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THE TEST WEIGHT OF GRAIN: A SIMPLE METHOD OF DETERMINING THE ACCURACY OF THE TESTING APPARATUS.

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CONTENTS.

TEST WEIGHT PER BUSHEL AND APPARATUS FOR TAKING IT.

The "test weight per bushel" is one of the governing factors in assigning grades to grain. It is therefore highly essential that the "test weight" be accurately determined, as it affects market values.

The "weight-per-bushel tester," shown in figure 1 and described in United States Department of Agriculture Bulletin 472, was designed by the Department of Agriculture to provide means by which the "test weight per bushel" of grain might be rapidly and accurately determined. This apparatus and the method of use there described have been adopetd as the standard apparatus and method in connection with the enforcement of the United States grain standards Act.

The term "test weight per bushel" as applied to grain is a grading designation used in the official grain standards promulgated by the Secretary of Agriculture under authority of the United States grain standards Act. The meaning of the term "test weight per bushel" should not be confused with the meaning of the term "legal bushel," which is used in connection with the United States customs and for commercial purposes, as these two terms are fundamentally different in meaning. Test weight per bushel is the weight of the volume of

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grain required to fill level full a Winchester bushel measure of 2150.42 cubic inches capacity. The legal bushel is based on weight instead of measure or volume. For each of several grains a fixed number of pounds is considered a legal bushel; for example, for wheat 60 pounds constitutes a legal bushel; corn, rye, and flaxseed, 56 pounds; barley 48 pounds; and oats 32 pounds.

The standard Winchester bushel measure contains 32 quarts, whereas the actual volume in quarts of a legal bushel of grain de-

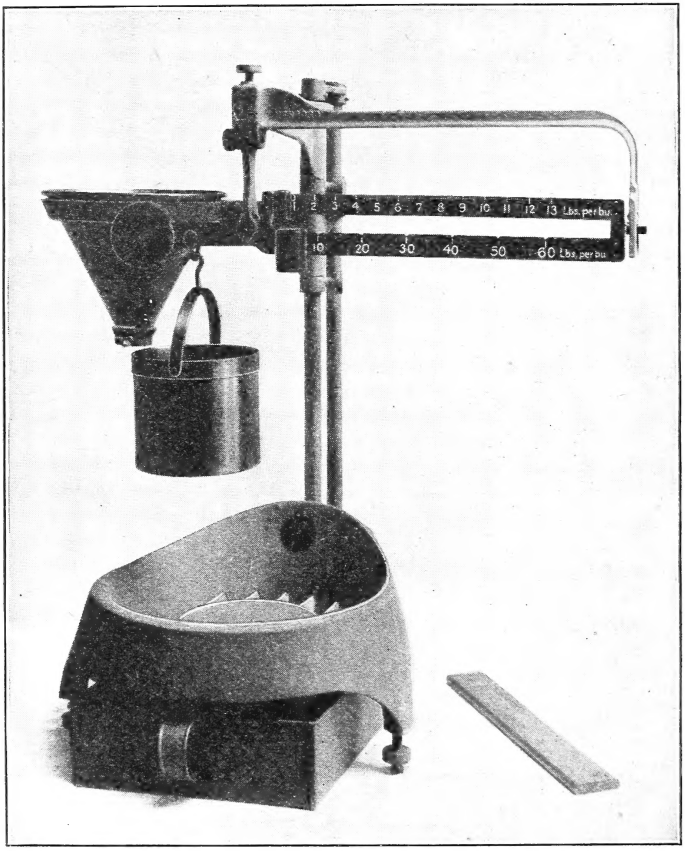

FIG. 1.—Standard apparatus for determining the test weight per bushel of grain.

pends upon its test weight. This is illustrated in figure 2. The volume in quarts required for a legal bushel by weight may be determined by multiplying the legal weight per bushel by 32 and dividing that product by the test weight per bushel of the grain in question. For example, the legal weight of wheat being 60 pounds for a bushel and the test weight of the wheat in question being 50 pounds, how many quarts will be required to weigh 60 pounds? Solution: Multiply 60 by 32 and divide by 50, as follows: $60 \times 32 = 1920 \div 50 = 38.4$ quarts, the volume required to weigh 60 pounds or a legal bushel

of wheat for commercial purposes. The chart in figure 3 shows graphically the number of quarts of grain for various test weights required to weigh the number of pounds fixed by law as a bushel for various grains.[1]

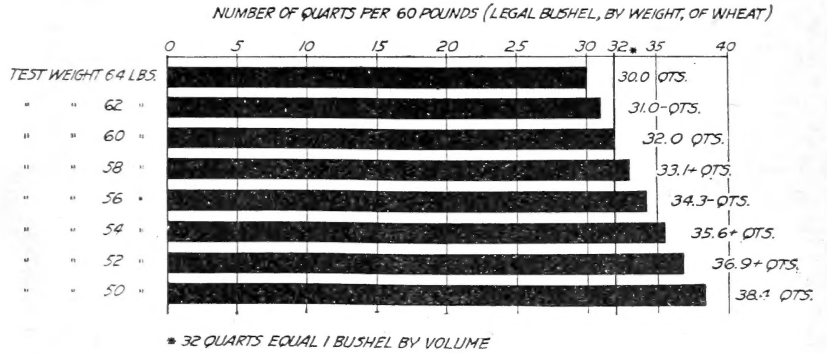

FIG. 2.—Comparison of the volume of 60 pounds of wheat of various test weights.

