ by ¾ by ⅛ inch angle iron. From this angle to top angle, two ¼-inch round rods are set 1¼ inches apart center to center, between which the gas line pipe is passed and a lock or clamp nut is placed on pipe on either side of rods for clamping pipe into position, making same adjustable up and down.

The center of gas line should be 3¼ inches from front of base.

The gas pipe should be three-fourths inch inside diameter.

Pet cocks for gas burners are mounted on pipe line, the center of which coincides with centers of compartments.

Figure 3 is a working drawing of the Brown-Duvel tester, equipped with gas heaters.

DESCRIPTION OF ACCESSORIES

THERMOMETERS

It is of the utmost importance that the thermometers be of extra quality and not the ordinary grade of chemical thermometers which are commonly furnished with apparatus of this general character. The success of this method of making moisture determinations depends largely upon the accuracy with which the temperature readings are made, and any thermometer showing an error of more than one-half of a degree at any of the prescribed points should not be used unless such errors are known and provided for in the readings.

It is also necessary that the mercury bulbs of each of the thermometers be of approximately the same length, so that uniformity can be had as to the depth to which the thermometers are immersed in the oil, the correct depth being four-fifths immersion, as shown in Figure 2.

The thermometer used in this apparatus should be made of suitable glass properly annealed for use at high temperatures, and should be free from defects which would prevent making accurate readings.

The graduations of the thermometer should be in whole degrees from 0° to 220° C., and it should have a white background on the stem. Errors in scale graduations should not exceed 1° at any point and between 170° and 200° C. should not exceed 0.5°. The diameter of the stem of the thermometer should be nine thirty-seconds inch, so that it will properly fit into a No. 5 one-hole rubber stopper. The length of the mercury bulb should be approximately three-fourths inch (19 mm.) and its diameter should be approximately 5 millimeters.

Variation from the dimensions given above and pictured in Figure 4 should be not greater than 0.25 millimeter on the stem and bulb diameters and one-sixteenth inch (1.6 mm.) in the bulb length.

Manufacturers should be required to furnish certificates of correction with all thermometers showing errors in calibration and graduation exceeding 0.5° at 175° and 200° C.

A standard thermometer for use in the Brown-Duvel moisture tester is illustrated in Figure 4.

GRADUATED MEASURING CYLINDERS

The full-sized graduated cylinders for measuring the moisture content of the grain being tested should have a capacity of 25 cubic centimeters.

The graduates should be made to contain the indicated volume at 20° C., and the graduations in whole cubic centimeters and either one-tenth or two-tenths of a cubic centimeter should be legible and conspicuously and permanently marked on one side of the graduate.

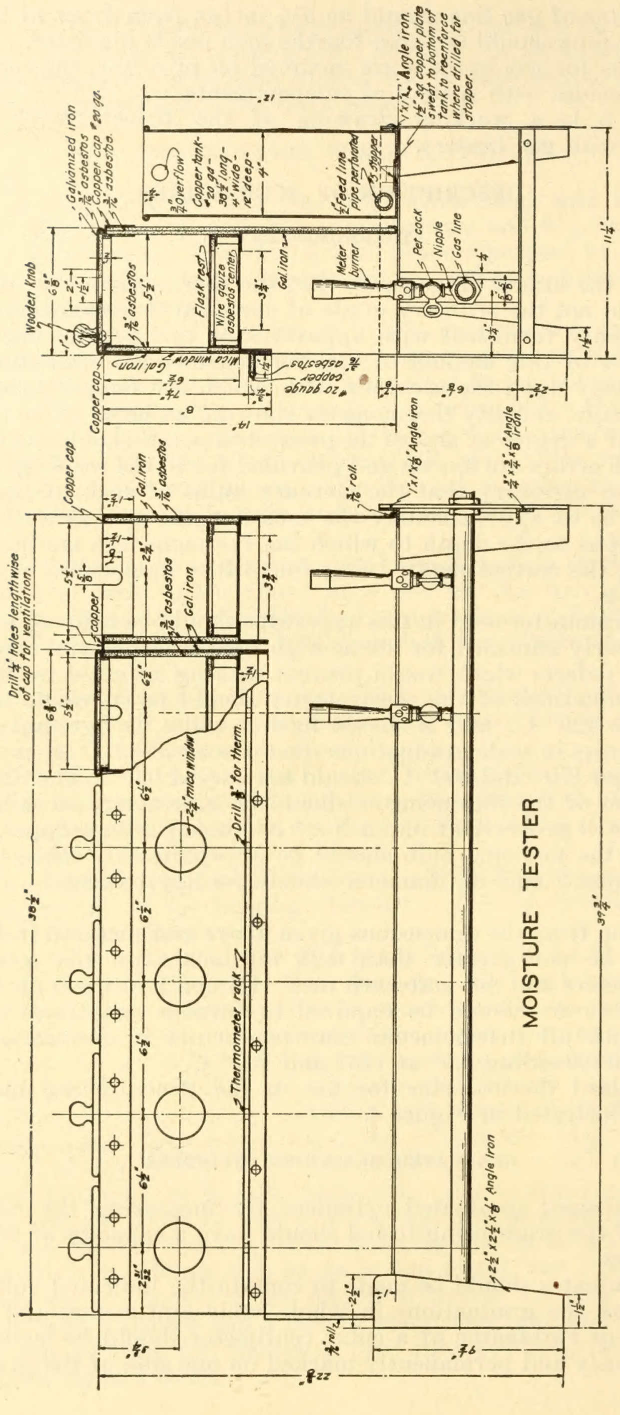

FIG. 3.—Longitudinal section of Brown-Duvel moisture tester, showing detailed construction of the apparatus

All graduation marks should be perpendicular to the axis and parallel to the base and to each other. The graduation marks should be clear and distinct and uniform in character and should be etched or engraved and should not exceed 0.38 milimeter in width. Blown

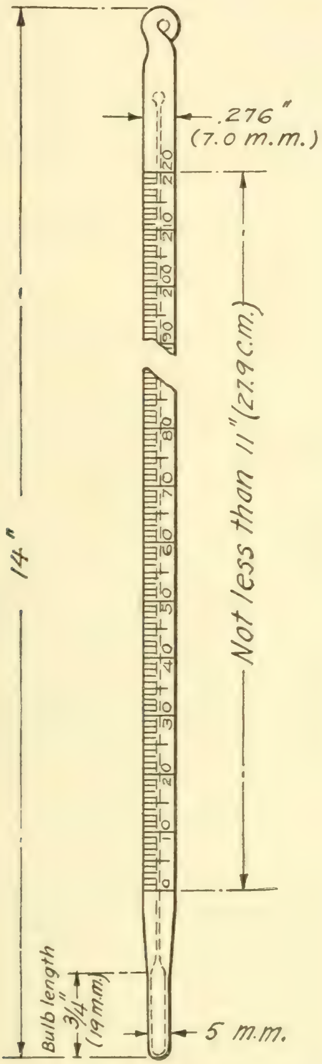

FIG. 4.—Standard thermometer with the proper shape and dimensions for use in the Brown-Duvel moisture tester

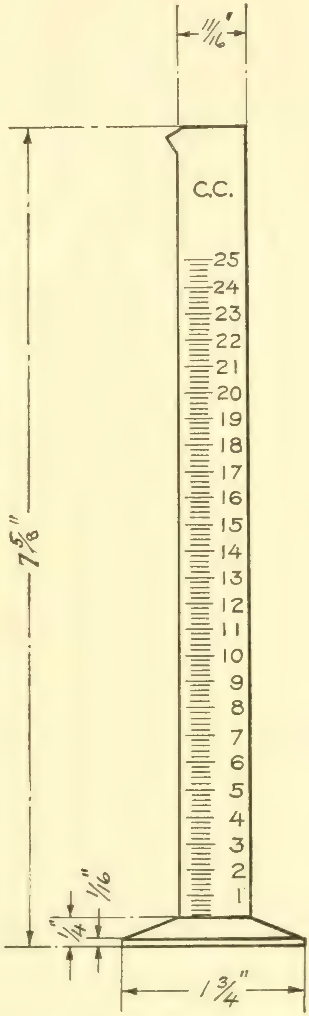

FIG. 5.—Standard moisture-testing graduate, 25 cubic centimeters capacity

or pressed graduation marks should not be used. The clear interval between graduation marks should be not less than 1 millimeter. The value of the main graduation marks should be plainly designated, as shown in Figure 5. The tolerance to be allowed in excess or deficiency in the capacity of the graduates should be not greater than 0.05 cubic centimeter at the points 5, 10, 15, 20, and 25 cubic centimeters. The base of the graduates should be ground to rest evenly on a flat surface at right angles to the axis of the diameter. The graduates should be cylindrical in form, 7⅝ inches high and eleven-sixteenths inch inside diameter, as shown in Figure 5. They should be of good quality glass, thoroughly annealed, clear, transparent, of uniform but not excessive thickness, and free from bubbles and streaks.

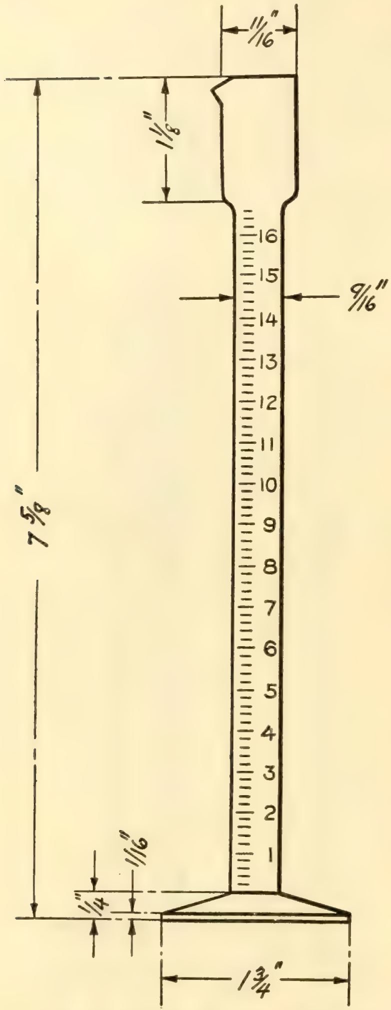

Fig. 6.—Special moisture-testing graduate, 16 per cent capacity, for use in testing moisture content of oats and other lightweight material

In using the graduates where 100 grams of the material being tested are used for the test, the number of cubic centimeters of water which collects in the graduate corresponds to the percentage of moisture originally contained in the sample.

In making the moisture determination, a small quantity of oil—usually less than 0.5 cubic centimeter—is carried over into the measuring cylinder or graduate and collects on the surface of the water, so that the moisture readings should be made at the bottom of the meniscus between the oil and the water. Should the oil and the water not separate readily, the graduated cylinder should be whirled by rolling quickly between the two hands.

SPECIAL GRADUATE

In making moisture tests of oats it is necessary, on account of the bulkiness of the sample, to use only half the quantity of sample ordinarily used for other grains, so that a special graduate of smaller capacity is necessary. In using the special graduates in connection with tests in which only 50 grams of the material to be tested are used, the number of cubic centimeters of water which collects in the graduates corresponds to only one-half of the moisture contained in a full-sized sample of 100 grams, but the graduates are so calibrated that the results are read in direct percentages. All the requirements noted for the manufacture of the regular 25 cubic centimeter graduate obtain for this one also, except that the dimensions for this graduate are 7⅝ inches high, nine-sixteenths inch inside diameter, with 1⅛ inches of the top portion flared to eleven-sixteenths inch in diameter, as shown in Figure 6.

After each test the cylinders must be cleaned and dried, which can best be done with a swab or test-tube cleaner with a small sponge attached to one end, as shown in Figure 7. Satisfactory cleaners can also be made as needed by twisting cotton waste, strips of cheesecloth, or some other similar substance about one end of a piece of fairly heavy wire.

If the graduate is not thoroughly clean, water from the following test will hang along the sides, making a correct reading exceedingly difficult; if the graduate is not thoroughly dry, the following test will of course show an inaccurate result.

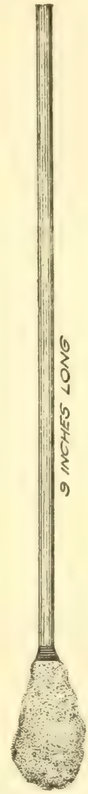

FIG. 7. — Swab for cleaning graduated measuring cylinders

DISTILLATION FLASKS

The distillation flasks, with a capacity of approximately 1,000 cubic centimeters, should be made of the best grade of resistant glass and should be well annealed to withstand sudden changes in temperature without breaking. The necks of the flasks should be sufficiently heavy to stand tight corking. Figure 8 shows one of these flasks in which the dimensions of the different parts are given in both centimeters and inches.

Flasks showing wide variations in the dimensions are useless. It is therefore recommended that in ordering flasks it be definitely stated that they must be in accordance with the specifications given in this bulletin. In case the dimensions of the flasks, as well as other parts of the apparatus, are not approximately as herein specified, they should not be accepted or used.

The most important points regarding the distillation flasks are the diameter of the flask, the dimensions of the neck, the distance from the bottom of the flask to where the outlet tube is formed, and the angle of the outlet tube. If the distance from the bottom of the flask to the outlet tube is not correct, the flasks will not rest in the compartments of the tester in the proper manner. This condition makes it impossible to place on correctly the cover of the compartment.

It is recommended that a plaster of Paris mold, as illustrated in Figure 9, be made of a flask of the proper dimensions and that all flasks be tested in this mold before being accepted from the manufacturer.

COPPER DISTILLATION FLASKS

Numerous requests for information are received from time to time as to the advisability of using copper instead of glass flasks for making moisture determinations by the method described in this circular. The results of investigations by J. H. Cox, of the Grain Division, Bureau of Agricultural Economics, have shown that copper flasks may be used in the tester, although glass flasks have proved more satisfactory for careful work. In making moisture determinations of corn and oats, the same treatment is required in the use of copper flasks, when spun from 16-ounce sheet copper and used in the tester described in this bulletin, as is required when the tests are made in

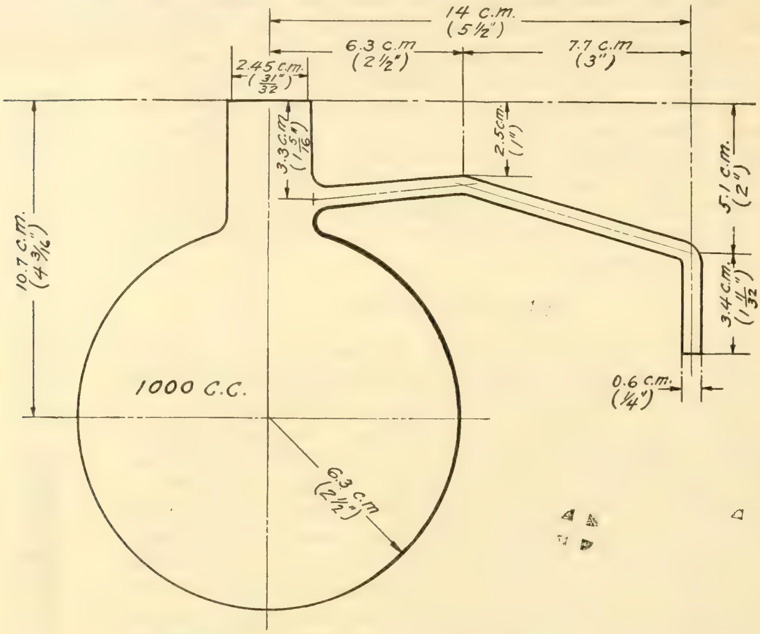

FIG. 8.—Standard single-walled distillation flask, 1,000 cubic centimeters capacity

glass flasks, the essential feature being to extinguish the flame promptly when the thermometer reaches a temperature of 190° for corn and 195° C. for oats. In using copper flasks in this machine

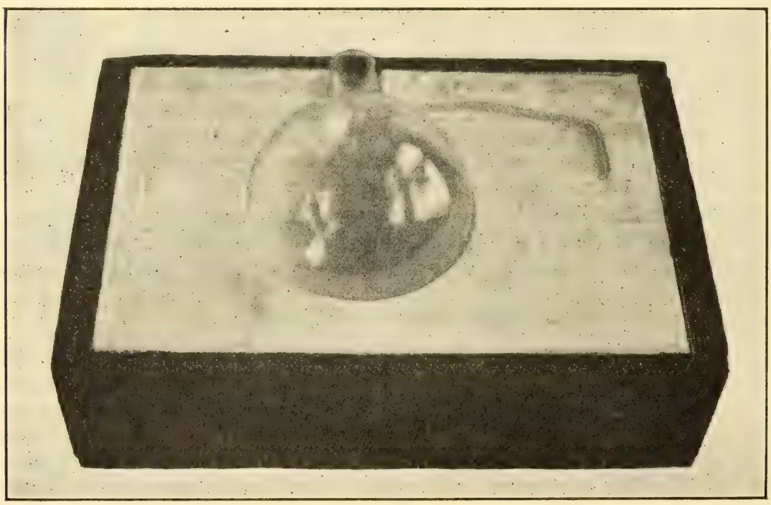

FIG. 9.—Plaster of Paris mold for determining the accuracy in size and shape of distillation flasks

for making moisture determinations of wheat, however, the flame should be extinguished when the thermometer reaches a temperature of 185° and not at 180° C., as is required when using glass flasks, otherwise the treatment should be the same. Correct temperatures for use with copper flasks in making moisture determinations of the other grains have not been determined.

SPECIAL DOUBLE-WALLED DISTILLATION FLASK FOR TESTING FLOUR AND MEAL [3]

A special double-walled flask designed for use in connection with the Brown-Duvel tester for making moisture determinations of flour and meal has the same outside dimensions as the regular distillation flask which is illustrated in Figure 8. The double-walled flask can

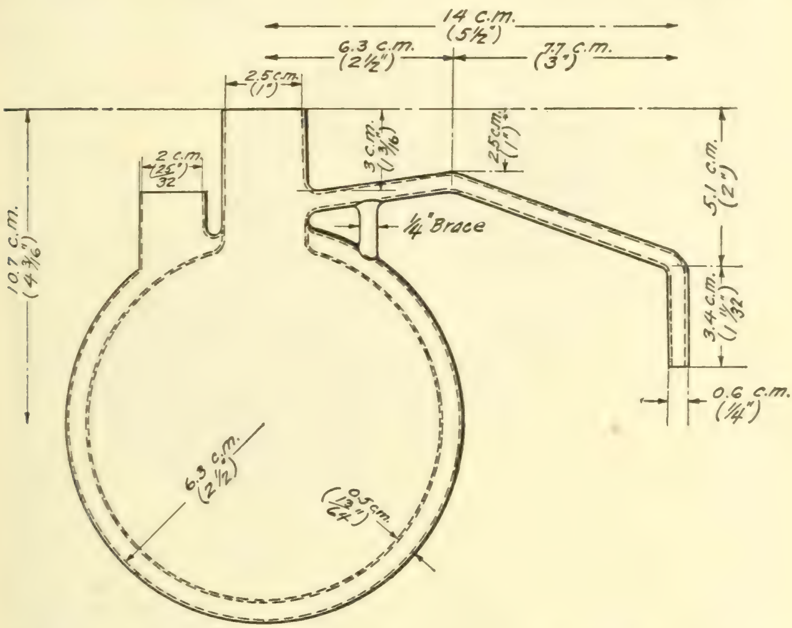

FIG. 10.—Special double-walled distillation flask for testing moisture content in flour and meal

be made of either glass or copper. It is illustrated in Figure 10. The inner flask has a capacity of approximately 900 cubic centimeters and the space between the two walls should hold not less than 250 nor more than 300 cubic centimeters.

If the flasks are made of copper, the thickness of the copper before it is spun should be 0.022 inch, or 16 ounces to the square foot. The copper flasks will have to be made in two sections and the sections soldered together in the middle with a very hard solder. The soft solder commonly used by plumbers is not suitable for this work. Success with these flasks has been attained only when they were soldered together with a silver solder. The neck of the flask must be

[3] This task was developed by J. H. Cox of the Grain Division, Bureau of Agricultural Economics. The flask and its manner of construction are fully described in Department Bulletin No. 56.

of but one thickness of copper, for if it is too heavy it will melt the rubber stoppers.

If the flasks are made of glass, they should be made of the best grade of resistant glass and well annealed, and the necks should be sufficiently heavy to stand tight corking.

When 150 cubic centimeters of oil is poured in between the two walls, the top of the oil should be about halfway up the sides of the flasks. If the flasks do not meet these specifications they should not be used.

FLASK SUPPORTS

The flask supports used in this apparatus consist of an asbestos ring of ¼-inch transite board, 4¼ inches in diameter, incased in a galvanized-iron frame 5½ inches square, the iron frame being flanged on either two sides or on all four sides to a depth of 1½

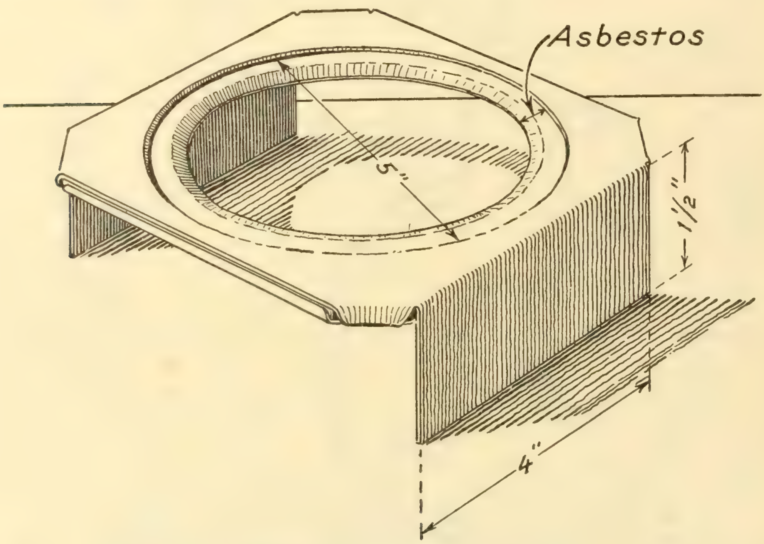

FIG. 11.—Flask support upon which the distillation flask rests when in place in the moisture tester

inches. Each corner of the casing is cut in such a manner that a ⅞-inch opening is formed. The flask support is shown in Figure 11. This form of support exposes the bottom of the flask uniformly to the action of the heat, and at the same time is so made that a sufficient quantity of heat comes in contact with the upper part of the flask.

The asbestos ring in the top of the support should be cut so that the bottom of the flask when in place on the support will be not less than three-eighths inch above the asbestos center of the wire gauze, as shown in Figure 2. The support should be 1½ inches high.

WIRE GAUZE

The wire gauze in the bottom of each compartment between the flask and the flame should be made of iron wire, from 0.016 to 0.020

inch in diameter, with 20 wires to the inch and with a 2-inch asbestos center, as shown in Figure 12.

The asbestos center insures a uniform distribution of heat and adds greatly to the life of the wire. It can readily be put in by mixing asbestos cement with water and rubbing it into the mesh of the gauze. The asbestos center should always be kept in good condition in order to prevent the flame from playing directly on the bottom of the flask.

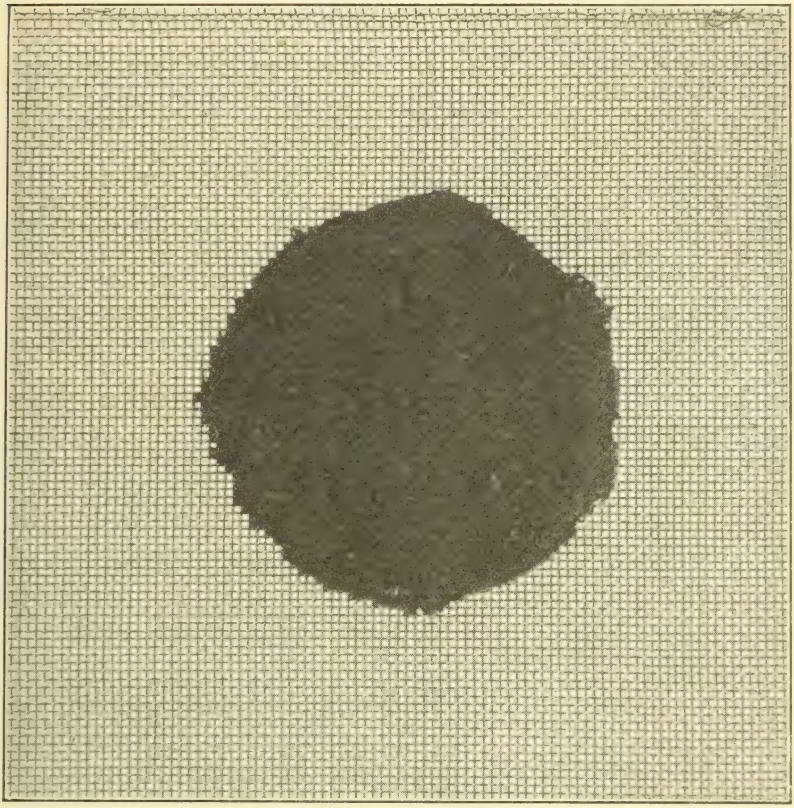

Fig. 12.—Wire gauze, with asbestos center

CONDENSER TUBES

The glass condenser tubes are 34 centimeters in total length, 0.70 centimeter in diameter, and the upper 3 centimeters flanged to an inside diameter of 2.1 centimeters so that it just fits a No. 3 stopper. The tubes should be so adjusted in the No. 5 rubber stoppers that, when the latter are firmly pressed into the holes in the bottom of the cold-water tank, the tops of the tubes will be approximately one-fourth inch above the top of the tank.

RUBBER STOPPERS

The No. 5 one-hole rubber stoppers which carry the thermometers and the No. 3 one-hole rubber stoppers used on the side tubes of the flasks should be of such quality as will withstand comparatively high temperatures and resist the action of the oil. Stoppers containing a large percentage of pure gum are not desirable, as they soon swell and become unfit for use. Before attempting to put any of the glass parts through the holes in the rubber stoppers, they should be moistened with oil or water, thereby lessening the chances of breaking the tubes and cutting the hands. A good grade of stopper should last through 400 tests.