The standard weight-per-bushel tester is so designed that when the kettle is properly filled and struck off it contains exactly 1 dry quart,

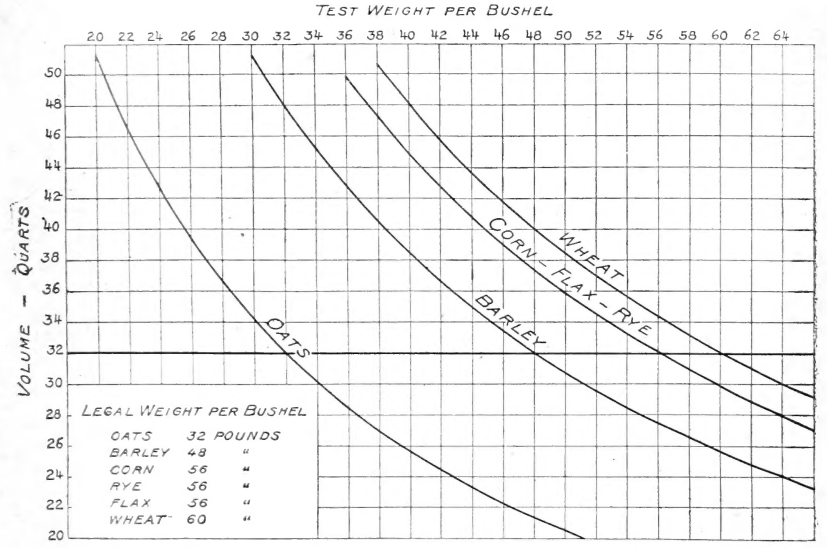

Fig. 3.—The number of quarts, by measure, of grain of various test weights required for a "legal bushel" by weight.

or 67.2 cubic inches. When the filled kettle is hung on its proper hook on the short end of the beam of the official testing apparatus,

[1] Milling and baking tests conducted by this bureau and by other authorities have furnished conclusive proof that 60 pounds of wheat which has a high test weight per bushel, say 60 pounds, will yield more flour of better quality than can be obtained from 60 pounds of wheat which has a lower test weight per bushel, as for instance, 48 pounds.

the weight of its contents may be determined directly in terms of pounds per bushel by means of the counterpoise and the graduations on the beam. As there are 32 quarts to the bushel, the beam is graduated to indicate 32 times the actual weight of the contents of the kettle; therefore, 1 pound in the kettle is equivalent to 32 pounds per bushel on the beam, 1 ounce to 2 pounds, ½ ounce to 1 pound, etc. When these facts are borne in mind the necessity for great care in following the prescribed method in making the weight-per-bushel test and for having an accurate kettle and beam will be realized.

The apparatus for determining weight-per-bushel tests shown in figure 1 and the method of making the test have been carefully developed and are officially approved. It has been demonstrated that if the prescribed method is followed and the apparatus is accurate, weight-per-bushel determinations can be made rapidly and accurately by any one familiar with the test. The two main factors affecting the accuracy of "test weight" determinations are the method used in making the test, and the accuracy of the apparatus. Whether or not the proper method is used depends entirely upon the person making the test, as the official method is clearly defined, but the most careful application of the prescribed method will not give accurate results if the apparatus used in making the test is insensitive or incorrect. The accuracy of the apparatus depends first, upon the capacity of the test kettle, and second, upon the correctness of the weighing mechanism. If the apparatus is purchased from a reliable manufacturer both the kettle capacity and the beam are usually accurate when it leaves the hands of the factory inspector, but even if it is absolutely correct at that time, it may not be correct when set up in the office or laboratory. No test-weight device should be used for determining grades of grain until it has been checked for accuracy by a properly conducted test, and this test should be repeated periodically as a general precaution. In addition to the periodic tests a special test should be made whenever the device has been shipped and particularly whenever any deformation of either kettle or beam is noticed. Any kettle or beam which has been deformed by bending or denting enough to render such deformation visible should be considered incorrect until a thorough test has been made.

Methods of checking the capacity of the standard quart test kettle and the accuracy and sensitiveness of the beam have been developed and are given on pages 8 and 11.

When the test weight per bushel of grain is determined with the standard apparatus in correct adjustment and with careful application of the correct method of use, uniform results are obtained.