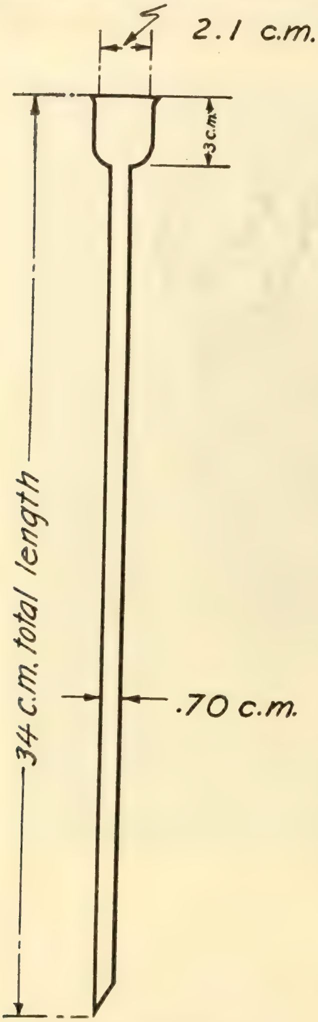

Fig. 13.—Condenser tube

OIL FOR THE MOISTURE TESTS

In making moisture tests a good grade of mineral engine oil must be used. The oil must be free from water, should have a specific gravity of about 0.9000, or 25° Baumé, should have a viscosity at 20° C. of from 342 to 513 seconds Saybolt. Its flash point in open cup should be between 350° to 400° F. Fire point should not be over 450° F. The higher the viscosity, the greater the danger of boiling over, and for this reason cylinder oils should not be used.

AUTOMATIC OIL-MEASURING DEVICE

The automatic oil-measuring device consists of a container to which is attached an automatic measuring gauge. The gauge must be sufficiently accurate to measure and deliver not less than 150 cubic centimeters and not more than 155 cubic centimeters of testing oil in one draft. The device is operated by an upward pressure of the neck of the flask against an automatic catch on the gauge. The cover for the container should have a strainer sieve for straining all the oil used in the tests. One form of the device is illustrated in Figure 14.

OIL-RECOVERY AND OIL-STORAGE CANS

The oil-recovery and oil-storage cans are made similar to 5-gallon milk cans. The storage can is equipped with a standard faucet at its base. The oil-recovery can is supplied with a strainer funnel, the sides of which are made of heavy-weight tin. The hopper of the funnel should be 12 inches in diameter at the top, 7 inches deep, with an opening 5¾ inches at the base. The collar should be 2½ inches wide, having an outside diameter of 5¾ inches. A brass mesh filter screen of fine dimensions should be soldered over the opening of the funnel where the collar joins the hopper. The top edge of the funnel should be finished with a $\frac{3}{16}$-inch roll. These devices are shown in Figure 15.

BALANCE FOR WEIGHING SAMPLES

Though not a part of the moisture tester, a balance is necessary for weighing the samples of grain to be tested. A balance of simple construction, having an accuracy and sensitiveness of not less than 0.1 gram, has been found satisfactory. Balances similar to the type shown in Figure 16 will meet all requirements.

Whatever the type of balance used, it should rest on a firm support, preferably a heavy shelf securely fastened to a solid wall of the building. Such a shelf will greatly facilitate the keeping of it in balance, which is absolutely essential for reliable work.

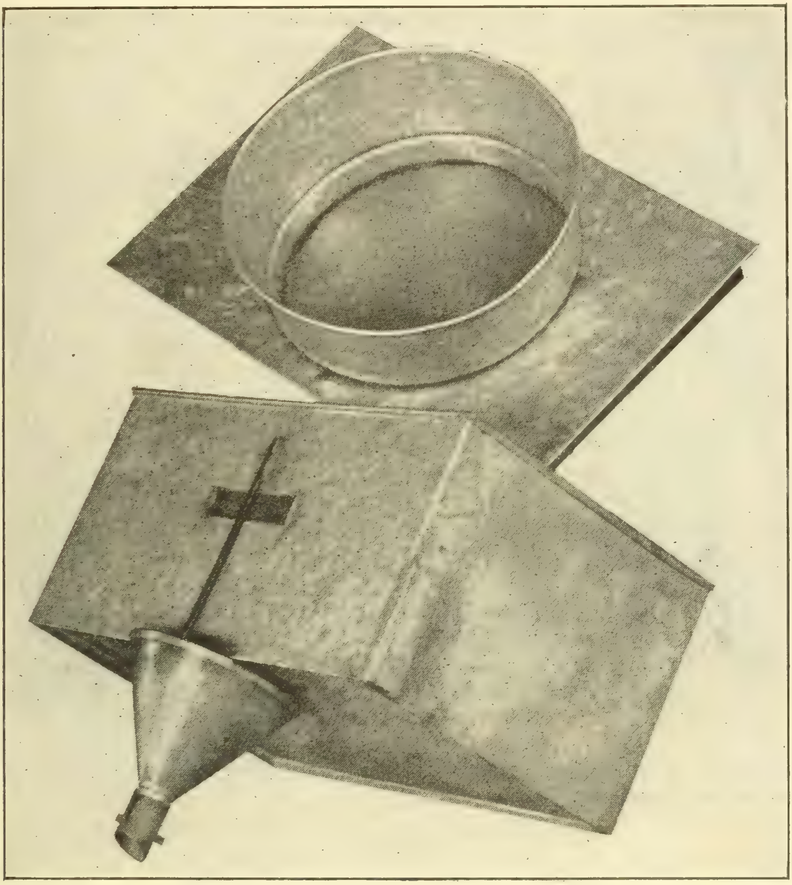

FIG. 14.—Automatic oil-measuring device

SUPPLY PIPES FOR GAS-HEATED MOISTURE TESTERS

It is absolutely necessary that a plentiful supply of gas be on hand to operate a moisture tester. The only way to assure this is to have gas pipes of sufficient size. The gas pipe on a single 6-compartment tester should be at least one-half inch inside diameter and preferably three-fourths inch. Cases are known where from two to four machines have been attached to a ½-inch supply line, and in every case serious errors have resulted in the moisture-test results. The errors were the result of an insufficient supply of gas to the burners when more than one machine was operated at the same time.

The installation of gas supply pipes for moisture machines depends to a large extent upon where the moisture machines are to be located in the laboratory. They should be installed in a place where they will not be exposed to air currents. If the moisture machines are placed so that they are all in the same direction, the size of the gas pipes or manifolds on each machine should each, in a general way, be of a different size. For example, if four machines are to be placed in a line, the machine nearest the supply line should have a manifold 1¼ inches inside diameter, the machine next in line should have a 1-inch manifold, the next machine a ¾-inch manifold, and the last machine also a ¾-inch manifold. Of equal importance is the capacity of the pipe line from the meter. Under no consideration should this be smaller than 1 inch, and for a set-up as described above this pipe should be not less than 1½ inches.

FIG. 15.—Oil-recovery and oil-storage cans

In some laboratories it is not possible to place all the machines in one line. In such cases they are usually placed in a formation at right angles to the supply line. Under these circumstances the main supply line should be larger than in the set-up mentioned. With testers in an angular position, each machine should be supplied by a ¾-inch pipe, and these should each be tapped into a 2½-inch main-line pipe. It is of further decided advantage to eliminate as many angles, turns, and tappings as possible on the main supply line; that is, the meter line. No particular advantage appears to accrue from leading a supply pipe to both ends of the manifold.

BURNERS

It is not essential to have any particular type of burner for gas-heated machines. Almost any burner having a diameter of 20 millimeters and 130 millimeters in height will suit the purpose. The important thing concerning any burners that are used is that, after being once adjusted, they stay adjusted to give off a uniform quantity of heat. When Meker burners are used the burners should be equipped with wing-nut set screws placed on the burner to anchor the air valve to any desired position. When Bunsen burners are used they should be equipped with set screws for both the air and gas valves.

HOW TO MAKE A MOISTURE TEST

The method of making moisture tests with a Brown-Duvel tester consists of heating the whole kernels of the various grains, rice, seeds, spices, or the flour, meal, broken grains, or other material to be tested in a mineral oil having a flashing point much above the boiling point of water, in condensing the water which distills off, and in collecting and measuring the moisture in a suitable graduate. The method is so simple that the tests can be made by any careful worker who is

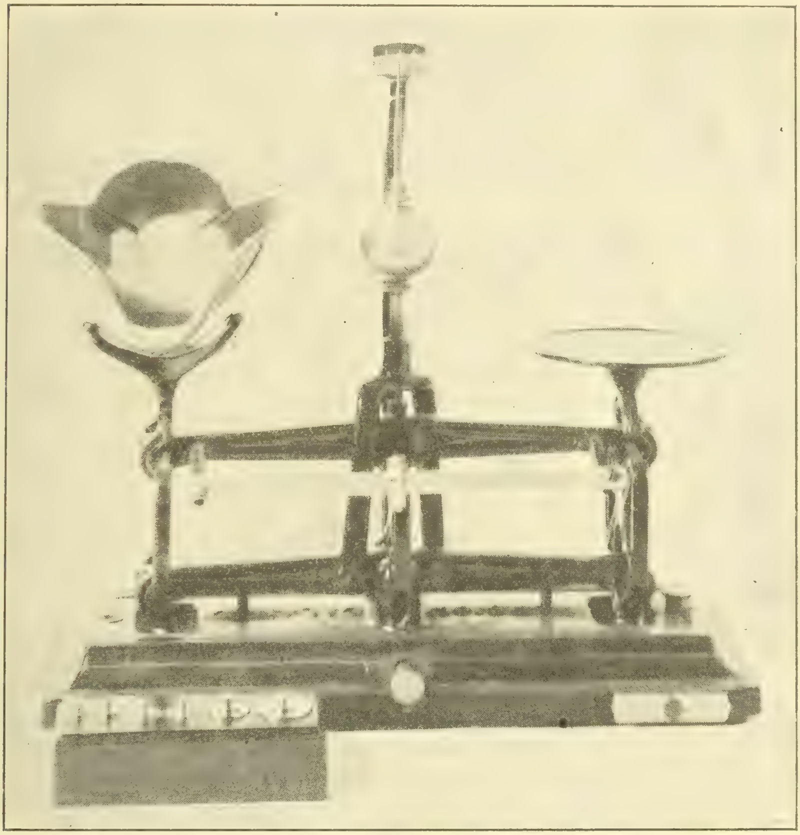

FIG. 16.—Balance for weighing samples to be tested for moisture content

able to follow simple instructions, but it is essential for uniformly accurate results that the tests be made in strict accordance with the details of the method here described.

After properly mixing the bulk sample to be tested, carefully weigh the desired quantity for the moisture test and empty immediately into the distillation flask, to which add the oil and then shake, with a slight whirling motion, until the two become well mixed. Grasp the neck of the flask in one hand and hold it in such a manner that when the No. 5 rubber stopper carrying the thermometer is inserted it can be readily determined that the mercury bulk of the thermometer is exactly four-fifths immersed in the oil, as shown in Figure 2. Place the flask in the proper compartment of the tester and proceed in a similar manner with the remaining samples.

The correct adjustment of the thermometer is a factor which must not be ignored. If the mercury bulb of the thermometer is too near the bottom of the flask, the percentage of moisture will be too low; and if the mercury bulb is placed too high, the percentage of moisture will be too high. For the same reason it is important that there be uniformity in the length of the mercury bulbs of the thermometers, which, as previously stated, should be approximately three-fourths inch.

As the thermometer is being inserted, glance along the side tube of the flask to make certain that it has not become stopped by the lodgment of some particle while the flask was being emptied or filled. If the side tube is not open to permit the free escape of the rapidly forming steam the pressure during the heating will become sufficient to blow out the stopper and thermometer or possibly to burst the flask.

When the flasks have been filled and placed in the compartments of the tester, connect the side tubes of the flasks by means of the No. 3 rubber stoppers with the thimbles of the glass condenser tubes which extend down through the cold-water tank, so that the moisture which is liberated from the grain or other substance will be condensed and then collected in the graduated cylinders beneath the tank. Figure 2 shows the correct manner of adjusting the various parts of the apparatus.

Place the cover over the flask, then ignite the gas, the heating capacity of which has already been adjusted, as described on page 22. When the desired temperature is reached, extinguish the flame quickly, after which the thermometer will show a slight gradual increase in temperature, approximately 5 to 6°. Let the thermometer recede to 160° C. before making a reading. Before reading, remove the covers and then disconnect the flasks from the condenser tubes to allow the small quantity of moisture which sometimes collects at the base of the No. 3 rubber stoppers to drop into the graduated measuring cylinders. The percentage of moisture which has collected in the graduates is read beneath the layer of oil on top of the water. To guard against possible error, it is desirable to make duplicate tests of all samples, and if there is no appreciable variation, to take the average of the two readings as the correct percentage of moisture.

While the contents of the flasks are still hot, remove the thermometer, take the flask by the side tube and after giving a slight whirling motion, invert quickly, emptying the contents into a suitable strainer, so that the oil can be recovered for further use.

When the flasks are not in use, keep them in place in the compartments and make all connections the same as for a test. In using a new flask for the first time, or when the machine has been idle over 24 hours, "run" a preliminary sample previous to making a regular test so that all the flasks will be in uniform condition.

HOW TO TEST DIFFERENT SUBSTANCES

Detailed instructions have been worked out for making moisture determinations of a limited number of substances, as follows:

Barley.—Use 100 grams of grain and 150 cubic centimeters of oil, and extinguish the flame when the thermometer registers 190° C.

Barley malt.—Use 100 grams of malted barley and 200 cubic centimeters of oil, and extinguish the flame promptly when the thermometer registers a temperature of 168° C. The flame should be adjusted so that it will require approximately 20 minutes to reach the prescribed temperature.

Buckwheat.—Use 100 grams of grain and 150 cubic centimeters of oil and extinguish the flame when the thermometer registers 185° C.

Corn (maize).—Use 100 grams of grain and 150 cubic centimeters of oil, and extinguish the flame when the thermometer registers 190° C. This method, however, can not be used with pop corn.

Corn meal.—Use the double-wall flask with 100 grams of the corn meal and 150 cubic centimeters of oil in the inner flask and 150 cubic centimeters of oil between the walls. Extinguish the flame when the temperature reaches 175° C. The oil in the inner flask should reach 175° C. in 26 minutes.

Corncobs.—Use 50 grams of cob cut in pieces that can be easily removed from the flask and 250 cubic centimeters of oil, and extinguish the flame when the thermometer registers 190° C.

Cottonseed.—Use 50 grams of seed and 150 cubic centimeters of oil and extinguish the flame when the thermometer registers 190° C.

Distillers' dried grains.—Use 50 grams of distillers' dried grains and 200 cubic centimeters of oil, and extinguish the flame promptly when the thermometer registers a temperature of 190° C. Special care should be taken to see that the oil and the distillers' dried grains are thoroughly mixed before beginning the test.

Emmer.—Use 100 grams of grain and 150 cubic centimeters of oil and extinguish the flame when the thermometer registers 190° C.

Flaxseed.—Use 100 grams of seed and 150 cubic centimeters of oil, and extinguish the flame when the thermometer registers 175° C.

Grain sorghums.—Use 100 grams of grain and 150 cubic centimeters of oil, and extinguish the flame when the thermometer registers 190° C.

Navy beans.—Use 100 grams of grain and 150 cubic centimeters of oil and extinguish the flame when the thermometer reaches 175° C.

Oats.—Use 50 grams of grain and 150 cubic centimeters of oil, and extinguish the flame when the thermometer registers 195° C. In oats that are light and chaffy, special care should be taken to insure the thorough mixing of the oil and grain and to heat with a slower flame in order to reduce the foaming to a minimum. In extreme cases it may be necessary to add an extra 50 cubic centimeters of oil. Use special graduate which is one-half the volume of the regular graduate; or, if the regular graduate is used, double the moisture test reading.

Rice (unhulled).—Use 100 grams of grain and 150 cubic centimeters of oil, and extinguish the flame when the thermometer registers 200° C.

Milled rice, first and second head, and brown rice.—Use 100 grams of grain and 150 cubic centimeters of oil. Place a glass-wool pad 2 inches in diameter and 1/4 inch thick in bottom of the flask. Care should be taken not to displace the glass wool. Extinguish the flame when the thermometer registers 200° C.

Rice screenings and brewers' rice.—For each of these use the special double-walled flask with 100 grams of rice screenings, or brewers' rice, as the case may be, and 150 cubic centimeters of oil in the inner flask and 150 cubic centimeters between the walls. Extinguish the flame when the thermometer reaches 200° C. The oil in the inner flask should reach 200° C. in 26 minutes.

Rye.—Use 100 grams of grain and 150 cubic centimeters of oil. Place a glass-wool pad, 2 inches in diameter and 1/4 inch thick, in the bottom of the flask, taking care not to disturb it when putting in the grain and oil. Extinguish the flame when the thermometer registers 175° C.

Shelled peanuts.—Use 100 grams of shelled peanuts and 150 cubic centimeters of oil, and extinguish the flame when the thermometer registers 175° C.

Soy beans.—Use 100 grams of soy beans and 150 cubic centimeters of oil, and extinguish the flame when the thermometer registers 175° C.

Wheat.—Use 100 grams of grain and 150 cubic centimeters of oil, and extinguish the flame when the thermometer registers 180° C.

Wheat flour.—Use the double-wall flask with 150 cubic centimeters of oil in the inner flask and 150 cubic centimeters of oil between the walls, and 50 grams of flour. Extinguish the flame when the thermometer reaches 190° C. Use the special 16 per cent graduate or, if the regular graduate is used, double the moisture test reading. The oil in the inner flask should reach 190° C. in 30 minutes.

Tabulative specifications and special points for consideration are given in the summary on page 42.

STANDARDIZING THE MOISTURE TESTER

The earlier directions for operating the Brown-Duvel moisture tester called for adjusting the flame so that it would require about 20 minutes to reach the temperature prescribed for the substance being tested. This required the constant attention of the operator, with frequent adjustments of the air and gas valves on the burners, while the moisture tests were being made. At intervals the tests would be running too rapidly, at other times not fast enough. Several years of observation have shown that these recommendations have frequently been overlooked. Often when tests are started, no further attention is given them until the flame is extinguished when the temperature prescribed for the substance being tested is reached, regardless of whether it took the right number of minutes or not. This leads to irregular results.

Errors resulting from incorrect heating time are illustrated in Figure 17, wherein the heating time has been varied with tests on different portions of the same sample, with the result that the moisture obtained from a sample of wheat varied by as much as 0.4 per cent. The data further showed that, other things being equal, as the heating time of the moisture test increased beyond the correct number of minutes, there was a corresponding decrease in moisture-test results. Furthermore, if the heating time was fast, the moisture tests showed not only too much moisture but were more irregular than when the tests were made at a slower heating time. Moreover, careful investigations in this field showed that for certain moisture contents, particularly low-moisture contents, 20 minutes was too long to heat the sample, whereas the reverse was true if the moisture content was high.

It therefore became a necessity in order to obtain accuracy and uniformity of results, to standardize the heating time of each individual burner. The standard chosen was 20 minutes, the same as in the earlier method. In these experiments, however, the standard heating time was made specific for only one moisture content; namely, 18 per cent, and the grain was specified as corn. This percentage of moisture was chosen because it was known that at this figure the moisture in corn is uniformly distributed, and this figure is halfway between the maximum and minimum grade requirements for the Federal grades for corn.

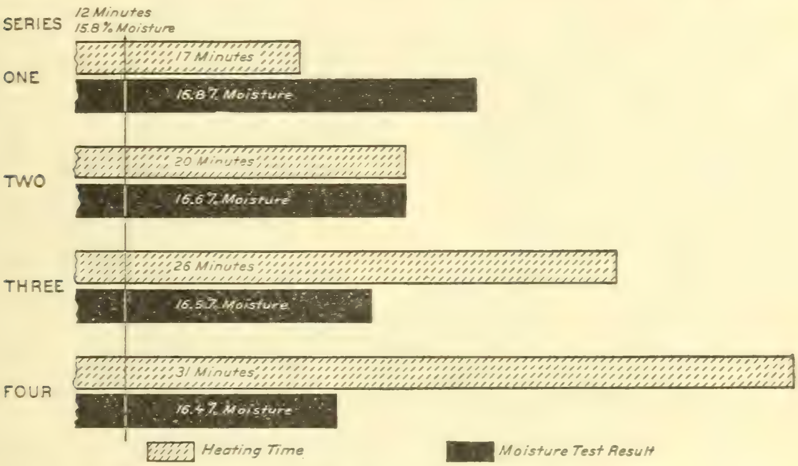

FIG. 17—Effect of heating time on the moisture test result on a sample of wheat

It is apparent that grain that is drier than this (18 per cent) will take less than 20 minutes to reach 190° C., the proper cut-off temperature for corn, and likewise that grain having moisture in excess of 18 per cent will take a somewhat longer time than 20 minutes, roughly one-half minute for every 1 per cent of moisture over and above 18 per cent. In other words, in place of the earlier method of trying to manipulate the burners to make them consume 20 minutes of time to reach a specified temperature, regardless of the moisture content of the material being tested, a standard of heat has been defined equivalent to that which will drive the moisture out of 18 per cent corn in exactly 20 minutes. Realizing that one would have to know accurately beforehand whether he had 18 per cent corn in order to standardize his tester; and, knowing that this type of corn is not always easy to obtain, a simple method for standardizing the gas flame has been developed that gives equivalent results and at the same time is easy of application. This method is generally referred to as the "oil test."

OIL TEST FOR STANDARDIZING GAS FLAMES

To standardize the heating time for making the moisture test proceed as follows: Place 450 cubic centimeters of oil (the regular moisture testing oil) of room temperature into the flasks of each compartment of the tester. This oil should be accurately measured in a cylinder and not by three trips of the oil measuring device. Insert the thermometer and regulate the mercury bulb so that it is completely immersed and the top of it just flush with the surface of

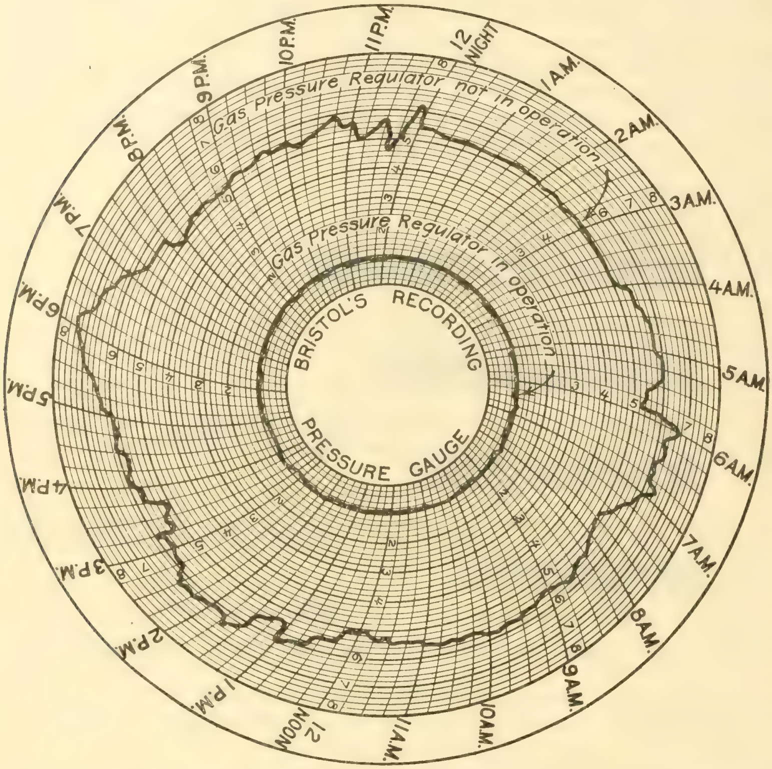

FIG. 18.—Bristol recording gauge chart of gas pressure over a 24-hour period at the Grain Research Laboratory at Washington, D. C. The chart also shows the uniformity of the gas pressure obtained by use of a gas pressure regulator attached to the moisture tester

the oil. Connect the flasks with the condensing tube, replace the covers, light the gas, and note the time. Apply heat until the temperature of the oil reaches 175° C. and again note time. The time elapsed should be 20 minutes. If more than 20 minutes is required to reach a temperature of 175° C., the holes in the bases of the burners should be slightly opened; if less than 20 minutes, the holes should be closed somewhat. The holes may be closed by lightly tapping the top of the base with a small hammer or any blunt instrument. They may be opened with a suitable reaming tool, such as a fine brooch, used by jewelers. Trial tests should be continued until the required time for heating all compartments does not vary more than one-half minute from 20 minutes; that is, not less than 19½ minutes or more than 20½ minutes, should be necessary to raise the temperature of the 450 cubic centimeters of oil to 175° C.

The only way in which this check test differs from the making of an ordinary moisture test is that 450 cubic centimeters of oil are used instead of 150 cubic centimeters, and that the thermometer is adjusted so that the top of the mercury bulb is just flush with the surface of the oil rather than being four-fifths immersed.

If an automatic gas-pressure regulator is used, and the correct heating time for each burner has been adjusted, as described on page 22, a uniform heating time for all compartments is assured. If, however, a gas governor is not available, it will be necessary for the operator to fix in his mind the flame necessary to heat the tester in the proper time, and, in case the gas pressure varies, to compensate for this by adjusting the keys and air valves at the base of the burner.

VARIATIONS IN HEATING TIME CAUSED BY VARIATIONS IN GAS PRESSURE

Originally it was found difficult to maintain a standard heating time. In making a study of the reason for this, several factors appeared. The gas pressure on the supply line of a moisture tester varies at different periods of the day, at different seasons of the year, for different cities, and with the number of burners in operation. From Figure 18, which is a Bristol recording gauge chart of gas pressure on the supply line of the moisture tester installed in the grain chemical research laboratory at Washington, D. C., it will be seen that the gas pressure at this laboratory varies from 6.7 inches to 5 inches, or a range of 1.7 inches during the working period of the day. Table 1 gives the gas pressure that was found on the supply line of moisture testers at 13 field offices of Federal grain supervision:

TABLE 1.—*Variation in the gas pressure on the supply lines for moisture testers located at different cities*

Federal grain supervision office located at—	Average gas pressure on supply line for moisture testers in inches head of water	Federal grain supervision office located at—	Average gas pressure on supply line for moisture testers in inches head of water
Baltimore	4.5	Minneapolis	5.6
Buffalo	7.0	Milwaukee	5.0
Chicago	4.8	Omaha	4.6
Cincinnati	10.0	Peoria	5.6
Duluth	7.5	St. Louis	4.0
Indianapolis	4.2	Toledo	9.0
Kansas City	4.0		

TABLE 2.—*Variation in the gas pressure in the supply line on a moisture tester when a varying number of gas burners are in operation*

Number of burners in operation	Gas pressure on supply line—inches head of water	Number of burners in operation	Gas pressure on supply line—inches head of water
0	4.6	7	2.3
1	4.0	9	2.0
2	3.7	10	1.8
4	3.2	12	1.2
6	2.6		

Table 2 gives the results of tests of the gas pressures on the supply line of a 12-compartment moisture tester with varying numbers of burners in operation.