VARIATIONS IN MAKING WEIGHT-PER-BUSHEL DETERMINATIONS.

Any variation from the standard apparatus or the standard method of making the test may, and often does, result in an inaccu-

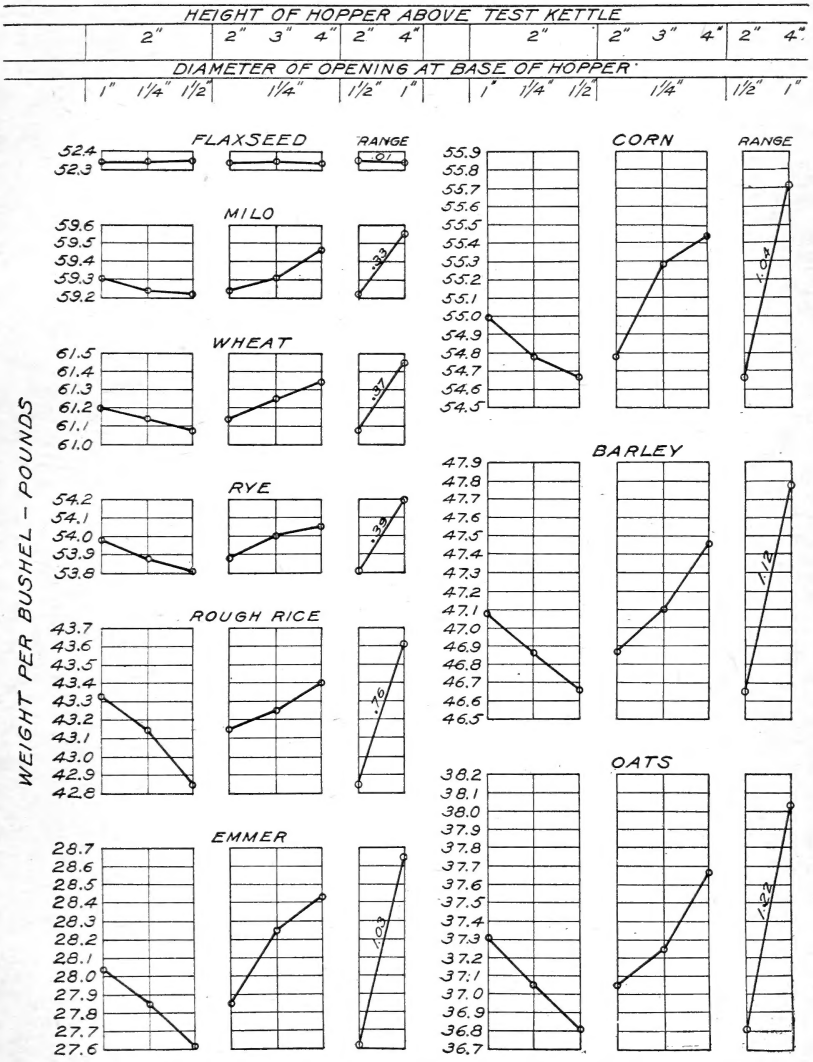

FIG. 4.—The test weight of grain is affected by the height of fall from the filling hopper and the size of the grain stream used in filling the test kettle.

rate test weight. Errors in the test weight may result from any of the following variations:

1. A tester having a beam that is inaccurate, insensitive, or "slow," or having a kettle that is dented, bent, or worn, or a kettle of 1 pint,

2 quarts, or 4 quarts capacity in place of the standard quart-size kettle.

2. A kettle having rough edges on top instead of smooth edges, which cause the stroker to jar the kettle and the grain in the kettle to settle down during the stroking operation.

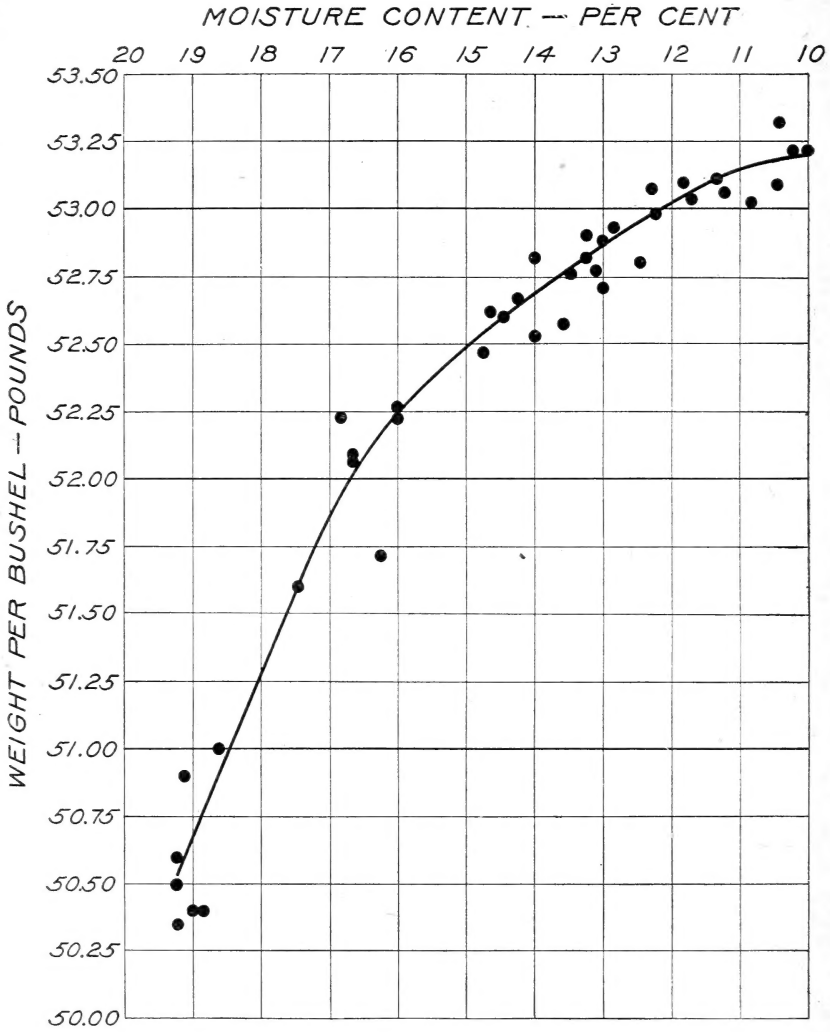

FIG. 5.—The influence of moisture content on the test weight of corn. This illustrates the necessity of making the weight-per-bushel test immediately after the samples have been delivered to the inspection or testing room.

3. Instead of having the kettle rest on a firm base and filling it from a standard hopper, it is pulled through the grain until it is full; or it is sunk part way into the grain and filled by pulling the grain over the edge by hand; or it is filled by a few handfuls and

sometimes by several small handfuls; or it is filled from a pan or bag or from a funnel not of standard design.

4. The bag, pan, or funnel in some cases is held at a point either higher or lower than 2 inches above the top of the kettle, sometimes almost even with the top and at other times raised to a considerable height above the kettle; or it is filled from such bag, pan, or funnel sometimes with a thin small stream and at other times with a large heavy stream. (See fig. 4.)

5. Instead of striking off the excess grain with the standard stroker, the grain is struck off with the scalebeam, a sawed-off piece of broomstick, a pencil or other implement, or with a worn-out standard stroker having rough edges.

6. The kettle is tapped or jarred before the surplus grain is struck off; or the grain is pressed into the kettle before it is stroked off; or when the standard stroker is used, the stroke is not made with three full-length motions; or the stroker is held inclined forward or backward instead of vertically; or the stroker is allowed to jar the kettle when it is placed in position; or it is held pressed too tightly against the kettle during the stroke, thereby causing a jarring of the kettle.

7. In the case of wheat, the test, instead of being made on the dockage-free wheat, which is the correct method, is made on wheat containing the dockage.

Allowing samples having a high moisture content to lie around and dry out for some time will also seriously affect their test weight, as is shown in figure 5.

TABLE 1.—*Variations in the test weight per bushel of oats obtained by filling the test kettle by different methods.*

Test kettle filled—	Weight per bushel (pounds).							
	Individual tests.					Minimum.	Maximum.	Average.
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.			
From a bag held 2 to 3 inches above the kettle.	37	37.5	37.5	38.25	37	37	38.25	37.45
By sinking it into the grain and pulling the grain into the kettle by hand:								
(1) By one motion of both hands	36.5	36.5	36.5	36.5	36.25	36.25	36.5	36.45
(2) By 9 to 11 motions of both hands	37	37	37	36.75	37	36.75	37	36.95
By dipping it into the grain	38.75	39.25	39	39.5	39.5	38.75	39.5	39.20
By pulling it through the grain with about a 2-foot sweep:								
(1) Through loose, worked-over grain	38	38.25	38.25	38.25	39.5	38	38.5	38.45
(2) Through the packed surface of the grain in a car before the grain had been worked over	39.75	40.75	39.5	39	39.75	39	40.75	39.75
From a hopper having an outlet opening 1¼ inches in diameter held 2 inches above the kettle (official method)	37.2	37.2	37.3	37.2	37.2	37.2	37.3	37.22

SPECIAL POINTS TO OBSERVE IN MAKING CORRECT WEIGHT-PER-BUSHEL TESTS.