Other things being equal, a low gas pressure will result in a longer heating time and in a lower moisture test, and a high gas pressure will result in a shorter heating time and in a higher moisture test. From tests made, data for which are given in Table 3 and illustrated

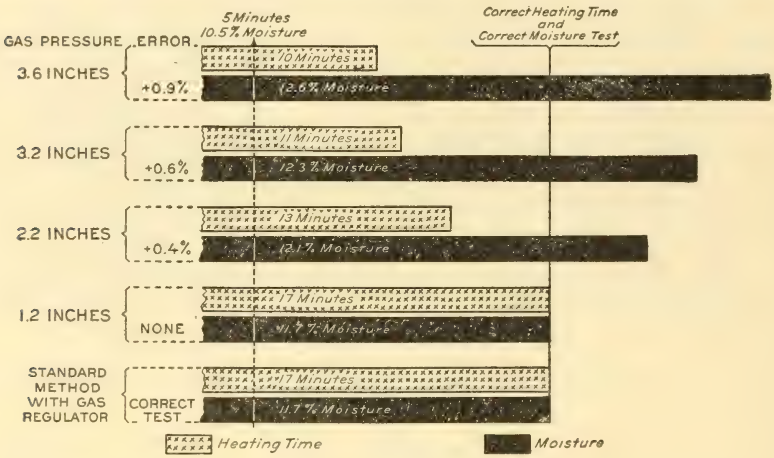

FIG. 19.—Effect of gas pressure on the heating time and the moisture test result

in Figure 19, it was found that when the burners of the compartments were set to give the correct heating time at the minimum gas pressure on the supply line, which in this case was 1.2 inches, the heating time was reduced and the moisture test result was increased very appreciably when the gas pressure was increased. It will be noted that the moisture test result increased in direct proportion to the increase in the gas pressure.

TABLE 3.—*Variations in gas pressure affect the heating time and cause variations in moisture test results*

[Excessive pressure results in too fast heating time and too high moisture test. Burners adjusted to 1.2 inches gas pressure]

Gas pressure	Average		Maximum		Minimum		Range		Average error from correct method	
	Heating time	Moisture	Heating time	Moisture	Heating time	Moisture	Heating time	Moisture	Heating time	Moisture
Inches	*Min.*	*Per cent*	*Min.*	*Per cent*	*Min.*	*Per cent*	*Min.*	*Per cent*	*Min.*	*Per cent*
1.2	17	11.7	18	11.9	16	11.6	2	0.3	0	0
2.2	13	12.1	14	12.4	12	11.8	2	0.6	−4	.4
3.2	11	12.3	11	12.7	10	12.0	1	0.7	−6	.6
3.6	10	12.6	10	13.0	9	12.1	2	0.9	−7	.9
Correct (1.2 inches) with gas regulator control	17	11.7	17	11.9	16	11.6	1	0.3		

NOTE.—Data given in this table summarize 18 tests for each gas-pressure series on the same sample of wheat.

Conversely, if the burners are adjusted to give the correct heating time at a higher gas pressure on the supply lines and the gas pressure decreases, a corresponding increase in the time of heating and a decrease in moisture results. Such variation in pressure must be overcome to give accurate results.

GAS PRESSURE REGULATOR

Variations in gas pressure can be overcome by the use of a gas pressure regulator, commonly called a gas governor. One type of gas governor is shown in Figure 1, attached to a moisture tester, and diagrammatically in Figure 20.

In operation, the gas pressure regulator, when once correctly adjusted, will deliver gas to the burners of the tester at a constant pressure regardless of pressure variations on the gas supply line, or of variations in the number of burners in operation simultaneously; whereas, without the use of a gas pressure regulator, it is necessary for correct and uniform moisture test results to adjust the gas valve which regulates the gas supply (pressure) to the burners of the moisture tester at different periods of the day and to adjust the flame for every burner still in use each time that one of the burners is cut off.

Table 4 gives the correct size of gas pressure regulator for moisture testers having varying numbers of burners. The table also gives the various sizes of gas supply lines to be used and the minimum gas pressure on the supply lines at which the regulators will operate. The size of regulator and pipe lines for moisture testers should conform to the specifications given in the table to insure against possible overtaxing of the gas supply.

The regulator may be installed at any place on the gas supply line between the meter and the moisture tester, although it is desirable to place it as close to the tester as is possible. A gas pressure regulator, however, is not capable of compensating for changes in the British thermal units, or for changes in the density of the gas supplied the consumer. If these change, the heating time will change, and the burners in the moisture tester will have to be restandardized.

TABLE 4.—*Correct sizes of gas pressure regulators for moisture tester or testers having various number of burners, varying sizes of gas supply lines, and the minimum gas pressure on the supply line at which the regulators will operate*

Number of burners	Size of regulator		Required size of supply pipe (inside diameter)	Minimum pressure at which regulator will operate
	Inside diameter of inlet and outlet	Trade designation		
	Inches		*Inches*	*Inches*
2	¾	5-light	½	0.3
4	¾	do	¾	.3
6	¾	do	¾	.3
12	1	10-light	1	.3
18	1	do	1	.3
24	1¼	30-light	1¼	.3
30	1¼	do	1¼	.3

NOTE.—Gas pressure measured in inches head of water.

HOW TO ADJUST A GAS PRESSURE REGULATOR

After the pressure regulator has been installed on the supply line as near to the tester as possible it must be adjusted to give a standard heating time. The following method of procedure in making such an adjustment is necessary:

(1) Overhaul the moisture tester thoroughly by:

(*a*) Replacing all cracked or burned-off wire gauzes with new ones and adjusting them so that the flame will strike the asbestos center of the gauze.

(*b*) Adjust the asbestos ring of the flask rest so that the bottom of the flask is approximately three-eighths inch above the wire gauze.

(*c*) Take down each burner and clean it thoroughly. In this operation special care should be given to the cleaning of grids in the top of the burner, the needle hole in the burner base, and the burner valve.

(*d*) Test all gas connections for leaks, and if any are found tighten or replace the fittings.

(2) Determine the gas pressure on the supply line of the tester or testers *when all burners are in operation*, by the use of a pressure gauge connected to the supply line and which will register gas pressure in inches head of water. To do this, throw the regulator out of operation by pressing down the valve in the top.

(3) With the pressure gauge still connected to the supply line and all burners in operation, release the valve of the regulator.

(4) Place a weight on the valve that will set the regulator to deliver gas at a pressure of approximately 2.5 inches less (as determined by readings of the pressure gauge) than the gas pressure as determined in item 2 above.

(5) Make a preliminary heating time test (oil test) on every compartment of the tester or testers, with the flasks containing 450 cubic centimeters of oil alone and the mercury bulbs of the thermometers completely buried in the oil, as described on page 22. If the 450 cubic centimeters of oil in all compartments heat to 175° C. in less than 20 minutes, place a lighter weight on the valve in the regulator. Repeat the tests, adjusting the weight on the regulator after each

trial until *one or more* compartments show the correct heating time. If, on the other hand, the 450 cubic centimeters of oil show a heating time of more than 20 minutes to reach 175° C., the needle holes in the bases of the burners should be opened as explained in item 6 following. Repeat the oil test, opening or closing the needle holes after each test until *one or more* compartments have the correct heating time. For all heating time trial tests use oil at room temperature, and in every instance the machines should be given time to cool thoroughly before the next trial test is made.

GAS PRESSURE REGULATOR

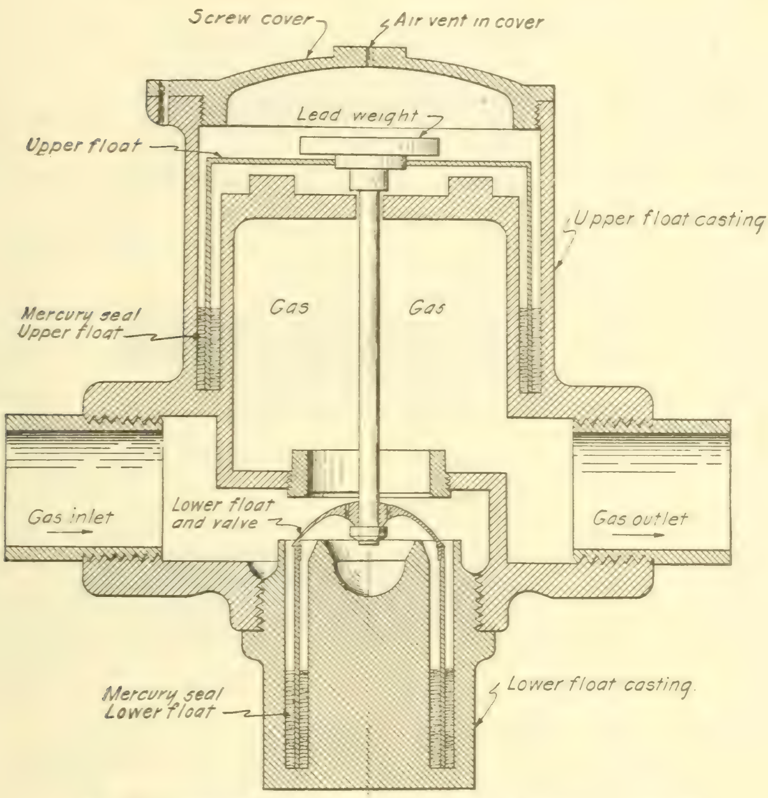

FIG. 20.—Sectional view of one form of gas pressure regulator

(6) When the preliminary adjustments have been made so that one or more burners of each moisture tester will heat the 450 cubic centimeters of oil to a temperature of 175° C. in 20 minutes, the remaining burners should be adjusted, with the corrected burners as a standard, to show the correct heating time. These adjustments are made by opening or closing the needle hole in the base of the burner. If the burner is too fast, the hole may be closed by lightly tapping the top of the base with a small hammer or any blunt tool. If the burner is too slow, the hole may be opened with a suitable reaming tool, such as the fine brooch used by jewelers.

(7) Trial tests should be repeated until the heating time for all compartments does not vary more than half a minute from 20 minutes; that is, the heating time should not be less than 19½ minutes or more than 20½ minutes to raise the temperature of the 450 cubic centimeters of oil to 175° C.

VARIATIONS IN HEATING TIME AND MOISTURE-TEST RESULT CAUSED BY POSITION AND CONDITION OF WIRE GAUZE

The wire gauze used in the bottom of the tester compartment will cause variations in heating time, with consequent errors in the moisture test result when the gauzes are burned off, cracked, have

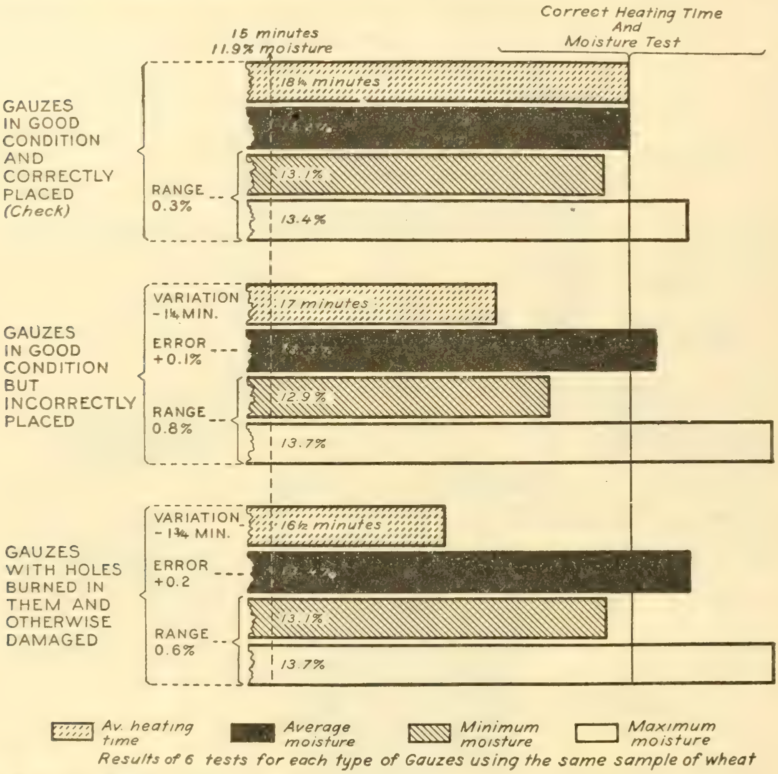

FIG. 21.—Effect of the condition and position of the wire gauze in the moisture tester on the moisture test result

holes burned in the asbestos center or in the gauze itself, or when they are incorrectly placed.