1. Use an accurate quart-size weight-per-bushel testing apparatus.
2. Fill the kettle from a hopper.
3. The opening at bottom of hopper must be round and exactly $1\frac{1}{4}$ inches in diameter.
4. The bottom of the hopper must be held exactly 2 inches above the center of the kettle.
5. Mark the hopper on the inside at a point where it will hold just enough grain to cause an overflow over all sides of the kettle.
6. Use the same volume of grain for each test.
7. Use a stroker made of hardwood, with smooth rounded edges, 12 inches long, $\frac{3}{8}$ inch thick, and $1\frac{3}{8}$ inches broad.
8. Place the stroker on the edge of the kettle lightly without jarring the kettle.
9. Hold the stroker on the kettle with its sides in a vertical position.
10. Stroke the grain from the kettle with three full-length zigzag motions of the stroker.
11. Make the stroke clean all the way across the kettle.
12. Have the kettle rest on a firm base.
13. Do not jar the kettle before or during the stroking operation.
14. If the top of the kettle is rough, smooth down the roughness with a rounded metal bar but do not use a file.
15. Make the test immediately after the sample has been brought to the inspection room, office, or laboratory, to prevent the grain from drying out with consequent change in test weight.
16. In the case of wheat and other grains for which the standards provide a specification for " dockage," make the test after the dockage has been removed.
17. The quart kettle must have a capacity of exactly 67.2 cubic inches.
18. Use a beam which is both accurately graduated and sensitive to $\frac{1}{10}$ pound per bushel.
19. Have the grain tester tested periodically for—
    (a) Accuracy of kettle capacity;
    (b) Accuracy of beam readings; and
    (c) Sensitiveness of beam.

Any office of Federal grain supervision will be glad to test any apparatus for accuracy, or arrange to have it tested free of charge.

METHOD OF DETERMINING ACCURACY OF TEST KETTLE.

Apparatus required: (See fig. 6.)

1. Kettle to be tested.
2. Slicker plate, plate glass 5 inches in diameter.

3. A correct even-arm balance.

4. One standard weight weighing 1,098.08 grams, or standard weights from which this amount can be built up.

5. One tolerance weight (1 gram).

6. A supply of distilled or pure water.

7. A chemical thermometer reading 20° C. or 68° F.

To make the test:

1. Remove scoop from balance and place the test kettle, slicker plate, and standard weight on scoop bracket and bring the scale to exact balance by means of weights and sliding poise, as shown in figure 7.

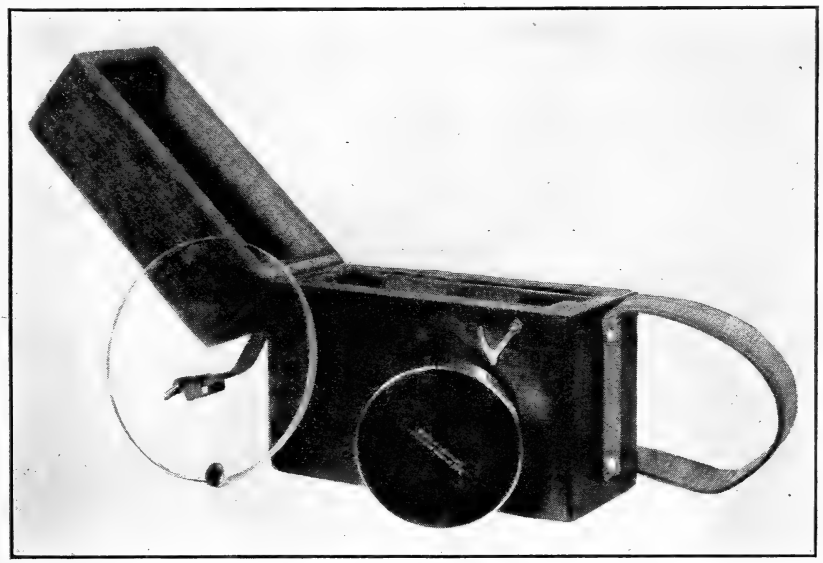

FIG. 6.—Special apparatus consisting of a metal weight weighing 1,098.08 grams, glass, slicker plate, and a 1-gram tolerance weight used in connection with a sensitive even-arm balance for determining the accuracy of quart weight-per-bushel testing kettles.

2. Remove kettle, slicker plate, and standard weight from one arm of the balance, being careful to avoid disturbing the weights or counterpoise on the other arm of the balance. Fill the kettle full to overflowing with distilled water which has been brought to the required temperature of 20° C. or 68° F. and place slicker plate on top of kettle to remove excess water, leaving the kettle exactly level full. The purpose of this action is similar to that of "striking-off" the excess grain in a test kettle when making a weight-per-bushel test. To eliminate all air bubbles from beneath the plate and the inside of the kettle it may be necessary to repeat this operation several times, refilling the kettle each time. When there are no air bubbles in the kettle carefully wipe off all moisture on outside and bottom of kettle.