Data given in Table 5 and illustrated in Figure 21 show that the use of wire gauzes that are burned off, cracked, have holes burned in them, or are incorrectly placed will cause a faster heating time than the standard time, and an increase in the moisture test result over the correct result. The results also show that the use of damaged or incorrectly placed gauzes will cause an appreciably wider range between results of tests than when gauzes are in good condition and in correct position.

TABLE 5.—*Damaged or incorrectly placed wire gauzes cause errors in moisture test results in testing wheat*

[Wire gauzes that are damaged or incorrectly placed in the compartments of the moisture tester affect the heating time of tests and cause variations in moisture results]

Compartment No.	Condition of wire gauze							
	Good and correctly placed (check)		Good, but flame striking edge of asbestos center		Damaged (asbestos burned off and holes in gauze)		Good and correctly placed (check)	
	Heating time	Moisture	Heating time	Moisture	Heating time	Moisture	Heating time	Moisture
	Minutes	*Per cent*	*Minutes*	*Per cent*	*Minutes*	*Per cent*	*Minutes*	*Per cent*
1	18½	13.1	17½	13.3	17¼	13.3	18	13.0
2	18	13.3	17	13.4	16½	13.6	18½	13.2
3	18¼	13.2	18¼	13.6	17¾	13.5	18	13.2
4	18½	13.4	17½	13.7	15	13.7	18¼	13.3
5	18¼	13.3	15½	12.9	15	13.1	18½	13.2
6	18	13.1	16¼	13.1	17	13.2	18	13.1
Average	18¼	13.2	17	13.3	16½	13.4	18¼	13.2
Range	½	0.3	2¾	0.8	2¾	0.6	½	0.3
Average error from checks			−1¼	+0.1	−1¾	+0.2		

VARIATIONS IN HEATING TIME CAUSED BY VARIATIONS IN THERMOMETER-BULB IMMERSION

Data in Table 6, illustrated in Figure 22, show that a deeper immersion than the correct depth of four-fifths immersion of the mercury bulb of the thermometer in the oil will cause a faster heating time and a lower percentage of moisture, and that a shallower depth of immersion will cause a slower heating time and a higher percentage of moisture.

To insure correct moisture test results from the standpoint of this factor, the depth of immersion of the mercury bulb of each thermometer should be carefully noted and adjusted to the correct four-fifths immersion for each test.

TABLE 6.—*Variations in the depth of immersion in oil of the thermometer bulb will affect the heating time and cause errors in the moisture-test result*

Bulb immersion	Average		Maximum		Minimum		Range		Average variation from correct (four-fifths) immersion	
	Heating time	Moisture	Heating time	Moisture	Heating time	Moisture	Heating time	Moisture	Heating time	Moisture
	Minutes	*Per cent*	*Minutes*	*Per cent*	*Minutes*	*Per cent*	*Minutes*	*Per cent*	*Minutes*	*Per cent*
Bulb touching surface	19	10.5	19½	10.6	18½	10.4	1	0.2	2⅔	+0.4
Bulb one-fifth immersed	17⅓	10.3	17¾	10.4	17	10.3	¾	0.1	1	+0.2
Bulb one-half immersed	16¾	10.2	17	10.3	16½	10.0	½	0.3	½	+0.1
Bulb four-fifths immersed [1]	16⅓	10.1	16¾	10.2	16	10.0	¾	0.2		
Bulb totally immersed	16	10.0	16¼	10.2	15½	9.9	¾	0.3	−⅓	−0.1

[1] Correct position

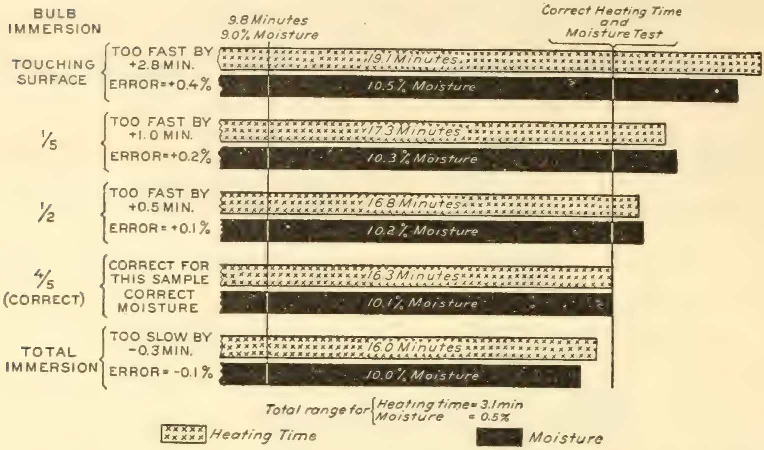

FIG. 22.—Effect of variations in the depth of immersion of the thermometer bulb in the oil on the moisture-test result

INFLUENCE OF COOLING TIME ON MOISTURE-TEST RESULTS

When the flame under the moisture testing flask has been extinguished, the material in the flask must be allowed to cool before making the moisture reading, for the reason that moisture will continue to distill off the material in the flask for several minutes after the flame has been extinguished. In case the moisture reading is made before the temperature has dropped to a point at which no further moisture will pass into the graduate, the result will be inaccurate in that it will indicate less moisture than is actually present. The rate at which the grain and oil in the flasks cool after the flame is cut off is also important. Too rapid cooling will cause low moisture results, and if the compartment covers are removed too soon low results will also prevail. The thermometer reading should drop to 160° C., a point where no further accumulation of moisture takes place, before the reading is made. Table 7 and Figure 23 summarize the errors that result if the moisture readings are made previous to the thermometer receding to 160° C.

TABLE 7.—*Insufficient cooling time causes low moisture-test results*

	Covers removed							
	After tests had cooled to 160° C. (correct method)		10 minutes after cut-off temperature was reached (thermometer reading 180° C.)		5 minutes after cut-off temperature was reached (thermometer reading 186° C.)		Immediately after cut-off temperature was reached (thermometer reading 190° C.)	
	Cooling time to 160° C.	Moisture	Cooling time to 160° C	Moisture	Cooling time to 160° C	Moisture	Cooling time to 160° C.	Moisture
	Minutes	*Per cent*	*Minutes*	*Per cent*	*Minutes*	*Per cent*	*Minutes*	*Per cent*
Average	18¼	18.3	16½	18.0	15⅔	17.9	8¼	17.5
Maximum	19	18.4	17	18.1	15½	18.0	9	17.6
Minimum	17	18.1	16	17.9	14¼	17.7	7½	17.3
Range	2	0.3	1	0.2	1¼	0.3	1½	0.3
Average variation from correct method			−1¾	−0.3	−2¾	−0.4	−10	−0.8

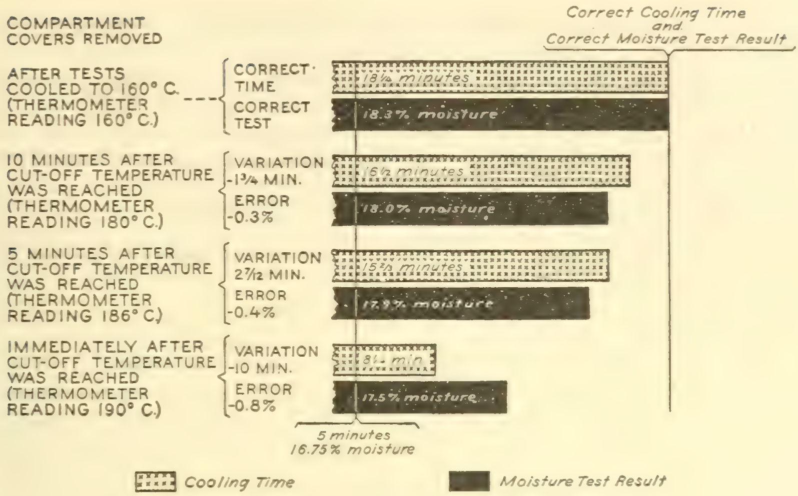

Fig. 23.—Effect of cooling time on the moisture-test result

PRIMING TESTS

In making a moisture test with the Brown-Duvel tester, all of the moisture which is distilled from the grain is not obtained in the graduate during the first test with a new flask. Some of it stays behind on the walls of the glassware. To accomplish accurate results, it is therefore necessary to make a preliminary or priming test in all the compartments of a new moisture tester, or when new distillation flasks are used, before a regular test is made. This is also true when a machine has been standing idle or standing open for any appreciable length of time. The length of time a tester may stand idle, after which it will be necessary to make a priming test before the regular test is made, depends somewhat upon the state of the machine when not in use.

The data, which are summarized in Tables 8 and 9, and shown graphically in Figures 24 and 25, show that a failure to make a

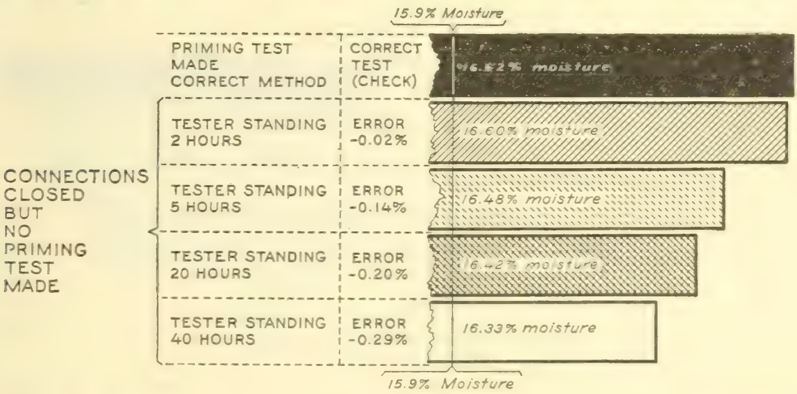

Fig. 24.—Necessity of making a priming test before making moisture test after the moisture tester, with all connections closed, has been standing idle for any appreciable length of time is here shown

priming test before a regular test, after the machine has stood idle or disconnected for an appreciable length of time, will cause low moisture-test results, the amount that the results are low depending upon the time that the tester has stood idle. The method for avoiding errors from this source is to connect the apparatus, as for use, immediately after every test is completed, and to make a priming test before making a regular test every time new glassware is used or when the tester has stood idle for any considerable length of time.

TABLE 8.—*Failure to make a priming test before the regular test, after the machine has been standing idle with all connections made, causes a low moisture-test result*

	Priming test made by correct method (per cent moisture)	No priming test made			
		Tester standing 2 hours (per cent moisture)	Tester standing 5 hours (per cent moisture)	Tester standing 20 hours (per cent moisture)	Tester standing 40 hours (per cent moisture)
Average	16.62	16.60	16.48	16.42	16.33
Maximum	16.7	16.7	16.7	16.5	16.5
Minimum	16.4	16.5	16.3	16.3	16.1
Range	0.3	.2	.4	.2	.4
Average error from correct method		−.02	−.14	−.20	−.29

TABLE 9.—*Failure to make a priming test before the regular test, after the machine has been standing open with no connections, causes a low moisture result*

	Priming test made by correct method (per cent moisture)	No priming test made				
		Tester standing 1 hour (per cent moisture)	Tester standing 3 hours (per cent moisture)	Tester standing 6 hours (per cent moisture)	Tester standing 20 hours (per cent moisture)	Tester standing 40 hours (per cent moisture)
Average	10.57	10.50	10.50	10.38	10.33	10.15
Maximum	10.6	10.6	10.6	10.5	10.5	10.4
Minimum	10.5	10.3	10.4	10.2	10.0	10.0
Range	.1	.3	.2	.3	.5	.4
Average error from correct method		−.07	−.07	−.19	−.24	−.42

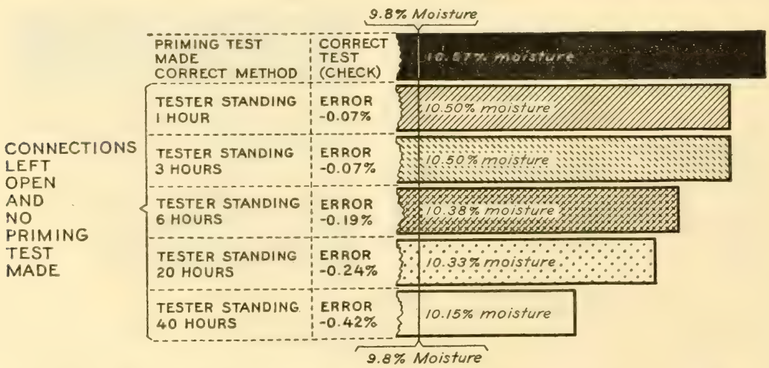

FIG. 25.—Errors resulting from failure to make a priming test before a regular test, after the tester has stood idle and disconnected for one hour or longer, are here shown

VOLUME OF OIL VERSUS MOISTURE-TEST RESULT

Variation in the volume of oil used in making a moisture test may cause variation in the moisture-test result. Five series of 12 moisture tests each were made on the same sample of corn, using varying volumes of oil in each series.

The data, as shown in Table 10, indicate that there is an increase in the moisture-test result when less than 150 cubic centimeters of oil is used but show no appreciable variation in the moisture-test result from using slightly more than 150 cubic centimeters of oil.