3. Replace kettle filled with the distilled water and covered with the slicker plate, omitting the standard weight, on scoop bracket of balance without spilling water or disturbing weights previously set, release the arrest or damper, and let the pointer on balance come to rest.

4. If when the pointer has ceased oscillating it indicates an exact balance, the capacity of the kettle is correct and this test is satisfactorily completed.

5. If the pointer comes to rest at any other position than the center of the graduated arc, or center of balance, place the tolerance

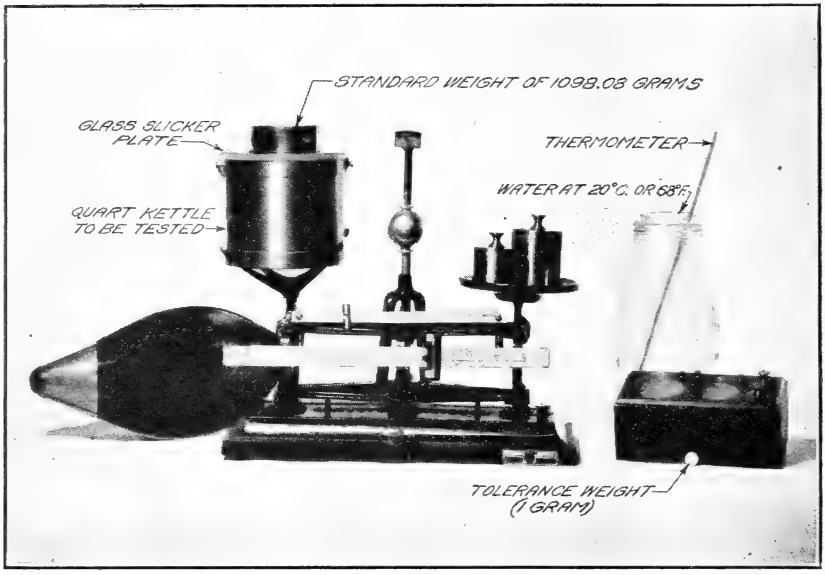

FIG. 7.—Apparatus required for determining the accuracy of the quart-sized kettle. The standard weight shown on top of the glass slicker plate over the test kettle is equal in weight (1,098.08 grams) to 1 quart of water at 20° C. (68° F.).

weight (1 gram) on the light side of the balance. If the tolerance weight is sufficient to swing the pointer to or across the center mark, the error in kettle capacity is within the allowable tolerance and the kettle may be used. But should the tolerance weight be insufficient to swing the pointer to the center of its arc, or bring the scale to balance, the error in the kettle capacity exceeds the allowable tolerance and the kettle should not be used in making official tests.

To insure a correct test it is of course essential that the balance used in making the test be sufficiently sensitive to indicate a change in the pointer or beam reading when the tolerance weight is added to or taken from either arm of the loaded balance.

METHOD OF DETERMINING ACCURACY AND SENSITIVENESS OF BEAM.

Before attempting to check the accuracy of the beam the base of the tester should be leveled and, if it is of the standard type with horizontal arm and trig loop, this level should be tested by examining the position of the projection or pointer on the end of the beam in its relation to the trig loop. The pointer should be in the center of the trig loop both horizontally and vertically when the empty kettle is on the beam and the counterpoises are at zero. If this is not the case the leveling screws should be adjusted until it is true.

There are two methods of checking the accuracy of the beam graduations. In the more simple and direct method a special set of 14 accurate testing weights is used while in the other method an ordinary set of metric weights is used.

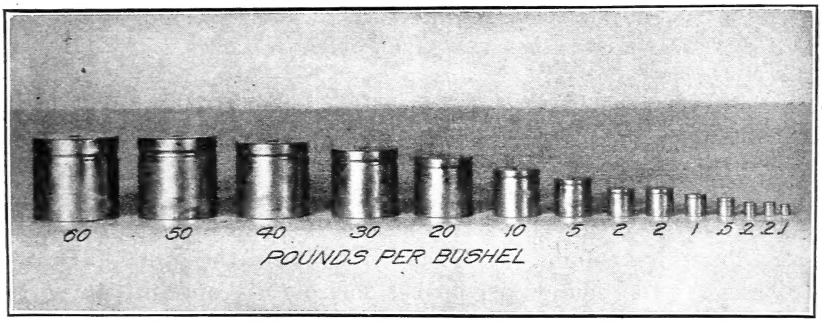

FIG. 8.—Special weights used in determining the accuracy of the beam in the weight-per-bushel testing apparatus. In making the test these weights are placed in the test kettle.

The 14 special weights illustrated in figure 8 are marked to represent the following number of pounds per bushel: 60, 50, 40, 30, 20, 10, 5, 2, 2, 1, 0.5, 0.2, and 0.1. Each weight actually weighs $\frac{1}{32}$ of its marked value. To test the beam place any weight or combination of weights, within the range of the beam graduations, in the kettle and bring the beam to balance by means of the counterpoise. The combined readings of the counterpoises should now equal the combined represented weights in the kettle, and the difference between the weight represented in the kettle and on the beams, if any, is the error of the beam.