TABLE 10.—*A decrease in oil volume below 150 cubic centimeters causes an increase in the moisture-test result; an increase in oil volume above 150 cubic centimeters will only slightly effect the moisture-test result*

	Volume of oil used				
	115 c. c. (per cent moisture)	135 c. c. (per cent moisture)	150 c. c. (standard) (per cent moisture)	165 c. c. (per cent moisture)	185 c. c. (per cent moisture)
Average	19.03	18.98	18.86	18.85	18.83
Maximum	19.2	19.1	19.1	19.1	19.1
Minimum	18.9	18.8	18.7	18.6	18.7
Range	.3	.3	.4	.5	.4
Average variation from standard 150 c. c. series	+.17	.12		—.01	—.03

BROWN-DUVEL MOISTURE TESTERS EQUIPPED WITH ELECTRIC HEATERS

Reports are frequently received stating that it is difficult to obtain the same moisture-test results when making comparative moisture tests on grain with the gas-heated and the electrically-heated Brown-Duvel moisture testers. In most instances, the reports show that the moisture tests on the electric machines run lower than the tests on the standard gas machines, although there are instances at some of the markets where the tests on the electrically-heated tester give moisture-test results higher than the results obtained when made on the standard gas tester, some of them reported as being higher by over 2 per cent.

To determine the efficiency of the electrically-heated tester and the reasons for its failure always to check results obtained on the standard gas machine, investigations were conducted for the purpose of studying and comparing the factors which influence moisture-test results as made with the electrically-heated tester. These investigations covered such points as the types of heaters now employed (in 1925), their heat capacity, their efficiency in transmitting heat to the moisture flask, their durability, the nature and uniformity of the electric service supplied, loss of current due to conditions of wiring, and how fluctuations or lack of voltage and current will affect the wattage or heat developed. Finally, how lowered voltage affects the time of making the tests and how this time factor influences the moisture-test result.

ELECTRICAL TERMS

Attention is called to some facts that should be generally known about electricity before an electrically heated moisture tester is installed. To illustrate some of the factors involved, consider electricity as water. The size of the stream of water flowing through a pipe would be indicated in "amperes" for electricity. The pressure of the water, or the speed with which it flows, is measured in "volts" for electricity. The quantity of water passing through, or the gallons of water flowing, is measured in "watts" for electricity. The term "kilowatts" merely means 1,000 watts by the regular metric system. The term "kilowatt hour," means a kilowatt quantity of electric current used for an hour's time to light or blow breezes or fry an egg or sweep the floor or run a moisture machine, or to do anything else.

The large quantity of current consumed by relatively small electrical heating units is generally not appreciated by the ordinary layman not versed in electricity. Take for example, one 6-compartment moisture testing machine heated by electricity. Each compartment requires 5.4 amperes of current at 110 volts pressure or 594 watts, making 3,564 watts for the whole machine. This amount of energy is sufficient to light 125 ordinary 25-watt electric lamps. It would generate mechanical power at the rate of almost 5 horsepower.

TYPES OF HEATERS NOW IN USE

The electric heaters in use in 1925 are of two general types. One of these general types consists of a sheet-metal box 5 by 5 inches square, 1½ inches deep, the upper side of which is open except for a heavy wire netting which allows the developed heat to rise into the compartment of the tester. The heating elements or resistance coils of this type of heater stretch between two porcelain barriers within the box. The heaters are fastened to the outer edge of the tester compartment with hinges and are held in place under the compartment by a spring metal clip at the rear. On the floor of the heater is a thin sheet of asbestos which prevents the resistance coils from touching the metal boxes and which functions at the same time as a means of keeping some heat from being lost to the outside. As a rule, these heaters are wired to take a voltage or pressure of 110 or 220 volts and the resistance wire within the heater is made of such diameter and length as to take a current of 4.6 amperes for the 110-volt current or 2.3 amperes for the 220-volt circuit. Expressed differently, they are so wired that they will develop 500 watts of heat energy per heater. It will be shown later, however, that 500 watts will not develop sufficient heat to give a standard heating time of 20 minutes.

Experiments have demonstrated that because of the excessive heat leakage from this type of heater, caused by lack of insulating material at the base and sides of the heater, not more than 25 per cent of the possible heat energy developed by the heater is transmitted to the compartment of the tester when this heater is in operation. Furthermore, since this type of heater has very little heat-retaining capacity, it has to be used on a constant and uniform electric circuit where the specified voltage and amperage is always at the maximum point. As the heat energy developed is proportionate to the voltage supplied, a lag or drop in the voltage for a few minutes will be readily noticed when this type of heater is used, inasmuch as there is no provision for retaining any heat for an emergency period, as would be the case if the inside of the heaters were well insulated with asbestos or fire clay.

Another heater of this general style, but of slightly different design, is used to some extent. This is identical in all respects with the one just described, with the exception that both the top and bottom of the box are absent and the coils are suspended between mica supports within the walls of the box. Necessarily less of the possible heat generated is transmitted to the compartments of the tester by this type of heater than with the one described before. These heaters are being gradually eliminated from service, and for moisture-testing purposes should be eliminated entirely.

The second type of heater in general use consists of a reinforced fire-clay block $4\frac{1}{2}$ by $4\frac{1}{2}$ by 1 inch deep with recessed portions on the upper side for installing the heating coils. These heaters are wired for 110 or 220-volt circuits, but the resistance coils are of such a size that they take only 3.2 amperes of current, and therefore are possible of developing only 350 watts of energy. Because of their fire-clay structure, much more of the heat energy is transmitted to the compartments of the tester from this heater than from the other type. The heater swings on an improvised hinge attached to the inside of the back of the compartment and is raised and lowered by means of a cam attached to a rod.

ELECTRICAL ENERGY FOR STANDARD HEATER

From a theoretical standpoint, enough heat will be supplied from a heater properly constructed and delivering 300 watts of energy to operate a moisture tester properly, providing none of the heat is lost during the interval of the test. But, as a practical matter, the electric heaters commonly used to-day in moisture testers must be wired to deliver approximately twice this amount of heat energy, or 600 watts, on account of the excessive heat leakage which they permit.

WIRING FOR ELECTRICALLY-HEATED MOISTURE MACHINES

Observations have shown that although these heaters are wired to take either a 110 or 220-volt circuit, it is not always that the specified voltage is delivered in every installation to the switch board of the moisture tester. Observations have shown that the voltage supplied is usually below 110 or 220, apparently for two reasons.

In the first place, the necessary voltage is not delivered to the moisture-testing laboratory by the electric service companies. This is notably true at certain large terminal or export elevators which are located from 1 to 10 miles from the generating plant. Moreover, many isolated plants furnish their own electrical energy, and the required 110 volts are not always available. As a general rule, large city service is rather regular, although there are notable exceptions.

Electric service is usually delivered to large terminal elevators at high voltage, such as 550, 1,100, or 2,200 volts, and is then cut down by means of a transformer in the power plant to the subvoltage required. Instances of this are cuts to 440 volts, as used by some elevators to run the belts, and 110 or 220 for lighting or other low-power service. A number of instances have been noted where the voltage received is considerably under that expected, in which case the difference is automatically carried forward when a subdivision of the original voltage is made at several points. Tests on electric circuits before entering the heaters of moisture testers have given figures varying from 95 to 115 volts on 110-volt circuits.

There always is an additional drop in pressure or in voltage as the heaters are put into operation, provided nothing is done to keep the voltage bolstered up to the point specified on the heating apparatus. If one will think of a large tank of water of definite volume with a series of spigots turned on, one after the other, it will soon become apparent that the rate or speed at which any spigot, or series of spigots for that matter, will flow is decidedly influenced by the number of other spigots running at the same time. This is more and more noticeable as the tank empties. If the tank receives a renewed supply of water as fast as it runs out at the base, the rate of flow will be constant. Electric pressure is influenced in the same way. All other interfering factors eliminated, if the voltage remains constant, the rate of flow of electric energy or the watts will also remain constant.

The second important factor regarding drops in voltage is found in the wiring conditions from the power station or from the transforming box to the machine. Wiring circuits installed in buildings are usually designed to carry current for a certain number of electric lamps, usually not more than ten 100-watt lamps. In such case this number, or the equivalent current, should not be exceeded. *To use an ordinary lighting circuit for a four or six compartment moisture tester* is not only entirely unsatisfactory as far as moisture testing is concerned, but *is a very dangerous fire risk.* The danger comes from excessive heat developed in the line by forcing too large a current of electricity over a small wire. This feature is taken care of by the national underwriters, who specify certain maximum allowable current strength for all wires used in interior wiring.

Table 11 shows the allowable current for both "rubber" and "other than rubber" insulated wires. The values for wires of various sizes are given in the first two horizontal columns of the table. These values should never be exceeded. The current and voltage at which an electrically heated moisture machine is designed to work is usually given on a plate attached to the machine as it comes from the factory. The vertical column in Table 11, headed "Amperes required by machine," gives the amperes required by one of the common types of electrically heated testers, of two, four, and six compartments.

The application of the table as to length of circuit can best be shown by an example. Assume a 6-compartment moisture testing machine operated on 220 volts, located so that it will require a circuit 40 feet long. In Table 11, under the subheading "For 220 volt circuits," read along the horizontal line starting with six compartments, amperes required, 13.8. A size 14 wire is large enough to carry the current if it is "other than rubber insulated," but 30 feet of this wire will give a line drop in voltage of 1 per cent so that it would not be desirable to use that size. Size 12 requires 48 feet to give a 1 per cent drop, hence, would be the size to select. Should it be desired to decrease further the drop in voltage, any larger size wire could be used, as for instance a No. 6 wire, and the drop determined by dividing 40 by the length for 1 per cent drop, or 193, giving practically 0.2 per cent drop.

It is important that all wiring for electrically-heated moisture machines be done by a competent electrician. Even then he should be impressed with the fact that the voltage at the machine must be kept as nearly constant as possible, whether one compartment or several dozen are operating.

TABLE 11.—*Wiring for electrically heated moisture machines*

		Size of wire B. & S. gauge					
		14	12	10	8	6	5
Amperes allowed, insulation other than rubber		*16*	*23*	*32*	*46*	*65*	*77*
Amperes allowed, rubber covered		12	17	24	33	46	54
	Amperes required by machine	Length of circuit for 1 per cent drop					
		Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
On 110-volt circuit:							
2 compartments	9.2	22	36	57	91	144	182
4 compartments	18.4		18	28	45	72	91
6 compartments	27.6			19	30	48	60
On 220-volt circuit:							
2 compartments	4.6	90	144	228			
4 compartments	9.2	45	72	114	182	290	
6 compartments	13.8	*30*	48	76	121	193	244

Values in italic figures refer to "insulation other than rubber"; all other values refer to either method of insulation.

EFFECT OF LOW VOLTAGE ON MOISTURE-TEST RESULTS

Investigations have shown that there is a wide variation in the electric pressure available at various markets. Studies were made to determine what influence that fluctuation or drop in voltage has on the heating time in making moisture tests with testers equipped with electric heaters and its effect on the moisture-test result. Experiments to determine the influence of a drop in voltage on the heating time were made at the electric measurement division of the United States Bureau of Standards. The results obtained from these tests are given in Table 12. The table shows the maximum, minimum, average, and range in results of all series of tests on both the electric testers and the gas-heated testers. The table also shows the minus or plus variations, in time of heating and percentage of moisture obtained for all voltage series on the electric tester, from the same series of samples when tested on the standard gas-heated tester.

TABLE 12.—*Influence of low voltage on the moisture-test results*

110-volt circuit:								(1)
Voltage	90	95	100	105	110	112	115	
Amperage	24.4	25.6	26.8	28.4	29.6	30.4	31.0	
Wattage	2,196	2,432	2,680	2,982	3,256	3,420	3,565	
220-volt circuit:								
Voltage	180	190	200	210	220	225	230	
Amperage	12.2	12.8	13.4	14.2	14.8	15.2	15.5	Gas tester.
Wattage	2,196	2,432	2,680	2,982	3,256	3,420	3,565	
Maximum:								
Time (minutes)	33½	31	27½	25	23	21½	20½	19¾
Moisture (per cent)	16.9	17.0	17.1	17.2	17.3	17.3	17.5	17.5
Minimum:								
Time (minutes)	30½	28½	23¾	22¾	20¾	19½	17½	19
Moisture (per cent)	16.6	16.8	16.9	16.9	17.1	17.2	17.3	17.3
Average:								
Time (minutes)	31½	29½	26¼	24	22	20¼	19	19½
Moisture (per cent)	16.8	16.9	17.0	17.1	17.2	17.3	17.4	17.4
Range:								
Time (minutes)	3	2½	2¾	2¼	2¼	2	3	¾
Moisture (per cent)	0.3	0.3	0.3	0.3	0.2	0.1	0.2	0.2
Average variation, standard gas tester:								
Time (minutes)	12	10	6¾	4½	2½	¾	−½	
Moisture (per cent)	−0.6	−0.5	−0.4	−0.3	−0.2	−0.1	Trace.	

[1] Results obtained with standard gas tester.

The results obtained in these experiments with a Brown-Duvel moisture tester, electrically heated, operated at varying voltages, show that as the voltage and wattage increase to optimum conditions the time of heating decreases, and that the percentage of moisture obtained increases. It shows, also that the heating time is dependent upon the wattage developed and delivered by the heater. A drop in voltage of over 5 per cent will cause a decrease in wattage sufficient to cause appreciable variations in moisture-test results and these results will always be low.