It is equally essential in making correct weight-per-bushel tests, especially on "line" samples, that the beam should not only indicate an apparently correct reading when a given weight is placed in the test kettle but that it should also be sensitive to within one-tenth of a pound per bushel. That is, the beam should be sufficiently sensitive to move either up or down noticeably, and in the case of a

tester having a trig loop the beam should move from the center position to either the top or the bottom of the trig loop whenever the poise on the beam is shifted one-tenth pound under or over the correct position for the load that is being weighed in the test kettle. Beams are occasionally found in use which are "slow" and which do not show a change in the beam reading until the poise is moved along the beam often to the extent of an indicated half pound or more per bushel.

In testing the beam by the second method, an accurate set of ordinary metric weights, comprising weights from 1,000 grams to 0.1 gram, is used. However, if 0.1 gram weights are not available, 1 gram weights may be used to check to within one-tenth of a pound per bushel.

The table of equivalents (Table 2) has been prepared to facilitate the use of metric weights for checking beams.

HOW TO USE THE TABLE OF EQUIVALENTS.

It must be remembered that the pounds per bushel in the table are shown on the beam of the tester, and that the equivalent grams per quart in the table are to be placed in the kettle. The first column in the table contains the even pounds per bushel and the second column headed "0.0" (tenths) contains the grams-per-quart equivalent. The third column headed "0.1" contains the grams-per-quart equivalent to the pounds per bushel horizontally opposite any gram figures plus 0.1, or in the last column headed "0.9" the figures in grams horizontally opposite to any pounds per bushel in the first column represent that number of pounds plus "0.9."

Example: How many grams per quart are equivalent to 50.9 pounds per bushel?

Follow down the left-hand column of the table to 50.0, then on that line horizontally to the right to the column headed 0.9 and find 721.5 grams, which if placed in the kettle should balance 50.9 pounds per bushel on the beam.

If it is practicable to determine the weight in grams of the contents of a quart test kettle, this weight per quart in grams may be transposed by the use of the table to pounds per bushel.

Example: If 1 quart of grain is found to weigh 781 grams, what is the weight per bushel?

Find 781.0 grams in the column headed 0.1. It is horizontally opposite 55.0; therefore, 781.0 grams per quart is equivalent to 55.1 pounds per bushel.