The experiments also demonstrated that the results obtained with the electrically-heated tester can be made to check with the results obtained with a gas-heated tester by means of wiring the electric heaters to such a capacity that each heater will develop approximately 600 watts of energy per heater, or 3,600 watts per 6-compartment machine. To attain these results on a constant pressure, 110-volt circuit, the heaters must be wired to carry 5.4 amperes of current. If the voltage is not constant at 110 but fluctuates, as for instance from 103 to 95 volts, it will be necessary to rewire the heaters so as to produce a current which will develop 600 watts per heater. For illustration, the amperage necessary on a 95-volt circuit is 6.2 amperes and on a 103-volt circuit it is 5.8 amperes. If the voltage is fluctuating badly, the average voltage will have to be ascertained for the circuit on which the moisture machine is to be operated and the heaters overwired; that is, so wired as to give more wattage than is necessary, and the excess cut out by means of a point rheostat. This, of course, necessitates the constant use of a voltmeter, ammeter, and rheostat on the line.

HOW TO TELL IF THE ELECTRIC HEATER IS WORKING AT STANDARD CONDITION

By the combined use of a voltmeter and an ammeter it can readily be determined whether the proper wattage is being developed for the type of heaters used. As these instruments are not always available, however, the oil test (p. 22) is the best test to apply. The standard heating time is the same regardless of the sources of heat energy, whether gas, electricity, alcohol, or gasoline.

If, on making a check test with the oil-test method, all heaters do not rise uniformly within one-half minute of 20 minutes, they are not standard and will give either high or low moisture-test results, and the services of a competent electrician are needed.

To make an electric-heated machine check with the gas-heated machine, the electric heaters of the box type in which the upper side is open, if they are giving a standard output of heat, should be lowered after making the moisture test. If they are not giving a standard amount of heat, direct comparison with a standard gas tester is the only way in which one can determine in what position the heater should be left. When that type of box heater is used in which the top and bottom casing of the box is absent, the heater should be left in position to assure check results with the gas-heated testers. If this type of heater is lowered from its operating position when the current is turned off, heat is lost too rapidly from the compartment after the completion of the test.

The data obtained from these experiments show that the maximum difference between the results obtained on an electrically-heated machine, properly adjusted and carefully operated, and on a standard gas-heated tester should be very slight, with a voltage drop of not over 5 volts. Results, therefore, which are in excess of this are due to faulty operation of the machine, such as not waiting for the temperature of the oil in the flask to drop to 160° C. before making a reading; use of faulty equipment, including incorrectly graduated thermometers or measuring cylinders and spongy rubber stoppers; inaccurate weighings, or lack of priming tests.

TESTS WITH ALCOHOL AND GASOLINE BURNERS

Moisture tests can be made with a Brown-Duvel moisture tester heated with alcohol or gasoline burners, but such tests can not be made with the satisfaction attending the use of gas or electric-heating units. In making tests with alcohol or gasoline burners, the flame is very irregular and needs frequent adjustment of the burner valves during the progress of the test.

When the burners are used, they may be standardized by placing them at a distance of 2¾ inches from the wire gauze and the flame adjusted to a point where it will develop heat enough to raise the temperature of the oil and grain in the flask to 120° C. in 10 minutes and then to give a steady rise in temperature beyond this point of from 6° to 8° per minute, until the cut-off temperature is reached.

HOW TO CHOOSE EXTINGUISHING TEMPERATURES

The Brown-Duvel method has not yet been developed for testing a number of commodities for which the method is applicable. Questions are frequently asked regarding the procedure necessary to determine the proper extinguishing temperatures for different commodities.

The extinguishing temperatures for testing the moisture content of various commodities with the Brown-Duvel moisture tester are secured by checking the results obtained with the moisture tester against results obtained by making moisture determinations by drying to constant weight in the common type of double-walled oven filled with water maintained at the boiling point, except that the treatment for flaxseed is determined by checking with samples dried to constant weight in a 28-inch vacuum at a temperature of 99 to 100° C.

To determine the proper extinguishing point for the Brown-Duvel method, the following procedure takes place:

In the case of corn, the grain is heated in a water-jacketed oven at the temperature of boiling water, 99° to 100° C., until no further loss of weight occurs in 24-hour intervals. This usually takes about 96 hours. This loss in weight is considered moisture and is known as the standard moisture test. One hundred gram portions of the same grain are then treated in the Brown-Duvel way, the only variable being the temperature at which the flame is extinguished. The cut-off temperature is gradually changed through 5° or 10° units until the moisture test result by the Brown-Duvel method is the same as the moisture test obtained with the water-oven method. This temperature is then tried out in check tests on a large number of samples of corn having different moisture contents and further comparisons made with results as determined by the water-oven method.

TABLE 13.—*Comparison of the moisture machine method tests on a sample of corn at extinguishing temperatures of 160°, 170°, 180°, 190°, and 200° C. with oven test of the same sample*

Test No.	Percentage of moisture					
	Oven test	Machine tests				
		160° C.	170° C.	180° C.	190° C.	200° C.
1	14.24	12.4	12.8	13.6	14.0	14.8
2	14.21	12.4	13.1	13.5	14.0	14.8
3	14.27	12.3	12.9	13.6	14.1	14.6
4		12.4	13.1	13.4	13.9	14.5
5		12.5	13.1	13.5	14.2	14.6
6		12.3	13.0	13.4	14.2	14.6
Average	14.24	12.4	13.0	13.5	14.1	14.7
Variation from oven		−1.8	−1.2	−0.7	−0.1	+0.5

Table 13 illustrates how the preliminary extinguishing temperature was chosen for corn.

The cut-off temperatures are varied and comparisons continue to be made with results obtained with the water-oven method until the correct extinguishing temperature is found and this temperature is finally chosen as the proper cut-off temperature. The extinguishing temperatures that have been established to date for various commodities are listed in Table 14.

To determine the proper cut-off temperature for any commodity for which the test is applicable but for which the cut-off temperature has not yet been determined, proceed in a manner similar to that described for determining the proper cut-off temperature for corn.

DRAWING AND HANDLING SAMPLES

The sampling of grain is not a part of the moisture test itself, but an accurate sample of the lot of grain to be tested is essential for correct moisture tests. To obtain a representative sample is sometimes difficult, but the necessity of sparing no trouble in this respect is imperative for correct results.

Grain in cars, elevator bins, cargoes, and other similar places is seldom uniform in moisture content throughout the quantity, and among other variations often shows less moisture at the surface than in the body of the grain. In the case of corn in cars, it is not uncommon to find differences of several per cent between the moisture content of the layer of corn immediately at the surface and that of the body of the grain directly beneath. In an experimental shipment of three lots of corn contained in a single bulkheaded railroad car in which special care was taken to see that each lot of grain was loaded uniformly throughout, moisture tests at destination, 15 days after shipment, showed 14.1, 14.3, and 14.1 per cent, respectively, for the corn from the surface of each of the three lots, as compared with 17.3, 16.9, and 19.2 per cent, respectively, for the samples taken with a grain trier from the body of the grain 2 to 3½ feet below the surface, the latter percentages being practically the same as at the time of shipment.

TABLE 14.—*Summary of specifications for testing grain and other substances*

	Oil in flask	Weight of grain in flask	Extinguish the flame at—
Grains:	*C. c.*	*Grams*	*° C.*
Wheat	150	100	180
Shelled corn	150	100	190
Oats	150	[1] 50	195
Rye	150	100	175
Grain sorghums	150	100	190
Barley	150	100	190
Buckwheat	150	100	185
Flaxseed	150	100	175
Emmer	150	100	190
Head rice (milled) [2]	[3] 150	100	200
Second head rice [2]	[3] 150	100	[4] 200
Screenings rice [2]	[5] 150	100	[4] 200
Brewers' rice [2]	[5] 150	100	[6] 200
Brown rice	[3] 150	100	200
Rough rice	150	100	200
Other substances:			
Corncobs	250	[1] 50	190
Cottonseed	150	[3] 50	190
Navy beans	150	100	175
Shelled peanuts	150	100	175
Soy beans	150	100	175
Barley malt	200	100	168
Distillers' dried grains	200	[1] 50	190
Wheat flour	[5] 150	[1] 50	[7] 190
Corn meal	[5] 150	[1] 50	[8] 175

[1] Use special graduate which is one-half the volume of the regular graduate. However, the regular graduate may be used by doubling the moisture-test reading.
[2] In making tests of these classes of rice the distillate is sometimes cloudy. This in no way affects the accuracy of the test and may be disregarded.
[3] Use glass-wool pad 2 inches in diameter and ¼ inch thick in bottom of flask.
[4] Oil and grain in inner flask should reach a temperature of 200° C. in 28 to 30 minutes.
[5] Use double-wall copper flasks with 150 cubic centimeters of oil in the inner flask and 150 cubic centimeters between the walls.
[6] Oil and grain in inner flask should reach a temperature of 200° C. in about 26 minutes.
[7] Oil and flour in inner flask should reach a temperature of 190° C. in about 30 minutes.
[8] Oil and meal in inner flask should reach a temperature of 175° C. in about 26 minutes.

For correct results, it is essential that the same care which is used in obtaining the sample be observed in handling the sample after it is drawn from the grain or after it is weighed for the test. If exposed to the air, samples will lose moisture in accordance with the percentage of water in the sample and the condition of the atmosphere. An experimental test with 100 grams of wheat containing 14.5 per cent of moisture showed a loss of 0.20, 0.35, 1.10, and 1.90 per cent when exposed to the air of the laboratory for periods of one-half, 1, 4, and 26 hours, respectively. A second lot of wheat, containing 16.1 per cent of moisture, lost moisture to the extent of 0.50, 0.75, 1.75, and 3.20 per cent, respectively, during the same periods under identical treatment. Figure 26 shows the type of metal can and moisture-proof sample bag used by the offices of Federal Grain Supervision for the purpose of obtaining samples for moisture tests and other grading factors.

FIG. 26.—Air-tight sample can and moisture-proof sample bag used by Offices of Federal Grain Supervision for handling samples of grain to be tested for moisture content. The sample bag is not desirable for this purpose unless the moisture test can be made within an hour or two from time of sampling

The sampling devices and the methods used for obtaining correct samples of grain are fully described in United States Department of Agriculture Handbook, U. S. G. S. A. Form No. 90.

SPECIAL POINTS FOR CONSIDERATION

(1) The moisture tester should be installed in a place where it will not be exposed to strong air current.

(2) The standard tester is equipped for heating with illuminating gas.

(3) The wire gauze with asbestos center should be kept in good condition, and so adjusted that the flame plays directly in the center of the asbestos.

(4) The bottom of the flask should be not less than three-eighths inch above the wire gauze.

(5) The column of mercury in the thermometer should be continuous; if broken, it should be shaken down.

(6) The sample should be thoroughly mixed before weighing for tests; and unless the test is to be made immediately upon its arrival in the office, it should be placed in an air-tight container.

(7) Tests should be made in duplicate, and if duplicates vary over 0.3 per cent, another test should be made.

(8) The thermometers should be so adjusted that four-fifths of the mercury bulb is submerged in the grain and oil after the grain has been placed in the flask. (See to the adjustment each time. Do not guess.)

(9) Correctly graduated thermometers and graduates should be used.

(10) Mushy rubber stoppers must not be used as they absorb some of the moisture that should pass into the graduates.

(11) Each graduate should be cleaned and dried before using for a test. (Do not let them show any moisture in the bottom or along the sides.)

(12) Oil should not be used directly from the previous test. Used flasks should be emptied into a large storage can and never directly into the oil-measuring device.

(13) A good circulation of cold water should be maintained through the condenser tank.

(14) The heating apparatus should be so adjusted that the required temperature is reached in 20 minutes. A longer time will give results too low and a shorter time, too high.

(15) If the moisture content of the sample is high so that there is a tendency to boil over, the flame should be lowered until a considerable portion of the water is distilled over.

(16) The heat should be cut off at the exact temperature prescribed for each grain.

(17) After the flame is extinguished, a slight gradual rise in the temperature is to be expected. A sudden increase or sudden decrease in temperature of several degrees indicates that the flame was too intense during the latter part of the heating, and the test should be repeated.

(18) Covers and thermometers should not be removed until the temperature recedes to 160° C.

(19) After the temperature has fallen to 160° C. or lower, the thermometer is disconnected and then the delivery tube.

(20) The percentage of moisture in the graduated cylinder should be read after all the drops clinging to the sides of the graduates have been shaken down. The reading is taken beneath the layer of oil on top of the water.

(21) Results of tests need not be expressed more closely than 0.1 per cent.

(22) If the water which distills over is discolored, the substance has evidently been burned and the test should be repeated. (Note exception to this in the case of rice.)

(23) When machine is not in use, thermometers should be kept connected in the flasks and the flasks connected with the distilling tubes in the same manner as for making a test.

(24) Before making a test in a new flask, or before using a machine that has not been in use for a 24-hour period, a test should be made on a preliminary sample so that all the flasks will be uniform in condition.

(25) Scales should be placed on a firm support and care should be taken that they are in balance before making a weighing.

(26) The specific directions given above for making tests do not apply to modified forms of testers.

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