TABLE 2.—*Grams per quart equivalent to pounds per bushel.*

Pounds per bushel.	Tenths of pounds per bushel.									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	Grams per quart.									
0.....	0.0	1.4	2.8	4.2	5.7	7.1	8.5	9.9	11.3	12.8
1.....	14.2	15.6	17.0	18.4	19.8	21.3	22.7	24.1	25.5	26.9
2.....	28.3	29.8	31.2	32.6	34.0	35.4	36.8	38.3	39.7	41.1
3.....	42.5	43.9	45.4	46.8	48.2	49.6	51.0	52.4	53.0	55.3
4.....	56.7	58.1	59.5	60.9	62.4	63.8	65.2	66.6	68.0	69.5
5.....	70.9	72.3	73.7	75.1	76.5	78.0	79.4	80.8	82.2	83.6
6.....	85.0	86.5	87.9	89.3	90.7	92.1	93.5	95.0	96.4	97.8
7.....	99.2	100.6	102.1	103.5	104.9	106.3	107.7	109.1	110.6	112.0
8.....	113.4	114.8	116.2	117.6	119.1	120.5	121.9	123.3	124.7	126.2
9.....	127.6	129.0	130.4	131.8	133.2	134.7	136.1	137.5	138.9	140.3
10.....	141.7	143.2	144.6	146.0	147.4	148.8	150.2	151.7	153.1	154.5
11.....	155.9	157.3	158.8	160.2	161.6	163.0	164.4	165.8	167.3	168.7
12.....	170.1	171.5	172.9	174.3	175.8	177.2	178.6	180.0	181.4	182.8
13.....	184.3	185.7	187.1	188.5	189.9	191.4	192.8	194.2	195.6	197.0
14.....	198.4	199.9	201.3	202.7	204.1	205.5	206.9	208.4	209.8	211.2
15.....	212.6	214.0	215.5	216.9	218.3	219.7	221.1	222.5	224.0	225.4
16.....	226.8	228.2	229.6	231.0	232.5	233.9	235.3	236.7	238.1	239.5
17.....	241.0	242.4	243.8	245.2	246.6	248.1	249.5	250.9	252.3	253.7
18.....	255.1	256.6	258.0	259.4	260.8	262.2	263.6	265.1	266.5	267.9
19.....	269.3	270.7	272.2	273.6	275.0	276.4	277.8	279.2	280.7	282.1
20.....	283.5	284.9	286.3	287.7	289.2	290.6	292.0	293.4	294.8	296.2
21.....	297.7	299.1	300.5	301.9	303.3	304.8	306.2	307.6	309.0	310.4
22.....	311.8	313.3	314.7	316.1	317.5	318.9	320.3	321.8	323.2	324.6
23.....	326.0	327.4	328.8	330.3	331.7	333.1	334.5	335.9	337.4	338.8
24.....	340.2	341.6	343.0	344.4	345.9	347.3	348.7	350.1	351.5	352.9
25.....	354.4	355.8	357.2	358.6	360.0	361.5	362.9	364.3	365.7	367.1
26.....	368.5	370.0	371.4	372.8	374.2	375.6	377.0	378.5	379.9	381.3
27.....	382.7	384.1	385.5	387.0	388.4	389.8	391.2	392.6	394.1	395.5
28.....	396.9	398.3	399.7	401.1	402.6	404.0	405.4	406.8	408.2	409.6
29.....	411.1	412.5	413.9	415.3	416.7	418.2	419.6	421.0	422.4	423.8
30.....	425.2	426.7	428.1	429.5	430.9	432.3	433.7	435.2	436.6	438.0
31.....	439.4	440.8	442.2	443.7	445.1	446.5	447.9	449.3	450.8	452.2
32.....	453.6	455.0	456.4	457.8	459.3	460.7	462.1	463.5	464.9	466.3
33.....	467.8	469.2	470.6	472.0	473.4	474.8	476.3	477.7	479.1	480.5
34.....	481.9	483.4	484.8	486.2	487.6	489.0	490.4	491.9	493.3	494.7
35.....	496.1	497.5	498.9	500.4	501.8	503.2	504.6	506.0	507.5	508.9
36.....	510.3	511.7	513.1	514.5	516.0	517.4	518.8	520.2	521.6	523.0
37.....	524.5	525.9	527.3	528.7	530.1	531.5	533.0	534.4	535.8	537.2
38.....	538.6	540.1	541.5	542.9	544.3	545.7	547.1	548.6	550.0	551.4
39.....	552.8	554.2	555.6	557.1	558.5	559.9	561.3	562.7	564.2	565.6
40.....	567.0	568.4	569.8	571.2	572.7	574.1	575.5	576.9	578.3	579.7
41.....	581.2	582.6	584.0	585.4	586.8	588.2	589.7	591.1	592.5	593.9
42.....	595.3	596.8	598.2	599.6	601.0	602.4	603.8	605.3	606.7	608.1
43.....	609.5	610.9	612.3	613.8	615.2	616.6	618.0	619.4	620.8	622.3
44.....	623.7	625.1	626.5	627.9	629.4	630.8	632.2	633.6	635.0	636.4
45.....	637.9	639.3	640.7	642.1	643.5	644.9	646.4	647.8	649.2	650.6
46.....	652.0	653.5	654.9	656.3	657.7	659.1	660.5	662.0	663.4	664.8
47.....	666.2	667.6	669.0	670.5	671.9	673.3	674.7	676.1	677.5	679.0
48.....	680.4	681.8	683.2	684.6	686.1	687.5	688.9	690.3	691.7	693.1
49.....	694.6	696.0	697.4	698.8	700.2	701.6	703.1	704.5	705.9	707.3
50.....	708.7	710.2	711.6	713.0	714.4	715.8	717.2	718.2	720.1	721.5
51.....	722.9	724.3	725.7	727.2	728.6	730.0	731.4	732.8	734.2	735.7
52.....	737.1	738.5	739.9	741.3	742.8	744.2	745.6	747.0	748.4	749.8
53.....	751.3	752.7	754.1	755.5	756.9	758.3	759.8	761.2	762.6	764.0
54.....	765.4	766.8	768.3	769.7	771.1	772.5	773.9	775.4	776.8	778.2
55.....	779.6	781.0	782.4	783.9	785.3	786.7	788.1	789.5	790.9	792.4
56.....	793.8	795.2	796.6	798.0	799.5	800.9	802.3	803.7	805.1	806.5
57.....	808.0	809.4	810.8	812.2	813.6	815.0	816.5	817.9	819.3	820.7
58.....	822.1	823.5	825.0	826.4	827.8	829.2	830.6	832.1	833.5	834.9
59.....	836.3	837.7	839.1	840.6	842.0	843.4	844.8	846.2	847.6	849.1
60.....	850.5	851.9	853.3	854.7	856.2	857.6	859.0	860.4	861.8	863.2
61.....	864.7	866.1	867.5	868.9	870.3	871.7	873.2	874.6	876.0	877.4
62.....	878.8	880.2	881.7	883.1	884.5	885.9	887.3	888.8	890.2	891.6
63.....	893.0	894.4	895.8	897.3	898.7	900.1	901.5	902.9	904.3	905.8

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